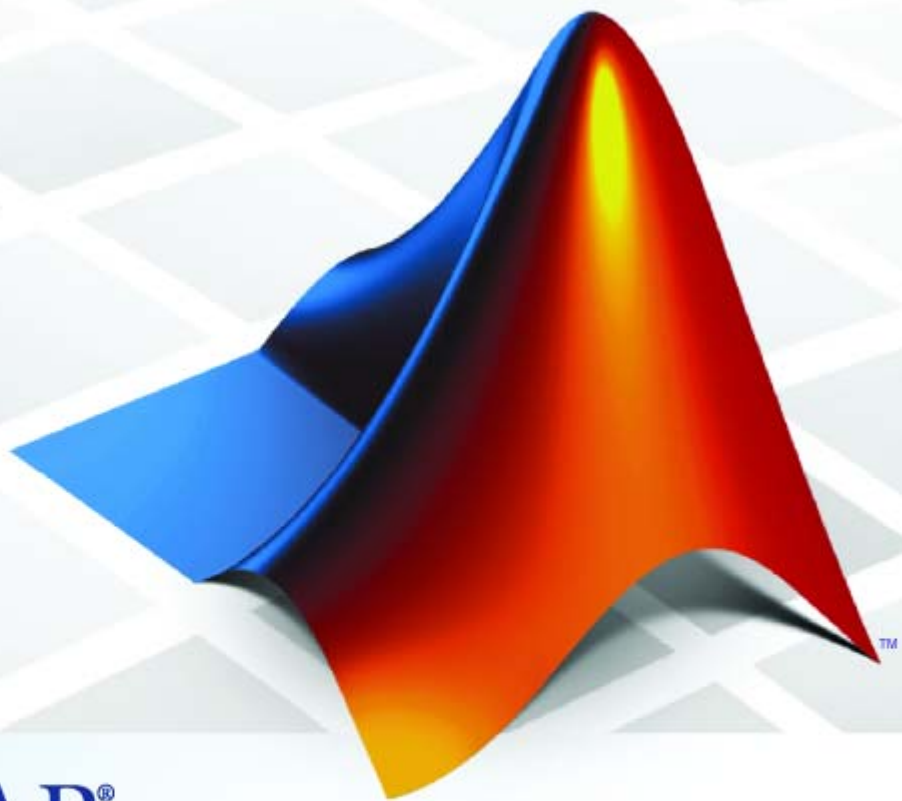


MATLAB® 7

Function Reference: P - Z



MATLAB®

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MATLAB Function Reference

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Function Reference

Desktop Tools and Development Environment (p. 1-3)

Startup, Command Window, help, editing and debugging, tuning, other general functions

Mathematics (p. 1-13)

Arrays and matrices, linear algebra, other areas of mathematics

Data Analysis (p. 1-43)

Basic data operations, descriptive statistics, covariance and correlation, filtering and convolution, numerical derivatives and integrals, Fourier transforms, time series analysis

Programming and Data Types (p. 1-51)

Function/expression evaluation, program control, function handles, object oriented programming, error handling, operators, data types, dates and times, timers

Object-Oriented Programming (p. 1-77)

Functions for working with classes and objects

File I/O (p. 1-81)

General and low-level file I/O, plus specific file formats, like audio, spreadsheet, HDF, images

Graphics (p. 1-93)

Line plots, annotating graphs, specialized plots, images, printing, Handle Graphics

3-D Visualization (p. 1-104)

Surface and mesh plots, view control, lighting and transparency, volume visualization

GUI Development (p. 1-110)

GUIDE, programming graphical user interfaces

External Interfaces (p. 1-115)

Interfaces to shared libraries, Java, .NET, COM and ActiveX, Web services, and serial port devices, and C and Fortran routines

Desktop Tools and Development Environment

Startup and Shutdown (p. 1-3)	Startup and shutdown options, preferences
Command Window and History (p. 1-4)	Control Command Window and History, enter statements and run functions
Help for Using MATLAB (p. 1-5)	Command line help, online documentation in the Help browser, demos
Workspace, Search Path, and File Operations (p. 1-6)	Work with files, MATLAB search path, manage variables
Programming Tools (p. 1-8)	Edit and debug M-files, improve performance, source control, publish results
System (p. 1-11)	Identify current computer, license, product version, and more

Startup and Shutdown

exit	Terminate MATLAB® program (same as quit)
finish	Termination M-file for MATLAB program
matlab (UNIX)	Start MATLAB program (UNIX® platforms)
matlab (Windows)	Start MATLAB program (Windows® platforms)
matlabrc	Startup M-file for MATLAB program
prefdir	Directory containing preferences, history, and layout files
preferences	Open Preferences dialog box
quit	Terminate MATLAB program

startup	Startup M-file for user-defined options
userpath	View or change user portion of search path

Command Window and History

clc	Clear Command Window
commandhistory	Open Command History window, or select it if already open
commandwindow	Open Command Window, or select it if already open
diary	Save session to file
dos	Execute DOS command and return result
format	Set display format for output
home	Move cursor to upper-left corner of Command Window
matlabcolon (matlab:)	Run specified function via hyperlink
more	Control paged output for Command Window
perl	Call Perl script using appropriate operating system executable
system	Execute operating system command and return result
unix	Execute UNIX command and return result

Help for Using MATLAB

builddocsearchdb	Build searchable documentation database
demo	Access product demos via Help browser
doc	Reference page in Help browser
docsearch	Open Help browser and search for specified term
echodemo	Run M-file demo step-by-step in Command Window
help	Help for functions in Command Window
helpbrowser	Open Help browser to access all online documentation and demos
helpwin	Provide access to M-file help for all functions
info	Information about contacting The MathWorks
lookfor	Search for keyword in all help entries
playshow	Run M-file demo (deprecated; use echodemo instead)
support	Open MathWorks Technical Support Web page
whatsnew	Release Notes for MathWorks™ products

Workspace, Search Path, and File Operations

Workspace (p. 1-6)

Manage variables

Search Path (p. 1-6)

View and change MATLAB search path

File Operations (p. 1-7)

View and change files and directories

Workspace

assignin

Assign value to variable in specified workspace

clear

Remove items from workspace, freeing up system memory

evalin

Execute MATLAB expression in specified workspace

exist

Check existence of variable, function, directory, or Java™ programming language class

openvar

Open workspace variable in Variable Editor or other graphical editing tool

pack

Consolidate workspace memory

uiimport

Open Import Wizard to import data

which

Locate functions and files

who, whos

List variables in workspace

workspace

Open Workspace browser to manage workspace

Search Path

addpath

Add directories to search path

genpath

Generate path string

<code>partialpath</code>	Partial pathname description
<code>path</code>	View or change search path
<code>path2rc</code>	Save current search path to <code>pathdef.m</code> file
<code>pathsep</code>	Path separator for current platform
<code>pathtool</code>	Open Set Path dialog box to view and change search path
<code>restoredefaultpath</code>	Restore default search path
<code>rmpath</code>	Remove directories from search path
<code>savepath</code>	Save current search path
<code>userpath</code>	View or change user portion of search path

File Operations

See also “File I/O” on page 1-81 functions.

<code>cd</code>	Change working directory
<code>copyfile</code>	Copy file or directory
<code>delete</code>	Remove files or graphics objects
<code>dir</code>	Directory listing
<code>exist</code>	Check existence of variable, function, directory, or Java programming language class
<code>fileattrib</code>	Set or get attributes of file or directory
<code>filebrowser</code>	Open Current Directory browser, or select it if already open
<code>isdir</code>	Determine whether input is directory
<code>lookfor</code>	Search for keyword in all help entries

ls	Directory contents
matlabroot	Root directory
mkdir	Make new directory
movefile	Move file or directory
pwd	Identify current directory
recycle	Set option to move deleted files to recycle folder
rehash	Refresh function and file system path caches
rmdir	Remove directory
toolboxdir	Root directory for specified toolbox
type	Display contents of file
visdiff	Compare two text files, MAT-Files, or binary files
what	List MATLAB files in current directory
which	Locate functions and files

Programming Tools

M-File Editing and Debugging (p. 1-9)	Edit and debug M-files
M-File Performance (p. 1-9)	Improve performance and find potential problems in M-files
Source Control (p. 1-10)	Interface MATLAB with source control system
Publishing (p. 1-10)	Publish M-file code and results

M-File Editing and Debugging

clipboard	Copy and paste strings to and from system clipboard
datatipinfo	Produce short description of input variable
dbclear	Clear breakpoints
dbcont	Resume execution
dbdown	Reverse workspace shift performed by dbup, while in debug mode
dbquit	Quit debug mode
dbstack	Function call stack
dbstatus	List all breakpoints
dbstep	Execute one or more lines from current breakpoint
dbstop	Set breakpoints
dbtype	List M-file with line numbers
dbup	Shift current workspace to workspace of caller, while in debug mode
debug	List M-file debugging functions
edit	Edit or create M-file
keyboard	Input from keyboard

M-File Performance

bench	MATLAB benchmark
mlint	Check M-files for possible problems
mlintrpt	Run <code>mlint</code> for file or directory, reporting results in browser
pack	Consolidate workspace memory

profile	Profile execution time for function
profsave	Save profile report in HTML format
rehash	Refresh function and file system path caches
sparse	Create sparse matrix
zeros	Create array of all zeros

Source Control

checkin	Check files into source control system (UNIX platforms)
checkout	Check files out of source control system (UNIX platforms)
cmopts	Name of source control system
customverctrl	Allow custom source control system (UNIX platforms)
undocheckout	Undo previous checkout from source control system (UNIX platforms)
verctrl	Source control actions (Windows platforms)

Publishing

grabcode	MATLAB code from M-files published to HTML
notebook	Open M-book in Microsoft® Word software (on Microsoft Windows platforms)
publish	Publish M-file containing cells, saving output to file of specified type
snapnow	Force snapshot of image for inclusion in published document

System

Operating System Interface (p. 1-11)	Exchange operating system information and commands with MATLAB
MATLAB Version and License (p. 1-12)	Information about MATLAB version and license

Operating System Interface

clipboard	Copy and paste strings to and from system clipboard
computer	Information about computer on which MATLAB software is running
dos	Execute DOS command and return result
getenv	Environment variable
hostid	Server host identification number
maxNumCompThreads	Control maximum number of computational threads
perl	Call Perl script using appropriate operating system executable
setenv	Set environment variable
system	Execute operating system command and return result
unix	Execute UNIX command and return result
winqueryreg	Item from Windows registry

MATLAB Version and License

<code>ismac</code>	Determine if version is for Mac OS® X platform
<code>ispc</code>	Determine if version is for Windows (PC) platform
<code>isstudent</code>	Determine if version is Student Version
<code>isunix</code>	Determine if version is for UNIX platform
<code>javachk</code>	Generate error message based on Sun™ Java feature support
<code>license</code>	Return license number or perform licensing task
<code>prefdir</code>	Directory containing preferences, history, and layout files
<code>usejava</code>	Determine whether Sun Java feature is supported in MATLAB software
<code>ver</code>	Version information for MathWorks products
<code>verLessThan</code>	Compare toolbox version to specified version string
<code>version</code>	Version number for MATLAB

Mathematics

Arrays and Matrices (p. 1-14)	Basic array operators and operations, creation of elementary and specialized arrays and matrices
Linear Algebra (p. 1-20)	Matrix analysis, linear equations, eigenvalues, singular values, logarithms, exponentials, factorization
Elementary Math (p. 1-24)	Trigonometry, exponentials and logarithms, complex values, rounding, remainders, discrete math
Polynomials (p. 1-28)	Multiplication, division, evaluation, roots, derivatives, integration, eigenvalue problem, curve fitting, partial fraction expansion
Interpolation and Computational Geometry (p. 1-29)	Interpolation, Delaunay triangulation and tessellation, convex hulls, Voronoi diagrams, domain generation
Cartesian Coordinate System Conversion (p. 1-32)	Conversions between Cartesian and polar or spherical coordinates
Nonlinear Numerical Methods (p. 1-33)	Differential equations, optimization, integration
Specialized Math (p. 1-36)	Airy, Bessel, Jacobi, Legendre, beta, elliptic, error, exponential integral, gamma functions
Sparse Matrices (p. 1-37)	Elementary sparse matrices, operations, reordering algorithms, linear algebra, iterative methods, tree operations
Math Constants (p. 1-41)	Pi, imaginary unit, infinity, Not-a-Number, largest and smallest positive floating point numbers, floating point relative accuracy

Arrays and Matrices

Basic Information (p. 1-14)

Display array contents, get array information, determine array type

Operators (p. 1-15)

Arithmetic operators

Elementary Matrices and Arrays (p. 1-16)

Create elementary arrays of different types, generate arrays for plotting, array indexing, etc.

Array Operations (p. 1-17)

Operate on array content, apply function to each array element, find cumulative product or sum, etc.

Array Manipulation (p. 1-18)

Create, sort, rotate, permute, reshape, and shift array contents

Specialized Matrices (p. 1-19)

Create Hadamard, Companion, Hankel, Vandermonde, Pascal matrices, etc.

Basic Information

disp

Display text or array

display

Display text or array (overloaded method)

isempty

Determine whether array is empty

isequal

Test arrays for equality

isequalwithequalnans

Test arrays for equality, treating NaNs as equal

isfinite

Array elements that are finite

isfloat

Determine whether input is floating-point array

isinf

Array elements that are infinite

isinteger

Determine whether input is integer array

islogical	Determine whether input is logical array
isnan	Array elements that are NaN
isnumeric	Determine whether input is numeric array
isscalar	Determine whether input is scalar
issparse	Determine whether input is sparse
isvector	Determine whether input is vector
length	Length of vector
max	Largest elements in array
min	Smallest elements in array
ndims	Number of array dimensions
numel	Number of elements in array or subscripted array expression
size	Array dimensions

Operators

+	Addition
+	Unary plus
-	Subtraction
-	Unary minus
*	Matrix multiplication
^	Matrix power
\	Backslash or left matrix divide
/	Slash or right matrix divide
'	Transpose
.'	Nonconjugated transpose
.*	Array multiplication (element-wise)

<code>.^</code>	Array power (element-wise)
<code>.\</code>	Left array divide (element-wise)
<code>./</code>	Right array divide (element-wise)

Elementary Matrices and Arrays

<code>blkdiag</code>	Construct block diagonal matrix from input arguments
<code>create (RandStream)</code>	Create random number streams
<code>diag</code>	Diagonal matrices and diagonals of matrix
<code>eye</code>	Identity matrix
<code>freqspace</code>	Frequency spacing for frequency response
<code>get (RandStream)</code>	Random stream properties
<code>getDefaultStream (RandStream)</code>	Default random number stream
<code>ind2sub</code>	Subscripts from linear index
<code>linspace</code>	Generate linearly spaced vectors
<code>list (RandStream)</code>	Random number generator algorithms
<code>logspace</code>	Generate logarithmically spaced vectors
<code>meshgrid</code>	Generate X and Y arrays for 3-D plots
<code>ndgrid</code>	Generate arrays for N-D functions and interpolation
<code>ones</code>	Create array of all ones
<code>rand</code>	Uniformly distributed pseudorandom numbers
<code>rand (RandStream)</code>	Uniformly distributed random numbers

randi	Uniformly distributed pseudorandom integers
randi (RandStream)	Uniformly distributed pseudorandom integers
randn	Normally distributed pseudorandom numbers
randn (RandStream)	Normally distributed pseudorandom numbers
randperm (RandStream)	
RandStream	Random number stream
RandStream (RandStream)	Random number stream
set (RandStream)	Set random stream property
setDefaultStream (RandStream)	Set default random number stream
sub2ind	Single index from subscripts
zeros	Create array of all zeros

Array Operations

See “Linear Algebra” on page 1-20 and “Elementary Math” on page 1-24 for other array operations.

accumarray	Construct array with accumulation
arrayfun	Apply function to each element of array
bsxfun	Apply element-by-element binary operation to two arrays with singleton expansion enabled
cast	Cast variable to different data type
cross	Vector cross product
cumprod	Cumulative product
cumsum	Cumulative sum

dot	Vector dot product
idivide	Integer division with rounding option
kron	Kronecker tensor product
prod	Product of array elements
sum	Sum of array elements
tril	Lower triangular part of matrix
triu	Upper triangular part of matrix

Array Manipulation

blkdiag	Construct block diagonal matrix from input arguments
cat	Concatenate arrays along specified dimension
circshift	Shift array circularly
diag	Diagonal matrices and diagonals of matrix
end	Terminate block of code, or indicate last array index
flipdim	Flip array along specified dimension
fliplr	Flip matrix left to right
flipud	Flip matrix up to down
horzcat	Concatenate arrays horizontally
inline	Construct inline object
ipermute	Inverse permute dimensions of N-D array
permute	Rearrange dimensions of N-D array
repmat	Replicate and tile array
reshape	Reshape array

rot90	Rotate matrix 90 degrees
shiftdim	Shift dimensions
sort	Sort array elements in ascending or descending order
sortrows	Sort rows in ascending order
squeeze	Remove singleton dimensions
vectorize	Vectorize expression
vertcat	Concatenate arrays vertically

Specialized Matrices

compan	Companion matrix
gallery	Test matrices
hadamard	Hadamard matrix
hankel	Hankel matrix
hilb	Hilbert matrix
invhilb	Inverse of Hilbert matrix
magic	Magic square
pascal	Pascal matrix
rosser	Classic symmetric eigenvalue test problem
toeplitz	Toeplitz matrix
vander	Vandermonde matrix
wilkinson	Wilkinson's eigenvalue test matrix

Linear Algebra

Matrix Analysis (p. 1-20)	Compute norm, rank, determinant, condition number, etc.
Linear Equations (p. 1-21)	Solve linear systems, least squares, LU factorization, Cholesky factorization, etc.
Eigenvalues and Singular Values (p. 1-22)	Eigenvalues, eigenvectors, Schur decomposition, Hessenburg matrices, etc.
Matrix Logarithms and Exponentials (p. 1-23)	Matrix logarithms, exponentials, square root
Factorization (p. 1-23)	Cholesky, LU, and QR factorizations, diagonal forms, singular value decomposition

Matrix Analysis

cond	Condition number with respect to inversion
condeig	Condition number with respect to eigenvalues
det	Matrix determinant
norm	Vector and matrix norms
normest	2-norm estimate
null	Null space
orth	Range space of matrix
rank	Rank of matrix
rcond	Matrix reciprocal condition number estimate
rref	Reduced row echelon form

subspace	Angle between two subspaces
trace	Sum of diagonal elements

Linear Equations

chol	Cholesky factorization
cholinc	Sparse incomplete Cholesky and Cholesky-Infinity factorizations
cond	Condition number with respect to inversion
condest	1-norm condition number estimate
funm	Evaluate general matrix function
ilu	Sparse incomplete LU factorization
inv	Matrix inverse
linsolve	Solve linear system of equations
lscov	Least-squares solution in presence of known covariance
lsqnonneg	Solve nonnegative least-squares constraints problem
lu	LU matrix factorization
luinc	Sparse incomplete LU factorization
pinv	Moore-Penrose pseudoinverse of matrix
qr	Orthogonal-triangular decomposition
rcond	Matrix reciprocal condition number estimate

Eigenvalues and Singular Values

balance	Diagonal scaling to improve eigenvalue accuracy
cdf2rdf	Convert complex diagonal form to real block diagonal form
condeig	Condition number with respect to eigenvalues
eig	Eigenvalues and eigenvectors
eigs	Largest eigenvalues and eigenvectors of matrix
gsvd	Generalized singular value decomposition
hess	Hessenberg form of matrix
ordeig	Eigenvalues of quasitriangular matrices
ordqz	Reorder eigenvalues in QZ factorization
ordschur	Reorder eigenvalues in Schur factorization
poly	Polynomial with specified roots
polyeig	Polynomial eigenvalue problem
rsf2csf	Convert real Schur form to complex Schur form
schur	Schur decomposition
sqrtn	Matrix square root
ss2tf	Convert state-space filter parameters to transfer function form
svd	Singular value decomposition
svds	Find singular values and vectors

Matrix Logarithms and Exponentials

expm	Matrix exponential
logm	Matrix logarithm
sqrtm	Matrix square root

Factorization

balance	Diagonal scaling to improve eigenvalue accuracy
cdf2rdf	Convert complex diagonal form to real block diagonal form
chol	Cholesky factorization
cholinc	Sparse incomplete Cholesky and Cholesky-Infinity factorizations
cholupdate	Rank 1 update to Cholesky factorization
gsvd	Generalized singular value decomposition
ilu	Sparse incomplete LU factorization
lu	LU matrix factorization
luinc	Sparse incomplete LU factorization
planerot	Givens plane rotation
qr	Orthogonal-triangular decomposition
qrdelete	Remove column or row from QR factorization
qrinsert	Insert column or row into QR factorization
qrupdate	

qz	QZ factorization for generalized eigenvalues
rsf2csf	Convert real Schur form to complex Schur form
svd	Singular value decomposition

Elementary Math

Trigonometric (p. 1-24)	Trigonometric functions with results in radians or degrees
Exponential (p. 1-26)	Exponential, logarithm, power, and root functions
Complex (p. 1-26)	Numbers with real and imaginary components, phase angles
Rounding and Remainder (p. 1-27)	Rounding, modulus, and remainder
Discrete Math (p. 1-27)	Prime factors, factorials, permutations, rational fractions, least common multiple, greatest common divisor

Trigonometric

acos	Inverse cosine; result in radians
acosd	Inverse cosine; result in degrees
acosh	Inverse hyperbolic cosine
acot	Inverse cotangent; result in radians
acotd	Inverse cotangent; result in degrees
acoth	Inverse hyperbolic cotangent
acsc	Inverse cosecant; result in radians
acscd	Inverse cosecant; result in degrees
acsch	Inverse hyperbolic cosecant

asec	Inverse secant; result in radians
asecd	Inverse secant; result in degrees
asech	Inverse hyperbolic secant
asin	Inverse sine; result in radians
asind	Inverse sine; result in degrees
asinh	Inverse hyperbolic sine
atan	Inverse tangent; result in radians
atan2	Four-quadrant inverse tangent
atand	Inverse tangent; result in degrees
atanh	Inverse hyperbolic tangent
cos	Cosine of argument in radians
cosd	Cosine of argument in degrees
cosh	Hyperbolic cosine
cot	Cotangent of argument in radians
cotd	Cotangent of argument in degrees
coth	Hyperbolic cotangent
csc	Cosecant of argument in radians
cscd	Cosecant of argument in degrees
csch	Hyperbolic cosecant
hypot	Square root of sum of squares
sec	Secant of argument in radians
secd	Secant of argument in degrees
sech	Hyperbolic secant
sin	Sine of argument in radians
sind	Sine of argument in degrees
sinh	Hyperbolic sine of argument in radians
tan	Tangent of argument in radians

tand	Tangent of argument in degrees
tanh	Hyperbolic tangent

Exponential

exp	Exponential
expm1	Compute $\exp(x) - 1$ accurately for small values of x
log	Natural logarithm
log10	Common (base 10) logarithm
log1p	Compute $\log(1+x)$ accurately for small values of x
log2	Base 2 logarithm and dissect floating-point numbers into exponent and mantissa
nextpow2	Next higher power of 2
nthroot	Real n th root of real numbers
pow2	Base 2 power and scale floating-point numbers
reallog	Natural logarithm for nonnegative real arrays
realpow	Array power for real-only output
realsqrt	Square root for nonnegative real arrays
sqrt	Square root

Complex

abs	Absolute value and complex magnitude
angle	Phase angle

complex	Construct complex data from real and imaginary components
conj	Complex conjugate
cplxpair	Sort complex numbers into complex conjugate pairs
i	Imaginary unit
imag	Imaginary part of complex number
isreal	Check if input is real array
j	Imaginary unit
real	Real part of complex number
sign	Signum function
unwrap	Correct phase angles to produce smoother phase plots

Rounding and Remainder

ceil	Round toward positive infinity
fix	Round toward zero
floor	Round toward negative infinity
idivide	Integer division with rounding option
mod	Modulus after division
rem	Remainder after division
round	Round to nearest integer

Discrete Math

factor	Prime factors
factorial	Factorial function
gcd	Greatest common divisor

isprime	Array elements that are prime numbers
lcm	Least common multiple
nchoosek	Binomial coefficient or all combinations
perms	All possible permutations
primes	Generate list of prime numbers
rat, rats	Rational fraction approximation

Polynomials

conv	Convolution and polynomial multiplication
deconv	Deconvolution and polynomial division
poly	Polynomial with specified roots
polyder	Polynomial derivative
polyeig	Polynomial eigenvalue problem
polyfit	Polynomial curve fitting
polyint	Integrate polynomial analytically
polyval	Polynomial evaluation
polyvalm	Matrix polynomial evaluation
residue	Convert between partial fraction expansion and polynomial coefficients
roots	Polynomial roots

Interpolation and Computational Geometry

Interpolation (p. 1-29)	Data interpolation, data gridding, polynomial evaluation, nearest point search
Delaunay Triangulation and Tessellation (p. 1-30)	Delaunay triangulation and tessellation, triangular surface and mesh plots
Convex Hull (p. 1-32)	Plot convex hull, plotting functions
Voronoi Diagrams (p. 1-32)	Plot Voronoi diagram, patch graphics object, plotting functions
Domain Generation (p. 1-32)	Generate arrays for 3-D plots, or for N-D functions and interpolation

Interpolation

dsearch	Search Delaunay triangulation for nearest point
dsearchn	N-D nearest point search
griddata	Data gridding
griddata3	Data gridding and hypersurface fitting for 3-D data
griddatan	Data gridding and hypersurface fitting (dimension ≥ 2)
interp1	1-D data interpolation (table lookup)
interp1q	Quick 1-D linear interpolation
interp2	2-D data interpolation (table lookup)
interp3	3-D data interpolation (table lookup)
interpft	1-D interpolation using FFT method
interpn	N-D data interpolation (table lookup)
meshgrid	Generate X and Y arrays for 3-D plots

mkpp	Make piecewise polynomial
ndgrid	Generate arrays for N-D functions and interpolation
padecoeff	Padé approximation of time delays
pchip	Piecewise Cubic Hermite Interpolating Polynomial (PCHIP)
ppval	Evaluate piecewise polynomial
spline	Cubic spline data interpolation
tsearchn	N-D closest simplex search
unmkpp	Piecewise polynomial details

Delaunay Triangulation and Tessellation

baryToCart (TriRep)	Converts point coordinates from barycentric to Cartesian
cartToBary (TriRep)	Convert point coordinates from cartesian to barycentric
circumcenters (TriRep)	Circumcenters of specified simplices
convexHull (DelaunayTri)	Convex hull
delaunay	Delaunay triangulation
delaunay3	3-D Delaunay tessellation
delaunayn	N-D Delaunay tessellation
DelaunayTri	Construct Delaunay triangulation
DelaunayTri	Delaunay triangulation in 2-D and 3-D
dsearch	Search Delaunay triangulation for nearest point
dsearchn	N-D nearest point search
edgeAttachments (TriRep)	Simplices attached to specified edges
edges (TriRep)	Triangulation edges

faceNormals (TriRep)	Unit normals to specified triangles
featureEdges (TriRep)	Sharp edges of surface triangulation
freeBoundary (TriRep)	Facets referenced by only one simplex
incenters (TriRep)	Incenters of specified simplices
inOutStatus (DelaunayTri)	Status of triangles in 2-D constrained Delaunay triangulation
isEdge (TriRep)	Test if vertices are joined by edge
nearestNeighbor (DelaunayTri)	Point closest to specified location
neighbors (TriRep)	Simplex neighbor information
pointLocation (DelaunayTri)	Simplex containing specified location
size (TriRep)	Size of triangulation matrix
tetramesh	Tetrahedron mesh plot
trimesh	Triangular mesh plot
triplot	2-D triangular plot
TriRep	Triangulation representation
TriRep	Triangulation representation
TriScatteredInterp	Interpolate scattered data
TriScatteredInterp	
trisurf	Triangular surface plot
tsearch	Search for enclosing Delaunay triangle
tsearchn	N-D closest simplex search
vertexAttachments (TriRep)	Return simplices attached to specified vertices
voronoiDiagram (DelaunayTri)	Voronoi diagram

Convex Hull

convhull	Convex hull
convhulln	N-D convex hull
patch	Create patch graphics object
plot	2-D line plot
trisurf	Triangular surface plot

Voronoi Diagrams

dsearch	Search Delaunay triangulation for nearest point
patch	Create patch graphics object
plot	2-D line plot
voronoi	Voronoi diagram
voronoin	N-D Voronoi diagram

Domain Generation

meshgrid	Generate X and Y arrays for 3-D plots
ndgrid	Generate arrays for N-D functions and interpolation

Cartesian Coordinate System Conversion

cart2pol	Transform Cartesian coordinates to polar or cylindrical
cart2sph	Transform Cartesian coordinates to spherical

pol2cart	Transform polar or cylindrical coordinates to Cartesian
sph2cart	Transform spherical coordinates to Cartesian

Nonlinear Numerical Methods

Ordinary Differential Equations (p. 1-33)	Solve stiff and nonstiff differential equations, define the problem, set solver options, evaluate solution
Delay Differential Equations (p. 1-34)	Solve delay differential equations with constant and general delays, set solver options, evaluate solution
Boundary Value Problems (p. 1-35)	Solve boundary value problems for ordinary differential equations, set solver options, evaluate solution
Partial Differential Equations (p. 1-35)	Solve initial-boundary value problems for parabolic-elliptic PDEs, evaluate solution
Optimization (p. 1-35)	Find minimum of single and multivariable functions, solve nonnegative least-squares constraint problem
Numerical Integration (Quadrature) (p. 1-36)	Evaluate Simpson, Lobatto, and vectorized quadratures, evaluate double and triple integrals

Ordinary Differential Equations

decic	Compute consistent initial conditions for ode15i
deval	Evaluate solution of differential equation problem

ode15i	Solve fully implicit differential equations, variable order method
ode23, ode45, ode113, ode15s, ode23s, ode23t, ode23tb	Solve initial value problems for ordinary differential equations
odefile	Define differential equation problem for ordinary differential equation solvers
odeget	Ordinary differential equation options parameters
odeset	Create or alter options structure for ordinary differential equation solvers
odextend	Extend solution of initial value problem for ordinary differential equation

Delay Differential Equations

dde23	Solve delay differential equations (DDEs) with constant delays
ddeget	Extract properties from delay differential equations options structure
ddesd	Solve delay differential equations (DDEs) with general delays
ddeset	Create or alter delay differential equations options structure
deval	Evaluate solution of differential equation problem

Boundary Value Problems

bvp4c	Solve boundary value problems for ordinary differential equations
bvp5c	Solve boundary value problems for ordinary differential equations
bvpget	Extract properties from options structure created with <code>bvpset</code>
bvpinit	Form initial guess for <code>bvp4c</code>
bvpset	Create or alter options structure of boundary value problem
bvpxtend	Form guess structure for extending boundary value solutions
deval	Evaluate solution of differential equation problem

Partial Differential Equations

pdepe	Solve initial-boundary value problems for parabolic-elliptic PDEs in 1-D
pdeval	Evaluate numerical solution of PDE using output of <code>pdepe</code>

Optimization

fminbnd	Find minimum of single-variable function on fixed interval
fminsearch	Find minimum of unconstrained multivariable function using derivative-free method
fzero	Find root of continuous function of one variable

lsqnonneg	Solve nonnegative least-squares constraints problem
optimget	Optimization options values
optimset	Create or edit optimization options structure

Numerical Integration (Quadrature)

dblquad	Numerically evaluate double integral over a rectangle
quad	Numerically evaluate integral, adaptive Simpson quadrature
quad2d	Numerically evaluate double integral over planar region
quadgk	Numerically evaluate integral, adaptive Gauss-Kronrod quadrature
quadl	Numerically evaluate integral, adaptive Lobatto quadrature
quadv	Vectorized quadrature
triplequad	Numerically evaluate triple integral

Specialized Math

airy	Airy functions
besselh	Bessel function of third kind (Hankel function)
besseli	Modified Bessel function of first kind
besselj	Bessel function of first kind
besselk	Modified Bessel function of second kind
bessely	Bessel function of second kind

beta	Beta function
betainc	Incomplete beta function
betaincinv	Beta inverse cumulative distribution function
betaln	Logarithm of beta function
ellipj	Jacobi elliptic functions
ellipke	Complete elliptic integrals of first and second kind
erf, erfc, erfcx, erfinv, erfcinv	Error functions
expint	Exponential integral
gamma, gammainc, gammaln	Gamma functions
gammaincinv	Inverse incomplete gamma function
legendre	Associated Legendre functions
psi	Psi (polygamma) function

Sparse Matrices

Elementary Sparse Matrices (p. 1-38)	Create random and nonrandom sparse matrices
Full to Sparse Conversion (p. 1-38)	Convert full matrix to sparse, sparse matrix to full
Sparse Matrix Manipulation (p. 1-39)	Test matrix for sparseness, get information on sparse matrix, allocate sparse matrix, apply function to nonzero elements, visualize sparsity pattern
Reordering Algorithms (p. 1-39)	Random, column, minimum degree, Dulmage-Mendelsohn, and reverse Cuthill-McKee permutations

Linear Algebra (p. 1-40)

Compute norms, eigenvalues, factorizations, least squares, structural rank

Linear Equations (Iterative Methods) (p. 1-40)

Methods for conjugate and biconjugate gradients, residuals, lower quartile

Tree Operations (p. 1-41)

Elimination trees, tree plotting, factorization analysis

Elementary Sparse Matrices

spdiags

Extract and create sparse band and diagonal matrices

speye

Sparse identity matrix

sprand

Sparse uniformly distributed random matrix

sprandn

Sparse normally distributed random matrix

sprandsym

Sparse symmetric random matrix

Full to Sparse Conversion

find

Find indices and values of nonzero elements

full

Convert sparse matrix to full matrix

sparse

Create sparse matrix

spconvert

Import matrix from sparse matrix external format

Sparse Matrix Manipulation

issparse	Determine whether input is sparse
nnz	Number of nonzero matrix elements
nonzeros	Nonzero matrix elements
nzmax	Amount of storage allocated for nonzero matrix elements
spalloc	Allocate space for sparse matrix
spfun	Apply function to nonzero sparse matrix elements
spones	Replace nonzero sparse matrix elements with ones
spparms	Set parameters for sparse matrix routines
spy	Visualize sparsity pattern

Reordering Algorithms

amd	Approximate minimum degree permutation
colamd	Column approximate minimum degree permutation
colperm	Sparse column permutation based on nonzero count
dmperm	Dulmage-Mendelsohn decomposition
ldl	Block LDL' factorization for Hermitian indefinite matrices
randperm	Random permutation
symamd	Symmetric approximate minimum degree permutation
symrcm	Sparse reverse Cuthill-McKee ordering

Linear Algebra

cholinc	Sparse incomplete Cholesky and Cholesky-Infinity factorizations
condest	1-norm condition number estimate
eigs	Largest eigenvalues and eigenvectors of matrix
ilu	Sparse incomplete LU factorization
luinc	Sparse incomplete LU factorization
normest	2-norm estimate
spaugment	Form least squares augmented system
sprank	Structural rank
svds	Find singular values and vectors

Linear Equations (Iterative Methods)

bicg	Biconjugate gradients method
bicgstab	Biconjugate gradients stabilized method
bicgstabl	Biconjugate gradients stabilized (l) method
egs	Conjugate gradients squared method
gmres	Generalized minimum residual method (with restarts)
lsqr	LSQR method
minres	Minimum residual method
pcg	Preconditioned conjugate gradients method
qmr	Quasi-minimal residual method

<code>symmlq</code>	Symmetric LQ method
<code>tfqmr</code>	Transpose-free quasi-minimal residual method

Tree Operations

<code>etree</code>	Elimination tree
<code>etreeplot</code>	Plot elimination tree
<code>gplot</code>	Plot nodes and links representing adjacency matrix
<code>symbfact</code>	Symbolic factorization analysis
<code>treelayout</code>	Lay out tree or forest
<code>treeplot</code>	Plot picture of tree
<code>unmesh</code>	Convert edge matrix to coordinate and Laplacian matrices

Math Constants

<code>eps</code>	Floating-point relative accuracy
<code>i</code>	Imaginary unit
<code>Inf</code>	Infinity
<code>intmax</code>	Largest value of specified integer type
<code>intmin</code>	Smallest value of specified integer type
<code>j</code>	Imaginary unit
<code>NaN</code>	Not-a-Number
<code>pi</code>	Ratio of circle's circumference to its diameter, π

realmax	Largest positive floating-point number
realmin	Smallest positive normalized floating-point number

Data Analysis

Basic Operations (p. 1-43)	Sums, products, sorting
Descriptive Statistics (p. 1-43)	Statistical summaries of data
Filtering and Convolution (p. 1-44)	Data preprocessing
Interpolation and Regression (p. 1-44)	Data fitting
Fourier Transforms (p. 1-45)	Frequency content of data
Derivatives and Integrals (p. 1-45)	Data rates and accumulations
Time Series Objects (p. 1-46)	Methods for <code>timeseries</code> objects
Time Series Collections (p. 1-49)	Methods for <code>tscollection</code> objects

Basic Operations

<code>brush</code>	Interactively mark, delete, modify, and save observations in graphs
<code>cumprod</code>	Cumulative product
<code>cumsum</code>	Cumulative sum
<code>linkdata</code>	Automatically update graphs when variables change
<code>prod</code>	Product of array elements
<code>sort</code>	Sort array elements in ascending or descending order
<code>sortrows</code>	Sort rows in ascending order
<code>sum</code>	Sum of array elements

Descriptive Statistics

<code>corrcoef</code>	Correlation coefficients
<code>cov</code>	Covariance matrix

max	Largest elements in array
mean	Average or mean value of array
median	Median value of array
min	Smallest elements in array
mode	Most frequent values in array
std	Standard deviation
var	Variance

Filtering and Convolution

conv	Convolution and polynomial multiplication
conv2	2-D convolution
convn	N-D convolution
deconv	Deconvolution and polynomial division
detrend	Remove linear trends
filter	1-D digital filter
filter2	2-D digital filter

Interpolation and Regression

interp1	1-D data interpolation (table lookup)
interp2	2-D data interpolation (table lookup)
interp3	3-D data interpolation (table lookup)
interpn	N-D data interpolation (table lookup)
mldivide \, mrdivide /	Left or right matrix division
polyfit	Polynomial curve fitting
polyval	Polynomial evaluation

Fourier Transforms

abs	Absolute value and complex magnitude
angle	Phase angle
cplxpair	Sort complex numbers into complex conjugate pairs
fft	Discrete Fourier transform
fft2	2-D discrete Fourier transform
fftn	N-D discrete Fourier transform
fftshift	Shift zero-frequency component to center of spectrum
fftw	Interface to FFTW library run-time algorithm tuning control
ifft	Inverse discrete Fourier transform
ifft2	2-D inverse discrete Fourier transform
ifftn	N-D inverse discrete Fourier transform
ifftshift	Inverse FFT shift
nextpow2	Next higher power of 2
unwrap	Correct phase angles to produce smoother phase plots

Derivatives and Integrals

cumtrapz	Cumulative trapezoidal numerical integration
del2	Discrete Laplacian
diff	Differences and approximate derivatives

gradient	Numerical gradient
polyder	Polynomial derivative
polyint	Integrate polynomial analytically
trapz	Trapezoidal numerical integration

Time Series Objects

Utilities (p. 1-46)	Combine <code>timeseries</code> objects, query and set <code>timeseries</code> object properties, plot <code>timeseries</code> objects
Data Manipulation (p. 1-47)	Add or delete data, manipulate <code>timeseries</code> objects
Event Data (p. 1-48)	Add or delete events, create new <code>timeseries</code> objects based on event data
Descriptive Statistics (p. 1-48)	Descriptive statistics for <code>timeseries</code> objects

Utilities

<code>get (timeseries)</code>	Query <code>timeseries</code> object property values
<code>getdatasamplesize</code>	Size of data sample in <code>timeseries</code> object
<code>getqualitydesc</code>	Data quality descriptions
<code>isempty (timeseries)</code>	Determine whether <code>timeseries</code> object is empty
<code>length (timeseries)</code>	Length of time vector
<code>plot (timeseries)</code>	Plot time series
<code>set (timeseries)</code>	Set properties of <code>timeseries</code> object
<code>size (timeseries)</code>	Size of <code>timeseries</code> object

<code>timeseries</code>	Create <code>timeseries</code> object
<code>tsdata.event</code>	Construct event object for <code>timeseries</code> object
<code>tsprops</code>	Help on <code>timeseries</code> object properties
<code>tstool</code>	Open Time Series Tools GUI

Data Manipulation

<code>addsample</code>	Add data sample to <code>timeseries</code> object
<code>ctranspose (timeseries)</code>	Transpose <code>timeseries</code> object
<code>delsample</code>	Remove sample from <code>timeseries</code> object
<code>detrend (timeseries)</code>	Subtract mean or best-fit line and all NaNs from time series
<code>filter (timeseries)</code>	Shape frequency content of time series
<code>getabstime (timeseries)</code>	Extract date-string time vector into cell array
<code>getinterpmethod</code>	Interpolation method for <code>timeseries</code> object
<code>getsampleusingtime (timeseries)</code>	Extract data samples into new <code>timeseries</code> object
<code>idealfilter (timeseries)</code>	Apply ideal (noncausal) filter to <code>timeseries</code> object
<code>resample (timeseries)</code>	Select or interpolate <code>timeseries</code> data using new time vector
<code>setabstime (timeseries)</code>	Set times of <code>timeseries</code> object as date strings
<code>setinterpmethod</code>	Set default interpolation method for <code>timeseries</code> object

<code>synchronize</code>	Synchronize and resample two <code>timeseries</code> objects using common time vector
<code>transpose (timeseries)</code>	Transpose <code>timeseries</code> object
<code>vertcat (timeseries)</code>	Vertical concatenation of <code>timeseries</code> objects

Event Data

<code>addevent</code>	Add event to <code>timeseries</code> object
<code>delevent</code>	Remove <code>tsdata.event</code> objects from <code>timeseries</code> object
<code>gettsafteratevent</code>	New <code>timeseries</code> object with samples occurring at or after event
<code>gettsafterevent</code>	New <code>timeseries</code> object with samples occurring after event
<code>gettsatevent</code>	New <code>timeseries</code> object with samples occurring at event
<code>gettsbeforeatevent</code>	New <code>timeseries</code> object with samples occurring before or at event
<code>gettsbeforeevent</code>	New <code>timeseries</code> object with samples occurring before event
<code>gettsbetweenevents</code>	New <code>timeseries</code> object with samples occurring between events

Descriptive Statistics

<code>iqr (timeseries)</code>	Interquartile range of <code>timeseries</code> data
<code>max (timeseries)</code>	Maximum value of <code>timeseries</code> data
<code>mean (timeseries)</code>	Mean value of <code>timeseries</code> data
<code>median (timeseries)</code>	Median value of <code>timeseries</code> data

<code>min (timeseries)</code>	Minimum value of <code>timeseries</code> data
<code>std (timeseries)</code>	Standard deviation of <code>timeseries</code> data
<code>sum (timeseries)</code>	Sum of <code>timeseries</code> data
<code>var (timeseries)</code>	Variance of <code>timeseries</code> data

Time Series Collections

Utilities (p. 1-49)	Query and set <code>tscollection</code> object properties, plot <code>tscollection</code> objects
Data Manipulation (p. 1-50)	Add or delete data, manipulate <code>tscollection</code> objects

Utilities

<code>get (tscollection)</code>	Query <code>tscollection</code> object property values
<code>isempty (tscollection)</code>	Determine whether <code>tscollection</code> object is empty
<code>length (tscollection)</code>	Length of time vector
<code>plot (timeseries)</code>	Plot time series
<code>set (tscollection)</code>	Set properties of <code>tscollection</code> object
<code>size (tscollection)</code>	Size of <code>tscollection</code> object
<code>tscollection</code>	Create <code>tscollection</code> object
<code>tstool</code>	Open Time Series Tools GUI

Data Manipulation

<code>addsampletocollection</code>	Add sample to <code>tscollection</code> object
<code>addts</code>	Add <code>timeseries</code> object to <code>tscollection</code> object
<code>delsamplefromcollection</code>	Remove sample from <code>tscollection</code> object
<code>getabstime (tscollection)</code>	Extract date-string time vector into cell array
<code>getsamplingsusingtime (tscollection)</code>	Extract data samples into new <code>tscollection</code> object
<code>gettimeseriesnames</code>	Cell array of names of <code>timeseries</code> objects in <code>tscollection</code> object
<code>horzcat (tscollection)</code>	Horizontal concatenation for <code>tscollection</code> objects
<code>removets</code>	Remove <code>timeseries</code> objects from <code>tscollection</code> object
<code>resample (tscollection)</code>	Select or interpolate data in <code>tscollection</code> using new time vector
<code>setabstime (tscollection)</code>	Set times of <code>tscollection</code> object as date strings
<code>settimeseriesnames</code>	Change name of <code>timeseries</code> object in <code>tscollection</code>
<code>vertcat (tscollection)</code>	Vertical concatenation for <code>tscollection</code> objects

Programming and Data Types

Data Types (p. 1-51)	Numeric, character, structures, cell arrays, and data type conversion
Data Type Conversion (p. 1-59)	Convert one numeric type to another, numeric to string, string to numeric, structure to cell array, etc.
Operators and Special Characters (p. 1-61)	Arithmetic, relational, and logical operators, and special characters
Strings (p. 1-64)	Create, identify, manipulate, parse, evaluate, and compare strings
Bit-Wise Operations (p. 1-67)	Perform set, shift, and, or, compare, etc. on specific bit fields
Logical Operations (p. 1-67)	Evaluate conditions, testing for true or false
Relational Operations (p. 1-68)	Compare values for equality, greater than, less than, etc.
Set Operations (p. 1-68)	Find set members, unions, intersections, etc.
Date and Time Operations (p. 1-69)	Obtain information about dates and times
Programming in MATLAB (p. 1-69)	M-files, function/expression evaluation, program control, function handles, object oriented programming, error handling

Data Types

Numeric Types (p. 1-52)	Integer and floating-point data
Characters and Strings (p. 1-53)	Characters and arrays of characters
Structures (p. 1-54)	Data of varying types and sizes stored in fields of a structure

Cell Arrays (p. 1-55)	Data of varying types and sizes stored in cells of array
Function Handles (p. 1-56)	Invoke a function indirectly via handle
Java Classes and Objects (p. 1-56)	Access Java classes through MATLAB interface
Data Type Identification (p. 1-58)	Determine data type of a variable

Numeric Types

arrayfun	Apply function to each element of array
cast	Cast variable to different data type
cat	Concatenate arrays along specified dimension
class	Create object or return class of object
find	Find indices and values of nonzero elements
intmax	Largest value of specified integer type
intmin	Smallest value of specified integer type
intwarning	Control state of integer warnings
ipermute	Inverse permute dimensions of N-D array
isa	Determine whether input is object of given class
isequal	Test arrays for equality
isequalwithequalnans	Test arrays for equality, treating NaNs as equal
isfinite	Array elements that are finite

<code>isinf</code>	Array elements that are infinite
<code>isnan</code>	Array elements that are NaN
<code>isnumeric</code>	Determine whether input is numeric array
<code>isreal</code>	Check if input is real array
<code>isscalar</code>	Determine whether input is scalar
<code>isvector</code>	Determine whether input is vector
<code>permute</code>	Rearrange dimensions of N-D array
<code>realmax</code>	Largest positive floating-point number
<code>realmin</code>	Smallest positive normalized floating-point number
<code>reshape</code>	Reshape array
<code>squeeze</code>	Remove singleton dimensions
<code>zeros</code>	Create array of all zeros

Characters and Strings

See “Strings” on page 1-64 for all string-related functions.

<code>cellstr</code>	Create cell array of strings from character array
<code>char</code>	Convert to character array (string)
<code>eval</code>	Execute string containing MATLAB expression
<code>findstr</code>	Find string within another, longer string
<code>isstr</code>	Determine whether input is character array
<code>regexp, regexpi</code>	Match regular expression
<code>sprintf</code>	Write formatted data to string

sscanf	Read formatted data from string
strcat	Concatenate strings horizontally
strcmp, strcmpi	Compare strings
strings	String handling
strjust	Justify character array
strmatch	Find possible matches for string
strread	Read formatted data from string
strrep	Find and replace substring
strtrim	Remove leading and trailing white space from string
strvcat	Concatenate strings vertically

Structures

arrayfun	Apply function to each element of array
cell2struct	Convert cell array to structure array
class	Create object or return class of object
deal	Distribute inputs to outputs
fieldnames	Field names of structure, or public fields of object
getfield	Field of structure array
isa	Determine whether input is object of given class
isequal	Test arrays for equality
isfield	Determine whether input is structure array field
isscalar	Determine whether input is scalar
isstruct	Determine whether input is structure array

isvector	Determine whether input is vector
orderfields	Order fields of structure array
rmfield	Remove fields from structure
setfield	Set value of structure array field
struct	Create structure array
struct2cell	Convert structure to cell array
structfun	Apply function to each field of scalar structure

Cell Arrays

cell	Construct cell array
cell2mat	Convert cell array of matrices to single matrix
cell2struct	Convert cell array to structure array
celldisp	Cell array contents
cellfun	Apply function to each cell in cell array
cellplot	Graphically display structure of cell array
cellstr	Create cell array of strings from character array
class	Create object or return class of object
deal	Distribute inputs to outputs
isa	Determine whether input is object of given class
iscell	Determine whether input is cell array
iscellstr	Determine whether input is cell array of strings

isequal	Test arrays for equality
isscalar	Determine whether input is scalar
isvector	Determine whether input is vector
mat2cell	Divide matrix into cell array of matrices
num2cell	Convert numeric array to cell array
struct2cell	Convert structure to cell array

Function Handles

class	Create object or return class of object
feval	Evaluate function
func2str	Construct function name string from function handle
functions	Information about function handle
function_handle (@)	Handle used in calling functions indirectly
isa	Determine whether input is object of given class
isequal	Test arrays for equality
str2func	Construct function handle from function name string

Java Classes and Objects

cell	Construct cell array
class	Create object or return class of object
clear	Remove items from workspace, freeing up system memory
depfun	List dependencies of M-file or P-file

exist	Check existence of variable, function, directory, or Java programming language class
fieldnames	Field names of structure, or public fields of object
im2java	Convert image to Java image
import	Add package or class to current import list
inmem	Names of M-files, MEX-files, Sun Java classes in memory
isa	Determine whether input is object of given class
isjava	Determine whether input is Sun Java object
javaaddpath	Add entries to dynamic Sun Java class path
javaArray	Construct Sun Java array
javachk	Generate error message based on Sun Java feature support
javaclasspath	Get and set Sun Java class path
javaMethod	Call Sun Java method
javaMethodEDT	Call Sun Java method from Event Dispatch Thread (EDT)
javaObject	Construct Sun Java object
javaObjectEDT	Construct Sun Java object on Event Dispatch Thread (EDT)
javarmpath	Remove entries from dynamic Sun Java class path
methods	Information on class methods
methodsview	Information on class methods in separate window

usejava	Determine whether Sun Java feature is supported in MATLAB software
which	Locate functions and files

Data Type Identification

is*	Detect state
isa	Determine whether input is object of given class
iscell	Determine whether input is cell array
iscellstr	Determine whether input is cell array of strings
ischar	Determine whether item is character array
isfield	Determine whether input is structure array field
isfloat	Determine whether input is floating-point array
isinteger	Determine whether input is integer array
isjava	Determine whether input is Sun Java object
islogical	Determine whether input is logical array
isnumeric	Determine whether input is numeric array
isobject	Determine if input is MATLAB object
isreal	Check if input is real array
isstr	Determine whether input is character array

<code>isstruct</code>	Determine whether input is structure array
<code>validateattributes</code>	Check validity of array
<code>who, whos</code>	List variables in workspace

Data Type Conversion

Numeric (p. 1-59)	Convert data of one numeric type to another numeric type
String to Numeric (p. 1-60)	Convert characters to numeric equivalent
Numeric to String (p. 1-60)	Convert numeric to character equivalent
Other Conversions (p. 1-61)	Convert to structure, cell array, function handle, etc.

Numeric

<code>cast</code>	Cast variable to different data type
<code>double</code>	Convert to double precision
<code>int8, int16, int32, int64</code>	Convert to signed integer
<code>single</code>	Convert to single precision
<code>typecast</code>	Convert data types without changing underlying data
<code>uint8, uint16, uint32, uint64</code>	Convert to unsigned integer

String to Numeric

base2dec	Convert base N number string to decimal number
bin2dec	Convert binary number string to decimal number
cast	Cast variable to different data type
hex2dec	Convert hexadecimal number string to decimal number
hex2num	Convert hexadecimal number string to double-precision number
str2double	Convert string to double-precision value
str2num	Convert string to number
unicode2native	Convert Unicode® characters to numeric bytes

Numeric to String

cast	Cast variable to different data type
char	Convert to character array (string)
dec2base	Convert decimal to base N number in string
dec2bin	Convert decimal to binary number in string
dec2hex	Convert decimal to hexadecimal number in string
int2str	Convert integer to string
mat2str	Convert matrix to string
native2unicode	Convert numeric bytes to Unicode characters
num2str	Convert number to string

Other Conversions

cell2mat	Convert cell array of matrices to single matrix
cell2struct	Convert cell array to structure array
datestr	Convert date and time to string format
func2str	Construct function name string from function handle
logical	Convert numeric values to logical
mat2cell	Divide matrix into cell array of matrices
num2cell	Convert numeric array to cell array
num2hex	Convert singles and doubles to IEEE [®] hexadecimal strings
str2func	Construct function handle from function name string
str2mat	Form blank-padded character matrix from strings
struct2cell	Convert structure to cell array

Operators and Special Characters

Arithmetic Operators (p. 1-62)	Plus, minus, power, left and right divide, transpose, etc.
Relational Operators (p. 1-62)	Equal to, greater than, less than or equal to, etc.
Logical Operators (p. 1-62)	Element-wise and short circuit and, or, not
Special Characters (p. 1-63)	Array constructors, line continuation, comments, etc.

Arithmetic Operators

+	Plus
-	Minus
.	Decimal point
=	Assignment
*	Matrix multiplication
/	Matrix right division
\	Matrix left division
^	Matrix power
'	Matrix transpose
.*	Array multiplication (element-wise)
./	Array right division (element-wise)
.\	Array left division (element-wise)
.^	Array power (element-wise)
.'	Array transpose

Relational Operators

<	Less than
<=	Less than or equal to
>	Greater than
>=	Greater than or equal to
==	Equal to
~=	Not equal to

Logical Operators

See also “Logical Operations” on page 1-67 for functions like `xor`, `all`, `any`, etc.

&&	Logical AND
	Logical OR
&	Logical AND for arrays
	Logical OR for arrays
~	Logical NOT

Special Characters

:	Create vectors, subscript arrays, specify for-loop iterations
()	Pass function arguments, prioritize operators
[]	Construct array, concatenate elements, specify multiple outputs from function
{}	Construct cell array, index into cell array
.	Insert decimal point, define structure field, reference methods of object
.()	Reference dynamic field of structure
..	Reference parent directory
...	Continue statement to next line
,	Separate rows of array, separate function input/output arguments, separate commands
;	Separate columns of array, suppress output from current command
%	Insert comment line into code
%{ %}	Insert block of comments into code
!	Issue command to operating system
''	Construct character array
@	Construct function handle, reference class directory

Strings

Description of Strings in MATLAB (p. 1-64)	Basics of string handling in MATLAB
String Creation (p. 1-64)	Create strings, cell arrays of strings, concatenate strings together
String Identification (p. 1-65)	Identify characteristics of strings
String Manipulation (p. 1-65)	Convert case, strip blanks, replace characters
String Parsing (p. 1-66)	Formatted read, regular expressions, locate substrings
String Evaluation (p. 1-66)	Evaluate stated expression in string
String Comparison (p. 1-66)	Compare contents of strings

Description of Strings in MATLAB

strings	String handling
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String Creation

blanks	Create string of blank characters
cellstr	Create cell array of strings from character array
char	Convert to character array (string)
sprintf	Write formatted data to string
strcat	Concatenate strings horizontally
strvcat	Concatenate strings vertically

String Identification

<code>class</code>	Create object or return class of object
<code>isa</code>	Determine whether input is object of given class
<code>iscellstr</code>	Determine whether input is cell array of strings
<code>ischar</code>	Determine whether item is character array
<code>isletter</code>	Array elements that are alphabetic letters
<code>isscalar</code>	Determine whether input is scalar
<code>isspace</code>	Array elements that are space characters
<code>isstrprop</code>	Determine whether string is of specified category
<code>isvector</code>	Determine whether input is vector
<code>validatestring</code>	Check validity of text string

String Manipulation

<code>deblank</code>	Strip trailing blanks from end of string
<code>lower</code>	Convert string to lowercase
<code>strjust</code>	Justify character array
<code>strrep</code>	Find and replace substring
<code>strtrim</code>	Remove leading and trailing white space from string
<code>upper</code>	Convert string to uppercase

String Parsing

findstr	Find string within another, longer string
regexp, regexpi	Match regular expression
regexprep	Replace string using regular expression
regexptranslate	Translate string into regular expression
sscanf	Read formatted data from string
strfind	Find one string within another
strread	Read formatted data from string
strtok	Selected parts of string

String Evaluation

eval	Execute string containing MATLAB expression
evalc	Evaluate MATLAB expression with capture
evalin	Execute MATLAB expression in specified workspace

String Comparison

strcmp, strcmpi	Compare strings
strmatch	Find possible matches for string
strncmp, strncmpi	Compare first n characters of strings

Bit-Wise Operations

bitand	Bitwise AND
bitemp	Bitwise complement
bitget	Bit at specified position
bitmax	Maximum double-precision floating-point integer
bitor	Bitwise OR
bitset	Set bit at specified position
bitshift	Shift bits specified number of places
bitxor	Bitwise XOR
swapbytes	Swap byte ordering

Logical Operations

all	Determine whether all array elements are nonzero
and	Find logical AND of array or scalar inputs
any	Determine whether any array elements are nonzero
false	Logical 0 (false)
find	Find indices and values of nonzero elements
isa	Determine whether input is object of given class
iskeyword	Determine whether input is MATLAB keyword
isvarname	Determine whether input is valid variable name
logical	Convert numeric values to logical

not	Find logical NOT of array or scalar input
or	Find logical OR of array or scalar inputs
true	Logical 1 (true)
xor	Logical exclusive-OR

See “Operators and Special Characters” on page 1-61 for logical operators.

Relational Operations

eq	Test for equality
ge	Test for greater than or equal to
gt	Test for greater than
le	Test for less than or equal to
lt	Test for less than
ne	Test for inequality

See “Operators and Special Characters” on page 1-61 for relational operators.

Set Operations

intersect	Find set intersection of two vectors
ismember	Array elements that are members of set
issorted	Determine whether set elements are in sorted order
setdiff	Find set difference of two vectors
setxor	Find set exclusive OR of two vectors

union	Find set union of two vectors
unique	Find unique elements of vector

Date and Time Operations

addtodate	Modify date number by field
calendar	Calendar for specified month
clock	Current time as date vector
cputime	Elapsed CPU time
date	Current date string
datenum	Convert date and time to serial date number
datestr	Convert date and time to string format
datevec	Convert date and time to vector of components
eomday	Last day of month
etime	Time elapsed between date vectors
now	Current date and time
weekday	Day of week

Programming in MATLAB

M-Files and Scripts (p. 1-70)	Declare functions, handle arguments, identify dependencies, etc.
Evaluation (p. 1-71)	Evaluate expression in string, apply function to array, run script file, etc.
Timer (p. 1-72)	Schedule execution of MATLAB commands

Variables and Functions in Memory (p. 1-73)	List files in memory, clear M-files in memory, assign to variable in nondefault workspace, refresh caches
Control Flow (p. 1-74)	if-then-else, for loops, switch-case, try-catch
Error Handling (p. 1-75)	Generate warnings and errors, test for and catch errors, retrieve most recent error message
MEX Programming (p. 1-76)	Compile MEX function from C or Fortran code, list MEX-files in memory, debug MEX-files

M-Files and Scripts

addOptional (inputParser)	Add optional argument to inputParser schema
addParamValue (inputParser)	Add parameter-value argument to inputParser schema
addRequired (inputParser)	Add required argument to inputParser schema
createCopy (inputParser)	Create copy of inputParser object
demdir	List dependent directories of M-file or P-file
depfun	List dependencies of M-file or P-file
echo	Echo M-files during execution
end	Terminate block of code, or indicate last array index
function	Declare M-file function
input	Request user input
inputname	Variable name of function input
inputParser	Construct input parser object

mfilename	Name of currently running M-file
namelengthmax	Maximum identifier length
nargchk	Validate number of input arguments
nargin, nargout	Number of function arguments
nargoutchk	Validate number of output arguments
parse (inputParser)	Parse and validate named inputs
pcode	Create protected M-file (P-file)
script	Script M-file description
syntax	Two ways to call MATLAB functions
varargin	Variable length input argument list
varargout	Variable length output argument list

Evaluation

ans	Most recent answer
arrayfun	Apply function to each element of array
assert	Generate error when condition is violated
builtin	Execute built-in function from overloaded method
cellfun	Apply function to each cell in cell array
echo	Echo M-files during execution
eval	Execute string containing MATLAB expression
evalc	Evaluate MATLAB expression with capture

<code>evalin</code>	Execute MATLAB expression in specified workspace
<code>feval</code>	Evaluate function
<code>iskeyword</code>	Determine whether input is MATLAB keyword
<code>isvarname</code>	Determine whether input is valid variable name
<code>pause</code>	Halt execution temporarily
<code>run</code>	Run script that is not on current path
<code>script</code>	Script M-file description
<code>structfun</code>	Apply function to each field of scalar structure
<code>symvar</code>	Determine symbolic variables in expression
<code>tic, toc</code>	Measure performance using stopwatch timer

Timer

<code>delete (timer)</code>	Remove timer object from memory
<code>disp (timer)</code>	Information about timer object
<code>get (timer)</code>	Timer object properties
<code>isvalid (timer)</code>	Determine whether timer object is valid
<code>set (timer)</code>	Configure or display timer object properties
<code>start</code>	Start timer(s) running
<code>startat</code>	Start timer(s) running at specified time
<code>stop</code>	Stop timer(s)

timer	Construct timer object
timerfind	Find timer objects
timerfindall	Find timer objects, including invisible objects
wait	Wait until timer stops running

Variables and Functions in Memory

ans	Most recent answer
assignin	Assign value to variable in specified workspace
datatipinfo	Produce short description of input variable
genvarname	Construct valid variable name from string
global	Declare global variables
inmem	Names of M-files, MEX-files, Sun Java classes in memory
isglobal	Determine whether input is global variable
memory	Display memory information
mislocked	Determine whether M-file or MEX-file cannot be cleared from memory
mlock	Prevent clearing M-file or MEX-file from memory
munlock	Allow clearing M-file or MEX-file from memory
namelengthmax	Maximum identifier length
pack	Consolidate workspace memory

persistent	Define persistent variable
rehash	Refresh function and file system path caches

Control Flow

break	Terminate execution of <code>for</code> or <code>while</code> loop
case	Execute block of code if condition is <code>true</code>
catch	Specify how to respond to error in <code>try</code> statement
continue	Pass control to next iteration of <code>for</code> or <code>while</code> loop
else	Execute statements if condition is <code>false</code>
elseif	Execute statements if additional condition is <code>true</code>
end	Terminate block of code, or indicate last array index
error	Display message and abort function
for	Execute block of code specified number of times
if	Execute statements if condition is <code>true</code>
otherwise	Default part of <code>switch</code> statement
parfor	Parallel <code>for</code> -loop
return	Return to invoking function
switch	Switch among several cases, based on expression

try	Attempt to execute block of code, and catch errors
while	Repeatedly execute statements while condition is true

Error Handling

addCause (MException)	Append MException objects
assert	Generate error when condition is violated
catch	Specify how to respond to error in try statement
disp (MException)	Display MException object
eq (MException)	Compare MException objects for equality
error	Display message and abort function
error	Query MATLAB software about errors in file input or output
getErrorReport (MException)	Get error message for exception
intwarning	Control state of integer warnings
isequal (MException)	Compare MException objects for equality
last (MException)	Last uncaught exception
lasterr	Last error message
lasterror	Last error message and related information
lastwarn	Last warning message
MException	Construct MException object
ne (MException)	Compare MException objects for inequality
rethrow	Reissue error

rethrow (MException)	Reissue existing exception
throw (MException)	Terminate function and issue exception
try	Attempt to execute block of code, and catch errors
warning	Warning message

MEX Programming

dbmex	Enable MEX-file debugging (on UNIX platforms)
inmem	Names of M-files, MEX-files, Sun Java classes in memory
mex	Compile MEX-function from C/ C++ or Fortran source code
mex.getCompilerConfigurations	Get compiler configuration information for building MEX-files
mexext	Binary MEX-file name extension

Object-Oriented Programming

Classes and Objects (p. 1-77)	Get information about classes and objects
Handle Classes (p. 1-78)	Define and use handle classes
Events and Listeners (p. 1-79)	Define and use events and listeners
Meta-Classes (p. 1-79)	Access information about classes without requiring instances

Classes and Objects

<code>class</code>	Create object or return class of object
<code>classdef</code>	Class definition key words
<code>fieldnames</code>	Field names of structure, or public fields of object
<code>import</code>	Add package or class to current import list
<code>inferiorto</code>	Specify inferior class relationship
<code>isa</code>	Determine whether input is object of given class
<code>isobject</code>	Determine if input is MATLAB object
<code>loadobj</code>	Modify how <code>load</code> function loads objects
<code>methods</code>	Information on class methods
<code>methodsview</code>	Information on class methods in separate window
<code>properties</code>	Display class property names
<code>saveobj</code>	Modify how <code>save</code> function saves objects
<code>subsasgn</code>	Subscripted assignment for objects

<code>subsindex</code>	Subscripted indexing using object as index
<code>suboref</code>	Subscripted reference for objects
<code>substruct</code>	Create structure argument for <code>subsasgn</code> or <code>suboref</code>
<code>superiorto</code>	Establish superior class relationship

Handle Classes

<code>addlistener</code> (handle)	Create event listener
<code>addprop</code> (dynamicprops)	Add dynamic property
<code>delete</code> (handle)	Handle object destructor function
<code>dynamicprops</code>	Abstract class used to derive handle class with dynamic properties
<code>findobj</code> (handle)	Find objects matching specified conditions
<code>findprop</code> (handle)	Find <code>meta.property</code> object associated with property name
<code>get</code> (hgsetget)	Query property values of handle objects derived from <code>hgsetget</code> class
<code>getdisp</code> (hgsetget)	Override to change command window display
<code>handle</code>	Abstract class for deriving handle classes
<code>hgsetget</code>	Abstract class used to derive handle class with set and get methods
<code>isvalid</code> (handle)	Is object valid handle class object
<code>notify</code> (handle)	Notify listeners that event is occurring
<code>relationaloperators</code> (handle)	Equality and sorting of handle objects

<code>set (hgsetget)</code>	Assign property values to handle objects derived from <code>hgsetget</code> class
<code>setdisp (hgsetget)</code>	Override to change command window display

Events and Listeners

<code>addlistener (handle)</code>	Create event listener
<code>event.EventData</code>	Base class for all data objects passed to event listeners
<code>event.listener</code>	Class defining listener objects
<code>event.PropertyEvent</code>	Listener for property events
<code>event.proplistener</code>	Define listener object for property events
<code>events</code>	Display class event names
<code>notify (handle)</code>	Notify listeners that event is occurring

Meta-Classes

<code>meta.class</code>	<code>meta.class</code> class describes MATLAB classes
<code>meta.class.fromName</code>	Return <code>meta.class</code> object associated with named class
<code>meta.DynamicProperty</code>	<code>meta.DynamicProperty</code> class describes dynamic property of MATLAB object
<code>meta.event</code>	<code>meta.event</code> class describes MATLAB class events
<code>meta.method</code>	<code>meta.method</code> class describes MATLAB class methods

<code>meta.package</code>	<code>meta.package</code> class describes MATLAB packages
<code>meta.package.fromName</code>	Return <code>meta.package</code> object for specified package
<code>meta.package.getAllPackages</code>	Get all top-level packages
<code>meta.property</code>	<code>meta.property</code> class describes MATLAB class properties
<code>metaclass</code>	Return <code>meta.class</code> object

File I/O

File Name Construction (p. 1-81)	Get path, directory, filename information; construct filenames
File Opening, Loading, and Saving (p. 1-82)	Open files; transfer data between files and MATLAB workspace
Memory Mapping (p. 1-82)	Access file data via memory map using MATLAB array indexing
Low-Level File I/O (p. 1-82)	Low-level operations that use a file identifier
Text Files (p. 1-83)	Delimited or formatted I/O to text files
XML Documents (p. 1-84)	Documents written in Extensible Markup Language
Spreadsheets (p. 1-84)	Excel and Lotus 1-2-3 files
Scientific Data (p. 1-85)	CDF, FITS, HDF formats
Audio and Audio/Video (p. 1-88)	General audio functions; SparcStation, WAVE, AVI files
Images (p. 1-90)	Graphics files
Internet Exchange (p. 1-91)	URL, FTP, zip, tar, and e-mail

To see a listing of file formats that are readable from MATLAB, go to file formats.

File Name Construction

filemarker	Character to separate file name and internal function name
fileparts	Parts of file name and path
filesep	Directory separator for current platform
fullfile	Build full filename from parts

tempdir	Name of system's temporary directory
tempname	Unique name for temporary file

File Opening, Loading, and Saving

daqread	Read Data Acquisition Toolbox™ (.daq) file
importdata	Load data from disk file
load	Load workspace variables from disk
open	Open files based on extension
save	Save workspace variables to disk
uiimport	Open Import Wizard to import data
winopen	Open file in appropriate application (Windows)

Memory Mapping

disp (memmapfile)	Information about memmapfile object
get (memmapfile)	Memmapfile object properties
memmapfile	Construct memmapfile object

Low-Level File I/O

fclose	Close one or more open files
feof	Test for end-of-file
ferror	Query MATLAB software about errors in file input or output

<code>fgetl</code>	Read line from file, discarding newline characters
<code>fgets</code>	Read line from file, keeping newline characters
<code>fopen</code>	Open file, or obtain information about open files
<code>fprintf</code>	Write formatted data to file
<code>fread</code>	Read binary data from file
<code>frewind</code>	Move file position indicator to beginning of open file
<code>fscanf</code>	Read formatted data from a text file
<code>fseek</code>	Set file position indicator
<code>ftell</code>	File position indicator
<code>fwrite</code>	Write binary data to file

Text Files

<code>csvread</code>	Read comma-separated value file
<code>csvwrite</code>	Write comma-separated value file
<code>dlmread</code>	Read ASCII-delimited file of numeric data into matrix
<code>dlmwrite</code>	Write matrix to ASCII-delimited file
<code>fileread</code>	Return contents of file as string vector
<code>textread</code>	Read data from text file; write to multiple outputs
<code>textscan</code>	Read formatted data from text file or string

XML Documents

xmlread	Parse XML document and return Document Object Model node
xmlwrite	Serialize XML Document Object Model node
xslt	Transform XML document using XSLT engine

Spreadsheets

Microsoft Excel (p. 1-84)	Read and write Microsoft Excel spreadsheet
Lotus 1-2-3 (p. 1-84)	Read and write Lotus WK1 spreadsheet

Microsoft Excel

xlsinfo	Determine whether file contains a Microsoft® Excel® spreadsheet
xlsread	Read Microsoft Excel spreadsheet file
xlswrite	Write Microsoft Excel spreadsheet file

Lotus 1-2-3

wk1info	Determine whether file contains 1-2-3 WK1 worksheet
wk1read	Read Lotus 1-2-3 WK1 spreadsheet file into matrix
wk1write	Write matrix to Lotus 1-2-3 WK1 spreadsheet file

Scientific Data

Common Data Format (p. 1-85)	Work with CDF files
Network Common Data Form (p. 1-85)	Work with netCDF files
Flexible Image Transport System (p. 1-87)	Work with FITS files
Hierarchical Data Format (p. 1-87)	Work with HDF files
Band-Interleaved Data (p. 1-88)	Work with band-interleaved files

Common Data Format

<code>cdfepoch</code>	Construct <code>cdfepoch</code> object for Common Data Format (CDF) export
<code>cdfinfo</code>	Information about Common Data Format (CDF) file
<code>cdfread</code>	Read data from Common Data Format (CDF) file
<code>cdfwrite</code>	Write data to Common Data Format (CDF) file
<code>todatenum</code>	Convert CDF epoch object to MATLAB <code>datenum</code>

Network Common Data Form File Operations

<code>netcdf</code>	Summary of MATLAB Network Common Data Form (netCDF) capabilities
<code>netcdf.abort</code>	Revert recent netCDF file definitions
<code>netcdf.close</code>	Close netCDF file
<code>netcdf.create</code>	Create new netCDF dataset

<code>netcdf.endDef</code>	End netCDF file define mode
<code>netcdf.getConstant</code>	Return numeric value of named constant
<code>netcdf.getConstantNames</code>	Return list of constants known to netCDF library
<code>netcdf.inq</code>	Return information about netCDF file
<code>netcdf.inqLibVers</code>	Return netCDF library version information
<code>netcdf.open</code>	Open netCDF file
<code>netcdf.reDef</code>	Put open netCDF file into define mode
<code>netcdf.setDefaultFormat</code>	Change default netCDF file format
<code>netcdf.setFill</code>	Set netCDF fill mode
<code>netcdf.sync</code>	Synchronize netCDF file to disk

Dimensions

<code>netcdf.defDim</code>	Create netCDF dimension
<code>netcdf.inqDim</code>	Return netCDF dimension name and length
<code>netcdf.inqDimID</code>	Return dimension ID
<code>netcdf.renameDim</code>	Change name of netCDF dimension

Variables

<code>netcdf.defVar</code>	Create netCDF variable
<code>netcdf.getVar</code>	Return data from netCDF variable
<code>netcdf.inqVar</code>	Return information about variable
<code>netcdf.inqVarID</code>	Return ID associated with variable name

netcdf.putVar	Write data to netCDF variable
netcdf.renameVar	Change name of netCDF variable

Attributes

netcdf.copyAtt	Copy attribute to new location
netcdf.delAtt	Delete netCDF attribute
netcdf.getAtt	Return netCDF attribute
netcdf.inqAtt	Return information about netCDF attribute
netcdf.inqAttID	Return ID of netCDF attribute
netcdf.inqAttName	Return name of netCDF attribute
netcdf.putAtt	Write netCDF attribute
netcdf.renameAtt	Change name of attribute

Flexible Image Transport System

fitsinfo	Information about FITS file
fitsread	Read data from FITS file

Hierarchical Data Format

hdf	Summary of MATLAB HDF4 capabilities
hdf5	Summary of MATLAB HDF5 capabilities
hdf5info	Information about HDF5 file
hdf5read	Read HDF5 file
hdf5write	Write data to file in HDF5 format

hdffinfo	Information about HDF4 or HDF-EOS file
hdfread	Read data from HDF4 or HDF-EOS file
hdftool	Browse and import data from HDF4 or HDF-EOS files

Band-Interleaved Data

multibandread	Read band-interleaved data from binary file
multibandwrite	Write band-interleaved data to file

Audio and Audio/Video

Utilities (p. 1-88)	Create audio player object, obtain information about multimedia files, convert to/from audio signal
SPARCstation-Specific Sound (p. 1-89)	Access NeXT/SUN (.au) sound files
Microsoft WAVE Sound (p. 1-89)	Access Microsoft WAVE (.wav) sound files
Audio/Video Interleaved (p. 1-90)	Access Audio/Video interleaved (.avi) sound files

Utilities

audiodevinfo	Information about audio device
audioplayer	Create audioplayer object
audiorecorder	Create audiorecorder object
beep	Produce beep sound

<code>lin2mu</code>	Convert linear audio signal to mu-law
<code>mmfileinfo</code>	Information about multimedia file
<code>mmreader</code>	Create multimedia reader object for reading video files
<code>mmreader.isPlatformSupported</code>	Determine whether <code>mmreader</code> function is available on current platform
<code>mu2lin</code>	Convert mu-law audio signal to linear
<code>read</code>	Read video frame data from multimedia reader object
<code>sound</code>	Convert vector into sound
<code>soundsc</code>	Scale data and play as sound

SPARCstation-Specific Sound

<code>aufinfo</code>	Information about NeXT/SUN (.au) sound file
<code>auread</code>	Read NeXT/SUN (.au) sound file
<code>auwrite</code>	Write NeXT/SUN (.au) sound file

Microsoft WAVE Sound

<code>wavinfo</code>	Information about Microsoft WAVE (.wav) sound file
<code>wavplay</code>	Play recorded sound on PC-based audio output device
<code>wavread</code>	Read Microsoft WAVE (.wav) sound file

wavrecord	Record sound using PC-based audio input device
wavwrite	Write Microsoft WAVE (.wav) sound file

Audio/Video Interleaved

addframe	Add frame to Audio/Video Interleaved (AVI) file
avifile	Create new Audio/Video Interleaved (AVI) file
aviinfo	Information about Audio/Video Interleaved (AVI) file
aviread	Read Audio/Video Interleaved (AVI) file
close (avifile)	Close Audio/Video Interleaved (AVI) file
movie2avi	Create Audio/Video Interleaved (AVI) movie from MATLAB movie

Images

exifread	Read EXIF information from JPEG and TIFF image files
im2java	Convert image to Java image
imfinfo	Information about graphics file
imread	Read image from graphics file
imwrite	Write image to graphics file

Internet Exchange

URL, Zip, Tar, E-Mail (p. 1-91)

Send e-mail, read from given URL, extract from tar or zip file, compress and decompress files

FTP (p. 1-91)

Connect to FTP server, download from server, manage FTP files, close server connection

URL, Zip, Tar, E-Mail

gunzip

Uncompress GNU zip files

gzip

Compress files into GNU zip files

sendmail

Send e-mail message to address list

tar

Compress files into tar file

untar

Extract contents of tar file

unzip

Extract contents of zip file

urlread

Read content at URL

urlwrite

Save contents of URL to file

zip

Compress files into zip file

FTP

ascii

Set FTP transfer type to ASCII

binary

Set FTP transfer type to binary

cd (ftp)

Change current directory on FTP server

close (ftp)

Close connection to FTP server

delete (ftp)

Remove file on FTP server

dir (ftp)

Directory contents on FTP server

ftp	Connect to FTP server, creating FTP object
mget	Download file from FTP server
mkdir (ftp)	Create new directory on FTP server
mput	Upload file or directory to FTP server
rename	Rename file on FTP server
rmdir (ftp)	Remove directory on FTP server

Graphics

Basic Plots and Graphs (p. 1-93)	Linear line plots, log and semilog plots
Plotting Tools (p. 1-94)	GUIs for interacting with plots
Annotating Plots (p. 1-94)	Functions for and properties of titles, axes labels, legends, mathematical symbols
Specialized Plotting (p. 1-95)	Bar graphs, histograms, pie charts, contour plots, function plotters
Bit-Mapped Images (p. 1-99)	Display image object, read and write graphics file, convert to movie frames
Printing (p. 1-99)	Printing and exporting figures to standard formats
Handle Graphics (p. 1-100)	Creating graphics objects, setting properties, finding handles

Basic Plots and Graphs

box	Axes border
errorbar	Plot error bars along curve
hold	Retain current graph in figure
LineStyle (Line Specification)	Line specification string syntax
loglog	Log-log scale plot
plot	2-D line plot
plot3	3-D line plot
plotyy	2-D line plots with y-axes on both left and right side
polar	Polar coordinate plot
semilogx, semilogy	Semilogarithmic plots
subplot	Create axes in tiled positions

Plotting Tools

figurepalette	Show or hide figure palette
pan	Pan view of graph interactively
plotbrowser	Show or hide figure plot browser
plotedit	Interactively edit and annotate plots
plottools	Show or hide plot tools
propertyeditor	Show or hide property editor
rotate3d	Rotate 3-D view using mouse
showplottool	Show or hide figure plot tool
zoom	Turn zooming on or off or magnify by factor

Annotating Plots

annotation	Create annotation objects
clabel	Contour plot elevation labels
datacursormode	Enable or disable interactive data cursor mode
datetick	Date formatted tick labels
gtext	Mouse placement of text in 2-D view
legend	Graph legend for lines and patches
line	Create line object
rectangle	Create 2-D rectangle object
texlabel	Produce TeX format from character string
title	Add title to current axes
xlabel, ylabel, zlabel	Label x -, y -, and z -axis

Specialized Plotting

Area, Bar, and Pie Plots (p. 1-95)	1-D, 2-D, and 3-D graphs and charts
Contour Plots (p. 1-96)	Unfilled and filled contours in 2-D and 3-D
Direction and Velocity Plots (p. 1-96)	Comet, compass, feather and quiver plots
Discrete Data Plots (p. 1-96)	Stair, step, and stem plots
Function Plots (p. 1-96)	Easy-to-use plotting utilities for graphing functions
Histograms (p. 1-97)	Plots for showing distributions of data
Polygons and Surfaces (p. 1-97)	Functions to generate and plot surface patches in two or more dimensions
Scatter/Bubble Plots (p. 1-98)	Plots of point distributions
Animation (p. 1-98)	Functions to create and play movies of plots

Area, Bar, and Pie Plots

area	Filled area 2-D plot
bar, barh	Plot bar graph (vertical and horizontal)
bar3, bar3h	Plot 3-D bar chart
pareto	Pareto chart
pie	Pie chart
pie3	3-D pie chart

Contour Plots

<code>contour</code>	Contour plot of matrix
<code>contour3</code>	3-D contour plot
<code>contourc</code>	Low-level contour plot computation
<code>contourf</code>	Filled 2-D contour plot
<code>ezcontour</code>	Easy-to-use contour plotter
<code>ezcontourf</code>	Easy-to-use filled contour plotter

Direction and Velocity Plots

<code>comet</code>	2-D comet plot
<code>comet3</code>	3-D comet plot
<code>compass</code>	Plot arrows emanating from origin
<code>feather</code>	Plot velocity vectors
<code>quiver</code>	Quiver or velocity plot
<code>quiver3</code>	3-D quiver or velocity plot

Discrete Data Plots

<code>stairs</code>	Stairstep graph
<code>stem</code>	Plot discrete sequence data
<code>stem3</code>	Plot 3-D discrete sequence data

Function Plots

<code>ezcontour</code>	Easy-to-use contour plotter
<code>ezcontourf</code>	Easy-to-use filled contour plotter
<code>ezmesh</code>	Easy-to-use 3-D mesh plotter

ezmeshc	Easy-to-use combination mesh/contour plotter
ezplot	Easy-to-use function plotter
ezplot3	Easy-to-use 3-D parametric curve plotter
ezpolar	Easy-to-use polar coordinate plotter
ezsurf	Easy-to-use 3-D colored surface plotter
ezsurfz	Easy-to-use combination surface/contour plotter
fplot	Plot function between specified limits

Histograms

hist	Histogram plot
histc	Histogram count
rose	Angle histogram plot

Polygons and Surfaces

convhull	Convex hull
cylinder	Generate cylinder
delaunay	Delaunay triangulation
delaunay3	3-D Delaunay tessellation
delaunayn	N-D Delaunay tessellation
dsearch	Search Delaunay triangulation for nearest point
dsearchn	N-D nearest point search
ellipsoid	Generate ellipsoid

fill	Filled 2-D polygons
fill3	Filled 3-D polygons
inpolygon	Points inside polygonal region
pcolor	Pseudocolor (checkerboard) plot
polyarea	Area of polygon
rectint	Rectangle intersection area
ribbon	Ribbon plot
slice	Volumetric slice plot
sphere	Generate sphere
tsearch	Search for enclosing Delaunay triangle
tsearchn	N-D closest simplex search
voronoi	Voronoi diagram
waterfall	Waterfall plot

Scatter/Bubble Plots

plotmatrix	Scatter plot matrix
scatter	Scatter plot
scatter3	3-D scatter plot

Animation

frame2im	Return image data associated with movie frame
getframe	Capture movie frame
im2frame	Convert image to movie frame

movie	Play recorded movie frames
noanimate	Change EraseMode of all objects to normal

Bit-Mapped Images

frame2im	Return image data associated with movie frame
im2frame	Convert image to movie frame
im2java	Convert image to Java image
image	Display image object
imagesc	Scale data and display image object
imfinfo	Information about graphics file
imformats	Manage image file format registry
imread	Read image from graphics file
imwrite	Write image to graphics file
ind2rgb	Convert indexed image to RGB image

Printing

hgexport	Export figure
orient	Hardcopy paper orientation
print, printopt	Print figure or save to file and configure printer defaults
printdlg	Print dialog box
printpreview	Preview figure to print
saveas	Save figure or Simulink block diagram using specified format

Handle Graphics

Graphics Object Identification (p. 1-100)	Find and manipulate graphics objects via their handles
Object Creation (p. 1-101)	Constructors for core graphics objects
Plot Objects (p. 1-101)	Property descriptions for plot objects
Figure Windows (p. 1-102)	Control and save figures
Axes Operations (p. 1-103)	Operate on axes objects
Object Property Operations (p. 1-103)	Query, set, and link object properties

Graphics Object Identification

allchild	Find all children of specified objects
ancestor	Ancestor of graphics object
copyobj	Copy graphics objects and their descendants
delete	Remove files or graphics objects
findall	Find all graphics objects
findfigs	Find visible offscreen figures
findobj	Locate graphics objects with specific properties
gca	Current axes handle
gcbf	Handle of figure containing object whose callback is executing
gcbo	Handle of object whose callback is executing
gco	Handle of current object
get	Query Handle Graphics® object properties

ishandle	Determine whether input is valid Handle Graphics handle
propedit	Open Property Editor
set	Set Handle Graphics object properties

Object Creation

axes	Create axes graphics object
figure	Create figure graphics object
hggroup	Create hggroup object
hgtransform	Create hgtransform graphics object
image	Display image object
light	Create light object
line	Create line object
patch	Create patch graphics object
rectangle	Create 2-D rectangle object
root object	Root
surface	Create surface object
text	Create text object in current axes
uicontextmenu	Create context menu

Plot Objects

Annotation Arrow Properties	Define annotation arrow properties
Annotation Doublearrow Properties	Define annotation doublearrow properties
Annotation Ellipse Properties	Define annotation ellipse properties
Annotation Line Properties	Define annotation line properties

Annotation Rectangle Properties	Define annotation rectangle properties
Annotation Textarrow Properties	Define annotation textarrow properties
Annotation Textbox Properties	Define annotation textbox properties
Areaseries Properties	Define areaseries properties
Barseries Properties	Define barseries properties
Contourgroup Properties	Define contourgroup properties
Errorbarseries Properties	Define errorbarseries properties
Image Properties	Define image properties
Lineseries Properties	Define lineseries properties
Quivergroup Properties	Define quivergroup properties
Scattergroup Properties	Define scattergroup properties
Stairseries Properties	Define stairseries properties
Stemseries Properties	Define stemseries properties
Surfaceplot Properties	Define surfaceplot properties

Figure Windows

clf	Clear current figure window
close	Remove specified figure
closereq	Default figure close request function
drawnow	Flush event queue and update figure window
gcf	Current figure handle
hgload	Load Handle Graphics object hierarchy from file
hgsave	Save Handle Graphics object hierarchy to file

newplot	Determine where to draw graphics objects
opengl	Control OpenGL® rendering
refresh	Redraw current figure
saveas	Save figure or Simulink block diagram using specified format

Axes Operations

axis	Axis scaling and appearance
box	Axes border
cla	Clear current axes
gca	Current axes handle
grid	Grid lines for 2-D and 3-D plots
ishold	Current hold state
makehgtform	Create 4-by-4 transform matrix

Object Property Operations

get	Query Handle Graphics object properties
linkaxes	Synchronize limits of specified 2-D axes
linkprop	Keep same value for corresponding properties
refreshdata	Refresh data in graph when data source is specified
set	Set Handle Graphics object properties

3-D Visualization

Surface and Mesh Plots (p. 1-104)	Plot matrices, visualize functions of two variables, specify colormap
View Control (p. 1-106)	Control the camera viewpoint, zooming, rotation, aspect ratio, set axis limits
Lighting (p. 1-108)	Add and control scene lighting
Transparency (p. 1-108)	Specify and control object transparency
Volume Visualization (p. 1-108)	Visualize gridded volume data

Surface and Mesh Plots

Surface and Mesh Creation (p. 1-104)	Visualizing gridded and triangulated data as lines and surfaces
Domain Generation (p. 1-105)	Gridding data and creating arrays
Color Operations (p. 1-105)	Specifying, converting, and manipulating color spaces, colormaps, colorbars, and backgrounds

Surface and Mesh Creation

hidden	Remove hidden lines from mesh plot
mesh, meshc, meshz	Mesh plots
peaks	Example function of two variables
surf, surfc	3-D shaded surface plot
surface	Create surface object
surfl	Surface plot with colormap-based lighting
tetramesh	Tetrahedron mesh plot

trimesh	Triangular mesh plot
triplot	2-D triangular plot
trisurf	Triangular surface plot

Domain Generation

griddata	Data gridding
meshgrid	Generate X and Y arrays for 3-D plots

Color Operations

brighten	Brighten or darken colormap
caxis	Color axis scaling
colorbar	Colorbar showing color scale
colordef	Set default property values to display different color schemes
colormap	Set and get current colormap
colormapeditor	Start colormap editor
ColorSpec (Color Specification)	Color specification
contrast	Grayscale colormap for contrast enhancement
graymon	Set default figure properties for grayscale monitors
hsv2rgb	Convert HSV colormap to RGB colormap
rgb2hsv	Convert RGB colormap to HSV colormap
rgbplot	Plot colormap
shading	Set color shading properties
spinmap	Spin colormap

surfnorm	Compute and display 3-D surface normals
whitebg	Change axes background color

View Control

Camera Viewpoint (p. 1-106)	Orbiting, dollying, pointing, rotating camera positions and setting fields of view
Aspect Ratio and Axis Limits (p. 1-107)	Specifying what portions of axes to view and how to scale them
Object Manipulation (p. 1-107)	Panning, rotating, and zooming views
Region of Interest (p. 1-107)	Interactively identifying rectangular regions

Camera Viewpoint

camdolly	Move camera position and target
cameratoolbar	Control camera toolbar programmatically
camlookat	Position camera to view object or group of objects
camorbit	Rotate camera position around camera target
campan	Rotate camera target around camera position
campos	Set or query camera position
camproj	Set or query projection type
camroll	Rotate camera about view axis
camtarget	Set or query location of camera target

camup	Set or query camera up vector
camva	Set or query camera view angle
camzoom	Zoom in and out on scene
makehgtform	Create 4-by-4 transform matrix
view	Viewpoint specification
viewmtx	View transformation matrices

Aspect Ratio and Axis Limits

daspect	Set or query axes data aspect ratio
pbaspect	Set or query plot box aspect ratio
xlim, ylim, zlim	Set or query axis limits

Object Manipulation

pan	Pan view of graph interactively
reset	Reset graphics object properties to their defaults
rotate	Rotate object in specified direction
rotate3d	Rotate 3-D view using mouse
selectmoveresize	Select, move, resize, or copy axes and uicontrol graphics objects
zoom	Turn zooming on or off or magnify by factor

Region of Interest

dragrect	Drag rectangles with mouse
rbbox	Create rubberband box for area selection

Lighting

camlight	Create or move light object in camera coordinates
diffuse	Calculate diffuse reflectance
light	Create light object
lightangle	Create or position <code>light</code> object in spherical coordinates
lighting	Specify lighting algorithm
material	Control reflectance properties of surfaces and patches
specular	Calculate specular reflectance

Transparency

alim	Set or query axes alpha limits
alpha	Set transparency properties for objects in current axes
alphamap	Specify figure alphamap (transparency)

Volume Visualization

coneplot	Plot velocity vectors as cones in 3-D vector field
contourslice	Draw contours in volume slice planes
curl	Compute curl and angular velocity of vector field
divergence	Compute divergence of vector field
flow	Simple function of three variables

interpstreamspeed	Interpolate stream-line vertices from flow speed
isocaps	Compute isosurface end-cap geometry
isocolors	Calculate isosurface and patch colors
isonormals	Compute normals of isosurface vertices
isosurface	Extract isosurface data from volume data
reducepatch	Reduce number of patch faces
reducevolume	Reduce number of elements in volume data set
shrinkfaces	Reduce size of patch faces
slice	Volumetric slice plot
smooth3	Smooth 3-D data
stream2	Compute 2-D streamline data
stream3	Compute 3-D streamline data
streamline	Plot streamlines from 2-D or 3-D vector data
streamparticles	Plot stream particles
streamribbon	3-D stream ribbon plot from vector volume data
streamslice	Plot streamlines in slice planes
streamtube	Create 3-D stream tube plot
subvolume	Extract subset of volume data set
surf2patch	Convert surface data to patch data
volumebounds	Coordinate and color limits for volume data

GUI Development

Predefined Dialog Boxes (p. 1-110)	Dialog boxes for error, user input, waiting, etc.
User Interface Deployment (p. 1-111)	Open GUIs, create the handles structure
User Interface Development (p. 1-111)	Start GUIDE, manage application data, get user input
User Interface Objects (p. 1-112)	Create GUI components
Objects from Callbacks (p. 1-113)	Find object handles from within callbacks functions
GUI Utilities (p. 1-113)	Move objects, wrap text
Program Execution (p. 1-114)	Wait and resume based on user input

Predefined Dialog Boxes

dialog	Create and display empty dialog box
errordlg	Create and open error dialog box
export2wsdlg	Export variables to workspace
helpdlg	Create and open help dialog box
inputdlg	Create and open input dialog box
listdlg	Create and open list-selection dialog box
msgbox	Create and open message box
printdlg	Print dialog box
printpreview	Preview figure to print
questdlg	Create and open question dialog box
uigetdir	Open standard dialog box for selecting directory

<code>uigetfile</code>	Open standard dialog box for retrieving files
<code>uigetpref</code>	Open dialog box for retrieving preferences
<code>uiopen</code>	Open file selection dialog box with appropriate file filters
<code>uiputfile</code>	Open standard dialog box for saving files
<code>uisave</code>	Open standard dialog box for saving workspace variables
<code>uisetcolor</code>	Open standard dialog box for setting object's <code>ColorSpec</code>
<code>uisetfont</code>	Open standard dialog box for setting object's font characteristics
<code>waitbar</code>	Open or update a wait bar dialog box
<code>warndlg</code>	Open warning dialog box

User Interface Deployment

<code>guidata</code>	Store or retrieve GUI data
<code>guihandles</code>	Create structure of handles
<code>movegui</code>	Move GUI figure to specified location on screen
<code>openfig</code>	Open new copy or raise existing copy of saved figure

User Interface Development

<code>addpref</code>	Add preference
<code>getappdata</code>	Value of application-defined data
<code>getpref</code>	Preference

<code>ginput</code>	Graphical input from mouse or cursor
<code>guidata</code>	Store or retrieve GUI data
<code>guide</code>	Open GUI Layout Editor
<code>inspect</code>	Open Property Inspector
<code>isappdata</code>	True if application-defined data exists
<code>ispref</code>	Test for existence of preference
<code>rmappdata</code>	Remove application-defined data
<code>rmpref</code>	Remove preference
<code>setappdata</code>	Specify application-defined data
<code>setpref</code>	Set preference
<code>uigetpref</code>	Open dialog box for retrieving preferences
<code>uisetpref</code>	Manage preferences used in <code>uigetpref</code>
<code>waitfor</code>	Wait for condition before resuming execution
<code>waitforbuttonpress</code>	Wait for key press or mouse-button click

User Interface Objects

<code>menu</code>	Generate menu of choices for user input
<code>uibbuttongroup</code>	Create container object to exclusively manage radio buttons and toggle buttons
<code>uicontextmenu</code>	Create context menu
<code>uicontrol</code>	Create user interface control object

<code>uimenu</code>	Create menus on figure windows
<code>uipanel</code>	Create panel container object
<code>uipushtool</code>	Create push button on toolbar
<code>uitable</code>	Create 2-D graphic table GUI component
<code>uitoggletool</code>	Create toggle button on toolbar
<code>uitoolbar</code>	Create toolbar on figure

Objects from Callbacks

<code>findall</code>	Find all graphics objects
<code>findfigs</code>	Find visible offscreen figures
<code>findobj</code>	Locate graphics objects with specific properties
<code>gcbf</code>	Handle of figure containing object whose callback is executing
<code>gcbo</code>	Handle of object whose callback is executing

GUI Utilities

<code>getpixelposition</code>	Get component position in pixels
<code>listfonts</code>	List available system fonts
<code>selectmoveresize</code>	Select, move, resize, or copy axes and uicontrol graphics objects
<code>setpixelposition</code>	Set component position in pixels
<code>textwrap</code>	Wrapped string matrix for given uicontrol
<code>uistack</code>	Reorder visual stacking order of objects

Program Execution

uiresume

Resume execution of blocked M-file

uiwait

Block execution and wait for resume

External Interfaces

Shared Libraries (p. 1-115)	Access functions stored in external shared library files
Java (p. 1-116)	Work with objects constructed from Java API and third-party class packages
.NET (p. 1-117)	Work with objects constructed from .NET assemblies
Component Object Model and ActiveX (p. 1-117)	Integrate COM components into your application
Web Services (p. 1-120)	Communicate between applications over a network using SOAP and WSDL
Serial Port Devices (p. 1-120)	Read and write to devices connected to your computer's serial port

See also MATLAB C and Fortran API Reference for functions you can use in external routines that interact with MATLAB programs and the data in MATLAB workspaces.

Shared Libraries

calllib	Call function in shared library
libfunctions	Return information on functions in shared library
libfunctionsview	View functions in shared library
libisloaded	Determine if shared library is loaded
libpointer	Create pointer object for use with shared libraries
libstruct	Create structure pointer for use with shared libraries

loadlibrary	Load shared library into MATLAB software
unloadlibrary	Unload shared library from memory

Java

class	Create object or return class of object
fieldnames	Field names of structure, or public fields of object
import	Add package or class to current import list
inspect	Open Property Inspector
isa	Determine whether input is object of given class
isjava	Determine whether input is Sun Java object
javaaddpath	Add entries to dynamic Sun Java class path
javaArray	Construct Sun Java array
jvachk	Generate error message based on Sun Java feature support
javaclasspath	Get and set Sun Java class path
javaMethod	Call Sun Java method
javaMethodEDT	Call Sun Java method from Event Dispatch Thread (EDT)
javaObject	Construct Sun Java object
javaObjectEDT	Construct Sun Java object on Event Dispatch Thread (EDT)
javarmpath	Remove entries from dynamic Sun Java class path
methods	Information on class methods

methodsview	Information on class methods in separate window
usejava	Determine whether Sun Java feature is supported in MATLAB software

.NET

NET.addAssembly	Make .NET assembly visible to MATLAB
NET.convertArray	Convert MATLAB array to .NET array
NET.createArray	Create single or multidimensional .NET array
NET.createGeneric	Create instance of specialized .NET generic type
NET.GenericClass	Represent parameterized generic type definitions
NET.GenericClass	Constructor for NET.GenericClass class

Component Object Model and ActiveX

actxcontrol	Create Microsoft® ActiveX® control in figure window
actxcontrollist	List all currently installed Microsoft ActiveX controls
actxcontrolselect	Open GUI to create Microsoft ActiveX control
actxGetRunningServer	Get handle to running instance of Automation server
actxserver	Create COM server
addproperty	Add custom property to COM object

class	Create object or return class of object
delete (COM)	Remove COM control or server
deleteproperty	Remove custom property from COM object
enableservice	Enable, disable, or report status of Automation server
eventlisteners	List all event handler functions registered for COM object
events (COM)	List of events COM object can trigger
Execute	Execute MATLAB command in Automation server
Feval (COM)	Evaluate MATLAB function in Automation server
fieldnames	Field names of structure, or public fields of object
get (COM)	Get property value from interface, or display properties
GetCharArray	Get character array from Automation server
GetFullMatrix	Get matrix from Automation server
GetVariable	Get data from variable in Automation server workspace
GetWorkspaceData	Get data from Automation server workspace
inspect	Open Property Inspector
interfaces	List custom interfaces to COM server
invoke	Invoke method on COM object or interface, or display methods
isa	Determine whether input is object of given class
iscom	Is input COM object

isevent	True if COM object event
isinterface	Is input COM interface
ismethod	Determine whether input is COM object method
isprop	Determine whether input is COM object property
load (COM)	Initialize control object from file
MaximizeCommandWindow	Open Automation server window
methods	Information on class methods
methodsview	Information on class methods in separate window
MinimizeCommandWindow	Minimize size of Automation server window
move	Move or resize control in parent window
propedit (COM)	Open built-in property page for control
PutCharArray	Store character array in Automation server
PutFullMatrix	Store matrix in Automation server
PutWorkspaceData	Store data in Automation server workspace
Quit (COM)	Terminate MATLAB Automation server
registerevent	Register event handler for COM object event at run-time
release	Release COM interface
save (COM)	Serialize control object to file
set (COM)	Set object or interface property to specified value

unregisterallevents

Unregister all event handlers for COM object event at run-time

unregisterevent

Unregister event handler for COM object event at run-time

Web Services

callSoapService

Send SOAP message to endpoint

createClassFromWsdll

Create MATLAB class based on WSDL document

createSoapMessage

Create SOAP message to send to server

parseSoapResponse

Convert response string from SOAP server into MATLAB types

Serial Port Devices

instrcallback

Event information when event occurs

instrfind

Read serial port objects from memory to MATLAB workspace

instrfindall

Find visible and hidden serial port objects

readasync

Read data asynchronously from device

record

Record data and event information to file

serial

Create serial port object

serial.clear

Remove serial port object from MATLAB workspace

serial.delete

Remove serial port object from memory

<code>serial.fgetl</code>	Read line of text from device and discard terminator
<code>serial.fgets</code>	Read line of text from device and include terminator
<code>serial.fopen</code>	Connect serial port object to device
<code>serial.fprintf</code>	Write text to device
<code>serial.fread</code>	Read binary data from device
<code>serial.fscanf</code>	Read data from device, and format as text
<code>serial.fwrite</code>	Write binary data to device
<code>serial.get</code>	Serial port object properties
<code>serial.isvalid</code>	Determine whether serial port objects are valid
<code>serial.length</code>	Length of serial port object array
<code>serial.load</code>	Load serial port objects and variables into MATLAB workspace
<code>serial.save</code>	Save serial port objects and variables to MAT-file
<code>serial.set</code>	Configure or display serial port object properties
<code>serial.size</code>	Size of serial port object array
<code>serialbreak</code>	Send break to device connected to serial port
<code>stopasync</code>	Stop asynchronous read and write operations

Alphabetical List

Arithmetic Operators + - * / \ ^ '
Relational Operators < > <= >= == ~=
Logical Operators: Elementwise & | ~
Logical Operators: Short-circuit && ||
Special Characters [] () { } = ' , ; : % ! @
colon (:)
abs
accumarray
acos
acosd
acosh
acot
acotd
acoth
acsc
acscd
acsch
actxcontrol
actxcontrollist
actxcontrolselect
actxGetRunningServer
actxserver
addCause (MException)
addevent
addframe
addlistener (handle)
addOptional (inputParser)
addParamValue (inputParser)

addpath
addpref
addprop (dynamicprops)
addproperty
addRequired (inputParser)
addsample
addsampletocollection
addtodate
addts
airy
align
alim
all
allchild
alpha
alphamap
amd
ancestor
and
angle
annotation
Annotation Arrow Properties
Annotation Doublearrow Properties
Annotation Ellipse Properties
Annotation Line Properties
Annotation Rectangle Properties
Annotation Textarrow Properties
Annotation Textbox Properties
ans
any
area
Areaseries Properties
arrayfun
ascii
asec
asecd
asech

asin
asind
asinh
assert
assignin
atan
atan2
atand
atanh
audiodevinfo
audioplayer
audiorecorder
auidinfo
auread
auwrite
avifile
aviinfo
aviread
axes
Axes Properties
axis
balance
bar, barh
bar3, bar3h
Barseries Properties
baryToCart
base2dec
beep
bench
besselh
besseli
besselj
besselk
bessely
beta
betainc
betaincinv

betaln
bicg
bicgstab
bicgstabl
bin2dec
binary
bitand
bitcmp
bitget
bitmax
bitor
bitset
bitshift
bitxor
blanks
blkdiag
box
break
brighten
brush
bsxfun
builddocsearchdb
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pack

Purpose Consolidate workspace memory

Syntax

```
pack
pack filename
pack('filename')
```

Description `pack` frees up needed space by reorganizing information so that it only uses the minimum memory required. All variables from your base and global workspaces are preserved. Any persistent variables that are defined at the time are set to their default value (the empty matrix, []).

The MATLAB software temporarily stores your workspace data in a file called `tp#####.mat` (where ##### is a numeric value) that is located in your temporary directory. (You can use the command `dir(tempdir)` to see the files in this directory).

`pack filename` frees space in memory, temporarily storing workspace data in a file specified by `filename`. This file resides in your current working directory and, unless specified otherwise, has a `.mat` file extension.

`pack('filename')` is the function form of `pack`.

Remarks You can only run `pack` from the MATLAB command line.

If you specify a `filename` argument, that file must reside in a directory for which you have write permission.

The `pack` function does not affect the amount of memory allocated to the MATLAB process. You must quit MATLAB to free up this memory.

Since MATLAB uses a heap method of memory management, extended MATLAB sessions may cause memory to become fragmented. When memory is fragmented, there may be plenty of free space, but not enough contiguous memory to store a new large variable.

If you get the `Out of memory` message from MATLAB, the `pack` function may find you some free memory without forcing you to delete variables.

The `pack` function frees space by

- Saving all variables in the base and global workspaces to a temporary file.
- Clearing all variables and functions from memory.
- Reloading the base and global workspace variables back from the temporary file and then deleting the file.

If you use `pack` and there is still not enough free memory to proceed, you must clear some variables. If you run out of memory often, you can allocate larger matrices earlier in the MATLAB session and use these system-specific tips:

- When running MATLAB on The Open Group UNIX platforms, ask your system manager to increase your swap space.
- On Microsoft Windows platforms, increase virtual memory using the Windows Control Panel.

To maintain persistent variables when you run `pack`, use `mlock` in the function.

Examples

Change the current directory to one that is writable, run `pack`, and return to the previous directory.

```
cwd = pwd;  
cd(tempdir);  
pack  
cd(cwd)
```

See Also

`clear`, `memory`

padecoeff

Purpose Padé approximation of time delays

Syntax [num,den] = padecoeff(T,N)

Description [num,den] = padecoeff(T,N) returns the Nth-order Padé approximation of the continuous-time delay T in transfer function form. The row vectors num and den contain the numerator and denominator coefficients in descending powers of T . Both are Nth-order polynomials.

Class support for input T :

float: double, single

Class Support Input T support floating-point values of type single or double.

References [1] Golub, G. H. and C. F. Van Loan *Matrix Computations*, 3rd ed. Johns Hopkins University Press, Baltimore: 1996, pp. 572–574.

See Also pade

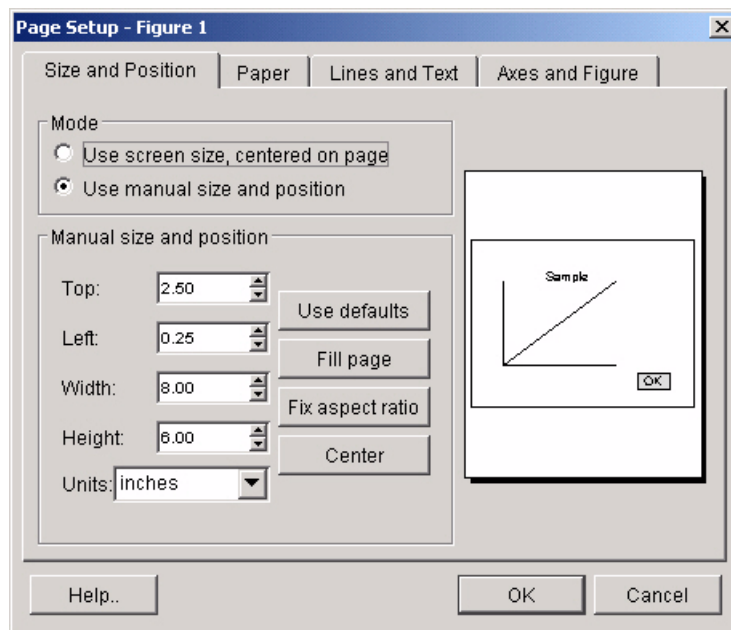
Purpose Page setup dialog box

Syntax `dlg = pagesetupdlg(fig)`

Note This function is obsolete. Use `printpreview` instead.

Description `dlg = pagesetupdlg(fig)` creates a dialog box from which a set of pagelayout properties for the figure window, `fig`, can be set. `pagesetupdlg` implements the "Page Setup..." option in the **Figure File Menu**.

`pagesetupdlg` supports setting the layout for a single figure. `fig` must be a single figure handle, not a vector of figures or a simulink diagram.



pagesetupdlg


See Also

printdlg, printpreview, printopt

Purpose

Pan view of graph interactively

GUI Alternatives

Use the **Pan** tool  on the figure toolbar to enable and disable pan mode on a plot, or select **Pan** from the figure's **Tools** menu. For details, see “Panning — Shifting Your View of the Graph” in the MATLAB Graphics documentation.

Syntax

```
pan on
pan xon
pan yon
pan off
pan
pan(figure_handle,...)
h = pan(figure_handle)
```

Description

`pan on` turns on mouse-based panning in the current figure.

`pan xon` turns on panning only in the x direction in the current figure.

`pan yon` turns on panning only in the y direction in the current figure.

`pan off` turns panning off in the current figure.

`pan` toggles the pan state in the current figure on or off.

`pan(figure_handle,...)` sets the pan state in the specified figure.

`h = pan(figure_handle)` returns the figure's pan *mode object* for the figure `figure_handle` for you to customize the mode's behavior.

Using Pan Mode Objects

Access the following properties of pan mode objects via `get` and modify some of them using `set`:

- *Enable* 'on' | 'off' — Specifies whether this figure mode is currently enabled on the figure
- *Motion* 'horizontal' | 'vertical' | 'both' — The type of panning enabled for the figure

- `FigureHandle` <handle> — The associated figure handle, a read-only property that cannot be set

Pan Mode Callbacks

You can program the following callbacks for pan mode operations.

- `ButtonDownFilter` <function_handle> — Function to intercept `ButtonDown` events

The application can inhibit the panning operation under circumstances the programmer defines, depending on what the callback returns. The input function handle should reference a function with two implicit arguments (similar to Handle Graphics object callbacks):

```
function [res] = myfunction(obj,event_obj)
% obj          handle to the object that has been clicked on
% event_obj    event data (empty in this release)
% res [output] a logical flag to determine whether the pan
%              operation should take place or the 'ButtonDownFcn'
%              property of the object should take precedence
```

- `ActionPreCallback` <function_handle> — Function to execute before panning

Set this callback to if you need to execute code when a pan operation begins. The function handle should reference a function with two implicit arguments (similar to Handle Graphics object callbacks):

```
function myfunction(obj,event_obj)
% obj          handle to the figure that has been clicked on
% event_obj    object containing struct of event data
```

The event data struct has the following field:

Axes	The handle of the axes that is being panned
------	---

- `ActionPostCallback` <function_handle> — Function to execute after panning

Set this callback if you need to execute code when a pan operation ends. The function handle should reference a function with two implicit arguments (similar to Handle Graphics object callbacks):

```
function myfunction(obj,event_obj)
% obj          handle to the figure that has been clicked on
% event_obj    object containing struct of event data (same as the
%              event data of the 'ActionPreCallback' callback)
```

Pan Mode Utility Functions

The following functions in pan mode query and set certain of its properties.

- `flags = isAllowAxesPan(h,axes)` — Function querying permission to pan axes

Calling the function `isAllowAxesPan` on the pan object, `h`, with a vector of axes handles, `axes`, as input returns a logical array of the same dimension as the axes handle vector, which indicates whether a pan operation is permitted on the axes objects.

- `setAllowAxesPan(h,axes,flag)` — Function to set permission to pan axes

Calling the function `setAllowAxesPan` on the pan object, `h`, with a vector of axes handles, `axes`, and a logical scalar, `flag`, either allows or disallows a pan operation on the axes objects.

- `info = getAxesPanMotion(h,axes)` — Function to get style of pan operations

Calling the function `getAxesPanMotion` on the pan object, `h`, with a vector of axes handles, `axes`, as input will return a character cell array of the same dimension as the axes handle vector, which indicates the type of pan operation for each axes. Possible values for the type of operation are 'horizontal', 'vertical' or 'both'.

- `setAxesPanMotion(h, axes, style)` — Function to set style of pan operations

Calling the function `setAxesPanMotion` on the pan object, `h`, with a vector of axes handles, `axes`, and a character array, `style`, sets the style of panning on each axes.

Examples

Example 1 – Entering Pan Mode

Plot a graph and turn on Pan mode:

```
plot(magic(10));  
pan on  
% pan on the plot
```

Example 2 – Constrained Pan

Constrain pan to *x*-axis using `set`:

```
plot(magic(10));  
h = pan;  
set(h, 'Motion', 'horizontal', 'Enable', 'on');  
% pan on the plot in the horizontal direction.
```

Example 3 – Constrained Pan in Subplots

Create four axes as subplots and give each one a different panning behavior:

```
ax1 = subplot(2,2,1);  
plot(1:10);  
h = pan;  
ax2 = subplot(2,2,2);  
plot(rand(3));  
setAllowAxesPan(h, ax2, false);  
ax3 = subplot(2,2,3);  
plot(peaks);  
setAxesPanMotion(h, ax3, 'horizontal');  
ax4 = subplot(2,2,4);
```

```

contour(peaks);
setAxesPanMotion(h,ax4,'vertical');
% pan on the plots.

```

Example 4 – Coding a ButtonDown Callback

Create a buttonDown callback for pan mode objects to trigger. Copy the following code to a new M-file, execute it, and observe panning behavior:

```

function demo
% Allow a line to have its own 'ButtonDownFcn' callback.
hLine = plot(rand(1,10));
set(hLine,'ButtonDownFcn','disp(''This executes'')');
set(hLine,'Tag','DoNotIgnore');
h = pan;
set(h,'ButtonDownFilter',@mycallback);
set(h,'Enable','on');
% mouse click on the line
%
function [flag] = mycallback(obj,event_obj)
% If the tag of the object is 'DoNotIgnore', then return true.
% Indicate what the target is
disp(['Clicked ' get(obj,'Type') ' object'])
objTag = get(obj,'Tag');
if strcmpi(objTag,'DoNotIgnore')
    flag = true;
else
    flag = false;
end

```

Example 5 – Coding Pre- and Post-Callback Behavior

Create callbacks for pre- and post-ButtonDown events for pan mode objects to trigger. Copy the following code to a new M-file, execute it, and observe panning behavior:

```

function demo
% Listen to pan events

```

```
plot(1:10);
h = pan;
set(h,'ActionPreCallback',@myprecallback);
set(h,'ActionPostCallback',@mypostcallback);
set(h,'Enable','on');
%
function myprecallback(obj,evd)
disp('A pan is about to occur.');
```

```
%
function mypostcallback(obj,evd)
newLim = get(evd.Axes,'XLim');
msgbox(sprintf('The new X-Limits are [%.2f %.2f].',newLim));
```

Example 6 – Creating a Context Menu for Pan Mode

Coding a context menu that lets the user to switch to Zoom mode by right-clicking:

```
figure; plot(magic(10));
hCM = uicontextmenu;
hMenu = uimenu('Parent',hCM,'Label','Switch to zoom',...
    'Callback','zoom(gcf,'on')');
```

```
hPan = pan(gcf);
set(hPan,'UIContextMenu',hCM);
pan('on')
```

You cannot add items to the built-in pan context menu, but you can replace it with your own.

Remarks

You can create a pan mode object once and use it to customize the behavior of different axes, as Example 3 illustrates. You can also change its callback functions on the fly.

Note Do not change figure callbacks within an interactive mode. While a mode is active (when panning, zooming, etc.), you will receive a warning if you attempt to change any of the figure's callbacks and the operation will not succeed. The one exception to this rule is the figure `WindowButtonMotionFcn` callback, which can be changed from within a mode. Therefore, if you are creating a GUI that updates a figure's callbacks, the GUI should some keep track of which interactive mode is active, if any, before attempting to do this.

When you assign different pan behaviors to different subplot axes via a mode object and then link them using the `linkaxes` function, the behavior of the axes you manipulate with the mouse carries over to the linked axes, regardless of the behavior you previously set for the other axes.

See Also

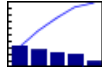
`zoom`, `linkaxes`, `rotate3d`

“Object Manipulation” on page 1-107 for related functions


pareto

Purpose

Pareto chart



GUI Alternatives

To graph selected variables, use the Plot Selector  in the Workspace Browser, or use the Figure Palette Plot Catalog. Manipulate graphs in *plot edit* mode with the Property Editor. For details, see Plotting Tools — Interactive Plotting in the MATLAB Graphics documentation and Creating Graphics from the Workspace Browser in the MATLAB Desktop Tools documentation.

Syntax

```
pareto(Y)
pareto(Y, names)
pareto(Y, X)
H = pareto(...)
```

Description

Pareto charts display the values in the vector `Y` as bars drawn in descending order. Values in `Y` must be nonnegative and not include NaNs. Only the first 95% of the cumulative distribution is displayed.

`pareto(Y)` labels each bar with its element index in `Y` and also plots a line displaying the cumulative sum of `Y`.

`pareto(Y, names)` labels each bar with the associated name in the string matrix or cell array `names`.

`pareto(Y, X)` labels each bar with the associated value from `X`.

`pareto(ax, ...)` plots a Pareto chart in existing axes `ax` rather than GCA.

`H = pareto(...)` returns a combination of patch and line object handles.

Examples

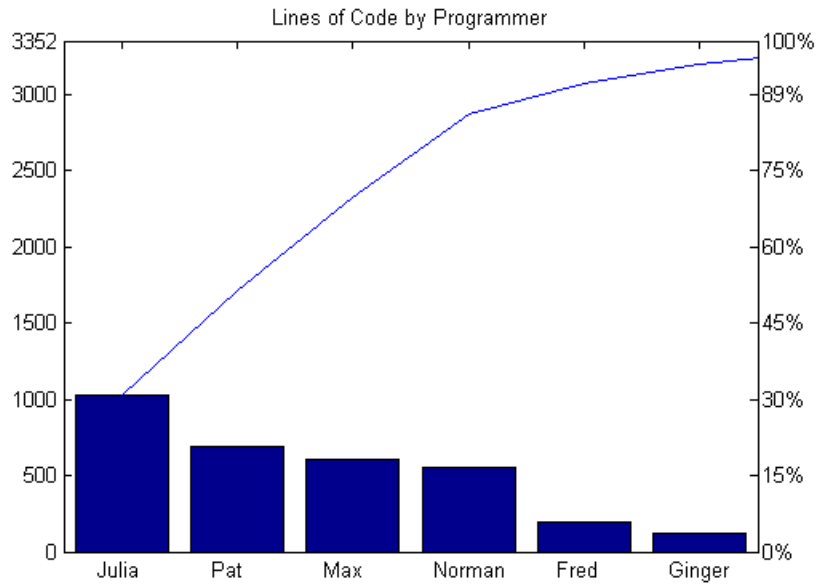
Example 1:

Examine the cumulative productivity of a group of programmers to see how normal its distribution is:

```

codelines = [200 120 555 608 1024 101 57 687];
coders = ...
{'Fred','Ginger','Norman','Max','Julia','Wally','Heidi','Pat'};
pareto(codelines, coders)
title('Lines of Code by Programmer')

```



Example 2:

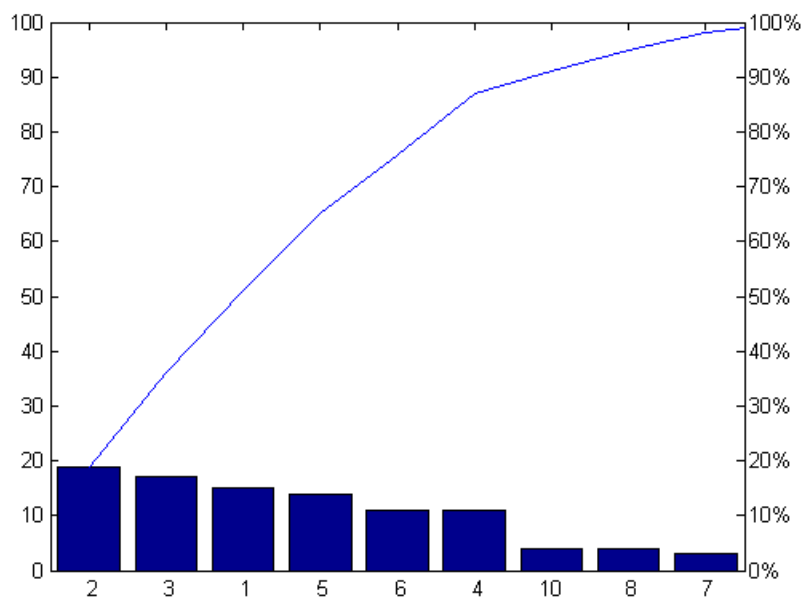
Generate a vector, X, representing diagnostic codes with values from 1 to 10 indicating various faults on devices emerging from a production line:

```
X = min(round(abs(randn(100,1)*4))+1,10);
```

Plot a Pareto chart showing the frequency of failure for each diagnostic code from the most to the least common:

```
pareto(hist(X))
```

pareto



Remarks

You can use `pareto` to display the output of `hist`, even for vectors that include negative numbers. Because only the first 95 percent of values are displayed, one or more of the smallest bars may not appear. If you extend the `Xlim` of your chart, you can display all the values, but the new bars will not be labeled.

You cannot place datatips (use the `Datacursor` tool) on graphs created with `pareto`.

See Also

`hist`, `bar`

Purpose

Parallel for-loop

Syntax

```
parfor loopvar = initval:endval; statements; end  
parfor (loopvar = initval:endval, M); statements; end
```

Description

`parfor loopvar = initval:endval; statements; end` executes a series of MATLAB commands denoted here as `statements` for values of `loopvar` between `initval` and `endval`, inclusive, which specify a vector of increasing integer values. Unlike a traditional for-loop, there is no guarantee of the order in which the loop iterations are executed.

The general format of a `parfor` statement is:

```
parfor loopvar = initval:endval  
    <statements>  
end
```

Certain restrictions apply to the `statements` to ensure that the iterations are independent, so that they can execute in parallel. If you have the Parallel Computing Toolbox™ software, the iterations of `statements` can execute in parallel on separate MATLAB workers on your multi-core computer or computer cluster.

To execute the loop body in parallel, you must open a pool of MATLAB workers using the `matlabpool` function, which is available in Parallel Computing Toolbox.

`parfor (loopvar = initval:endval, M); statements; end` executes `statements` in a loop using a maximum of `M` MATLAB workers to evaluate `statements` in the body of the `parfor`-loop. Input variable `M` must be a nonnegative integer. By default, MATLAB uses up to as many workers as it finds available.

When any of the following are true, MATLAB does not execute the loop in parallel:

- There are no workers in a MATLAB pool
- You set `M` to zero

parfor

- You do not have Parallel Computing Toolbox

If you have Parallel Computing Toolbox, you can read more about `parfor` and `matlabpool` by typing

```
doc distcomp/parfor
doc distcomp/matlabpool
```

Examples

Perform three large eigenvalue computations using three computers or cores:

```
matlabpool(3)
parfor i=1:3, c(:,i) = eig(rand(1000)); end
```

See Also

`for`

Purpose Parse and validate named inputs

Syntax `p.parse(arglist)`
`parse(p, arglist)`

Description `p.parse(arglist)` parses and validates the inputs named in `arglist`. `parse(p, arglist)` is functionally the same as the syntax above. For more information on the `inputParser` class, see “Parsing Inputs with `inputParser`” in the MATLAB Programming Fundamentals documentation.

Examples Write an M-file function called `publish_ip`, based on the MATLAB `publish` function, to illustrate the use of the `inputParser` class. Construct an instance of `inputParser` and assign it to variable `p`:

```
function publish_ip(script, varargin)
    p = inputParser; % Create an instance of the inputParser class.
```

Add arguments to the schema. See the reference pages for the `addRequired`, `addOptional`, and `addParamValue` methods for help with this:

```
p.addRequired('script', @ischar);
p.addOptional('format', 'html', ...
    @(x)any(strcmpi(x,{'html','ppt','xml','latex'})));
p.addParamValue('outputDir', pwd, @ischar);
p.addParamValue('maxHeight', [], @(x)x>0 && mod(x,1)==0);
p.addParamValue('maxWidth', [], @(x)x>0 && mod(x,1)==0);
```

Call the `parse` method of the object to read and validate each argument in the schema:

```
p.parse(script, varargin{:});
```

Execution of the `parse` method validates each argument and also builds a structure from the input arguments. The name of the structure is

parse (inputParser)

Results, which is accessible as a property of the object. To get the value of any input argument, type

```
p.Results.argname
```

Continuing with the `publish_ip` exercise, add the following lines to your M-file:

```
% Parse and validate all input arguments.
p.parse(script, varargin{:});

% Display the value for maxHeight.
disp(sprintf('\n\nThe maximum height is %d.\n', p.Results.maxHeight))

% Display all arguments.
disp 'List of all arguments:'
disp(p.Results)
```

When you call the program, MATLAB assigns those values you pass in the argument list to the appropriate fields of the `Results` structure. Save the M-file and execute it at the MATLAB command prompt with this command:

```
publish_ip('ipscript.m', 'ppt', 'outputDir', 'C:/matlab/test', ...
    'maxWidth', 500, 'maxHeight', 300);
```

```
The maximum height is 300.
```

```
List of all arguments:
    format: 'ppt'
    maxHeight: 300
    maxWidth: 500
    outputDir: 'C:/matlab/test'
    script: 'ipscript.m'
```

See Also

```
inputParser, addRequired(inputParser),
addOptional(inputParser), addParamValue(inputParser),
createCopy(inputParser)
```

Purpose Convert response string from SOAP server into MATLAB types

Syntax parseSoapResponse(response)

Description parseSoapResponse(response) extracts data from response a string returned by a SOAP server from the callSoapService function, and converts it to appropriate MATLAB classes (types).

Examples This example uses parseSoapResponse in conjunction with other SOAP functions to retrieve information about books from a library database, specifically, the author's name for a given book title.

Note The example does not use an actual endpoint; therefore, you cannot run it. The example only illustrates how to use the SOAP functions.

```
% Create the message:
message = createSoapMessage(...
    'urn:LibraryCatalog',...
    'getAuthor',...
    {'In the Fall'},...
    {'nameToLookUp'},...
    {'{http://www.w3.org/2001/XMLSchema}string'},...
    'rpc');
%
% Send the message to the service and get the response:
response = callSoapService(...
    'http://test/soap/services/LibraryCatalog',...
    'urn:LibraryCatalog#getAuthor',...
    message)
%
% Extract MATLAB data from the response
author = parseSoapResponse(response)
```

MATLAB returns:

parseSoapResponse

```
author = Kate Alvin
```

where author is a char class (type).

See Also

callSoapService, createClassFromWsd1, createSoapMessage,
urlread, xmlread

“Using Web Services with MATLAB” in the MATLAB External
Interfaces documentation

Purpose Partial pathname description

Description A partial pathname is the last portion of a full pathname for a file in a directory on the MATLAB search path. Use a partial pathname to locate private and method files, which are usually hidden. You can also use a partial pathname to restrict the search for files to a portion of the path when a file is overloaded, that is, when more than one file with the given name exists in different directories.

A partial pathname consists of the last directory or last several directories of the full pathname, with each directory separated by /, and followed by the filename. For example, `matfun/trace`, `private/cancel`, and `demos/clown.mat` are valid partial pathnames. Specifying the @ in method directory names is optional.

Partial pathnames also make it easy to specify a toolbox or a file in a directory on your path, independent of the location where MATLAB is installed.

Many commands accept partial pathnames instead of a full pathname. Some of these commands are: `dbclean`, `dbtype`, `dbstop`, `edit`, `exist`, `fopen`, `help`, `load`, `type`, `what`, `which`. The reference page for a function typically specifies if the function accepts partial pathnames.

Examples The following example uses a partial pathname:

```
what graph2d/@figobj
```

```
M-files in directory  
matlabroot\toolbox\matlab\graph2d\@figobj
```

```
deselectall    enddrag        middrag        subsref  
doclick       figobj        set  
doresize     get           subsasgn
```

The @ in the class directory name `@figobj` is not necessary. You get the same response from the following command:

```
what graph2d/figobj
```

partialpath

See Also

fileparts, matlabroot, path

“Workspace, Search Path, and File Operations” in the MATLAB Desktop Tools and Development Environment documentation.

Purpose Pascal matrix

Syntax
 A = pascal(n)
 A = pascal(n,1)
 A = pascal(n,2)

Description A = pascal(n) returns the Pascal matrix of order n: a symmetric positive definite matrix with integer entries taken from Pascal's triangle. The inverse of A has integer entries.

A = pascal(n,1) returns the lower triangular Cholesky factor (up to the signs of the columns) of the Pascal matrix. It is *involutary*, that is, it is its own inverse.

A = pascal(n,2) returns a transposed and permuted version of pascal(n,1). A is a cube root of the identity matrix.

Examples pascal(4) returns

1	1	1	1
1	2	3	4
1	3	6	10
1	4	10	20

A = pascal(3,2) produces

A =	1	1	1
	-2	-1	0
	1	0	0

See Also chol

patch

Purpose Create patch graphics object

Syntax

```
patch(X,Y,C)
patch(X,Y,Z,C)
patch(FV)
patch(... 'PropertyName',propertyvalue...)
patch('PropertyName',propertyvalue,...)
handle = patch(...)
```

Description `patch` is the low-level graphics function for creating patch graphics objects. A patch object is one or more polygons defined by the coordinates of its vertices. You can specify the coloring and lighting of the patch. See “Creating 3-D Models with Patches” in *MATLAB 3-D Visualization* for more information on using patch objects.

`patch(X,Y,C)` adds the filled two-dimensional patch to the current axes. The elements of `X` and `Y` specify the vertices of a polygon. If `X` and `Y` are matrices, MATLAB draws one polygon per column. `C` determines the color of the patch. It can be a single `ColorSpec`, one color per face, or one color per vertex (see “Specifying Patch Properties” on page 2-2703 and “Color Data Interpretation” on page 2-2704). If `C` is a 1-by-3 vector, it is assumed to be an RGB triplet, specifying a color directly.

`patch(X,Y,Z,C)` creates a patch in three-dimensional coordinates.

`patch(FV)` creates a patch using structure `FV`, which contains the fields `vertices`, `faces`, and optionally `facevertexcdata`. These fields correspond to the `Vertices`, `Faces`, and `FaceVertexCData` patch properties.

`patch(... 'PropertyName',propertyvalue...)` follows the `X`, `Y`, (`Z`), and `C` arguments with property name/property value pairs to specify additional patch properties.

`patch('PropertyName',propertyvalue,...)` specifies all properties using property name/property value pairs. This form enables you to omit the color specification because MATLAB uses the default face color and edge color unless you explicitly assign a value to the `FaceColor` and `EdgeColor` properties. This form also allows you to specify the

patch using the `Faces` and `Vertices` properties instead of `x`-, `y`-, and `z`-coordinates. See “Examples” on page 2-2706 for more information.

`handle = patch(...)` returns the handle of the patch object it creates.

Remarks

Unlike high-level area creation functions, such as `fill` or `area`, `patch` does not check the settings of the figure and axes `NextPlot` properties. It simply adds the patch object to the current axes.

If the coordinate data does not define closed polygons, `patch` closes the polygons. The data can define concave or intersecting polygons. However, if the edges of an individual patch face intersect themselves, the resulting face may or may not be completely filled. In that case, it is better to divide the face into smaller polygons.

Specifying Patch Properties

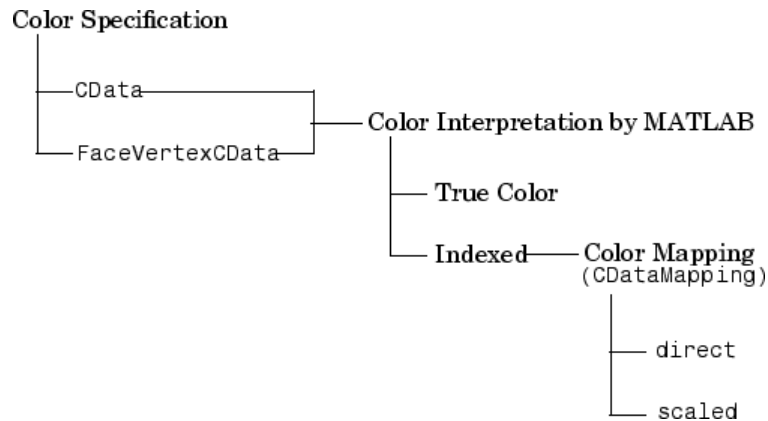
You can specify properties as property name/property value pairs, structure arrays, and cell arrays (see the `set` and `get` reference pages for examples of how to specify these data types).

There are two patch properties that specify color:

- `CData` — Use when specifying `x`-, `y`-, and `z`-coordinates (`XData`, `YData`, and `ZData`).
- `FaceVertexCData` — Use when specifying vertices and connection matrix (`Vertices` and `Faces`).

The `CData` and `FaceVertexCData` properties accept color data as indexed or true color (RGB) values. See the `CData` and `FaceVertexCData` property descriptions for information on how to specify color.

Indexed color data can represent either direct indices into the colormap or scaled values that map the data linearly to the entire colormap (see the `caxis` function for more information on this scaling). The `CDataMapping` property determines how MATLAB interprets indexed color data.



Color Data Interpretation

You can specify patch colors as:

- A single color for all faces
- One color for each face, enabling flat coloring
- One color for each vertex, enabling interpolated coloring

The following tables summarize how MATLAB interprets color data defined by the `CData` and `FaceVertexCData` properties, respectively.

In the following table, m (the number of rows) represents the number of vertices per face and n (the number of columns) represents the total number of faces (of that type of shape) per patch object. For example, if you want to create a patch object with four triangular faces, the `XData`, `YData`, and `ZData` would be 3-by-4 matrices. See “Creating Pictures with Multiple Patch Objects” on page 2-2709 for more information.

Interpretation of the CData Property

[X,Y,Z]Data	CData Required for		Results Obtained
Dimensions	Indexed	True Color	
m-by-n	scalar	1-by-1-by-3	Use the single color specified for all patch faces. Edges can be only a single color.
m-by-n	1-by-n (n >= 4)	1-by-n-by-3	Use one color for each patch face. Edges can be only a single color.
m-by-n	m-by-n	m-by-n-by-3	Assign a color to each vertex. Patch faces can be flat (a single color) or interpolated. Edges can be flat or interpolated.

In the following table, m represents the number of faces in a patch object, n represents the number of vertices per face, and k represents the total number of unique vertices per object. In addition, $3 \leq n \leq k$. See “Creating Pictures with Multiple Patch Objects” on page 2-2709 for more information.

Interpretation of the FaceVertexCData Property

Faces	Vertices	FaceVertexCData Required for		Results Obtained
Dimensions	Dimensions	Indexed	True Color	
m-by-n	k-by-3	scalar	1-by-3	Use the single color specified for all patch faces. Edges can be only a single color.
m-by-n	k-by-3	k-by-1	k-by-3	Use one color for each patch face. Edges can be only a single color.
m-by-n	k-by-3	m-by-1	m-by-3	Assign a color to each vertex. Patch faces can be flat (a single color) or interpolated. Edges can be flat or interpolated.

Examples

The next two examples create a patch object using two different methods:

- Specifying x -, y -, and z -coordinates and color data (XData, YData, ZData, and CData properties)
- Specifying vertices, the connection matrix, and color data (Vertices, Faces, FaceVertexCData, and FaceColor properties)

Specifying X-, Y-, and Z-Coordinates

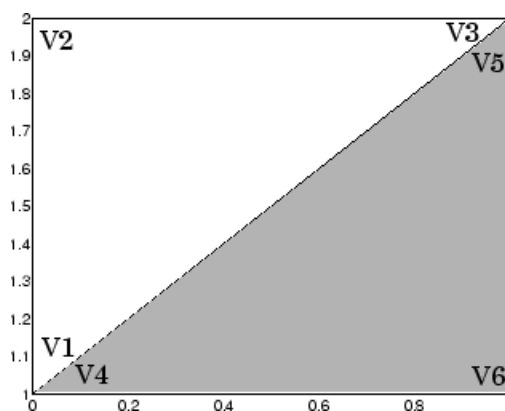
The first approach specifies the coordinates of each vertex. In this example, the coordinate data, a 3-by-2 matrix, defines two triangular faces, each having three vertices. Using true color, the top face is set to white and the bottom face to gray.

```
x = [0 0;  
0 1;  
1 1];
```

```

y = [1 1;
     2 2;
     2 1];
z = [1 1;
     1 1;
     1 1];
tcolor(1,1,1:3) = [1 1 1];
tcolor(1,2,1:3) = [.7 .7 .7];
patch(x,y,z,tcolor)

```



Notice that each face shares two vertices with the other face (V_1 - V_4 and V_3 - V_5).

Specifying Vertices and Faces

The Vertices property contains the coordinates of each *unique* vertex defining the patch. The Faces property specifies how to connect these vertices to form each face of the patch. For this example, two vertices share the same location so you need to specify only four of the six vertices. Each row contains the x -, y -, and z -coordinates of each vertex.

```
vert = [0 1 1;0 2 1;1 2 1;1 1 1];
```

There are only two faces, defined by connecting the vertices in the order indicated.

patch

```
fac = [1 2 3;1 3 4];
```

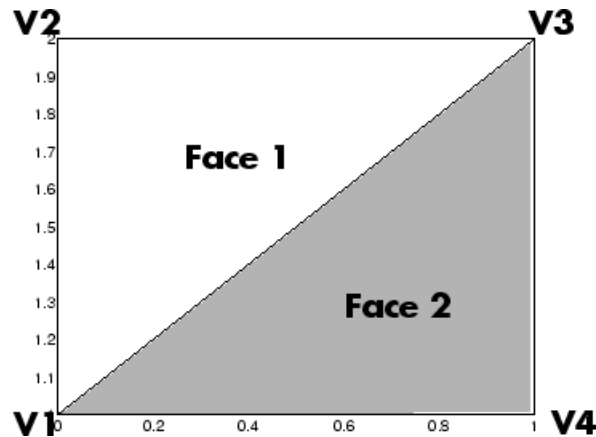
To specify the face colors, define a 2-by-3 matrix containing two RGB color definitions.

```
tcolor = [1 1 1;.7 .7 .7];
```

With two faces and two colors, MATLAB can color each face with flat shading. This means you must set the `FaceColor` property to `flat`, since the faces/vertices technique is available only as a low-level function call (i.e., only by specifying property name/property value pairs).

Create the patch by specifying the `Faces`, `Vertices`, and `FaceVertexCData` properties as well as the `FaceColor` property.

```
patch('Faces',fac,'Vertices',vert,'FaceVertexCData',...  
      tcolor,'FaceColor','flat');
```



Specifying only unique vertices and their connection matrix can reduce the size of the data for patches having many faces. See the descriptions of the `Faces`, `Vertices`, and `FaceVertexCData` properties for information on how to define them.

MATLAB does not require each face to have the same number of vertices. In cases where they do not, pad the end of the `Faces` matrix

with NaNs. To define a patch with faces that do not close, add one or more NaNs to the row in the `Vertices` matrix that defines the vertex you do not want connected.

Creating Pictures with Multiple Patch Objects

The following example recreates a popular puzzle game using 3- and 4-sided patch objects. The first method specifies the x -, y -, and z -coordinates and color data to draw the puzzle pieces in their original square formation. The second method rearranges those pieces into the form of a rabbit, but specifies vertices, the connection matrix, and color data. In each case, the matrices for the alternative specification method are presented beneath the created graphic.

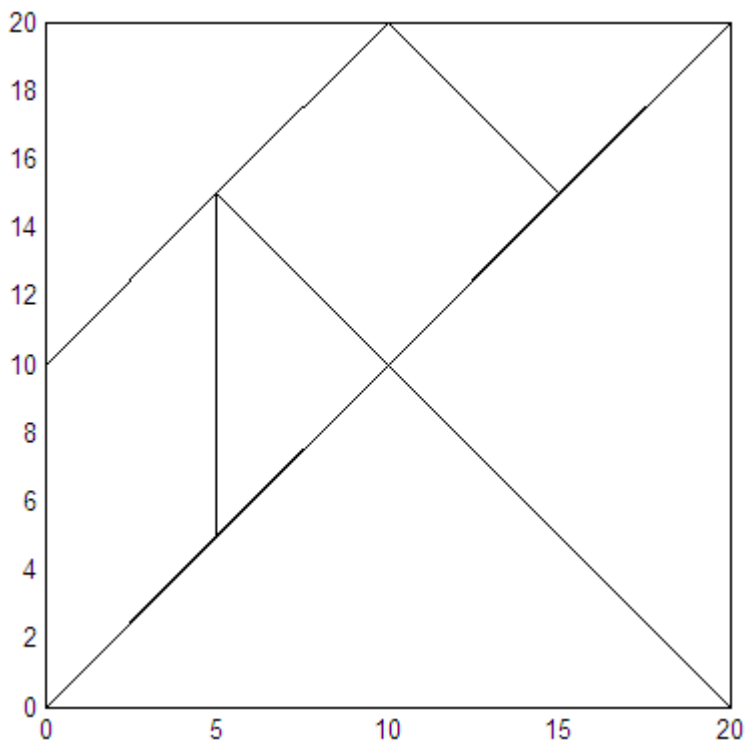
Using x -, y -, and z -coordinates and color data, define first the quadrilateral faces then the triangle face coordinates:

```
xquad = [5,0;10,0;15,5;10,5];  
yquad = [15,0;20,10;15,15;10,5];  
zquad = ones(4,2);  
xtri = [0,10,10,5,0;10,20,20,5,0;20,20,15,10,10];  
ytri = [0,10,20,5,10;10,20,20,15,20;0,0,15,10,20];  
ztri = zeros(3,5);
```

Create the patch faces, coloring them white:

```
p1 = patch(xtri,ytri,ztri,'FaceColor','w');  
p2 = patch(xquad,yquad,zquad,'FaceColor','w');  
set(gca,'DataAspectRatio',[1 1 1]);
```

patch



To create this image by specifying vertices and connection matrices, use the following inputs:

```
verts = [0 20 0;10 20 0;20 20 0;15 15 0;5 15 0;...  
0 10 0;10 10 0;5 5 0;0 0 0;20 0 0];  
facestri = [9 7 10;7 3 10;2 3 4;8 5 7;6 1 2];  
facesquad = [2 4 7 5;6 5 8 9];  
patch('Faces',facesquad,'Vertices',verts,'facecolor','w')  
patch('Faces',facestri,'Vertices',verts,'facecolor','w')
```

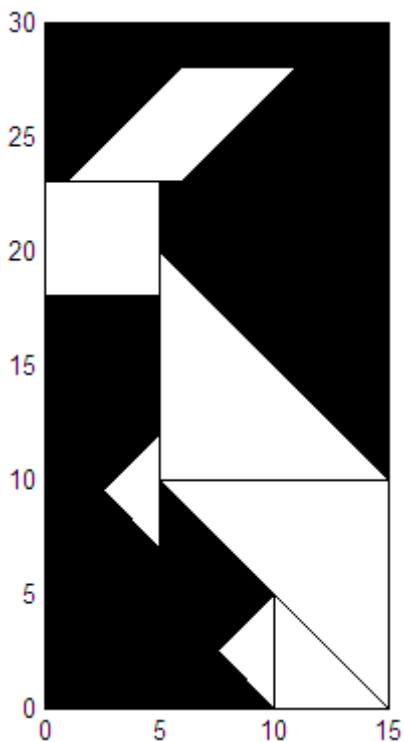
To create a white rabbit from the same shapes, use the following inputs to define the vertices and connection matrices:

```
rabvert = [11 28 0;6 28 0;6 23 0;5 23 0;1 23 0;0 23 0;...
```

```
5 20 0;0 18 0;5 18 0;5 12 0;2.5 9.5 0;5 7 0;...
5 10 0;15 10 0; 15 0 0;10 5 0;10 0 0;7.5 2.5 0]
rabquadface = [5 2 1 3;8 6 4 9];
rabtriface = [7 14 13;13 14 15;11 10 12;18 16 17;17 16 15];
```

Draw the patches in white and set the background to black:

```
patch('Faces',rabquadface,'Vertices',rabvert,'FaceColor','w')
patch('Faces',rabtriface,'Vertices',rabvert,'FaceColor','w')
set(gca,'Color','black','DataAspectRatio',[1 1 1]);
```



To create this image using x -, y -, and z -coordinates, use the following inputs:

```
rabxtri = [5,5,2.5,7.5,10;5,15,5,10,10;15,15,5,10,15];
```

```
rabytri = [10,10,9.5,2.5,0;20,10,12,5,5;10 0 7 0 0];
rabztri = [0,0,0,0,0;0,0,0,0,0;0,0,0,0,0];
rabxquad = [0,1;0,6;5,11;5,6];
rabyquad = [18,23;23,28;23,28;18,23];
rabzquad = [1,1;1,1;1,1;1,1];
patch(rabxtri,rabytri,rabztri,'FaceColor','w')
patch(rabxquad,rabyquad,rabzquad,'FaceColor','w')
set(gca,'Color','black','DataAspectRatio',[1 1 1])
```

Setting Default Properties

You can set default patch properties on the axes, figure, and root object levels:

```
set(0,'DefaultPatchPropertyName',PropertyValue...)
set(gcf,'DefaultPatchPropertyName',PropertyValue...)
set(gca,'DefaultPatchPropertyName',PropertyValue...)
```

PropertyName is the name of the patch property and *PropertyValue* is the value you are specifying. Use `set` and `get` to access patch properties.

See Also

`area`, `caxis`, `fill`, `fill3`, `isosurface`, `surface`

“Object Creation” on page 1-101 for related functions

Patch Properties for property descriptions

“Creating 3-D Models with Patches” for examples that use patches

Purpose

Patch properties

Modifying Properties

You can set and query graphics object properties in two ways:

- “The Property Editor” is an interactive tool that enables you to see and change object property values.
- The `set` and `get` commands enable you to set and query the values of properties.

To change the default values of properties, see “Setting Default Property Values”.

See “Core Graphics Objects” for general information about this type of object.

Patch Property Descriptions

This section lists property names along with the type of values each accepts. Curly braces `{ }` enclose default values.

`AlphaDataMapping`
`none | {scaled} | direct`

Transparency mapping method. This property determines how the MATLAB software interprets indexed alpha data. This property can be any of the following:

- `none` — The transparency values of `FaceVertexAlphaData` are between 0 and 1 or are clamped to this range.
- `scaled` — Transform the `FaceVertexAlphaData` to span the portion of the `alphamap` indicated by the axes `ALim` property, linearly mapping data values to alpha values. (`scaled` is the default)
- `direct` — Use the `FaceVertexAlphaData` as indices directly into the `alphamap`. When not scaled, the data are usually integer values ranging from 1 to `length(alphamap)`. MATLAB maps values less than 1 to the first alpha value in the `alphamap`, and values greater than `length(alphamap)`

Patch Properties

to the last alpha value in the alphamap. Values with a decimal portion are fixed to the nearest lower integer. If `FaceVertexAlphaData` is an array of `uint8` integers, then the indexing begins at 0 (i.e., MATLAB maps a value of 0 to the first alpha value in the alphamap).

AmbientStrength

scalar ≥ 0 and ≤ 1

Strength of ambient light. This property sets the strength of the ambient light, which is a nondirectional light source that illuminates the entire scene. You must have at least one visible light object in the axes for the ambient light to be visible. The axes `AmbientColor` property sets the color of the ambient light, which is therefore the same on all objects in the axes.

You can also set the strength of the diffuse and specular contribution of light objects. See the `DiffuseStrength` and `SpecularStrength` properties.

Annotation

hg.Annotation object Read Only

Control the display of patch objects in legends. The `Annotation` property enables you to specify whether this patch object is represented in a figure legend.

Querying the `Annotation` property returns the handle of an `hg.Annotation` object. The `hg.Annotation` object has a property called `LegendInformation`, which contains an `hg.LegendEntry` object.

Once you have obtained the `hg.LegendEntry` object, you can set its `IconDisplayStyle` property to control whether the patch object is displayed in a figure legend:

IconDisplayStyle Value	Purpose
on	Represent this patch object in a legend (default)
off	Do not include this patch object in a legend
children	Same as on because patch objects do not have children

Setting the `IconDisplayStyle` property

These commands set the `IconDisplayStyle` of a graphics object with handle `hobj` to `off`:

```
hAnnotation = get(hobj, 'Annotation');  
hLegendEntry = get(hAnnotation, 'LegendInformation');  
set(hLegendEntry, 'IconDisplayStyle', 'off')
```

Using the `IconDisplayStyle` property

See “Controlling Legends” for more information and examples.

Selecting which objects to display in legend

Some graphics functions create multiple objects. For example, `contour3` uses patch objects to create a 3D contour graph. You can use the `Annotation` property set to select a subset of the objects for display in the legend.

```
[X,Y] = meshgrid(-2:.1:2);  
[Cm hC] = contour3(X.*exp(-X.^2-Y.^2));  
hA = get(hC, 'Annotation');  
hLL = get([hA{:}], 'LegendInformation');  
% Set the IconDisplayStyle property to display  
% the first, fifth, and ninth patch in the legend  
set([hLL{:}], {'IconDisplayStyle'}, ...  
    {'on', 'off', 'off', 'off', 'on', 'off', 'off', 'off', 'on'})
```

Patch Properties

```
% Assign DisplayNames for the three patch
that are displayed in the legend
set(hC([1,5,9]),{'DisplayName'},{'bottom','middle','top'})
legend show
```

BackFaceLighting
unlit | lit | {reverselit}

Face lighting control. This property determines how faces are lit when their vertex normals point away from the camera:

- unlit — Face is not lit.
- lit — Face is lit in normal way.
- reverselit — Face is lit as if the vertex pointed towards the camera.

This property is useful for discriminating between the internal and external surfaces of an object. See the Using MATLAB Graphics manual for an example.

BeingDeleted
on | {off} Read Only

This object is being deleted. The `BeingDeleted` property provides a mechanism that you can use to determine if objects are in the process of being deleted. MATLAB sets the `BeingDeleted` property to `on` when the object's delete function callback is called (see the `DeleteFcn` property) It remains set to `on` while the delete function executes, after which the object no longer exists.

For example, an object's delete function might call other functions that act on a number of different objects. These functions may not need to perform actions on objects that are going to be deleted, and therefore, can check the object's `BeingDeleted` property before acting.

BusyAction
cancel | {queue}

Callback routine interruption. The `BusyAction` property enables you to control how MATLAB handles events that potentially interrupt executing callback routines. If there is a callback routine executing, callback routines invoked subsequently always attempt to interrupt it. If the `Interruptible` property of the object whose callback is executing is set to `on` (the default), then interruption occurs at the next point where the event queue is processed. If the `Interruptible` property is `off`, the `BusyAction` property (of the object owning the executing callback) determines how MATLAB handles the event. The choices are

- `cancel` — Discard the event that attempted to execute a second callback routine.
- `queue` — Queue the event that attempted to execute a second callback routine until the current callback finishes.

`ButtonDownFcn`

function handle, cell array containing function handle and additional arguments, or string (not recommended)

Button press callback routine. A callback routine that executes whenever you press a mouse button while the pointer is over the patch object.

See the figure's `SelectionType` property to determine if modifier keys were also pressed.

Set this property to a function handle that references the callback. You can also use a string that is a valid MATLAB expression or the name of an M-file. The expressions execute in the MATLAB workspace.

See “Function Handle Callbacks” for information on how to use function handles to define the callback function.

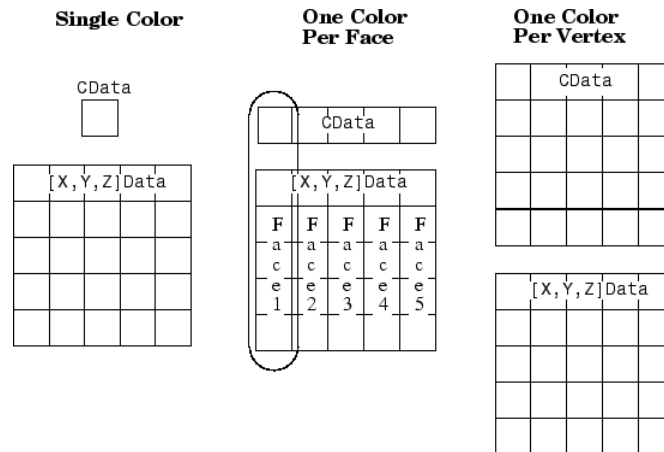
`CData`

scalar, vector, or matrix

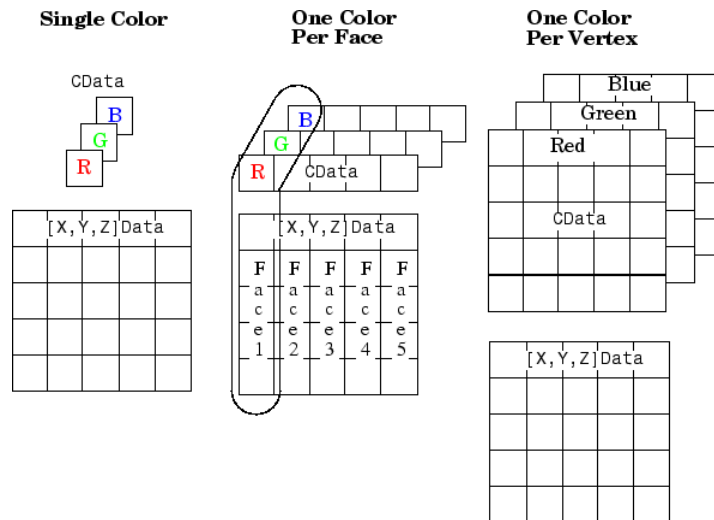
Patch Properties

Patch colors. This property specifies the color of the patch. You can specify color for each vertex, each face, or a single color for the entire patch. The way MATLAB interprets CData depends on the type of data supplied. The data can be numeric values that are scaled to map linearly into the current colormap, integer values that are used directly as indices into the current colormap, or arrays of RGB values. RGB values are not mapped into the current colormap, but interpreted as the colors defined. On true color systems, MATLAB uses the actual colors defined by the RGB triples.

The following two diagrams illustrate the dimensions of CData with respect to the coordinate data arrays, XData, YData, and ZData. The first diagram illustrates the use of indexed color.



The second diagram illustrates the use of true color. True color requires m -by- n -by-3 arrays to define red, green, and blue components for each color.



Note that if CData contains NaNs, MATLAB does not color the faces.

See also the Faces, Vertices, and FaceVertexCData properties for an alternative method of patch definition.

CDataMapping
 {scaled} | direct

Direct or scaled color mapping. This property determines how MATLAB interprets indexed color data used to color the patch. (If you use true color specification for CData or FaceVertexCData, this property has no effect.)

- **scaled** — Transform the color data to span the portion of the colormap indicated by the axes CLim property, linearly mapping data values to colors. See the `caxis` command for more information on this mapping.
- **direct** — Use the color data as indices directly into the colormap. When not scaled, the data are usually integer values

Patch Properties

ranging from 1 to `length(colormap)`. MATLAB maps values less than 1 to the first color in the colormap, and values greater than `length(colormap)` to the last color in the colormap. Values with a decimal portion are fixed to the nearest lower integer.

Children
matrix of handles

Always the empty matrix; patch objects have no children.

Clipping
{on} | off

Clipping to axes rectangle. When **Clipping** is on, MATLAB does not display any portion of the patch outside the axes rectangle.

CreateFcn
string or function handle

Callback routine executed during object creation. This property defines a callback routine that executes when MATLAB creates a patch object. You must define this property as a default value for patches or in a call to the `patch` function that creates a new object.

For example, the following statement creates a patch (assuming `x`, `y`, `z`, and `c` are defined), and executes the function referenced by the function handle `@myCreateFcn`.

```
patch(x,y,z,c,'CreateFcn',@myCreateFcn)
```

MATLAB executes the create function after setting all properties for the patch created. Setting this property on an existing patch object has no effect.

The handle of the object whose `CreateFcn` is being executed is accessible only through the root `CallbackObject` property, which you can query using `gcbo`.

See “Function Handle Callbacks” for information on how to use function handles to define the callback function.

DeleteFcn

string or function handle

Delete patch callback routine. A callback routine that executes when you delete the patch object (e.g., when you issue a `delete` command or clear the axes (`cla`) or figure (`clf`) containing the patch). MATLAB executes the routine before deleting the object’s properties so these values are available to the callback routine.

The handle of the object whose `DeleteFcn` is being executed is accessible only through the root `CallbackObject` property, which you can query using `gcbo`.

See Function Handle Callbacks for information on how to use function handles to define the callback function.

DiffuseStrength

scalar ≥ 0 and ≤ 1

Intensity of diffuse light. This property sets the intensity of the diffuse component of the light falling on the patch. Diffuse light comes from light objects in the axes.

You can also set the intensity of the ambient and specular components of the light on the patch object. See the `AmbientStrength` and `SpecularStrength` properties.

DisplayName

string (default is empty string)

String used by legend for this patch object. The `legend` function uses the string defined by the `DisplayName` property to label this patch object in the legend.

Patch Properties

- If you specify string arguments with the `legend` function, `DisplayName` is set to this patch object's corresponding string and that string is used for the legend.
- If `DisplayName` is empty, legend creates a string of the form, `['data' n]`, where n is the number assigned to the object based on its location in the list of legend entries. However, legend does not set `DisplayName` to this string.
- If you edit the string directly in an existing legend, `DisplayName` is set to the edited string.
- If you specify a string for the `DisplayName` property and create the legend using the figure toolbar, then MATLAB uses the string defined by `DisplayName`.
- To add programmatically a legend that uses the `DisplayName` string, call `legend` with the `toggle` or `show` option.

See “Controlling Legends” for more examples.

EdgeAlpha

`{scalar = 1} | flat | interp`

Transparency of the edges of patch faces. This property can be any of the following:

- `scalar` — A single non-NaN scalar value between 0 and 1 that controls the transparency of all the edges of the object. 1 (the default) means fully opaque and 0 means completely transparent.
- `flat` — The alpha data (`FaceVertexAlphaData`) of each vertex controls the transparency of the edge that follows it.
- `interp` — Linear interpolation of the alpha data (`FaceVertexAlphaData`) at each vertex determines the transparency of the edge.

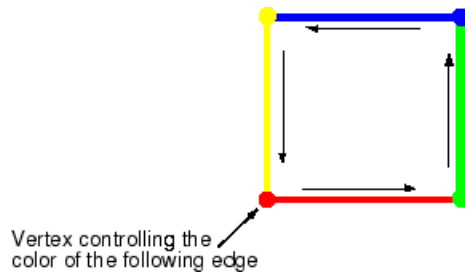
Note that you cannot specify `flat` or `interp` `EdgeAlpha` without first setting `FaceVertexAlphaData` to a matrix containing one alpha value per face (`flat`) or one alpha value per vertex (`interp`).

EdgeColor

`{ColorSpec} | none | flat | interp`

Color of the patch edge. This property determines how MATLAB colors the edges of the individual faces that make up the patch.

- `ColorSpec` — A three-element RGB vector or one of the MATLAB predefined names, specifying a single color for edges. The default edge color is black. See `ColorSpec` for more information on specifying color.
- `none` — Edges are not drawn.
- `flat` — The color of each vertex controls the color of the edge that follows it. This means `flat` edge coloring is dependent on the order in which you specify the vertices:



- `interp` — Linear interpolation of the `CData` or `FaceVertexCData` values at the vertices determines the edge color.

EdgeLighting

`{none} | flat | gouraud | phong`

Algorithm used for lighting calculations. This property selects the algorithm used to calculate the effect of light objects on patch edges. Choices are

Patch Properties

- `none` — Lights do not affect the edges of this object.
- `flat` — The effect of light objects is uniform across each edge of the patch.
- `gouraud` — The effect of light objects is calculated at the vertices and then linearly interpolated across the edge lines.
- `phong` — The effect of light objects is determined by interpolating the vertex normals across each edge line and calculating the reflectance at each pixel. Phong lighting generally produces better results than Gouraud lighting, but takes longer to render.

EraseMode

{normal} | none | xor | background

Erase mode. This property controls the technique MATLAB uses to draw and erase patch objects. Alternative erase modes are useful in creating animated sequences, where control of the way individual objects redraw is necessary to improve performance and obtain the desired effect.

- `normal` — Redraw the affected region of the display, performing the three-dimensional analysis necessary to ensure that all objects are rendered correctly. This mode produces the most accurate picture, but is the slowest. The other modes are faster, but do not perform a complete redraw and are therefore less accurate.
- `none` — Do not erase the patch when it is moved or destroyed. While the object is still visible on the screen after erasing with `EraseMode none`, you cannot print it because MATLAB stores no information about its former location.
- `xor` — Draw and erase the patch by performing an exclusive OR (XOR) with each pixel index of the screen behind it. Erasing the patch does not damage the color of the objects behind it. However, patch color depends on the color of the screen behind it and is correctly colored only when over the axes background

Color, or the figure background Color if the axes Color is set to none.

- **background** — Erase the patch by drawing it in the axes background Color, or the figure background Color if the axes Color is set to none. This damages objects that are behind the erased patch, but the patch is always properly colored.

Printing with Nonnormal Erase Modes

MATLAB always prints figures as if the `EraseMode` of all objects is `normal`. This means graphics objects created with `EraseMode` set to `none`, `xor`, or `background` can look different on screen than on paper. On screen, MATLAB may mathematically combine layers of colors (e.g., perform an XOR of a pixel color with that of the pixel behind it) and ignore three-dimensional sorting to obtain greater rendering speed. However, these techniques are not applied to the printed output.

You can use the MATLAB `getframe` command or other screen capture application to create an image of a figure containing nonnormal mode objects.

FaceAlpha

{scalar = 1} | flat | interp

Transparency of the patch face. This property can be any of the following:

- **A scalar** — A single non-NaN value between 0 and 1 that controls the transparency of all the faces of the object. 1 (the default) means fully opaque and 0 means completely transparent (invisible).
- **flat** — The values of the alpha data (`FaceVertexAlphaData`) determine the transparency for each face. The alpha data at the first vertex determines the transparency of the entire face.
- **interp** — Bilinear interpolation of the alpha data (`FaceVertexAlphaData`) at each vertex determines the transparency of each face.

Patch Properties

Note that you cannot specify `flat` or `interp` `FaceAlpha` without first setting `FaceVertexAlphaData` to a matrix containing one alpha value per face (`flat`) or one alpha value per vertex (`interp`).

FaceColor

`{ColorSpec} | none | flat | interp`

Color of the patch face. This property can be any of the following:

- `ColorSpec` — A three-element RGB vector or one of the MATLAB predefined names, specifying a single color for faces. See `ColorSpec` for more information on specifying color.
- `none` — Do not draw faces. Note that edges are drawn independently of faces.
- `flat` — The `CData` or `FaceVertexCData` property must contain one value per face and determines the color for each face in the patch. The color data at the first vertex determines the color of the entire face.
- `interp` — Bilinear interpolation of the color at each vertex determines the coloring of each face. The `CData` or `FaceVertexCData` property must contain one value per vertex.

FaceLighting

`{none} | flat | gouraud | phong`

Algorithm used for lighting calculations. This property selects the algorithm used to calculate the effect of light objects on patch faces. Choices are

- `none` — Lights do not affect the faces of this object.
- `flat` — The effect of light objects is uniform across the faces of the patch. Select this choice to view faceted objects.
- `gouraud` — The effect of light objects is calculated at the vertices and then linearly interpolated across the faces. Select this choice to view curved surfaces.

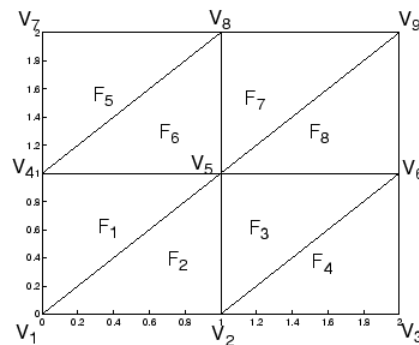
- phong — The effect of light objects is determined by interpolating the vertex normals across each face and calculating the reflectance at each pixel. Select this choice to view curved surfaces. Phong lighting generally produces better results than Gouraud lighting, but takes longer to render.

Faces

m-by-n matrix

Vertex connection defining each face. This property is the connection matrix specifying which vertices in the Vertices property are connected. The Faces matrix defines m faces with up to n vertices each. Each row designates the connections for a single face, and the number of elements in that row that are not NaN defines the number of vertices for that face.

The Faces and Vertices properties provide an alternative way to specify a patch that can be more efficient than using x , y , and z coordinates in most cases. For example, consider the following patch. It is composed of eight triangular faces defined by nine vertices.



Faces property Vertices property

F ₁	V ₁	V ₄	V ₅	V ₁	X ₁	Y ₁	Z ₁
F ₂	V ₁	V ₅	V ₂	V ₂	X ₂	Y ₂	Z ₂
F ₃	V ₂	V ₅	V ₆	V ₃	X ₃	Y ₃	Z ₃
F ₄	V ₂	V ₆	V ₃	V ₄	X ₄	Y ₄	Z ₄
F ₅	V ₄	V ₇	V ₈	V ₅	X ₅	Y ₅	Z ₅
F ₆	V ₄	V ₈	V ₅	V ₆	X ₆	Y ₆	Z ₆
F ₇	V ₅	V ₈	V ₉	V ₇	X ₇	Y ₇	Z ₇
F ₈	V ₅	V ₉	V ₆	V ₈	X ₈	Y ₈	Z ₈
				V ₉	X ₉	Y ₉	Z ₉

The corresponding Faces and Vertices properties are shown to the right of the patch. Note how some faces share vertices with

Patch Properties

other faces. For example, the fifth vertex (V5) is used six times, once each by faces one, two, and three and six, seven, and eight. Without sharing vertices, this same patch requires 24 vertex definitions.

FaceVertexAlphaData
m-by-1 matrix

Face and vertex transparency data. The FaceVertexAlphaData property specifies the transparency of patches that have been defined by the Faces and Vertices properties. The interpretation of the values specified for FaceVertexAlphaData depends on the dimensions of the data.

FaceVertexAlphaData can be one of the following:

- A single value, which applies the same transparency to the entire patch. The FaceAlpha property must be set to flat.
- An m-by-1 matrix (where m is the number of rows in the Faces property), which specifies one transparency value per face. The FaceAlpha property must be set to flat.
- An m-by-1 matrix (where m is the number of rows in the Vertices property), which specifies one transparency value per vertex. The FaceAlpha property must be set to interp.

The AlphaDataMapping property determines how MATLAB interprets the FaceVertexAlphaData property values.

FaceVertexCData
matrix

Face and vertex colors. The FaceVertexCData property specifies the color of patches defined by the Faces and Vertices properties. You must also set the values of the FaceColor, EdgeColor, MarkerFaceColor, or MarkerEdgeColor appropriately. The interpretation of the values specified for FaceVertexCData depends on the dimensions of the data.

For indexed colors, `FaceVertexCData` can be

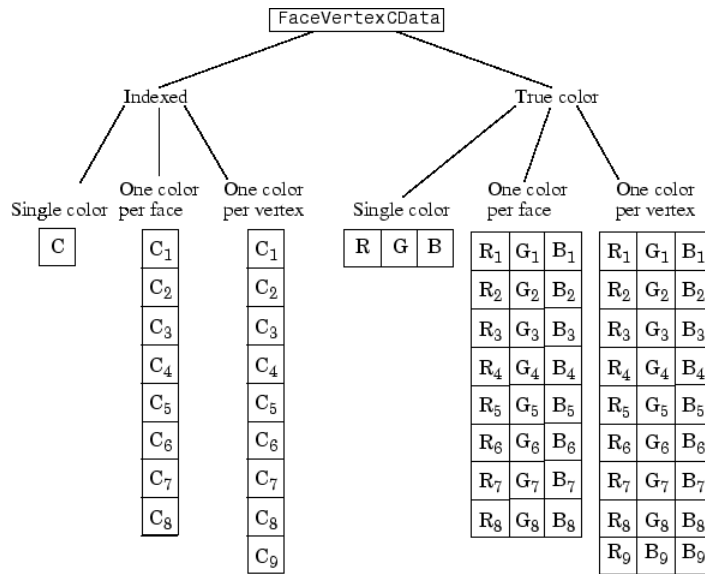
- A single value, which applies a single color to the entire patch
- An n -by-1 matrix, where n is the number of rows in the `Faces` property, which specifies one color per face
- An n -by-1 matrix, where n is the number of rows in the `Vertices` property, which specifies one color per vertex

For true colors, `FaceVertexCData` can be

- A 1-by-3 matrix, which applies a single color to the entire patch
- An n -by-3 matrix, where n is the number of rows in the `Faces` property, which specifies one color per face
- An n -by-3 matrix, where n is the number of rows in the `Vertices` property, which specifies one color per vertex

The following diagram illustrates the various forms of the `FaceVertexCData` property for a patch having eight faces and nine vertices. The `CDataMapping` property determines how MATLAB interprets the `FaceVertexCData` property when you specify indexed colors.

Patch Properties



`HandleVisibility`
{on} | callback | off

Control access to object's handle by command-line users and GUIs.
This property determines when an object's handle is visible in its parent's list of children. `HandleVisibility` is useful for preventing command-line users from accidentally drawing into or deleting a figure that contains only user interface devices (such as a dialog box).

Handles are always visible when `HandleVisibility` is on.

Setting `HandleVisibility` to `callback` causes handles to be visible from within callback routines or functions invoked by callback routines, but not from within functions invoked from the command line. This provides a means to protect GUIs from command-line users, while allowing callback routines to have complete access to object handles.

Setting `HandleVisibility` to `off` makes handles invisible at all times. This may be necessary when a callback routine invokes a function that might potentially damage the GUI (such as evaluating a user-typed string), and so temporarily hides its own handles during the execution of that function.

When a handle is not visible in its parent's list of children, it cannot be returned by functions that obtain handles by searching the object hierarchy or querying handle properties. This includes `get`, `findobj`, `gca`, `gcf`, `gco`, `newplot`, `cla`, `clf`, and `close`.

When a handle's visibility is restricted using `callback` or `off`, the object's handle does not appear in its parent's `Children` property, figures do not appear in the root's `CurrentFigure` property, objects do not appear in the root's `CallbackObject` property or in the figure's `CurrentObject` property, and axes do not appear in their parent's `CurrentAxes` property.

You can set the root `ShowHiddenHandles` property to `on` to make all handles visible regardless of their `HandleVisibility` settings (this does not affect the values of the `HandleVisibility` properties).

Handles that are hidden are still valid. If you know an object's handle, you can `set` and `get` its properties, and pass it to any function that operates on handles.

`HitTest`
{on} | off

Selectable by mouse click. `HitTest` determines if the patch can become the current object (as returned by the `gco` command and the figure `CurrentObject` property) as a result of a mouse click on the patch. If `HitTest` is `off`, clicking the patch selects the object below it (which may be the axes containing it).

`Interruptible`
{on} | off

Patch Properties

Callback routine interruption mode. The `Interruptible` property controls whether a patch callback routine can be interrupted by subsequently invoked callback routines. Only callback routines defined for the `ButtonDownFcn` are affected by the `Interruptible` property. MATLAB checks for events that can interrupt a callback routine only when it encounters a `drawnow`, `figure`, `getframe`, or `pause` command in the routine. See the `BusyAction` property for related information.

LineStyle

{-} | -- | : | -. | none

Edge linestyle. This property specifies the line style of the patch edges. The following table lists the available line styles.

Symbol	Line Style
-	Solid line (default)
--	Dashed line
:	Dotted line
-.	Dash-dot line
none	No line

You can use `LineStyle none` when you want to place a marker at each point but do not want the points connected with a line (see the `Marker` property).

LineWidth

scalar

Edge line width. The width, in points, of the patch edges (1 point = $\frac{1}{72}$ inch). The default `LineWidth` is 0.5 points.

Marker

character (see table)

Marker symbol. The Marker property specifies marks that locate vertices. You can set values for the Marker property independently from the LineStyle property. The following tables lists the available markers.

Marker Specifier	Description
+	Plus sign
o	Circle
*	Asterisk
.	Point
x	Cross
s	Square
d	Diamond
^	Upward-pointing triangle
v	Downward-pointing triangle
>	Right-pointing triangle
<	Left-pointing triangle
p	Five-pointed star (pentagram)
h	Six-pointed star (hexagram)
none	No marker (default)

MarkerEdgeColor

ColorSpec | none | {auto} | flat

Marker edge color. The color of the marker or the edge color for filled markers (circle, square, diamond, pentagram, hexagram, and the four triangles).

- **ColorSpec** — Defines the color to use.
- **none** — Specifies no color, which makes nonfilled markers invisible.

Patch Properties

- `auto` — Sets `MarkerEdgeColor` to the same color as the `EdgeColor` property.

`MarkerFaceColor`

`ColorSpec` | `{none}` | `auto` | `flat`

Marker face color. The fill color for markers that are closed shapes (circle, square, diamond, pentagram, hexagram, and the four triangles).

- `ColorSpec` — Defines the color to use.
- `none` — Makes the interior of the marker transparent, allowing the background to show through.
- `auto` — Sets the fill color to the axes color, or the figure color, if the axes `Color` property is set to `none`.

`MarkerSize`

size in points

Marker size. A scalar specifying the size of the marker, in points. The default value for `MarkerSize` is 6 points (1 point = $\frac{1}{72}$ inch). Note that MATLAB draws the point marker at $\frac{1}{3}$ of the specified size.

`NormalMode`

`{auto}` | `manual`

MATLAB generated or user-specified normal vectors. When this property is `auto`, MATLAB calculates vertex normals based on the coordinate data. If you specify your own vertex normals, MATLAB sets this property to `manual` and does not generate its own data. See also the `VertexNormals` property.

`Parent`

handle of axes, `hggroup`, or `hgtransform`

Parent of patch object. This property contains the handle of the patch object's parent. The parent of a patch object is the axes, hgroup, or hgtransform object that contains it.

See “Objects That Can Contain Other Objects” for more information on parenting graphics objects.

Selected
on | {off}

Is object selected? When this property is on, MATLAB displays selection handles or a dashed box (depending on the number of faces) if the **SelectionHighlight** property is also on. You can, for example, define the **ButtonDownFcn** to set this property, allowing users to select the object with the mouse.

SelectionHighlight
{on} | off

Objects are highlighted when selected. When the **Selected** property is on, MATLAB indicates the selected state by

- Drawing handles at each vertex for a single-faced patch
- Drawing a dashed bounding box for a multifaced patch

When **SelectionHighlight** is off, MATLAB does not draw the handles.

SpecularColorReflectance
scalar in the range 0 to 1

Color of specularly reflected light. When this property is 0, the color of the specularly reflected light depends on both the color of the object from which it reflects and the color of the light source. When set to 1, the color of the specularly reflected light depends only on the color of the light source (i.e., the light object **Color** property). The proportions vary linearly for values in between.

Patch Properties

SpecularExponent

scalar ≥ 1

Harshness of specular reflection. This property controls the size of the specular spot. Most materials have exponents in the range of 5 to 20.

SpecularStrength

scalar ≥ 0 and ≤ 1

Intensity of specular light. This property sets the intensity of the specular component of the light falling on the patch. Specular light comes from `light` objects in the axes.

You can also set the intensity of the ambient and diffuse components of the light on the patch object. See the `AmbientStrength` and `DiffuseStrength` properties.

Tag

string

User-specified object label. The `Tag` property provides a means to identify graphics objects with a user-specified label. This is particularly useful when you are constructing interactive graphics programs that would otherwise need to define object handles as global variables or pass them as arguments between callback routines.

For example, suppose you use patch objects to create borders for a group of `uicontrol` objects and want to change the color of the borders in a `uicontrol`'s callback routine. You can specify a `Tag` with the patch definition

```
patch(X,Y,'k','Tag','PatchBorder')
```

Then use `findobj` in the `uicontrol`'s callback routine to obtain the handle of the patch and set its `FaceColor` property.

```
set(findobj('Tag','PatchBorder'),'FaceColor','w')
```

Type

string (read only)

Class of the graphics object. For patch objects, Type is always the string 'patch'.

UIContextMenu

handle of a uicontextmenu object

Associate a context menu with the patch. Assign this property the handle of a uicontextmenu object created in the same figure as the patch. Use the uicontextmenu function to create the context menu. MATLAB displays the context menu whenever you right-click over the patch.

UserData

matrix

User-specified data. Any matrix you want to associate with the patch object. MATLAB does not use this data, but you can access it using set and get.

VertexNormals

matrix

Surface normal vectors. This property contains the vertex normals for the patch. MATLAB generates this data to perform lighting calculations. You can supply your own vertex normal data, even if it does not match the coordinate data. This can be useful to produce interesting lighting effects.

Vertices

matrix

Vertex coordinates. A matrix containing the x -, y -, z -coordinates for each vertex. See the Faces property for more information.

Visible

{on} | off

Patch Properties

Patch object visibility. By default, all patches are visible. When set to off, the patch is not visible, but still exists, and you can query and set its properties.

XData

vector or matrix

X-coordinates. The x -coordinates of the patch vertices. If XData is a matrix, each column represents the x -coordinates of a single face of the patch. In this case, XData, YData, and ZData must have the same dimensions.

YData

vector or matrix

Y-coordinates. The y -coordinates of the patch vertices. If YData is a matrix, each column represents the y -coordinates of a single face of the patch. In this case, XData, YData, and ZData must have the same dimensions.

ZData

vector or matrix

Z-coordinates. The z -coordinates of the patch vertices. If ZData is a matrix, each column represents the z -coordinates of a single face of the patch. In this case, XData, YData, and ZData must have the same dimensions.

See Also

patch

Purpose

View or change search path

GUI Alternatives

As an alternative to the `path` function, use the Set Path dialog box.

Syntax

```
path
path('newpath')
path(path,'newpath')
path('newpath',path)
p = path(...)
```

Description

`path` displays the current MATLAB search path. The search path is stored in the file `pathdef.m`.

`path('newpath')` changes the search path to `newpath`, where `newpath` is a string array of directories.

`path(path,'newpath')` adds the `newpath` directory to the bottom of the current search path. If `newpath` is already on the path, then `path(path,'newpath')` moves `newpath` to the end of the path.

`path('newpath',path)` adds the `newpath` directory to the top of the current search path. If `newpath` is already on the path, then `path('newpath',path)` moves `newpath` to the beginning of the path.

`p = path(...)` returns the specified path in string variable `p`.

Examples

To display the search path, run

```
path
```

MATLAB displays, for example

```
MATLABPATH
```

```
H:\My Documents\MATLAB
C:\Program Files\MATLAB\R2009a\toolbox\matlab\general
C:\Program Files\MATLAB\R2009a\toolbox\matlab\ops
C:\Program Files\MATLAB\R2009a\toolbox\matlab\lang
```

path

```
C:\Program Files\MATLAB\R2009a\toolbox\matlab\elmat  
C:\Program Files\MATLAB\R2009a\toolbox\matlab\elfun  
...
```

Add a new directory to the search path on Microsoft Windows platforms.

```
path(path, 'c:/tools/goodstuff')
```

Add a new directory to the search path on UNIX²¹ platforms.

```
path(path, '/home/tools/goodstuff')
```

See Also

addpath, cd, dir, genpath, matlabroot, partialpath, pathsep, pathtool, rehash, restoredefaultpath, rmpath, savepath, startup, userpath, what

Search Path in the MATLAB Desktop Tools and Development Environment documentation, especially “Programmatically Working with the Search Path”.

21. UNIX is a registered trademark of The Open Group in the United States and other countries.

Purpose Save current search path to pathdef.m file

Syntax path2rc

Description path2rc runs savepath. The savepath function is replacing path2rc. Use savepath instead of path2rc and replace instances of path2rc with savepath.

pathsep

Purpose Path separator for current platform

Syntax `c = pathsep`

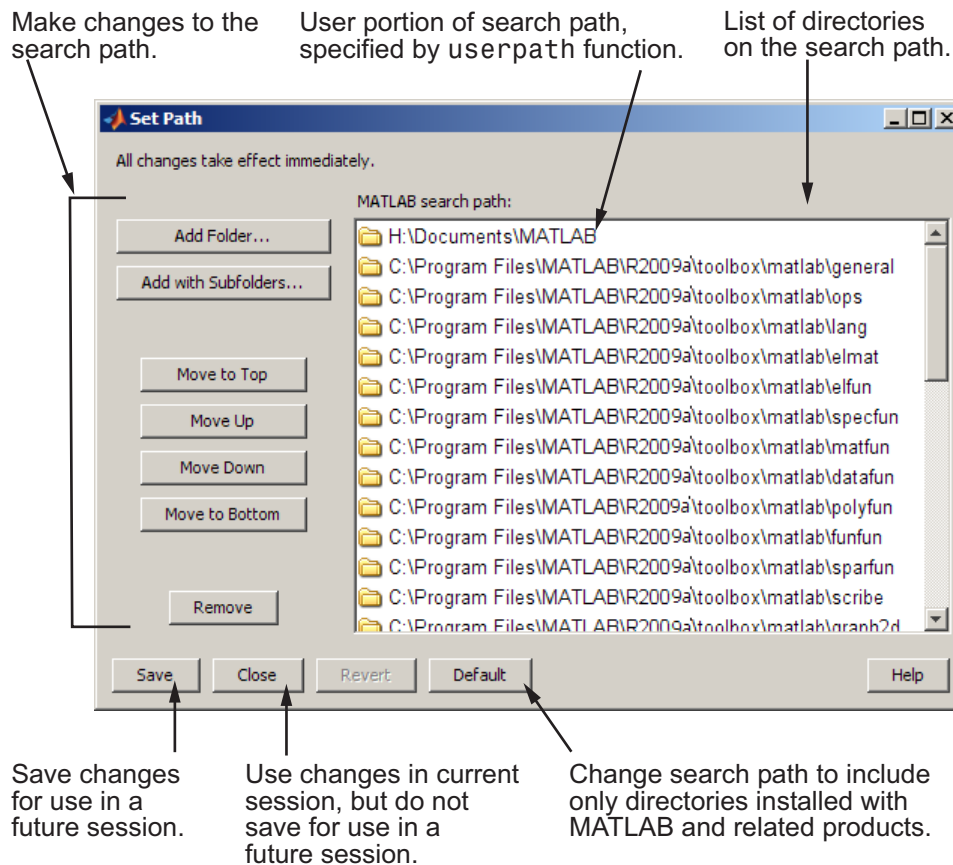
Description `c = pathsep` returns the path separator character for this platform. The path separator is the character that separates directories in the `pathdef.m` file. The character is a semicolon (;). For versions of MATLAB software prior to version 7.7 (R2008b), the character on UNIX²² platforms was a colon (:). Use `pathsep` when you need to work with the path file content programmatically, as a string.

See Also `fileparts`, `filesep`, `fullfile`, `partialpath`, `path`

22. UNIX is a registered trademark of The Open Group in the United States and other countries.

Purpose	Open Set Path dialog box to view and change search path
GUI Alternatives	As an alternative to the pathtool function, select File > Set Path in the MATLAB desktop.
Syntax	pathtool
Description	pathtool opens the Set Path dialog box, a graphical user interface you use to view and modify the search path MATLAB uses.

pathool



See Also

addpath, cd, dir, genpath, matlabroot, partialpath, path, pathsep, rehash, restoredefaultpath, rmpath, savepath, startup, what

Search Path topics, including “Overview of Viewing and Changing the Search Path”, in the MATLAB Desktop Tools and Development Environment documentation

Purpose Halt execution temporarily

Syntax

```

pause
pause(n)
pause on
pause off
pause query
state = pause('query')
oldstate = pause(newstate)

```

Description `pause`, by itself, causes the currently executing M-file to stop and wait for you to press any key before continuing. Pausing must be enabled for this to take effect. (See `pause on`, below). `pause` without arguments also blocks execution of Simulink models, but not repainting of them.

`pause(n)` pauses execution for `n` seconds before continuing, where `n` can be any nonnegative real number. The resolution of the clock is platform specific. A fractional pause of 0.01 seconds should be supported on most platforms. Pausing must be enabled for this to take effect.

Typing `pause(inf)` puts you into an infinite loop. To return to the MATLAB prompt, type **Ctrl+C**.

`pause on` enables the pausing of MATLAB execution via the `pause` and `pause(n)` commands. Pausing remains enabled until you enter `pause off` in your M-file or at the command line.

`pause off` disables the pausing of MATLAB execution via the `pause` and `pause(n)` commands. This allows normally interactive scripts to run unattended. Pausing remains disabled until you enter `pause on` in your M-file or at the command line, or start a new MATLAB session.

`pause query` displays 'on' if pausing is currently enabled. Otherwise, it displays 'off'.

`state = pause('query')` returns 'on' in character array `state` if pausing is currently enabled. Otherwise, the value of `state` is 'off'.

pause

`oldstate = pause(newstate)`, enables or disables pausing, depending on the 'on' or 'off' value in `newstate`, and returns the former setting (also either 'on' or 'off') in character array `oldstate`.

Remarks

While MATLAB is paused, the following continue to execute:

- Repainting of figure windows, Simulink block diagrams, and Java windows
- HG callbacks from figure windows
- Event handling from Java windows

See Also

`keyboard`, `input`, `drawnow`

Purpose Set or query plot box aspect ratio

Syntax

```
pbaspect
pbaspect([aspect_ratio])
pbaspect('mode')
pbaspect('auto')
pbaspect('manual')
pbaspect(axes_handle,...)
```

Description The plot box aspect ratio determines the relative size of the x -, y -, and z -axes.

`pbaspect` with no arguments returns the plot box aspect ratio of the current axes.

`pbaspect([aspect_ratio])` sets the plot box aspect ratio in the current axes to the specified value. Specify the aspect ratio as three relative values representing the ratio of the x -, y -, and z -axes size. For example, a value of `[1 1 1]` (the default) means the plot box is a cube (although with stretch-to-fill enabled, it may not appear as a cube). See Remarks.

`pbaspect('mode')` returns the current value of the plot box aspect ratio mode, which can be either `auto` (the default) or `manual`. See Remarks.

`pbaspect('auto')` sets the plot box aspect ratio mode to `auto`.

`pbaspect('manual')` sets the plot box aspect ratio mode to `manual`.

`pbaspect(axes_handle,...)` performs the set or query on the axes identified by the first argument, `axes_handle`. If you do not specify an axes handle, `pbaspect` operates on the current axes.

Remarks `pbaspect` sets or queries values of the axes object `PlotBoxAspectRatio` and `PlotBoxAspectRatioMode` properties.

When the plot box aspect ratio mode is `auto`, the MATLAB software sets the ratio to `[1 1 1]`, but may change it to accommodate manual settings of the data aspect ratio, camera view angle, or axis limits. See the axes `DataAspectRatio` property for a table listing the interactions between various properties.

Setting a value for the plot box aspect ratio or setting the plot box aspect ratio mode to `manual` disables the MATLAB stretch-to-fill feature (stretching of the axes to fit the window). This means setting the plot box aspect ratio to its current value,

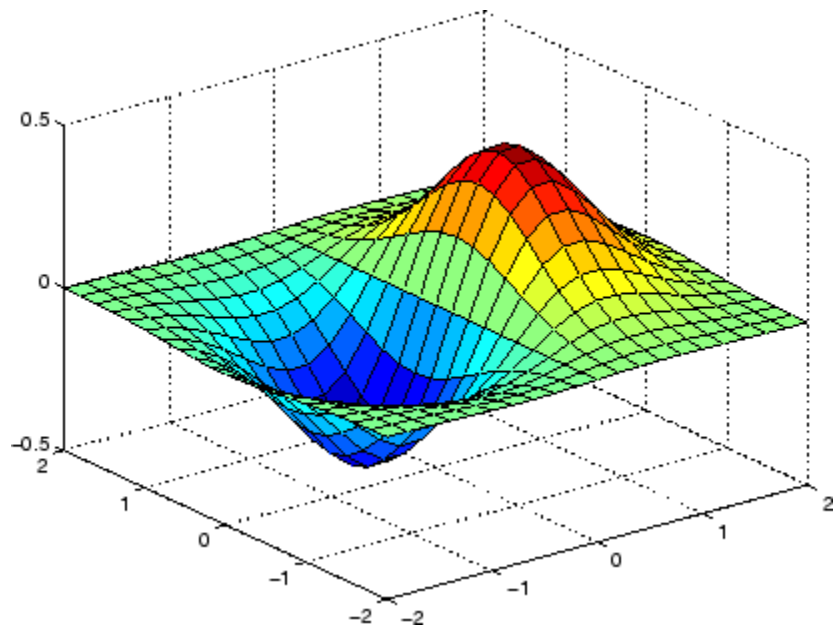
```
pbaspect(pbaspect)
```

can cause a change in the way the graphs look. See the Remarks section of the `axes` reference description, “Axes Aspect Ratio Properties” in the 3-D Visualization manual, and “Setting Aspect Ratio” in the MATLAB Graphics manual for a discussion of stretch-to-fill.

Examples

The following surface plot of the function $z = xe^{-x^2 - y^2}$ is useful to illustrate the plot box aspect ratio. First plot the function over the range $-2 \leq x \leq 2$, $-2 \leq y \leq 2$,

```
[x,y] = meshgrid([-2:.2:2]);  
z = x.*exp(-x.^2 - y.^2);  
surf(x,y,z)
```

Querying the plot box aspect ratio shows that the plot box is square.

```
pbaspect
ans =
    1    1    1
```

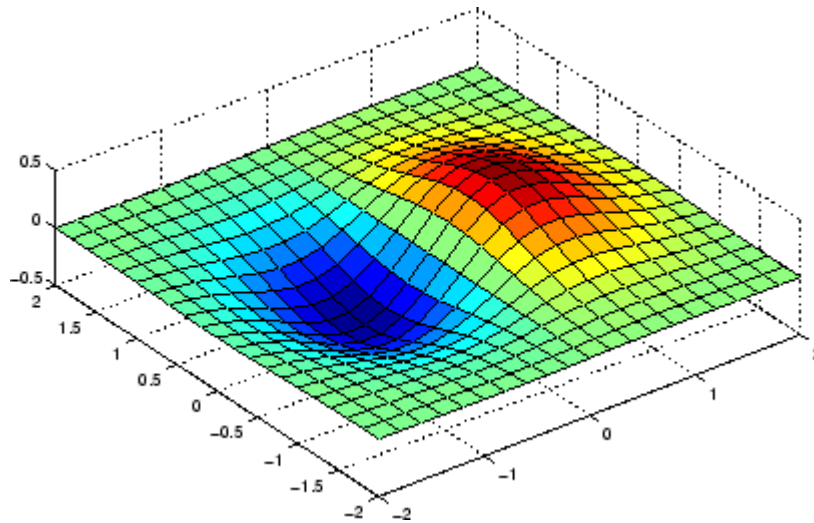
It is also interesting to look at the data aspect ratio selected by MATLAB.

```
daspect
ans =
    4    4    1
```

To illustrate the interaction between the plot box and data aspect ratios, set the data aspect ratio to [1 1 1] and again query the plot box aspect ratio.

```
daspect([1 1 1])
```

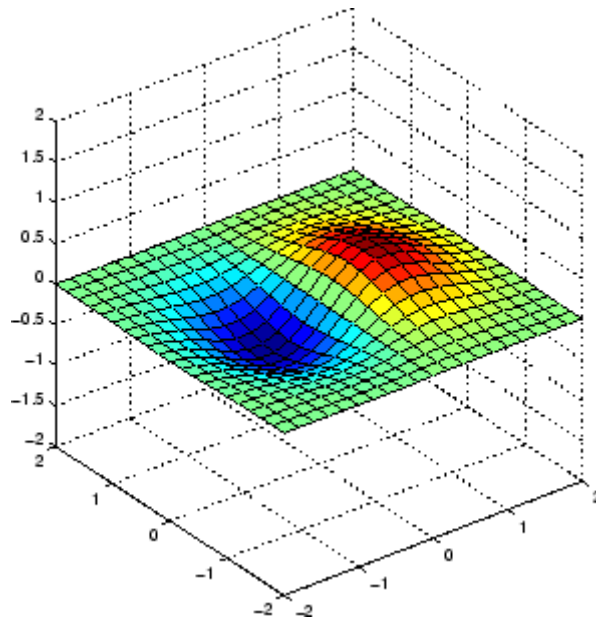
pbaspect



```
pbaspect
ans =
    4    4    1
```

The plot box aspect ratio has changed to accommodate the specified data aspect ratio. Now suppose you want the plot box aspect ratio to be [1 1 1] as well.

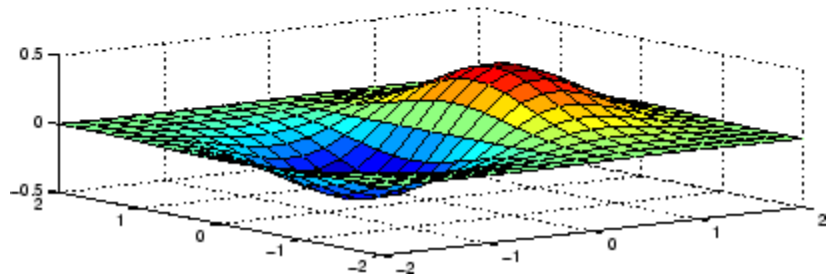
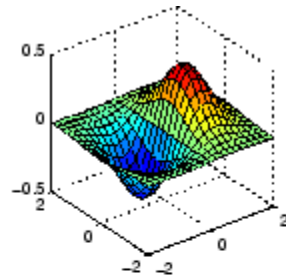
```
pbaspect([1 1 1])
```



Notice how MATLAB changed the axes limits because of the constraints introduced by specifying both the plot box and data aspect ratios.

You can also use `pbaspect` to disable stretch-to-fill. For example, displaying two subplots in one figure can give surface plots a squashed appearance. Disabling stretch-to-fill,

```
upper_plot = subplot(211);
surf(x,y,z)
lower_plot = subplot(212);
surf(x,y,z)
pbaspect(upper_plot, 'manual')
```



See Also

`axis`, `daspect`, `xlim`, `ylim`, `zlim`

The axes properties `DataAspectRatio`, `PlotBoxAspectRatio`, `XLim`, `YLim`, `ZLim`

Setting Aspect Ratio in the MATLAB Graphics manual

Axes Aspect Ratio Properties in the 3-D Visualization manual

Purpose Preconditioned conjugate gradients method

Syntax

```
x = pcg(A,b)
pcg(A,b,tol)
pcg(A,b,tol,maxit)
pcg(A,b,tol,maxit,M)
pcg(A,b,tol,maxit,M1,M2)
pcg(A,b,tol,maxit,M1,M2,x0)
[x,flag] = pcg(A,b,...)
[x,flag,relres] = pcg(A,b,...)
[x,flag,relres,iter] = pcg(A,b,...)
[x,flag,relres,iter,resvec] = pcg(A,b,...)
```

Description `x = pcg(A,b)` attempts to solve the system of linear equations $A*x=b$ for x . The n -by- n coefficient matrix A must be symmetric and positive definite, and should also be large and sparse. The column vector b must have length n . A can be a function handle `afun` such that `afun(x)` returns $A*x$. See Function Handles in the MATLAB Programming documentation for more information.

“Parametrizing Functions”, in the MATLAB Mathematics documentation, explains how to provide additional parameters to the function `afun`, as well as the preconditioner function `mfun` described below, if necessary.

If `pcg` converges, a message to that effect is displayed. If `pcg` fails to converge after the maximum number of iterations or halts for any reason, a warning message is printed displaying the relative residual $\text{norm}(b-A*x)/\text{norm}(b)$ and the iteration number at which the method stopped or failed.

`pcg(A,b,tol)` specifies the tolerance of the method. If `tol` is `[]`, then `pcg` uses the default, $1e-6$.

`pcg(A,b,tol,maxit)` specifies the maximum number of iterations. If `maxit` is `[]`, then `pcg` uses the default, $\min(n,20)$.

`pcg(A,b,tol,maxit,M)` and `pcg(A,b,tol,maxit,M1,M2)` use symmetric positive definite preconditioner M or $M = M1*M2$ and

effectively solve the system $\text{inv}(M) * A * x = \text{inv}(M) * b$ for x . If M is `[]` then `pcg` applies no preconditioner. M can be a function handle `mfun` such that `mfun(x)` returns $M \backslash x$.

`pcg(A,b,tol,maxit,M1,M2,x0)` specifies the initial guess. If `x0` is `[]`, then `pcg` uses the default, an all-zero vector.

`[x,flag] = pcg(A,b,...)` also returns a convergence flag.

Flag	Convergence
0	<code>pcg</code> converged to the desired tolerance <code>tol</code> within <code>maxit</code> iterations.
1	<code>pcg</code> iterated <code>maxit</code> times but did not converge.
2	Preconditioner M was ill-conditioned.
3	<code>pcg</code> stagnated. (Two consecutive iterates were the same.)
4	One of the scalar quantities calculated during <code>pcg</code> became too small or too large to continue computing.

Whenever `flag` is not 0, the solution x returned is that with minimal norm residual computed over all the iterations. No messages are displayed if the `flag` output is specified.

`[x,flag,relres] = pcg(A,b,...)` also returns the relative residual $\text{norm}(b-A*x)/\text{norm}(b)$. If `flag` is 0, `relres` \leq `tol`.

`[x,flag,relres,iter] = pcg(A,b,...)` also returns the iteration number at which x was computed, where $0 \leq \text{iter} \leq \text{maxit}$.

`[x,flag,relres,iter,resvec] = pcg(A,b,...)` also returns a vector of the residual norms at each iteration including $\text{norm}(b-A*x0)$.

Examples

Example 1

```
n1 = 21;
A = gallery('moler',n1);
b1 = A*ones(n1,1);
tol = 1e-6;
```

```

maxit = 15;
M = diag([10:-1:1 1 1:10]);
[x1,flag1,rr1,iter1,rv1] = pcg(A,b1,tol,maxit,M);

```

Alternatively, you can use the following parameterized matrix-vector product function `afun` in place of the matrix `A`:

```

afun = @(x,n)gallery('moler',n)*x;
n2 = 21;
b2 = afun(ones(n2,1),n2);
[x2,flag2,rr2,iter2,rv2] = pcg(@(x)afun(x,n2),b2,tol,maxit,M);

```

Example 2

```

A = delsq(numgrid('C',25));
b = ones(length(A),1);
[x,flag] = pcg(A,b)

```

`flag` is 1 because `pcg` does not converge to the default tolerance of $1e-6$ within the default 20 iterations.

```

R = cholinc(A,1e-3);
[x2,flag2,relres2,iter2,resvec2] = pcg(A,b,1e-8,10,R',R)

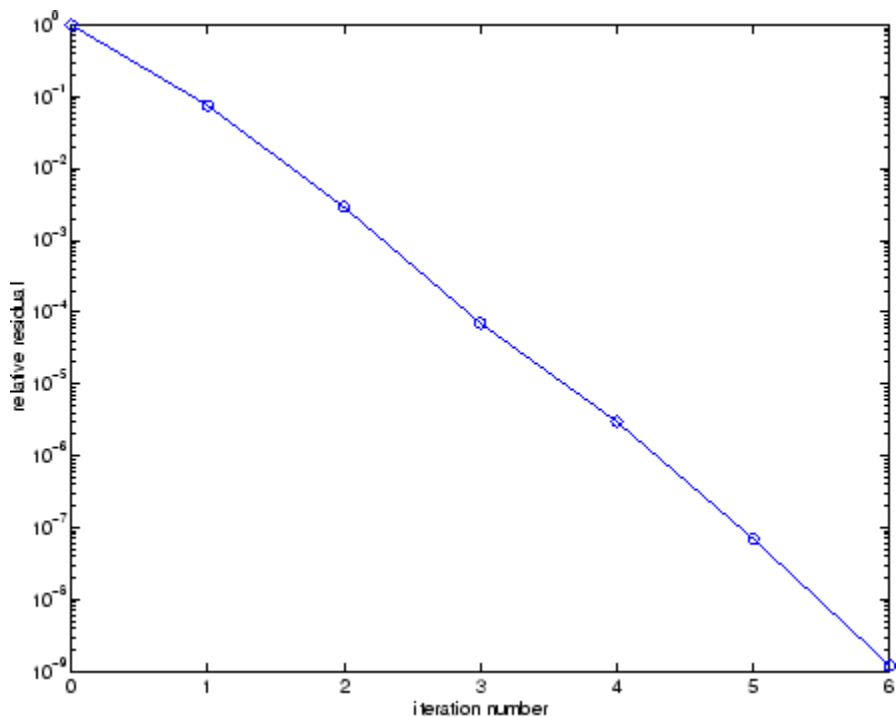
```

`flag2` is 0 because `pcg` converges to the tolerance of $1.2e-9$ (the value of `relres2`) at the sixth iteration (the value of `iter2`) when preconditioned by the incomplete Cholesky factorization with a drop tolerance of $1e-3$. `resvec2(1) = norm(b)` and `resvec2(7) = norm(b-A*x2)`. You can follow the progress of `pcg` by plotting the relative residuals at each iteration starting from the initial estimate (iterate number 0).

```

semilogy(0:iter2,resvec2/norm(b),'-o')
xlabel('iteration number')
ylabel('relative residual')

```



See Also

bicg, bicgstab, cgs, cholinc, gmres, lsqr, minres, qmr, symmlq
function_handle (@), mldivide (\)

References

[1] Barrett, R., M. Berry, T. F. Chan, et al., *Templates for the Solution of Linear Systems: Building Blocks for Iterative Methods*, SIAM, Philadelphia, 1994.

Purpose

Piecewise Cubic Hermite Interpolating Polynomial (PCHIP)

Syntax

```
yi = pchip(x,y,xi)
pp = pchip(x,y)
```

Description

`yi = pchip(x,y,xi)` returns vector `yi` containing elements corresponding to the elements of `xi` and determined by piecewise cubic interpolation within vectors `x` and `y`. The vector `x` specifies the points at which the data `y` is given. If `y` is a matrix, then the interpolation is performed for each column of `y` and `yi` is `length(xi)-by-size(y,2)`.

`pp = pchip(x,y)` returns a piecewise polynomial structure for use by `ppval`. `x` can be a row or column vector. `y` is a row or column vector of the same length as `x`, or a matrix with `length(x)` columns.

`pchip` finds values of an underlying interpolating function $P(x)$ at intermediate points, such that:

- On each subinterval $x_k \leq x \leq x_{k+1}$, $P(x)$ is the cubic Hermite interpolant to the given values and certain slopes at the two endpoints.
- $P(x)$ interpolates y , i.e., $P(x_j) = y_j$, and the first derivative $P'(x)$ is continuous. $P''(x)$ is probably not continuous; there may be jumps at the x_j .
- The slopes at the x_j are chosen in such a way that $P(x)$ preserves the shape of the data and respects monotonicity. This means that, on intervals where the data are monotonic, so is $P(x)$; at points where the data has a local extremum, so does $P(x)$.

Note If y is a matrix, $P(x)$ satisfies the above for each column of y .

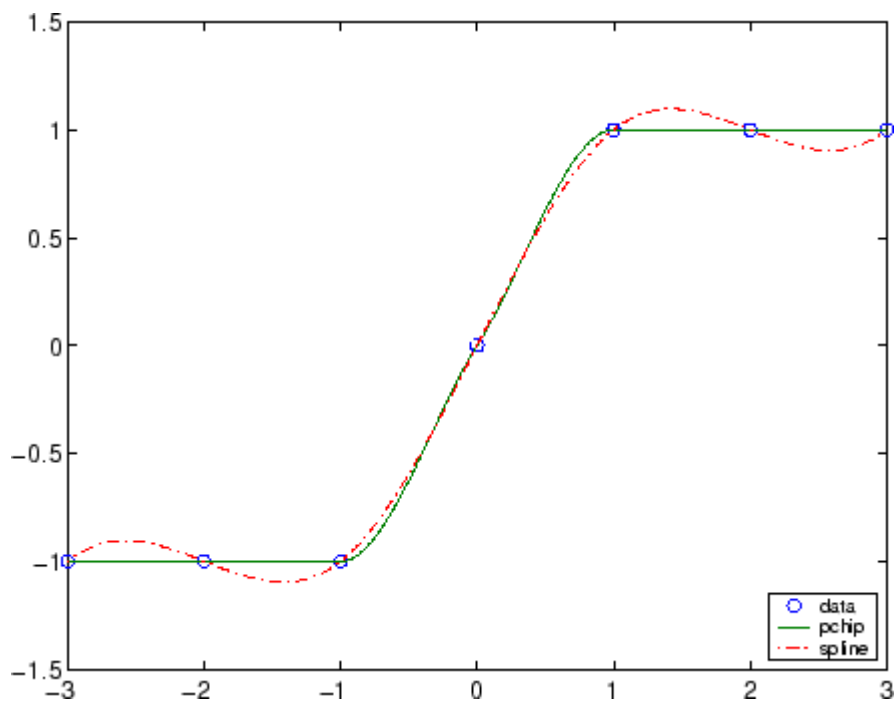
Remarks

`spline` constructs $S(x)$ in almost the same way `pchip` constructs $P(x)$. However, `spline` chooses the slopes at the x_j differently, namely to make even $S''(x)$ continuous. This has the following effects:

- `spline` produces a smoother result, i.e. $S''(x)$ is continuous.
- `spline` produces a more accurate result if the data consists of values of a smooth function.
- `pchip` has no overshoots and less oscillation if the data are not smooth.
- `pchip` is less expensive to set up.
- The two are equally expensive to evaluate.

Examples

```
x = -3:3;
y = [-1 -1 -1 0 1 1 1];
t = -3:.01:3;
p = pchip(x,y,t);
s = spline(x,y,t);
plot(x,y,'o',t,p,'-',t,s,'-.')
legend('data','pchip','spline',4)
```



See Also

`interp1`, `spline`, `ppval`

References

- [1] Fritsch, F. N. and R. E. Carlson, "Monotone Piecewise Cubic Interpolation," *SIAM J. Numerical Analysis*, Vol. 17, 1980, pp.238-246.
- [2] Kahaner, David, Cleve Moler, Stephen Nash, *Numerical Methods and Software*, Prentice Hall, 1988.

pcode

Purpose Create protected M-file (P-file)

Syntax

```
pcode fun
pcode *.m
pcode fun1 fun2 ...
pcode... -inplace
```

Description pcode *fun* obfuscates (i.e., *shrouds*) M-file *fun.m* for the purpose of protecting its proprietary source code. The encrypted M-code is written to P-file *fun.p* in the current directory. The original M-file can be anywhere on the search path.

If the input file resides within a package and/or class directory, then the same package and class directories are applied to the output file. See example 2, below.

pcode *.m creates P-files for all the M-files in the current directory.

pcode *fun1 fun2 ...* creates P-files for the listed functions.

pcode... -inplace creates P-files in the same directory as the M-files. An error occurs if the files cannot be created.

See “Creating P-Code Files” in the MATLAB Programming Fundamentals documentation for more information.

Examples

Example 1 – PCoding Multiple Files

Convert selected M-files from the sparfun directory into pcode files:

```
dir([matlabroot '\toolbox\matlab\sparfun\spr*.m'])
.    ..    sprand.m    sprandn.m    sprandsym.m    sprank.m

cd C:\work\pcodetest
pcode([matlabroot '\toolbox\matlab\sparfun\spr*.m'])

dir C:\work\pcodetest

.    sprand.m    sprandn.m    sprandsym.m    sprank.m
```

```
..      sprand.p      sprandn.p      sprandsym.p      sprank.p
```

Example 2 – Parsing Files That Belong to a Package and/or Class

This example takes an input file that is part of a package and class, and generates a pcode file for it in a separate directory. M-file `test.m` resides in the following package and class directory:

```
C:\work\+mypkg\@char\test.m
```

Set your current working directory to empty directory `math\pcodetest`. This is where you will generate the pcode file. This directory has no package or class structure associated with it at this time:

```
cd C:\math\pcodetest
dir
.   ..
```

Generate pcode for `test.m`. Because the input file is part of a package and class, MATLAB creates directories `+mypkg` and `@char` so that the output file belongs to the same:

```
pcode C:\work\+mypkg\@char\test.m
dir('C:\math\pcodetest\+mypkg\@char')
.   ..      test.p
```

Example 3 – PCoding In Place

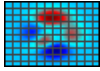
When you generate a pcode file `inplace`, MATLAB writes the output file to the same directory as the input file:

```
pcode C:\work\+mypkg\@char\test.m -inplace
dir C:\work\+mypkg\@char
.   ..      test.m  test.p
```


See Also

`depfun`, `depdir`,

Purpose Pseudocolor (checkerboard) plot



GUI Alternatives

To graph selected variables, use the Plot Selector  in the Workspace Browser, or use the Figure Palette Plot Catalog. Manipulate graphs in *plot edit* mode with the Property Editor. For details, see [Plotting Tools — Interactive Plotting in the MATLAB Graphics documentation](#) and [Creating Graphics from the Workspace Browser in the MATLAB Desktop Tools documentation](#).

Syntax

```
pcolor(C)
pcolor(X,Y,C)
pcolor(axes_handles,...)
h = pcolor(...)
```

Description

A pseudocolor plot is a rectangular array of cells with colors determined by **C**. MATLAB creates a pseudocolor plot using each set of four adjacent points in **C** to define a surface rectangle (i.e., cell).

The default shading is `faceted`, which colors each cell with a single color. The last row and column of **C** are not used in this case. With shading `interp`, each cell is colored by bilinear interpolation of the colors at its four vertices, using all elements of **C**.

The minimum and maximum elements of **C** are assigned the first and last colors in the colormap. Colors for the remaining elements in **C** are determined by a linear mapping from value to colormap element.

`pcolor(C)` draws a pseudocolor plot. The elements of **C** are linearly mapped to an index into the current colormap. The mapping from **C** to the current colormap is defined by `colormap` and `caxis`.

`pcolor(X,Y,C)` draws a pseudocolor plot of the elements of **C** at the locations specified by **X** and **Y**. The plot is a logically rectangular, two-dimensional grid with vertices at the points $[X(i,j), Y(i,j)]$. **X** and **Y** are vectors or matrices that specify the spacing of the grid lines. If

X and Y are vectors, X corresponds to the columns of C and Y corresponds to the rows. If X and Y are matrices, they must be the same size as C.

`pcolor(axes_handles,...)` plots into the axes with handle `axes_handle` instead of the current axes (`gca`).

`h = pcolor(...)` returns a handle to a surface graphics object.

Remarks

A pseudocolor plot is a flat surface plot viewed from above.

`pcolor(X,Y,C)` is the same as viewing `surf(X,Y,zeros(size(X)),C)` using `view([0 90])`.

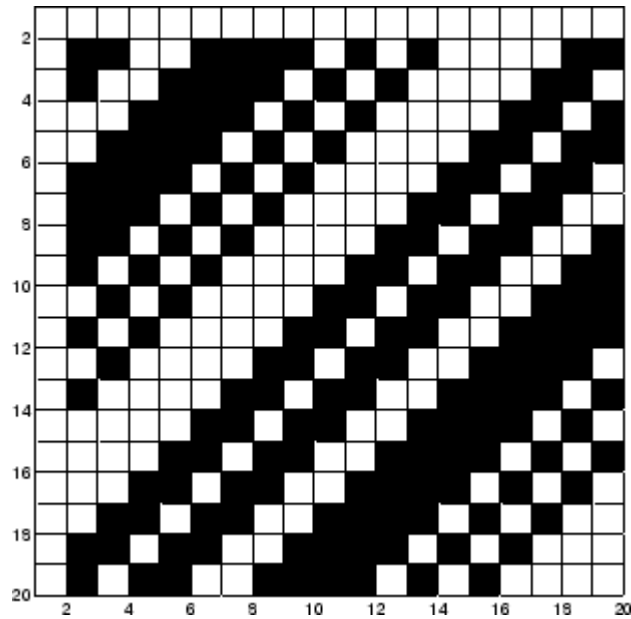
When you use `shading faceted` or `shading flat`, the constant color of each cell is the color associated with the corner having the smallest *x-y* coordinates. Therefore, `C(i,j)` determines the color of the cell in the *i*th row and *j*th column. The last row and column of C are not used.

When you use `shading interp`, each cell's color results from a bilinear interpolation of the colors at its four vertices, and all elements of C are used.

Examples

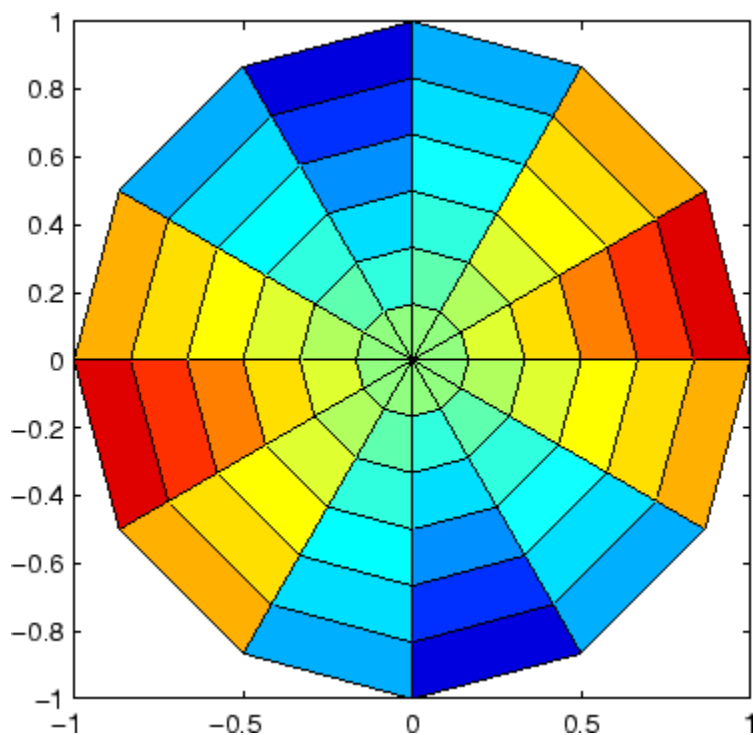
A Hadamard matrix has elements that are +1 and -1. A colormap with only two entries is appropriate when displaying a pseudocolor plot of this matrix.

```
pcolor(hadamard(20))
colormap(gray(2))
axis ij
axis square
```



A simple color wheel illustrates a polar coordinate system.

```
n = 6;  
r = (0:n)'/n;  
theta = pi*(-n:n)/n;  
X = r*cos(theta);  
Y = r*sin(theta);  
C = r*cos(2*theta);  
pcolor(X,Y,C)  
axis equal tight
```

Algorithm

The number of vertex colors for `pcolor(C)` is the same as the number of cells for `image(C)`. `pcolor` differs from `image` in that `pcolor(C)` specifies the colors of vertices, which are scaled to fit the colormap; changing the axes `clim` property changes this color mapping. `image(C)` specifies the colors of cells and directly indexes into the colormap without scaling. Additionally, `pcolor(X,Y,C)` can produce parametric grids, which is not possible with `image`.

See Also

`caxis`, `image`, `mesh`, `shading`, `surf`, `view`

pdepe

Purpose Solve initial-boundary value problems for parabolic-elliptic PDEs in 1-D

Syntax
`sol = pdepe(m,pdefun,icfun,bcfun,xmesh,tspan)`
`sol = pdepe(m,pdefun,icfun,bcfun,xmesh,tspan,options)`

Arguments

<code>m</code>	A parameter corresponding to the symmetry of the problem. <code>m</code> can be <code>slab = 0</code> , <code>cylindrical = 1</code> , or <code>spherical = 2</code> .
<code>pdefun</code>	A handle to a function that defines the components of the PDE.
<code>icfun</code>	A handle to a function that defines the initial conditions.
<code>bcfun</code>	A handle to a function that defines the boundary conditions.
<code>xmesh</code>	A vector [<code>x0</code> , <code>x1</code> , ..., <code>xn</code>] specifying the points at which a numerical solution is requested for every value in <code>tspan</code> . The elements of <code>xmesh</code> must satisfy <code>x0 < x1 < ... < xn</code> . The length of <code>xmesh</code> must be <code>>= 3</code> .
<code>tspan</code>	A vector [<code>t0</code> , <code>t1</code> , ..., <code>tf</code>] specifying the points at which a solution is requested for every value in <code>xmesh</code> . The elements of <code>tspan</code> must satisfy <code>t0 < t1 < ... < tf</code> . The length of <code>tspan</code> must be <code>>= 3</code> .
<code>options</code>	Some options of the underlying ODE solver are available in <code>pdepe</code> : <code>RelTol</code> , <code>AbsTol</code> , <code>NormControl</code> , <code>InitialStep</code> , and <code>MaxStep</code> . In most cases, default values for these options provide satisfactory solutions. See <code>odeset</code> for details.

Description `sol = pdepe(m,pdefun,icfun,bcfun,xmesh,tspan)` solves initial-boundary value problems for systems of parabolic and elliptic PDEs in the one space variable x and time t . `pdefun`, `icfun`, and

bcfun are function handles. See “Function Handles” in the MATLAB Programming documentation for more information. The ordinary differential equations (ODEs) resulting from discretization in space are integrated to obtain approximate solutions at times specified in tspan. The pdepe function returns values of the solution on a mesh provided in xmesh.

“Parametrizing Functions”, in the MATLAB Mathematics documentation, explains how to provide additional parameters to the functions pdefun, icfun, or bcfun, if necessary.

pdepe solves PDEs of the form:

$$c\left(x, t, u, \frac{\partial u}{\partial x}\right) \frac{\partial u}{\partial t} = x^{-m} \frac{\partial}{\partial x} \left(x^m f\left(x, t, u, \frac{\partial u}{\partial x}\right) \right) + s\left(x, t, u, \frac{\partial u}{\partial x}\right)$$

The PDEs hold for $t_0 \leq t \leq t_f$ and $a \leq x \leq b$. The interval $[a, b]$ must be finite. m can be 0, 1, or 2, corresponding to slab, cylindrical, or spherical symmetry, respectively. If $m > 0$, then a must be ≥ 0 .

In Equation 2-2, $f(x, t, u, \partial u/\partial x)$ is a flux term and $s(x, t, u, \partial u/\partial x)$ is a source term. The coupling of the partial derivatives with respect to time is restricted to multiplication by a diagonal matrix $c(x, t, u, \partial u/\partial x)$. The diagonal elements of this matrix are either identically zero or positive. An element that is identically zero corresponds to an elliptic equation and otherwise to a parabolic equation. There must be at least one parabolic equation. An element of c that corresponds to a parabolic equation can vanish at isolated values of x if those values of x are mesh points. Discontinuities in c and/or s due to material interfaces are permitted provided that a mesh point is placed at each interface.

For $t = t_0$ and all x , the solution components satisfy initial conditions of the form

$$u(x, t_0) = u_0(x) \quad (2-3)$$

For all t and either $x = a$ or $x = b$, the solution components satisfy a boundary condition of the form

$$p(x, t, u) + q(x, t) f\left(x, t, u, \frac{\partial u}{\partial x}\right) = 0 \quad (2-4)$$

Elements of q are either identically zero or never zero. Note that the boundary conditions are expressed in terms of the flux f rather than $\partial u / \partial x$. Also, of the two coefficients, only p can depend on u .

In the call `sol = pdepe(m, pdefun, icfun, bcfun, xmesh, tspan)`:

- `m` corresponds to m .
- `xmesh(1)` and `xmesh(end)` correspond to a and b .
- `tspan(1)` and `tspan(end)` correspond to t_0 and t_f .
- `pdefun` computes the terms c , f , and s (Equation 2-2). It has the form

$$[c, f, s] = pdefun(x, t, u, dudx)$$

The input arguments are scalars x and t and vectors u and `dudx` that approximate the solution u and its partial derivative with respect to x , respectively. c , f , and s are column vectors. c stores the diagonal elements of the matrix C (Equation 2-2).

- `icfun` evaluates the initial conditions. It has the form

$$u = icfun(x)$$

When called with an argument x , `icfun` evaluates and returns the initial values of the solution components at x in the column vector u .

- `bcfun` evaluates the terms p and q of the boundary conditions (Equation 2-4). It has the form

$$[pl, ql, pr, qr] = bcfun(xl, ul, xr, ur, t)$$

u_l is the approximate solution at the left boundary $x_l = a$ and u_r is the approximate solution at the right boundary $x_r = b$. p_l and q_l are column vectors corresponding to P and q evaluated at x_l , similarly p_r and q_r correspond to x_r . When $m > 0$ and $a = 0$, boundedness of the solution near $x = 0$ requires that the flux f vanish at $a = 0$. `pdepe` imposes this boundary condition automatically and it ignores values returned in p_l and q_l .

`pdepe` returns the solution as a multidimensional array `sol`.

$u_i = u_i = \text{sol}(:, :, i)$ is an approximation to the i th component of the solution vector u . The element $u_i(j, k) = \text{sol}(j, k, i)$ approximates u_i at $(t, x) = (\text{tspan}(j), \text{xmesh}(k))$.

$u_i = \text{sol}(j, :, i)$ approximates component i of the solution at time $\text{tspan}(j)$ and mesh points $\text{xmesh}(:)$. Use `pdeval` to compute the approximation and its partial derivative $\partial u_i / \partial x$ at points not included in xmesh . See `pdeval` for details.

`sol = pdepe(m, pdefun, icfun, bcfun, xmesh, tspan, options)` solves as above with default integration parameters replaced by values in `options`, an argument created with the `odeset` function. Only some of the options of the underlying ODE solver are available in `pdepe`: `RelTol`, `AbsTol`, `NormControl`, `InitialStep`, and `MaxStep`. The defaults obtained by leaving off the input argument `options` will generally be satisfactory. See `odeset` for details.

Remarks

- The arrays `xmesh` and `tspan` play different roles in `pdepe`.
 - tspan** – The `pdepe` function performs the time integration with an ODE solver that selects both the time step and formula dynamically. The elements of `tspan` merely specify where you want answers and the cost depends weakly on the length of `tspan`.
 - xmesh** – Second order approximations to the solution are made on the mesh specified in `xmesh`. Generally, it is best to use closely spaced mesh points where the solution changes rapidly. `pdepe` does *not* select the mesh in x automatically. You must provide an appropriate

fixed mesh in `xmesh`. The cost depends strongly on the length of `xmesh`. When $m > 0$, it is not necessary to use a fine mesh near $x = 0$ to account for the coordinate singularity.

- The time integration is done with `ode15s`. `pdepe` exploits the capabilities of `ode15s` for solving the differential-algebraic equations that arise when Equation 2-2 contains elliptic equations, and for handling Jacobians with a specified sparsity pattern.
- After discretization, elliptic equations give rise to algebraic equations. If the elements of the initial conditions vector that correspond to elliptic equations are not "consistent" with the discretization, `pdepe` tries to adjust them before beginning the time integration. For this reason, the solution returned for the initial time may have a discretization error comparable to that at any other time. If the mesh is sufficiently fine, `pdepe` can find consistent initial conditions close to the given ones. If `pdepe` displays a message that it has difficulty finding consistent initial conditions, try refining the mesh.

No adjustment is necessary for elements of the initial conditions vector that correspond to parabolic equations.

Examples

Example 1. This example illustrates the straightforward formulation, computation, and plotting of the solution of a single PDE.

$$\pi^2 \frac{\partial u}{\partial t} = \frac{\partial}{\partial x} \left(\frac{\partial u}{\partial x} \right)$$

This equation holds on an interval $0 \leq x \leq 1$ for times $t \geq 0$.

The PDE satisfies the initial condition

$$u(x, 0) = \sin \pi x$$

and boundary conditions

$$u(0, t) \equiv 0$$

$$\pi e^{-t} + \frac{\partial u}{\partial x}(1, t) = 0$$

It is convenient to use subfunctions to place all the functions required by pdepe in a single M-file.

```
function pdex1

m = 0;
x = linspace(0,1,20);
t = linspace(0,2,5);

sol = pdepe(m,@pdex1pde,@pdex1ic,@pdex1bc,x,t);
% Extract the first solution component as u.
u = sol(:,:,1);

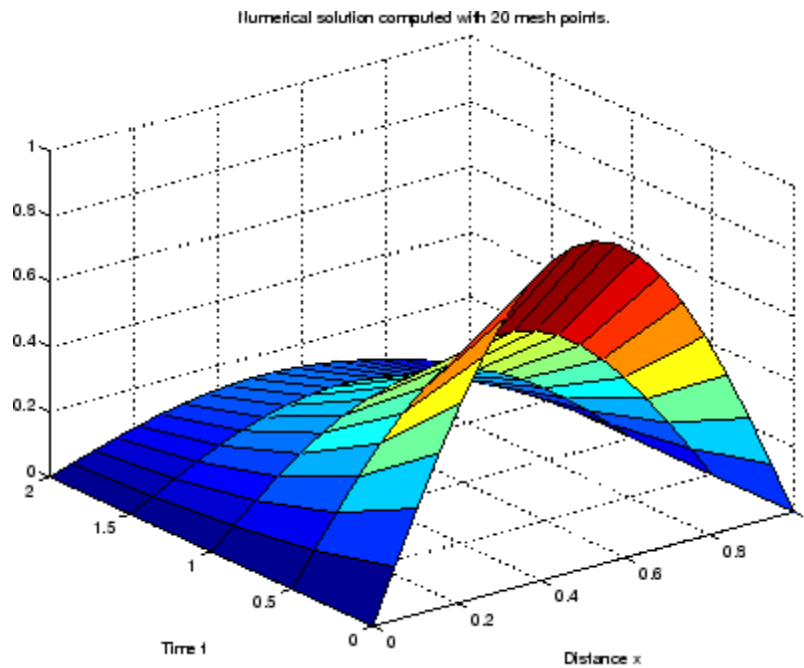
% A surface plot is often a good way to study a solution.
surf(x,t,u)
title('Numerical solution computed with 20 mesh points.')
xlabel('Distance x')
ylabel('Time t')

% A solution profile can also be illuminating.
figure
plot(x,u(end,:))
title('Solution at t = 2')
xlabel('Distance x')
ylabel('u(x,2)')
% -----
function [c,f,s] = pdex1pde(x,t,u,DuDx)
c = pi^2;
f = DuDx;
s = 0;
% -----
function u0 = pdex1ic(x)
u0 = sin(pi*x);
```

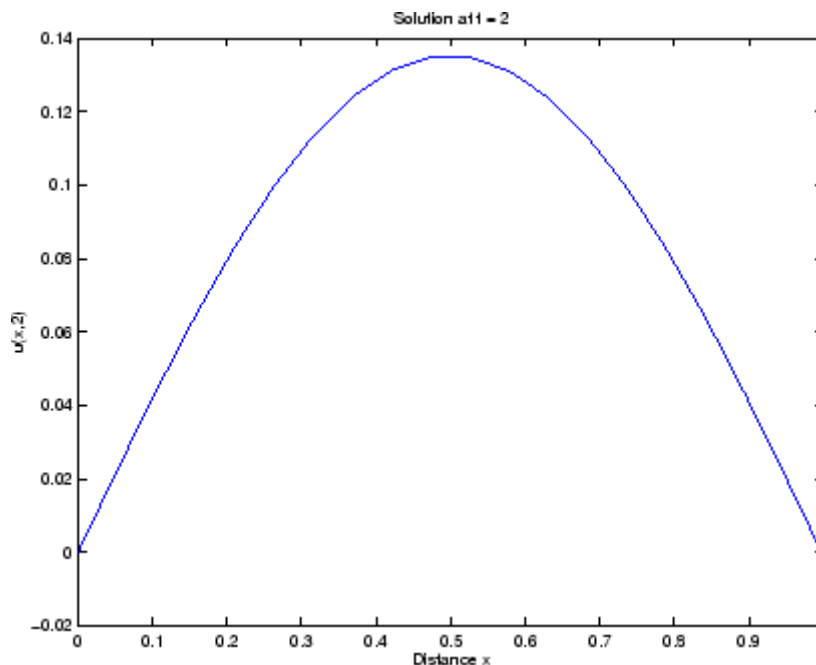
```
% -----  
function [pl,ql,pr,qr] = pdex1bc(xl,ul,xr,ur,t)  
pl = ul;  
ql = 0;  
pr = pi * exp(-t);  
qr = 1;
```

In this example, the PDE, initial condition, and boundary conditions are coded in subfunctions `pdex1pde`, `pdex1ic`, and `pdex1bc`.

The surface plot shows the behavior of the solution.



The following plot shows the solution profile at the final value of t (i.e., $t = 2$).



Example 2. This example illustrates the solution of a system of PDEs. The problem has boundary layers at both ends of the interval. The solution changes rapidly for small t .

The PDEs are

$$\frac{\partial u_1}{\partial t} = 0.024 \frac{\partial^2 u_1}{\partial x^2} - F(u_1 - u_2)$$

$$\frac{\partial u_2}{\partial t} = 0.170 \frac{\partial^2 u_2}{\partial x^2} + F(u_1 - u_2)$$

where $F(y) = \exp(5.73y) - \exp(-11.46y)$.

This equation holds on an interval $0 \leq x \leq 1$ for times $t \geq 0$.

The PDE satisfies the initial conditions

$$u_1(x, 0) \equiv 1$$

$$u_2(x, 0) \equiv 0$$

and boundary conditions

$$\frac{\partial u_1}{\partial x}(0, t) \equiv 0$$

$$u_2(0, t) \equiv 0$$

$$u_1(1, t) \equiv 1$$

$$\frac{\partial u_2}{\partial x}(1, t) \equiv 0$$

In the form expected by pdepe, the equations are

$$\begin{bmatrix} 1 \\ 1 \end{bmatrix} \cdot \frac{\partial}{\partial t} \begin{bmatrix} u_1 \\ u_2 \end{bmatrix} = \frac{\partial}{\partial x} \begin{bmatrix} 0.024(\partial u_1 / \partial x) \\ 0.170(\partial u_2 / \partial x) \end{bmatrix} + \begin{bmatrix} -F(u_1 - u_2) \\ F(u_1 - u_2) \end{bmatrix}$$

The boundary conditions on the partial derivatives of \mathbf{u} have to be written in terms of the flux. In the form expected by pdepe, the left boundary condition is

$$\begin{bmatrix} 0 \\ u_2 \end{bmatrix} + \begin{bmatrix} 1 \\ 0 \end{bmatrix} \cdot \begin{bmatrix} 0.024(\partial u_1 / \partial x) \\ 0.170(\partial u_2 / \partial x) \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$$

and the right boundary condition is

$$\begin{bmatrix} u_1 - 1 \\ 0 \end{bmatrix} + \begin{bmatrix} 0 \\ 1 \end{bmatrix} .* \begin{bmatrix} 0.024(\partial u_1 / \partial x) \\ 0.170(\partial u_2 / \partial x) \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$$

The solution changes rapidly for small t . The program selects the step size in time to resolve this sharp change, but to see this behavior in the plots, the example must select the output times accordingly. There are boundary layers in the solution at both ends of [0,1], so the example places mesh points near 0 and 1 to resolve these sharp changes. Often some experimentation is needed to select a mesh that reveals the behavior of the solution.

```
function pdex4
m = 0;
x = [0 0.005 0.01 0.05 0.1 0.2 0.5 0.7 0.9 0.95 0.99 0.995 1];
t = [0 0.005 0.01 0.05 0.1 0.5 1 1.5 2];

sol = pdepe(m,@pdex4pde,@pdex4ic,@pdex4bc,x,t);
u1 = sol(:,:,1);
u2 = sol(:,:,2);

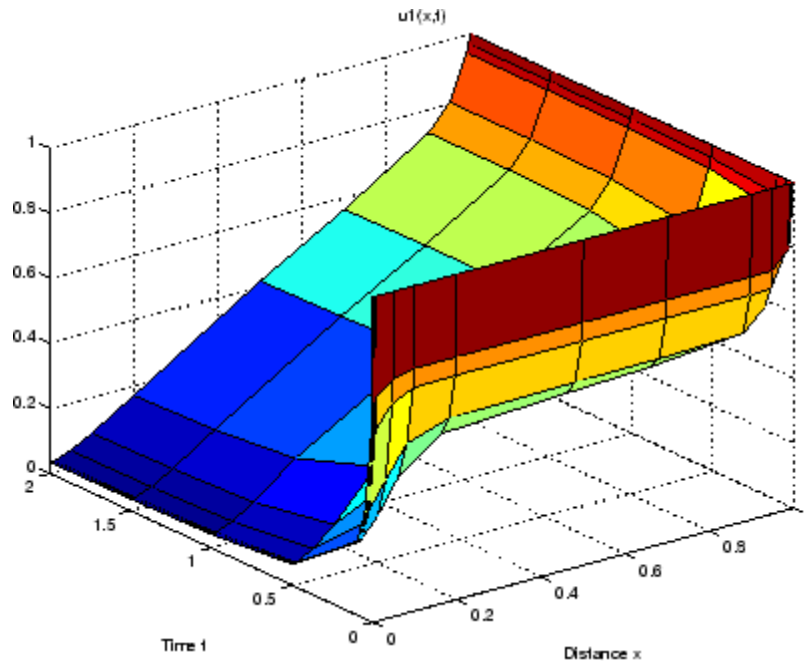
figure
surf(x,t,u1)
title('u1(x,t)')
xlabel('Distance x')
ylabel('Time t')

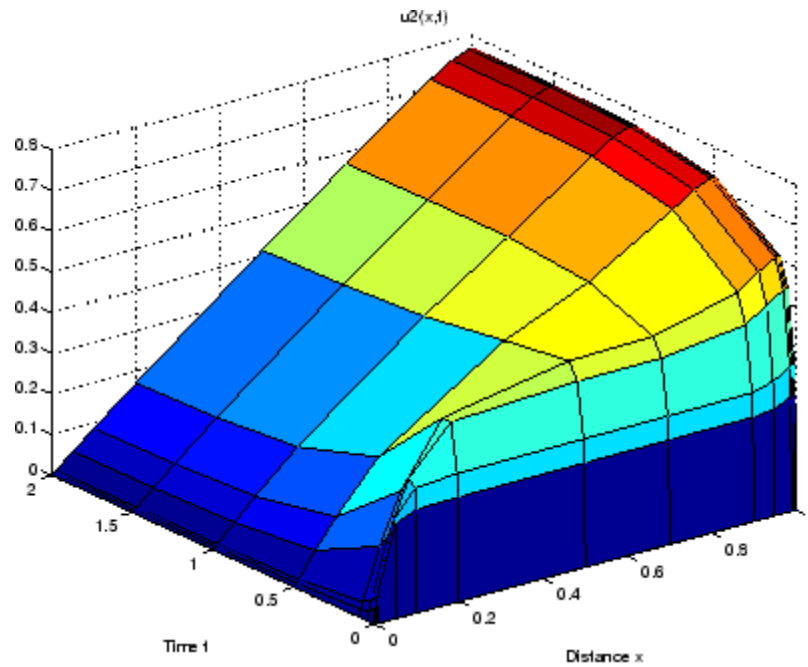
figure
surf(x,t,u2)
title('u2(x,t)')
xlabel('Distance x')
ylabel('Time t')
% -----
function [c,f,s] = pdex4pde(x,t,u,DuDx)
c = [1; 1];
f = [0.024; 0.17] .* DuDx;
y = u(1) - u(2);
```

```
F = exp(5.73*y)-exp(-11.47*y);  
s = [-F; F];  
% -----  
function u0 = pdex4ic(x);  
u0 = [1; 0];  
% -----  
function [p1,q1,pr,qr] = pdex4bc(x1,u1,xr,ur,t)  
p1 = [0; u1(2)];  
q1 = [1; 0];  
pr = [ur(1)-1; 0];  
qr = [0; 1];
```

In this example, the PDEs, initial conditions, and boundary conditions are coded in subfunctions `pdex4pde`, `pdex4ic`, and `pdex4bc`.

The surface plots show the behavior of the solution components.



**See Also**

`function_handle` (@), `pdeval`, `ode15s`, `odeset`, `odeget`

References

[1] Skeel, R. D. and M. Berzins, "A Method for the Spatial Discretization of Parabolic Equations in One Space Variable," *SIAM Journal on Scientific and Statistical Computing*, Vol. 11, 1990, pp.1-32.

pdeval

Purpose Evaluate numerical solution of PDE using output of pdepe

Syntax `[uout,duoutdx] = pdeval(m,x,ui,xout)`

Arguments

m	Symmetry of the problem: slab = 0, cylindrical = 1, spherical = 2. This is the first input argument used in the call to pdepe.
xmesh	A vector [x0, x1, ..., xn] specifying the points at which the elements of ui were computed. This is the same vector with which pdepe was called.
ui	A vector sol(j,:,i) that approximates component i of the solution at time t_f and mesh points xmesh, where sol is the solution returned by pdepe.
xout	A vector of points from the interval [x0,xn] at which the interpolated solution is requested.

Description

`[uout,duoutdx] = pdeval(m,x,ui,xout)` approximates the solution u_i and its partial derivative $\partial u_i / \partial x$ at points from the interval [x0,xn]. The pdeval function returns the computed values in uout and duoutdx, respectively.

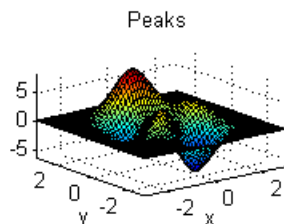
Note pdeval evaluates the partial derivative $\partial u_i / \partial x$ rather than the flux f . Although the flux is continuous, the partial derivative may have a jump at a material interface.

See Also

pdepe

Purpose

Example function of two variables

**Syntax**

```
Z = peaks;  
Z = peaks(n);  
Z = peaks(V);  
Z = peaks(X,Y);
```

```
peaks;  
peaks(N);  
peaks(V);  
peaks(X,Y);
```

```
[X,Y,Z] = peaks;  
[X,Y,Z] = peaks(n);  
[X,Y,Z] = peaks(V);
```

Description

`peaks` is a function of two variables, obtained by translating and scaling Gaussian distributions, which is useful for demonstrating `mesh`, `surf`, `pcolor`, `contour`, and so on.

`Z = peaks`; returns a 49-by-49 matrix.

`Z = peaks(n)`; returns an n-by-n matrix.

`Z = peaks(V)`; returns an n-by-n matrix, where `n = length(V)`.

`Z = peaks(X,Y)`; evaluates `peaks` at the given `X` and `Y` (which must be the same size) and returns a matrix the same size.

peaks

`peaks(...)` (with no output argument) plots the peaks function with `surf`.

`[X,Y,Z] = peaks(...)`; returns two additional matrices, X and Y, for parametric plots, for example, `surf(X,Y,Z,de12(Z))`. If not given as input, the underlying matrices X and Y are

$$[X,Y] = \text{meshgrid}(V,V)$$

where V is a given vector, or V is a vector of length n with elements equally spaced from -3 to 3. If no input argument is given, the default n is 49.

See Also

`meshgrid`, `surf`

Purpose	Call Perl script using appropriate operating system executable
Syntax	<pre>perl('perlfile') perl('perlfile',arg1,arg2,...) result = perl(...) [result, status] = perl(...)</pre>
Description	<code>perl('perlfile')</code> calls the Perl script <code>perlfile</code> , using the appropriate operating system Perl executable. Perl is included with the MATLAB software on Microsoft Windows systems, and thus MATLAB users

can run M-files containing the `perl` function. On UNIX ²³ systems, MATLAB calls the Perl interpreter available with the operating system.

`perl('perlfile', arg1, arg2, ...)` calls the Perl script `perlfile`, using the appropriate operating system Perl executable, and passes the arguments `arg1`, `arg2`, and so on, to `perlfile`.

`result = perl(...)` returns the results of attempted Perl call to `result`.

`[result, status] = perl(...)` returns the results of attempted Perl call to `result` and its exit status to `status`.

It is sometimes beneficial to use Perl scripts instead of MATLAB code. The `perl` function allows you to run those scripts from MATLAB. Specific examples where you might choose to use a Perl script include:

- Perl script already exists
- Perl script preprocesses data quickly, formatting it in a way more easily read by MATLAB
- Perl has features not supported by MATLAB

Examples

Given the Perl script, `hello.pl`:

```
$input = $ARGV[0];  
print "Hello $input.";
```

At the MATLAB command line, type:

```
perl('hello.pl', 'World')
```

MATLAB displays:

```
ans =  
Hello World.
```

23. UNIX is a registered trademark of The Open Group in the United States and other countries.

See Also ! (exclamation point), dos, regexp, system, unix

perms

Purpose All possible permutations

Syntax `P = perms(v)`

Description `P = perms(v)`, where `v` is a row vector of length `n`, creates a matrix whose rows consist of all possible permutations of the `n` elements of `v`. Matrix `P` contains `n!` rows and `n` columns.

Examples The command `perms(2:2:6)` returns *all* the permutations of the numbers 2, 4, and 6:

```
6     4     2
6     2     4
4     6     2
4     2     6
2     4     6
2     6     4
```

Limitations This function is only practical for situations where `n` is less than about 15.

See Also `nchoosek`, `permute`, `randperm`

Purpose Rearrange dimensions of N-D array

Syntax `B = permute(A,order)`

Description `B = permute(A,order)` rearranges the dimensions of `A` so that they are in the order specified by the vector `order`. `B` has the same values of `A` but the order of the subscripts needed to access any particular element is rearranged as specified by `order`. All the elements of `order` must be unique.

Remarks `permute` and `ipermute` are a generalization of transpose (`.'`) for multidimensional arrays.

Examples Given any matrix `A`, the statement

```
permute(A,[2 1])
```

is the same as `A.'`

For example:

```
A = [1 2; 3 4]; permute(A,[2 1])
ans =
     1     3
     2     4
```

The following code permutes a three-dimensional array:

```
X = rand(12,13,14);
Y = permute(X,[2 3 1]);
size(Y)
ans =
    13    14    12
```

See Also `ipermute`, `circshift`, `shiftdim`, `reshape`

persistent

Purpose Define persistent variable

Syntax `persistent X Y Z`

Description `persistent X Y Z` defines X, Y, and Z as variables that are local to the function in which they are declared; yet their values are retained in memory between calls to the function. Persistent variables are similar to global variables because the MATLAB software creates permanent storage for both. They differ from global variables in that persistent variables are known only to the function in which they are declared. This prevents persistent variables from being changed by other functions or from the MATLAB command line.

Persistent variables are cleared when the M-file is cleared from memory or when the M-file is changed. To keep an M-file in memory until MATLAB quits, use `mlock`.

If the persistent variable does not exist the first time you issue the `persistent` statement, it is initialized to the empty matrix.

It is an error to declare a variable persistent if a variable with the same name exists in the current workspace. MATLAB also errors if you declare any of a function's input or output arguments as persistent within that same function. For example, the following persistent declaration is invalid:

```
function myfun(argA, argB, argC)
persistent argB
```

Remarks There is no function form of the `persistent` command (i.e., you cannot use parentheses and quote the variable names).

Example This function prompts a user to enter a directory name to use in locating one or more files. If the user has already entered this information, and it requires no modification, they do not need to enter it again. This is because the function stores it in a persistent variable (`lastDir`), and offers it as the default selection. Here is the function definition:

```
function find_file(file)
persistent lastDir

if isempty(lastDir)
    prompt = 'Enter directory:  ';
else
    prompt = ['Enter directory[' lastDir ']:  '];
end
response = input(prompt, 's');

if ~isempty(response)
    dirName = response;
else
    dirName = lastDir;
end

dir(strcat(dirName, file))
lastDir = dirName;
```

Execute the function twice. The first time, it prompts you to enter the information and does not offer a default:

```
cd(matlabroot)

find_file('is*.m')
Enter directory:  toolbox/matlab/strfun/

iscellstr.m  ischar.m  isletter.m  isspace.m  isstr.m
isstrprop.m
```

The second time, it does offer a default taken from the persistent variable `dirName`:

```
find_file('is*.m')
Enter directory[toolbox/matlab/strfun/]:
toolbox/matlab/elmat/
```

persistent

<code>isempty.m</code>	<code>isfinite.m</code>	<code>isscalar.m</code>
<code>isequal.m</code>	<code>isinf.m</code>	<code>isvector.m</code>
<code>isequalwithequalnans.m</code>	<code>isnan.m</code>	

See Also

`global`, `clear`, `mislocked`, `mlock`, `munlock`, `isempty`

Purpose	Ratio of circle's circumference to its diameter, π
Syntax	<code>pi</code>
Description	<code>pi</code> returns the floating-point number nearest the value of π . The expressions <code>4*atan(1)</code> and <code>imag(log(-1))</code> provide the same value.
Examples	<p>The expression <code>sin(pi)</code> is not exactly zero because <code>pi</code> is not exactly π.</p> <pre>sin(pi) ans = 1.2246e-16</pre>
See Also	<code>ans</code> , <code>eps</code> , <code>i</code> , <code>Inf</code> , <code>j</code> , <code>NaN</code>


pie

Purpose

Pie chart



GUI Alternatives

To graph selected variables, use the Plot Selector  in the Workspace Browser, or use the Figure Palette Plot Catalog. Manipulate graphs in *plot edit* mode with the Property Editor. For details, see [Plotting Tools — Interactive Plotting in the MATLAB Graphics documentation](#) and [Creating Graphics from the Workspace Browser in the MATLAB Desktop Tools documentation](#).

Syntax

```
pie(X)
pie(X,explode)
pie(...,labels)
pie(axes_handle,...)
h = pie(...)
```

Description

`pie(X)` draws a pie chart using the data in `X`. Each element in `X` is represented as a slice in the pie chart.

`pie(X,explode)` offsets a slice from the pie. `explode` is a vector or matrix of zeros and nonzeros that correspond to `X`. A nonzero value offsets the corresponding slice from the center of the pie chart, so that `X(i,j)` is offset from the center if `explode(i,j)` is nonzero. `explode` must be the same size as `X`.

`pie(...,labels)` specifies text labels for the slices. The number of labels must equal the number of elements in `X`. For example,

```
pie(1:3,{'Taxes','Expenses','Profit'})
```

`pie(axes_handle,...)` plots into the axes with the handle `axes_handle` instead of into the current axes (`gca`).

`h = pie(...)` returns a vector of handles to patch and text graphics objects.

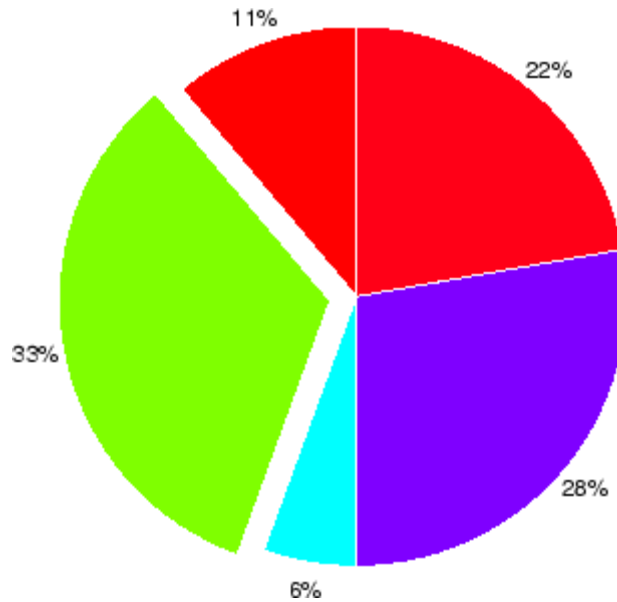
Remarks

The values in X are normalized via $X/\text{sum}(X)$ to determine the area of each slice of the pie. If $\text{sum}(X) \leq 1$, the values in X directly specify the area of the pie slices. MATLAB draws only a partial pie if $\text{sum}(X) < 1$.

Examples

Emphasize the second slice in the chart by setting its corresponding explode element to 1.

```
x = [1 3 0.5 2.5 2];  
explode = [0 1 0 0 0];  
pie(x,explode)  
colormap jet
```

**See Also**


pie3

pie3

Purpose 3-D pie chart



GUI Alternatives

To graph selected variables, use the Plot Selector  in the Workspace Browser, or use the Figure Palette Plot Catalog. Manipulate graphs in *plot edit* mode with the Property Editor. For details, see Plotting Tools — Interactive Plotting in the MATLAB Graphics documentation and Creating Graphics from the Workspace Browser in the MATLAB Desktop Tools documentation.

Syntax

```
pie3(X)
pie3(X,explode)
pie3(...,labels)
pie3(axes_handle,...)
h = pie3(...)
```

Description

`pie3(X)` draws a three-dimensional pie chart using the data in `X`. Each element in `X` is represented as a slice in the pie chart.

`pie3(X,explode)` specifies whether to offset a slice from the center of the pie chart. `X(i,j)` is offset from the center of the pie chart if `explode(i,j)` is nonzero. `explode` must be the same size as `X`.

`pie3(...,labels)` specifies text labels for the slices. The number of labels must equal the number of elements in `X`. For example,

```
pie3(1:3,{'Taxes','Expenses','Profit'})
```

`pie3(axes_handle,...)` plots into the axes with the handle `axes_handle` instead of into the current axes (`gca`).

`h = pie3(...)` returns a vector of handles to patch, surface, and text graphics objects.

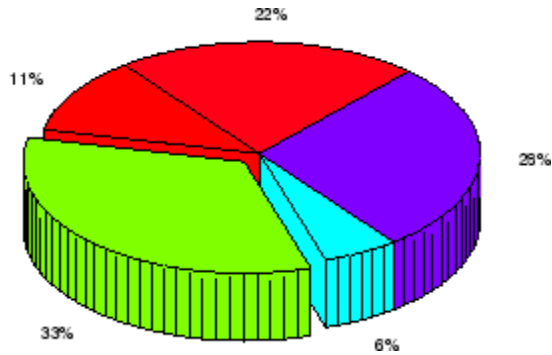
Remarks

The values in X are normalized via $X/\text{sum}(X)$ to determine the area of each slice of the pie. If $\text{sum}(X) \leq 1$, the values in X directly specify the area of the pie slices. MATLAB draws only a partial pie if $\text{sum}(X) < 1$.

Examples

Offset a slice in the pie chart by setting the corresponding `explode` element to 1:

```
x = [1 3 0.5 2.5 2];  
explode = [0 1 0 0 0];  
pie3(x,explode)  
colormap hsv
```

**See Also**

`pie`

pinv

Purpose Moore-Penrose pseudoinverse of matrix

Syntax
`B = pinv(A)`
`B = pinv(A,tol)`

Definition The Moore-Penrose pseudoinverse is a matrix B of the same dimensions as A' satisfying four conditions:

$A*B*A = A$
 $B*A*B = B$
 $A*B$ is Hermitian
 $B*A$ is Hermitian

The computation is based on `svd(A)` and any singular values less than `tol` are treated as zero.

Description `B = pinv(A)` returns the Moore-Penrose pseudoinverse of A .

`B = pinv(A,tol)` returns the Moore-Penrose pseudoinverse and overrides the default tolerance, `max(size(A))*norm(A)*eps`.

Examples If A is square and not singular, then `pinv(A)` is an expensive way to compute `inv(A)`. If A is not square, or is square and singular, then `inv(A)` does not exist. In these cases, `pinv(A)` has some of, but not all, the properties of `inv(A)`.

If A has more rows than columns and is not of full rank, then the overdetermined least squares problem

`minimize norm(A*x-b)`

does not have a unique solution. Two of the infinitely many solutions are

`x = pinv(A)*b`

and

`y = A\b`

These two are distinguished by the facts that $\text{norm}(x)$ is smaller than the norm of any other solution and that y has the fewest possible nonzero components.

For example, the matrix generated by

```
A = magic(8); A = A(:,1:6)
```

is an 8-by-6 matrix that happens to have $\text{rank}(A) = 3$.

```
A =
    64     2     3    61    60     6
     9    55    54    12    13    51
    17    47    46    20    21    43
    40    26    27    37    36    30
    32    34    35    29    28    38
    41    23    22    44    45    19
    49    15    14    52    53    11
     8    58    59     5     4    62
```

The right-hand side is $b = 260 \cdot \text{ones}(8, 1)$,

```
b =
    260
    260
    260
    260
    260
    260
    260
    260
    260
```

The scale factor 260 is the 8-by-8 magic sum. With all eight columns, one solution to $A \cdot x = b$ would be a vector of all 1's. With only six columns, the equations are still consistent, so a solution exists, but it is not all 1's. Since the matrix is rank deficient, there are infinitely many solutions. Two of them are

```
x = pinv(A)*b
```

which is

```
x =  
  1.1538  
  1.4615  
  1.3846  
  1.3846  
  1.4615  
  1.1538
```

and

```
y = A\b
```

which produces this result.

```
Warning: Rank deficient, rank = 3  tol = 1.8829e-013.  
y =  
  4.0000  
  5.0000  
   0  
   0  
   0  
 -1.0000
```

Both of these are exact solutions in the sense that $\text{norm}(A*x-b)$ and $\text{norm}(A*y-b)$ are on the order of roundoff error. The solution x is special because

```
norm(x) = 3.2817
```

is smaller than the norm of any other solution, including

```
norm(y) = 6.4807
```

On the other hand, the solution y is special because it has only three nonzero components.

See Also

inv, qr, rank, svd

Purpose	Givens plane rotation
Syntax	<code>[G,y] = planerot(x)</code>
Description	<code>[G,y] = planerot(x)</code> where x is a 2-component column vector, returns a 2-by-2 orthogonal matrix G so that $y = G*x$ has $y(2) = 0$.
Examples	<pre>x = [3 4]; [G,y] = planerot(x') G = 0.6000 0.8000 -0.8000 0.6000 y = 5 0</pre>
See Also	<code>qrdelete</code> , <code>qrinsert</code>

playshow

Purpose Run M-file demo (deprecated; use echodemo instead)

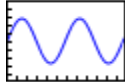
Syntax `playshow filename`

Description `playshow filename` runs `filename`, which is a demo. Replace `playshow filename` with `echodemo filename`. Note that other arguments supported by `playshow` are not supported by `echodemo`.

See Also `demo`, `echodemo`, `helpbrowser`

Purpose

2-D line plot

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**GUI
Alternatives**

Use the Plot Selector  to graph selected variables in the Workspace Browser and the Plot Catalog, accessed from the Figure Palette. Directly manipulate graphs in *plot edit* mode, and modify them using the Property Editor. For details, see *Using Plot Edit Mode*, and *The Figure Palette in the MATLAB Graphics documentation*, and also *Creating Graphics from the Workspace Browser in the MATLAB Desktop documentation*.

Syntax

```
plot(Y)
plot(X1,Y1,...)
plot(X1,Y1,LineStyle,...)
plot(...,'PropertyName',PropertyValue,...)
plot(axes_handle,...)
h = plot(...)
```

```
hlines = plot('v6',...)
```

Description

`plot(Y)` plots the columns of `Y` versus their index if `Y` is a real number. If `Y` is complex, `plot(Y)` is equivalent to `plot(real(Y), imag(Y))`. In all other uses of `plot`, the imaginary component is ignored.

`plot(X1, Y1, ...)` plots all lines defined by X_n versus Y_n pairs. If only one of X_n or Y_n is a matrix, the vector is plotted versus the rows or columns of the matrix, depending on whether the vector's row or column dimension matches the matrix. If X_n is a scalar and Y_n is a vector, disconnected line objects are created and plotted as discrete points vertically at X_n .

`plot(X1, Y1, LineSpec, ...)` plots all lines defined by the $X_n, Y_n, \text{LineSpec}$ triples, where `LineSpec` is a line specification that determines line type, marker symbol, and color of the plotted lines. You can mix $X_n, Y_n, \text{LineSpec}$ triples with X_n, Y_n pairs:
`plot(X1, Y1, X2, Y2, LineSpec, X3, Y3)`.

Note See `LineSpec` for a list of line style, marker, and color specifiers.

`plot(..., 'PropertyName', PropertyValue, ...)` sets properties to the specified property values for all lineseries graphics objects created by `plot`. (See the “Examples” on page 2-2802 section for examples.)

`plot(axes_handle, ...)` plots into the axes with the handle `axes_handle` instead of into the current axes (`gca`).

`h = plot(...)` returns a column vector of handles to lineseries graphics objects, one handle per line.

Backward-Compatible Version

`hlines = plot('v6', ...)` returns the handles to line objects instead of lineseries objects.

Note The v6 option enables users of Version 7.x of MATLAB to create FIG-files that previous versions can open. It is obsolete and will be removed in a future version of MATLAB.

See Plot Objects and Backward Compatibility for more information.

Remarks

Cycling Through Line Colors and Styles

If you do not specify a color when plotting more than one line, `plot` automatically cycles through the colors in the order specified by the current axes `ColorOrder` property. After cycling through all the colors defined by `ColorOrder`, `plot` then cycles through the line styles defined in the axes `LineStyleOrder` property.

The default `LineStyleOrder` property has a single entry (a solid line with no marker).

By default, MATLAB resets the `ColorOrder` and `LineStyleOrder` properties each time you call `plot`. If you want the changes you make to these properties to persist, you must define these changes as default values. For example,

```
set(0, 'DefaultAxesColorOrder', [0 0 0], ...  
      'DefaultAxesLineStyleOrder', '-|-.|--|:')
```

sets the default `ColorOrder` to use only the color black and sets the `LineStyleOrder` to use solid, dash-dot, dash-dash, and dotted line styles.

Prevent Resetting of Color and Styles with `hold all`

The `all` option to the `hold` command prevents the `ColorOrder` and `LineStyleOrder` from being reset in subsequent `plot` commands. In the following sequence of commands, MATLAB continues to cycle through the colors defined by the axes `ColorOrder` property (see above).

```
plot(rand(12,2))  
hold all
```

```
plot(randn(12,2))
```

Additional Information

- See [Creating Line Plots and Annotating Graphs](#) for more information on plotting.
- See [LineStyleSpec](#) for more information on specifying line styles and colors.

Examples

Specifying the Color and Size of Markers

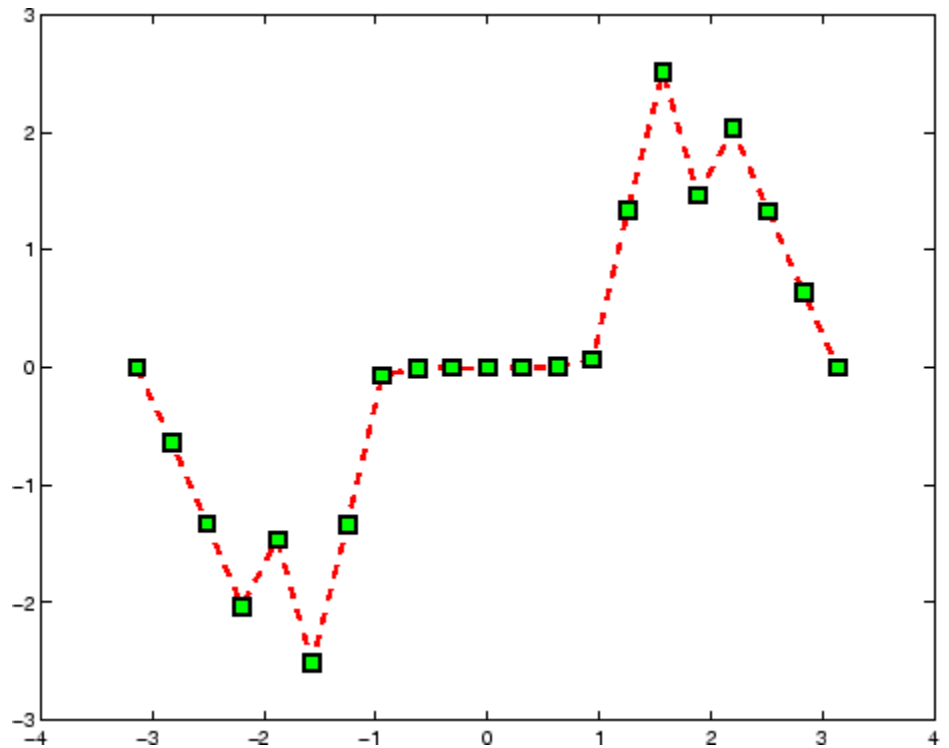
You can also specify other line characteristics using graphics properties (see [line](#) for a description of these properties):

- `LineWidth` — Specifies the width (in points) of the line.
- `MarkerEdgeColor` — Specifies the color of the marker or the edge color for filled markers (circle, square, diamond, pentagram, hexagram, and the four triangles).
- `MarkerFaceColor` — Specifies the color of the face of filled markers.
- `MarkerSize` — Specifies the size of the marker in units of points.

For example, these statements,

```
x = -pi:pi/10:pi;  
y = tan(sin(x)) - sin(tan(x));  
plot(x,y,'--rs','LineWidth',2,...  
      'MarkerEdgeColor','k',...  
      'MarkerFaceColor','g',...  
      'MarkerSize',10)
```

produce this graph.

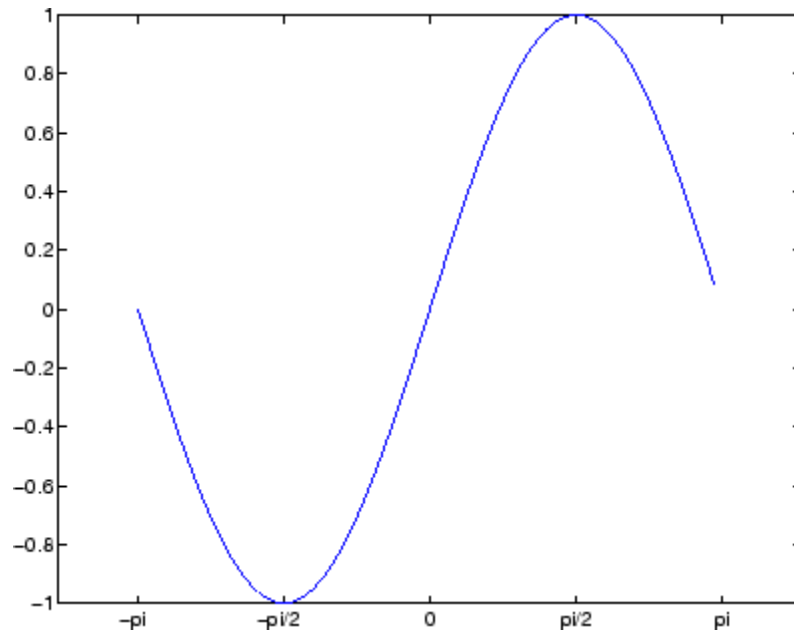


Specifying Tick-Mark Location and Labeling

You can adjust the axis tick-mark locations and the labels appearing at each tick. For example, this plot of the sine function relabels the x -axis with more meaningful values:

```
x = -pi:.1:pi;  
y = sin(x);  
plot(x,y)  
set(gca,'XTick',-pi:pi/2:pi)  
set(gca,'XTickLabel',{'-pi','-pi/2','0','pi/2','pi'})
```

Now add axis labels and annotate the point $-\pi/4, \sin(-\pi/4)$.



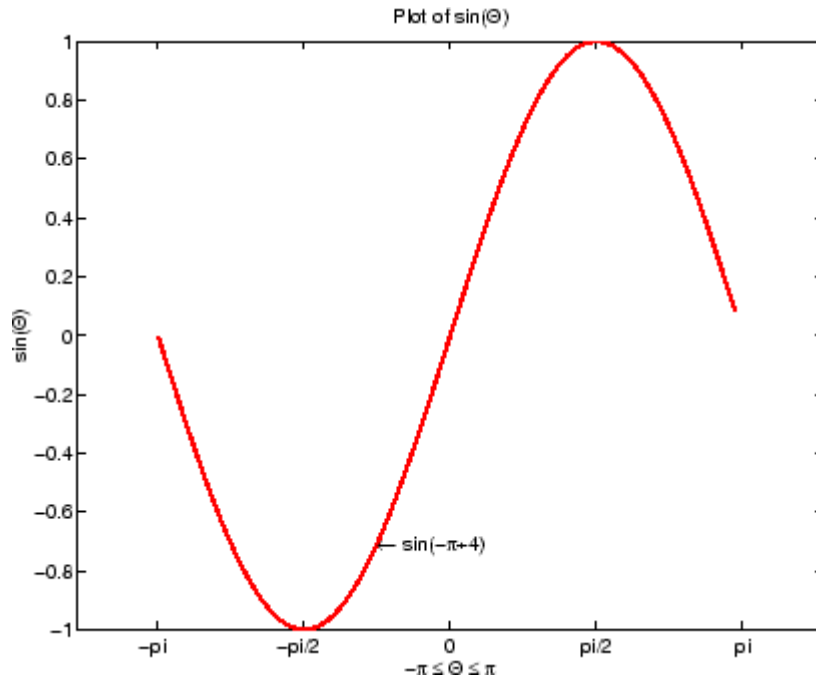
Adding Titles, Axis Labels, and Annotations

MATLAB enables you to add axis labels and titles. For example, using the graph from the previous example, add an x - and y -axis label:

```
xlabel('-\pi \leq \Theta \leq \pi')
ylabel('sin(\Theta)')
title('Plot of sin(\Theta)')
text(-pi/4,sin(-pi/4),'\leftarrow sin(-\pi\div4)',...
     'HorizontalAlignment','left')
```

Now change the line color to red by first finding the handle of the line object created by `plot` and then setting its `Color` property. In the same statement, set the `LineWidth` property to 2 points.

```
set(findobj(gca,'Type','line','Color',[0 0 1]),...
     'Color','red',...
     'LineWidth',2)
```

See Also

axis, bar, grid, hold, legend, line, LineSpec, loglog, plot3, plotyy, semilogx, semilogy, subplot, title, xlabel, xlim, ylabel, ylim, zlabel, zlim, stem

See the text String property for a list of symbols and how to display them.

See the Plot Editor for information on plot annotation tools in the figure window toolbar.

See “Basic Plots and Graphs” on page 1-93 for related functions.

plot (timeseries)

Purpose

Plot time series

Syntax

```
plot(ts)
plot(tsc.tsname)
plot(function)
```

Description

`plot(ts)` plots the time-series data `ts` against time and interpolates values between samples by using either zero-order-hold ('zoh') or linear interpolation.

`plot(tsc.tsname)` plots the timeseries object `tsname` that is part of the `tscollection tsc`.

`plot(function)` accepts the modifiers used by the MATLAB plotting utility for numerical arrays. These modifiers can be specified as auxiliary inputs for modifying the appearance of the plot. See Examples below.

Remarks

Time-series events, when defined, are marked in the plot by a red circular marker.

When you resize a timeseries plot to be narrower, the *x*-axis ticks and labels are readjusted so that they do not overlap one another. Unlike plots of regular variables, this behavior cannot be overridden (for example, by setting the axes `XTickMode` to 'Auto').

Examples


`plot(ts, '-r*')` uses a regular line with the color red and marker '*' to render the plot.

`plot(ts, 'ko', 'MarkerSize', 3)` uses black circular markers of size 3 to render the plot.

Purpose

3-D line plot

**GUI Alternatives**

To graph selected variables, use the Plot Selector  in the Workspace Browser, or use the Figure Palette Plot Catalog. Manipulate graphs in *plot edit* mode with the Property Editor. For details, see Plotting Tools — Interactive Plotting in the MATLAB Graphics documentation and Creating Graphics from the Workspace Browser in the MATLAB Desktop Tools documentation.

Syntax

```
plot3(X1,Y1,Z1,...)
plot3(X1,Y1,Z1,LineStyle,...)
plot3(...,'PropertyName',PropertyValue,...)
h = plot3(...)
```

Description

The `plot3` function displays a three-dimensional plot of a set of data points.

`plot3(X1,Y1,Z1,...)`, where `X1`, `Y1`, `Z1` are vectors or matrices, plots one or more lines in three-dimensional space through the points whose coordinates are the elements of `X1`, `Y1`, and `Z1`.

`plot3(X1,Y1,Z1,LineStyle,...)` creates and displays all lines defined by the `Xn`, `Yn`, `Zn`, `LineStyle` quads, where `LineStyle` is a line specification that determines line style, marker symbol, and color of the plotted lines.

`plot3(...,'PropertyName',PropertyValue,...)` sets properties to the specified property values for all line graphics objects created by `plot3`.

`h = plot3(...)` returns a column vector of handles to lineseries graphics objects, with one handle per object.

plot3

Remarks

If one or more of $X1$, $Y1$, $Z1$ is a vector, the vectors are plotted versus the rows or columns of the matrix, depending whether the vectors' lengths equal the number of rows or the number of columns.

You can mix Xn, Yn, Zn triples with $Xn, Yn, Zn, LineSpec$ quads, for example,

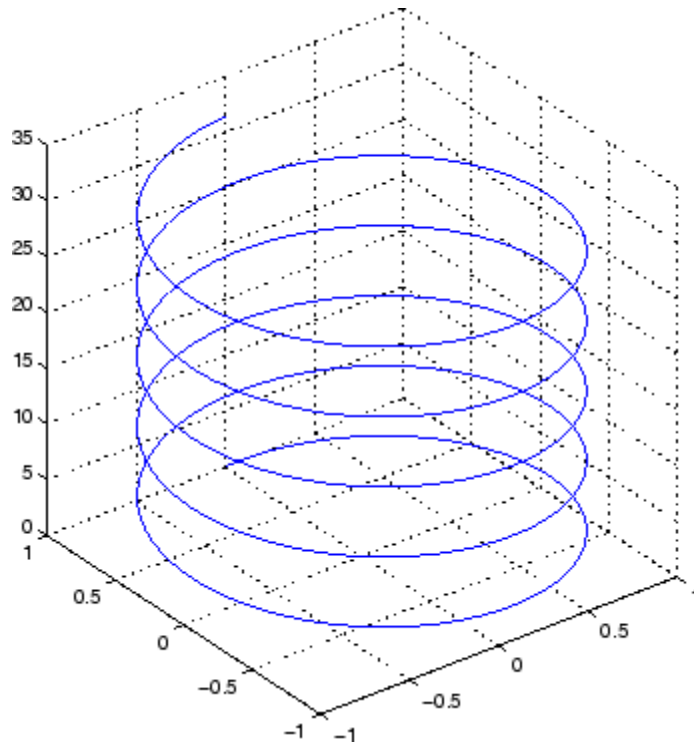
```
plot3(X1,Y1,Z1,X2,Y2,Z2,LineSpec,X3,Y3,Z3)
```

See `LineSpec` and `plot` for information on line types and markers.

Examples

Plot a three-dimensional helix.

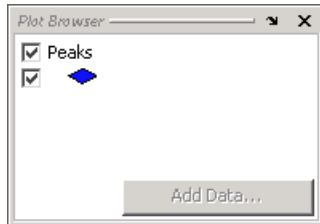
```
t = 0:pi/50:10*pi;  
plot3(sin(t),cos(t),t)  
grid on  
axis square
```

**See Also**



`axis`, `bar3`, `grid`, `line`, `LineStyle`, `loglog`, `plot`, `semilogx`, `semilogy`, `subplot`

plotbrowser

Purpose Show or hide figure plot browser



GUI Alternatives

Click the larger **Plotting Tools** icon  on the figure toolbar to collectively enable plotting tools, and the smaller icon  to collectively disable them. Open or close the **Plot Browser** tool from the figure's **View** menu. For details, see “The Plot Browser” in the MATLAB Graphics documentation.

Syntax

```
plotbrowser('on')  
plotbrowser('off')  
plotbrowser('toggle')  
plotbrowser  
plotbrowser(figure_handle,...)
```

Description

`plotbrowser('on')` displays the Plot Browser on the current figure.
`plotbrowser('off')` hides the Plot Browser on the current figure.
`plotbrowser('toggle')` or `plotbrowser` toggles the visibility of the Plot Browser on the current figure.
`plotbrowser(figure_handle,...)` shows or hides the Plot Browser on the figure specified by *figure_handle*.

See Also

`plottools`, `figurepalette`, `propertyeditor`

Purpose Interactively edit and annotate plots

Syntax

```

plottedit on
plottedit off
plottedit
plottedit(h)
plottedit('state')
plottedit(h, 'state')
```

Description `plottedit on` starts plot edit mode for the current figure, allowing you to use a graphical interface to annotate and edit plots easily. In plot edit mode, you can label axes, change line styles, and add text, line, and arrow annotations.

`plottedit off` ends plot mode for the current figure.

`plottedit` toggles the plot edit mode for the current figure.

`plottedit(h)` toggles the plot edit mode for the figure specified by figure handle `h`.

`plottedit('state')` specifies the `plottedit` state for the current figure. Values for `state` can be as shown.

Value for state	Description
on	Starts plot edit mode
off	Ends plot edit mode
showtoolsmenu	Displays the Tools menu in the menu bar
hidetoolsmenu	Removes the Tools menu from the menu bar

Note `hidetoolsmenu` is intended for GUI developers who do not want the **Tools** menu to appear in applications that use the figure window.

`plottedit(h, 'state')` specifies the plottedit state for figure handle `h`.

Remarks

Plot Editing Mode Graphical Interface Components

To start plot edit mode, click this button.

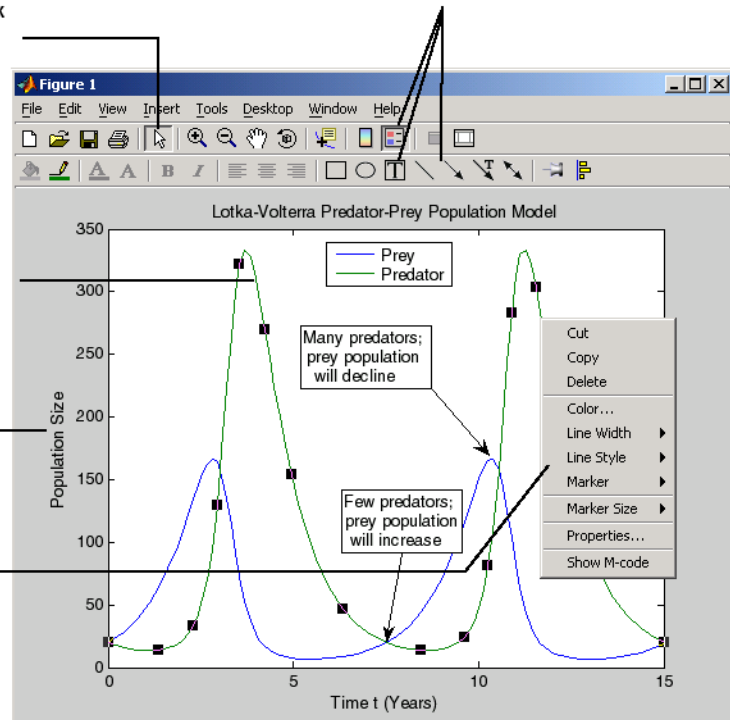
Use these toolbar buttons to add a legend, text, and arrows.

Use the Edit, Insert, and Tools menus to add objects or edit existing objects in a graph.

Double-click on an object to select it.

Position labels, legends, and other objects by clicking and dragging.

Access object-specific plot edit functions through context-sensitive pop-up menus.



Examples

Start plot edit mode for figure 2.

```
plottedit(2)
```

End plot edit mode for figure 2.

```
plottedit(2, 'off')
```


Hide the **Tools** menu for the current figure:

```
plottedit('hidetoolsmenu')
```

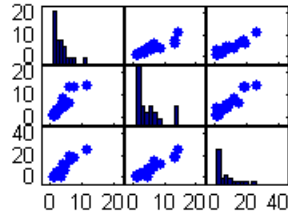
See Also

axes, line, open, plot, print, saveas, text, propedit

plotmatrix

Purpose

Scatter plot matrix



Syntax

```
plotmatrix(X,Y)
plotmatrix(X)
plotmatrix(...,'LineStyle')
[H,AX,BigAx,P] = plotmatrix(...)
```

Description

`plotmatrix(X,Y)` scatter plots the columns of X against the columns of Y . If X is p -by- m and Y is p -by- n , `plotmatrix` produces an n -by- m matrix of axes.

`plotmatrix(X)` is the same as `plotmatrix(X,X)`, except that the diagonal is replaced by `hist(X(:,i))`.

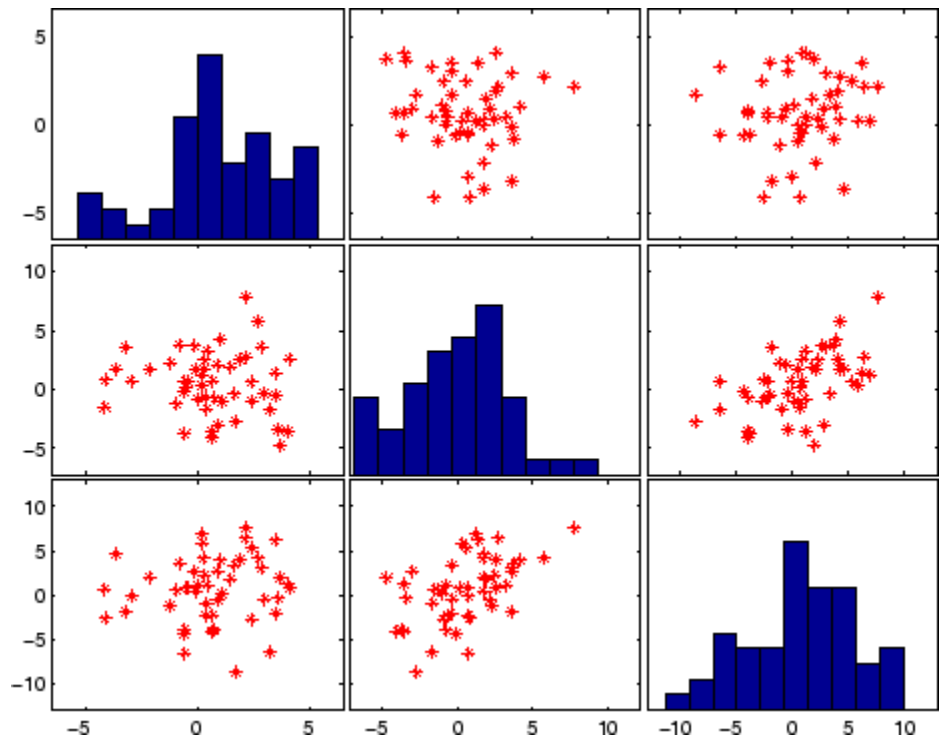
`plotmatrix(...,'LineStyle')` uses a `LineStyle` to create the scatter plot. The default is `'.'`.

`[H,AX,BigAx,P] = plotmatrix(...)` returns a matrix of handles to the objects created in `H`, a matrix of handles to the individual subaxes in `AX`, a handle to a big (invisible) axes that frames the subaxes in `BigAx`, and a matrix of handles for the histogram plots in `P`. `BigAx` is left as the current axes so that a subsequent `title`, `xlabel`, or `ylabel` command is centered with respect to the matrix of axes.

Examples

Generate plots of random data.

```
x = randn(50,3); y = x*[-1 2 1;2 0 1;1 -2 3]';
plotmatrix(y,'*r')
```

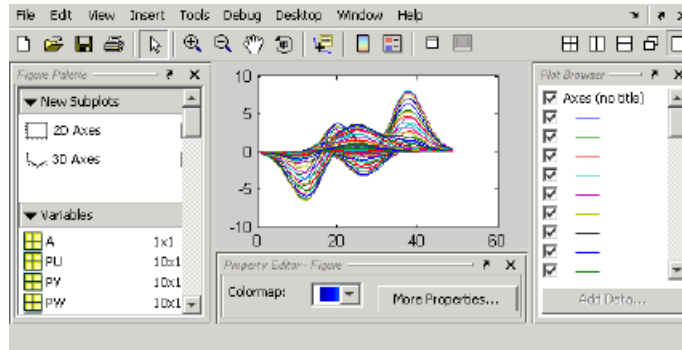


See Also



scatter, scatter3

Purpose

Show or hide plot tools



GUI Alternatives

Click the larger **Plotting Tools** icon  on the figure toolbar to collectively enable plotting tools, and the smaller icon  to collectively disable them. Individually select the **Figure Palette**, **Plot Browser**, and **Property Editor** tools from the figure's **View** menu. For details, see “Plotting Tools — Interactive Plotting” in the MATLAB Graphics documentation.

Syntax

```
plottools('on')
plottools('off')
plottools
plottools(figure_handle,...)
plottools(...,'tool')
```

Description

`plottools('on')` displays the Figure Palette, Plot Browser, and Property Editor on the current figure, configured as you last used them.

`plottools('off')` hides the Figure Palette, Plot Browser, and Property Editor on the current figure.

`plottools` with no arguments, is the same as `plottools('on')`

`plottools(figure_handle,...)` displays or hides the plot tools on the specified figure instead of on the current figure.

`plottools(..., 'tool')` operates on the specified tool only. *tool* can be one of the following strings:

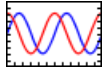
- `figurepalette`
- `plotbrowser`
- `propertyeditor`

Note The first time you open the plotting tools, all three of them appear, grouped around the current figure as shown above. If you close, move, or undock any of the tools, MATLAB remembers the configuration you left them in and restores it when you invoke the tools for subsequent figures, both within and across MATLAB sessions.


See Also

`figurepalette`, `plotbrowser`, `propertyeditor`

Purpose 2-D line plots with y-axes on both left and right side



GUI Alternatives

To graph selected variables, use the Plot Selector  in the Workspace Browser, or use the Figure Palette Plot Catalog. Manipulate graphs in *plot edit* mode with the Property Editor. For details, see “Plotting Tools — Interactive Plotting” in the MATLAB Graphics documentation and “Creating Plots from the Workspace Browser” in the MATLAB Desktop Tools documentation.

Syntax

```
plotyy(X1,Y1,X2,Y2)
plotyy(X1,Y1,X2,Y2,function)
plotyy(X1,Y1,X2,Y2,'function1','function2')
[AX,H1,H2] = plotyy(...)
```

Description

`plotyy(X1,Y1,X2,Y2)` plots $X1$ versus $Y1$ with y -axis labeling on the left and plots $X2$ versus $Y2$ with y -axis labeling on the right.

`plotyy(X1,Y1,X2,Y2,function)` uses the specified plotting function to produce the graph.

`function` can be either a function handle or a string specifying `plot`, `semilogx`, `semilogy`, `loglog`, `stem`, or any MATLAB function that accepts the syntax

```
h = function(x,y)
```

For example,

```
plotyy(x1,y1,x2,y2,@loglog) % function handle
plotyy(x1,y1,x2,y2,'loglog') % string
```

Function handles enable you to access user-defined subfunctions and can provide other advantages. See `@` for more information on using function handles.

`plotyy(X1,Y1,X2,Y2,'function1','function2')` uses `function1(X1,Y1)` to plot the data for the left axis and `function2(X2,Y2)` to plot the data for the right axis.

`[AX,H1,H2] = plotyy(...)` returns the handles of the two axes created in `AX` and the handles of the graphics objects from each plot in `H1` and `H2`. `AX(1)` is the left axes and `AX(2)` is the right axes.

Examples

This example graphs two mathematical functions using `plot` as the plotting function. The two y -axes enable you to display both sets of data on one graph even though relative values of the data are quite different.

```
x = 0:0.01:20;
y1 = 200*exp(-0.05*x).*sin(x);
y2 = 0.8*exp(-0.5*x).*sin(10*x);
[AX,H1,H2] = plotyy(x,y1,x,y2,'plot');
```

You can use the handles returned by `plotyy` to label the axes and set the line styles used for plotting. With the axes handles you can specify the `YLabel` properties of the left- and right-side y -axis:

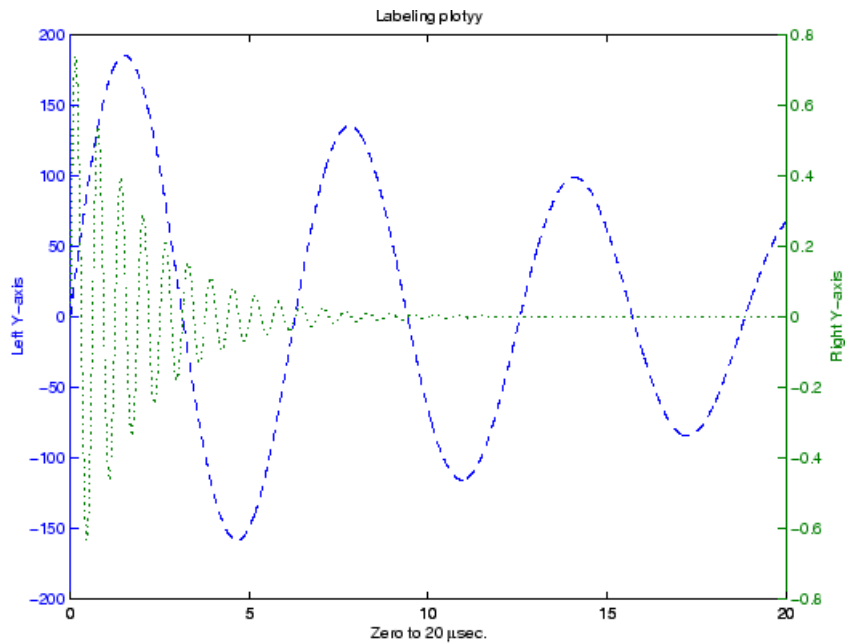
```
set(get(AX(1),'Ylabel'),'String','Slow Decay')
set(get(AX(2),'Ylabel'),'String','Fast Decay')
```

Use the `xlabel` and `title` commands to label the x -axis and add a title:

```
xlabel('Time (\musec)')
title('Multiple Decay Rates')
```

Use the line handles to set the `LineStyle` properties of the left- and right-side plots:

```
set(H1,'LineStyle','--')
set(H2,'LineStyle',':')
```



See Also

plot, loglog, semilogx, semilogy, XAxisLocation, YAxisLocation
See “Using Multiple X- and Y-Axes” for more information.

Purpose

Simplex containing specified location

Syntax

```
SI = pointLocation(DT,QX)  
SI = pointLocation(DT,QX,QY)  
SI = pointLocation(DT,QX,QY,QZ)  
[SI, BC] = pointLocation(DT,...)
```

Description

SI = pointLocation(DT,QX) returns the indices SI of the enclosing simplex (triangle/tetrahedron) for each query point location in QX. The enclosing simplex for point QX(k,:) is SI(k). pointLocation returns NaN for all points outside the convex hull.

SI = pointLocation(DT,QX,QY) and SI = pointLocation(DT,QX,QY,QZ) allow the query point locations to be specified in alternative column vector format when working in 2-D and 3-D.

[SI, BC] = pointLocation(DT,...) returns the barycentric coordinates BC.

Inputs

DT	Delaunay triangulation.
QX	Matrix of size mpts-by-ndim, mpts being the number of query points.

Outputs

SI	Column vector of length mpts containing the indices of the enclosing simplex for each query point. mpts is the number of query points.
BC	BC is a mpts-by-ndim matrix, each row BC(i,:) represents the barycentric coordinates of QX(i,:) with respect to the enclosing simplex SI(i).

DelaunayTri.pointLocation

Examples

Example 1

Create a 2-D Delaunay triangulation:

```
X = rand(10,2);  
dt = DelaunayTri(X);
```

Find the triangles that contain specified query points:

```
qrypts = [0.25 0.25; 0.5 0.5];  
triids = pointLocation(dt, qrypts)
```

Example 2

Create a 3-D Delaunay triangulation:

```
x = rand(10,1);  
y = rand(10,1);  
z = rand(10,1);  
dt = DelaunayTri(x,y,z);
```

Find the triangles that contain specified query points and evaluate the barycentric coordinates:

```
qrypts = [0.25 0.25 0.25; 0.5 0.5 0.5];  
[tetids, bcs] = pointLocation(dt, qrypts)
```

See Also

[nearestNeighbor](#)

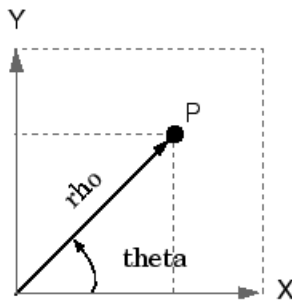
Purpose Transform polar or cylindrical coordinates to Cartesian

Syntax
 $[X, Y] = \text{pol2cart}(\text{THETA}, \text{RHO})$
 $[X, Y, Z] = \text{pol2cart}(\text{THETA}, \text{RHO}, Z)$

Description $[X, Y] = \text{pol2cart}(\text{THETA}, \text{RHO})$ transforms the polar coordinate data stored in corresponding elements of THETA and RHO to two-dimensional Cartesian, or *xy*, coordinates. The arrays THETA and RHO must be the same size (or either can be scalar). The values in THETA must be in radians.

xyz, $[X, Y, Z] = \text{pol2cart}(\text{THETA}, \text{RHO}, Z)$ transforms the cylindrical coordinate data stored in corresponding elements of THETA, RHO, and Z to three-dimensional Cartesian, or coordinates. The arrays THETA, RHO, and Z must be the same size (or any can be scalar). The values in THETA must be in radians.

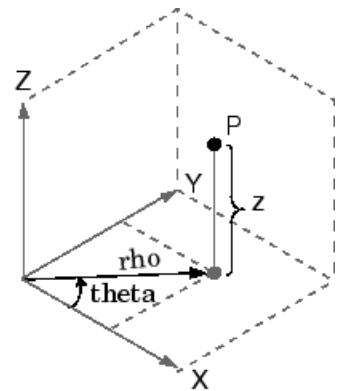
Algorithm The mapping from polar and cylindrical coordinates to Cartesian coordinates is:



Polar to Cartesian Mapping

$$\text{theta} = \text{atan2}(y, x)$$

$$\text{rho} = \text{sqrt}(x.^2 + y.^2)$$



Cylindrical to Cartesian Mapping

$$\text{theta} = \text{atan2}(y, x)$$

$$\text{rho} = \text{sqrt}(x.^2 + y.^2)$$

$$z = z$$

pol2cart


See Also

cart2pol, cart2sph, sph2cart

Purpose

Polar coordinate plot

**GUI Alternatives**

To graph selected variables, use the Plot Selector  in the Workspace Browser, or use the Figure Palette Plot Catalog. Manipulate graphs in *plot edit* mode with the Property Editor. For details, see Plotting Tools — Interactive Plotting in the MATLAB Graphics documentation and Creating Graphics from the Workspace Browser in the MATLAB Desktop Tools documentation.

Syntax

```
polar(theta,rho)
polar(theta,rho,LineStyle)
polar(axes_handle,...)
h = polar(...)
```

Description

The `polar` function accepts polar coordinates, plots them in a Cartesian plane, and draws the polar grid on the plane.

`polar(theta,rho)` creates a polar coordinate plot of the angle `theta` versus the radius `rho`. `theta` is the angle from the *x*-axis to the radius vector specified in radians; `rho` is the length of the radius vector specified in dataspace units.

`polar(theta,rho,LineStyle)` `LineStyle` specifies the line type, plot symbol, and color for the lines drawn in the polar plot.

`polar(axes_handle,...)` plots into the axes with the handle `axes_handle` instead of into the current axes (`gca`).

`h = polar(...)` returns the handle of a line object in `h`.

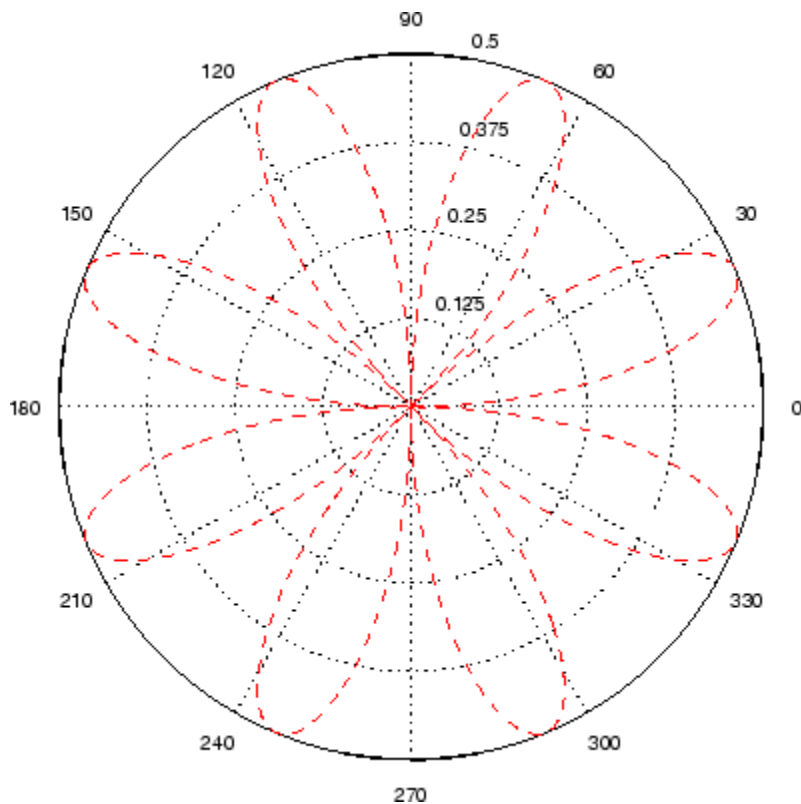
Remarks

Negative *r* values reflect through the origin, rotating by π (since (θ,r) transforms to $(r\cos(\theta), r\sin(\theta))$). If you want different behavior, you can manipulate *r* prior to plotting. For example, you can make *r* equal to $\max(0,r)$ or $\text{abs}(r)$.

Examples

Create a simple polar plot using a dashed red line:

```
t = 0:.01:2*pi;  
polar(t,sin(2*t).*cos(2*t),'--r')
```



See Also

[cart2pol](#), [compass](#), [LineStyle](#), [plot](#), [pol2cart](#), [rose](#)

Purpose

Polynomial with specified roots

Syntax

```
p = poly(A)
p = poly(r)
```

Description

$p = \text{poly}(A)$ where A is an n -by- n matrix returns an $n+1$ element row vector whose elements are the coefficients of the characteristic polynomial, $\det(sl - A)$. The coefficients are ordered in descending powers: if a vector c has $n+1$ components, the polynomial it represents is $c_1s^n + \dots + c_n s + c_{n+1}$

$p = \text{poly}(r)$ where r is a vector returns a row vector whose elements are the coefficients of the polynomial whose roots are the elements of r .

Remarks

Note the relationship of this command to

```
r = roots(p)
```

which returns a column vector whose elements are the roots of the polynomial specified by the coefficients row vector p . For vectors, `roots` and `poly` are inverse functions of each other, up to ordering, scaling, and roundoff error.

Examples

MATLAB displays polynomials as row vectors containing the coefficients ordered by descending powers. The characteristic equation of the matrix

```
A =
     1     2     3
     4     5     6
     7     8     0
```

is returned in a row vector by `poly`:

```
p = poly(A)
p =
```

```
1 -6 -72 -27
```

The roots of this polynomial (eigenvalues of matrix A) are returned in a column vector by `roots`:

```
r = roots(p)
```

```
r =
```

```
12.1229
```

```
-5.7345
```

```
-0.3884
```

Algorithm

The algorithms employed for `poly` and `roots` illustrate an interesting aspect of the modern approach to eigenvalue computation. `poly(A)` generates the characteristic polynomial of A, and `roots(poly(A))` finds the roots of that polynomial, which are the eigenvalues of A. But both `poly` and `roots` use `eig`, which is based on similarity transformations. The classical approach, which characterizes eigenvalues as roots of the characteristic polynomial, is actually reversed.

If A is an n-by-n matrix, `poly(A)` produces the coefficients `c(1)` through `c(n+1)`, with `c(1) = 1`, in

$$\det(\lambda I - A) = c_1 \lambda^n + \dots + c_n \lambda + c_{n+1}$$

The algorithm is

```
z = eig(A);  
c = zeros(n+1,1); c(1) = 1;  
for j = 1:n  
    c(2:j+1) = c(2:j+1) - z(j)*c(1:j);  
end
```

This recursion is easily derived by expanding the product.

$$(\lambda - \lambda_1)(\lambda - \lambda_2) \dots (\lambda - \lambda_n)$$

It is possible to prove that `poly(A)` produces the coefficients in the characteristic polynomial of a matrix within roundoff error of A . This is true even if the eigenvalues of A are badly conditioned. The traditional algorithms for obtaining the characteristic polynomial, which do not use the eigenvalues, do not have such satisfactory numerical properties.

See Also

`conv`, `polyval`, `residue`, `roots`

polyarea

Purpose Area of polygon

Syntax
`A = polyarea(X,Y)`
`A = polyarea(X,Y,dim)`

Description `A = polyarea(X,Y)` returns the area of the polygon specified by the vertices in the vectors `X` and `Y`.

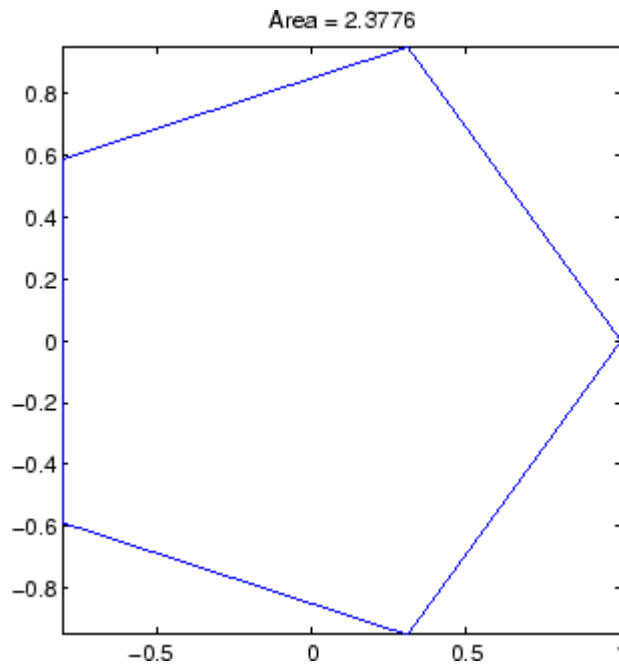
If `X` and `Y` are matrices of the same size, then `polyarea` returns the area of polygons defined by the columns `X` and `Y`.

If `X` and `Y` are multidimensional arrays, `polyarea` returns the area of the polygons in the first nonsingleton dimension of `X` and `Y`.

`A = polyarea(X,Y,dim)` operates along the dimension specified by scalar `dim`.

Examples

```
L = linspace(0,2.*pi,6); xv = cos(L)';yv = sin(L)';  
xv = [xv ; xv(1)]; yv = [yv ; yv(1)];  
A = polyarea(xv,yv);  
plot(xv,yv); title(['Area = ' num2str(A)]); axis image
```



See Also

convhull, inpolygon, rectint

polyder

Purpose Polynomial derivative

Syntax
`k = polyder(p)`
`k = polyder(a,b)`
`[q,d] = polyder(b,a)`

Description The `polyder` function calculates the derivative of polynomials, polynomial products, and polynomial quotients. The operands `a`, `b`, and `p` are vectors whose elements are the coefficients of a polynomial in descending powers.

`k = polyder(p)` returns the derivative of the polynomial `p`.

`k = polyder(a,b)` returns the derivative of the product of the polynomials `a` and `b`.

`[q,d] = polyder(b,a)` returns the numerator `q` and denominator `d` of the derivative of the polynomial quotient `b/a`.

Examples The derivative of the product

$$(3x^2 + 6x + 9)(x^2 + 2x)$$

is obtained with

```
a = [3 6 9];  
b = [1 2 0];  
k = polyder(a,b)  
k =  
    12    36    42    18
```

This result represents the polynomial

$$12x^3 + 36x^2 + 42x + 18$$

See Also `conv`, `deconv`

Purpose

Polynomial eigenvalue problem

Syntax

```
[X,e] = polyeig(A0,A1,...,Ap)
e = polyeig(A0,A1,...,Ap)
[X, e, s] = polyeig(A0,A1,...,AP)
```

Description

`[X,e] = polyeig(A0,A1,...,Ap)` solves the polynomial eigenvalue problem of degree p

$$(A_0 + \lambda A_1 + \dots + \lambda^p A_p)x = 0$$

where polynomial degree p is a non-negative integer, and A_0, A_1, \dots, A_p are input matrices of order n . The output consists of a matrix X of size n -by- $n \times p$ whose columns are the eigenvectors, and a vector e of length $n \times p$ containing the eigenvalues.

If λ is the j th eigenvalue in e , and x is the j th column of eigenvectors in X , then $(A_0 + \lambda A_1 + \dots + \lambda^p A_p)x$ is approximately 0.

`e = polyeig(A0,A1,...,Ap)` is a vector of length $n \times p$ whose elements are the eigenvalues of the polynomial eigenvalue problem.

`[X, e, s] = polyeig(A0,A1,...,AP)` also returns a vector s of length $p \times n$ containing condition numbers for the eigenvalues. At least one of A_0 and A_p must be nonsingular. Large condition numbers imply that the problem is close to a problem with multiple eigenvalues.

Remarks

Based on the values of p and n , `polyeig` handles several special cases:

- $p = 0$, or `polyeig(A)` is the standard eigenvalue problem: `eig(A)`.
- $p = 1$, or `polyeig(A,B)` is the generalized eigenvalue problem: `eig(A,-B)`.
- $n = 1$, or `polyeig(a0,a1,...,ap)` for scalars a_0, a_1, \dots, a_p is the standard polynomial problem: `roots([ap ... a1 a0])`.

If both A_0 and A_p are singular the problem is potentially ill-posed. Theoretically, the solutions might not exist or might not be unique. Computationally, the computed solutions might be inaccurate. If one, but not both, of A_0 and A_p is singular, the problem is well posed, but some of the eigenvalues might be zero or infinite.

Note that scaling A_0, A_1, \dots, A_p to have $\text{norm}(A_i)$ roughly equal 1 may increase the accuracy of `polyeig`. In general, however, this cannot be achieved. (See Tisseur [3] for more detail.)

Algorithm

The `polyeig` function uses the QZ factorization to find intermediate results in the computation of generalized eigenvalues. It uses these intermediate results to determine if the eigenvalues are well-determined. See the descriptions of `eig` and `qz` for more on this.

See Also

`condeig`, `eig`, `qz`

References

- [1] Dedieu, Jean-Pierre Dedieu and Françoise Tisseur, “Perturbation theory for homogeneous polynomial eigenvalue problems,” *Linear Algebra Appl.*, Vol. 358, pp. 71-94, 2003.
- [2] Tisseur, Françoise and Karl Meerbergen, “The quadratic eigenvalue problem,” *SIAM Rev.*, Vol. 43, Number 2, pp. 235-286, 2001.
- [3] Françoise Tisseur, “Backward error and condition of polynomial eigenvalue problems” *Linear Algebra Appl.*, Vol. 309, pp. 339-361, 2000.

Purpose Polynomial curve fitting

Syntax

```
p = polyfit(x,y,n)
[p,S] = polyfit(x,y,n)
[p,S,mu] = polyfit(x,y,n)
```

Description `p = polyfit(x,y,n)` finds the coefficients of a polynomial $p(x)$ of degree n that fits the data, $p(x(i))$ to $y(i)$, in a least squares sense. The result `p` is a row vector of length $n+1$ containing the polynomial coefficients in descending powers

$$p(x) = p_1x^n + p_2x^{n-1} + \dots + p_nx + p_{n+1}$$

`[p,S] = polyfit(x,y,n)` returns the polynomial coefficients `p` and a structure `S` for use with `polyval` to obtain error estimates or predictions. Structure `S` contains fields `R`, `df`, and `normr`, for the triangular factor from a QR decomposition of the Vandermonde matrix of `X`, the degrees of freedom, and the norm of the residuals, respectively. If the data `Y` are random, an estimate of the covariance matrix of `P` is $(R\text{inv}*R\text{inv}')*normr^2/df$, where `Rinv` is the inverse of `R`. If the errors in the data `y` are independent normal with constant variance, `polyval` produces error bounds that contain at least 50% of the predictions.

`[p,S,mu] = polyfit(x,y,n)` finds the coefficients of a polynomial in

$$\hat{x} = \frac{x - \mu_1}{\mu_2}$$

where $\mu_1 = \text{mean}(x)$ and $\mu_2 = \text{std}(x)$. `mu` is the two-element vector $[\mu_1, \mu_2]$. This centering and scaling transformation improves the numerical properties of both the polynomial and the fitting algorithm.

Examples This example involves fitting the error function, $\text{erf}(x)$, by a polynomial in x . This is a risky project because $\text{erf}(x)$ is a bounded function, while polynomials are unbounded, so the fit might not be very good.

First generate a vector of x points, equally spaced in the interval **[0, 2.5]**; then evaluate $\text{erf}(x)$ at those points.

```
x = (0: 0.1: 2.5)';  
y = erf(x);
```

The coefficients in the approximating polynomial of degree 6 are

```
p = polyfit(x,y,6)
```

```
p =
```

```
0.0084 -0.0983 0.4217 -0.7435 0.1471 1.1064 0.0004
```

There are seven coefficients and the polynomial is

$$0.0084x^6 - 0.0983x^5 + 0.4217x^4 - 0.7435x^3 + 0.1471x^2 + 1.1064x + 0.0004$$

To see how good the fit is, evaluate the polynomial at the data points with

```
f = polyval(p,x);
```

A table showing the data, fit, and error is

```
table = [x y f y-f]
```

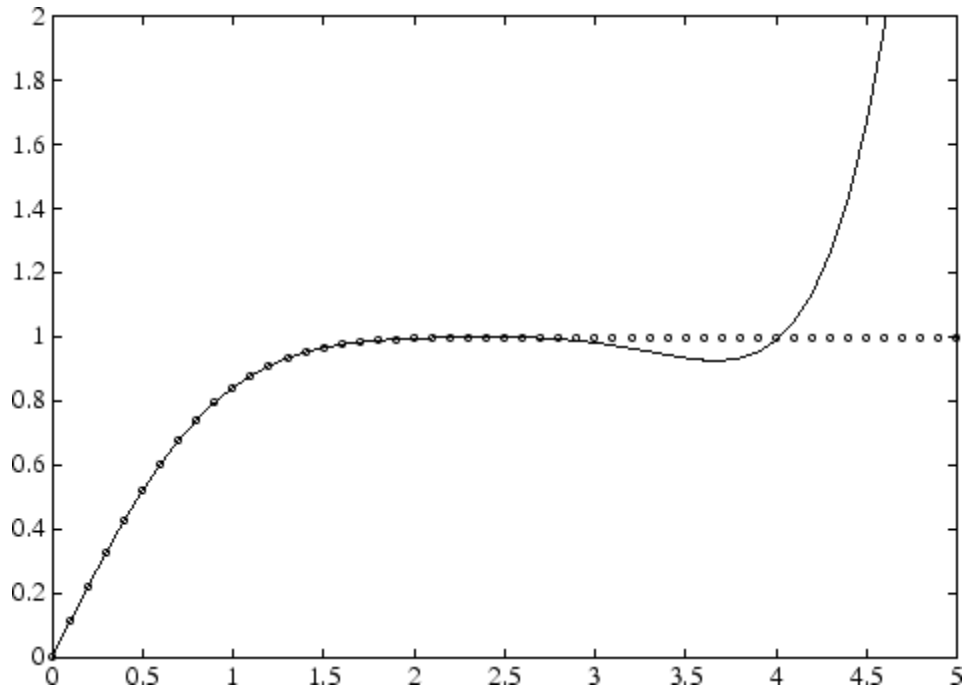
```
table =
```

0	0	0.0004	-0.0004
0.1000	0.1125	0.1119	0.0006
0.2000	0.2227	0.2223	0.0004
0.3000	0.3286	0.3287	-0.0001
0.4000	0.4284	0.4288	-0.0004
...			
2.1000	0.9970	0.9969	0.0001
2.2000	0.9981	0.9982	-0.0001
2.3000	0.9989	0.9991	-0.0003
2.4000	0.9993	0.9995	-0.0002


```
2.5000    0.9996    0.9994    0.0002
```

So, on this interval, the fit is good to between three and four digits. Beyond this interval the graph shows that the polynomial behavior takes over and the approximation quickly deteriorates.

```
x = (0: 0.1: 5)';
y = erf(x);
f = polyval(p,x);
plot(x,y,'o',x,f,'-')
axis([0 5 0 2])
```



Algorithm

The `polyfit` M-file forms the Vandermonde matrix, V , whose elements are powers of x .

polyfit

$$v_{i,j} = x_i^{n-j}$$

It then uses the backslash operator, `\`, to solve the least squares problem

$$Vp \cong y$$

You can modify the M-file to use other functions of x as the basis functions.

See Also

`poly`, `polyval`, `roots`, `lscov`

Purpose	Integrate polynomial analytically
Syntax	<code>polyint(p,k)</code> <code>polyint(p)</code>
Description	<code>polyint(p,k)</code> returns a polynomial representing the integral of polynomial <code>p</code> , using a scalar constant of integration <code>k</code> . <code>polyint(p)</code> assumes a constant of integration <code>k=0</code> .
See Also	<code>polyder</code> , <code>polyval</code> , <code>polyvalm</code> , <code>polyfit</code>

polyval

Purpose Polynomial evaluation

Syntax
`y = polyval(p,x)`
`y = polyval(p,x,[],mu)`
`[y,delta] = polyval(p,x,S)`
`[y,delta] = polyval(p,x,S,mu)`

Description `y = polyval(p,x)` returns the value of a polynomial of degree n evaluated at x . The input argument p is a vector of length $n+1$ whose elements are the coefficients in descending powers of the polynomial to be evaluated.

$$y = p_1x^n + p_2x^{n-1} + \dots + p_nx + p_{n+1}$$

x can be a matrix or a vector. In either case, `polyval` evaluates p at each element of x .

`y = polyval(p,x,[],mu)` uses $\hat{x} = (x - \mu_1)/\mu_2$ in place of x . In this equation, $\mu_1 = \text{mean}(x)$ and $\mu_2 = \text{std}(x)$. The centering and scaling parameters $\text{mu} = [\mu_1, \mu_2]$ are optional output computed by `polyfit`.

`[y,delta] = polyval(p,x,S)` and `[y,delta] = polyval(p,x,S,mu)` use the optional output structure S generated by `polyfit` to generate error estimates, $y\pm\text{delta}$. If the errors in the data input to `polyfit` are independent normal with constant variance, $y\pm\text{delta}$ contains at least 50% of the predictions.

Remarks The `polyvalm(p,x)` function, with x a matrix, evaluates the polynomial in a matrix sense. See `polyvalm` for more information.

Examples The polynomial $p(x) = 3x^2 + 2x + 1$ is evaluated at $x = 5, 7,$ and 9 with

```
p = [3 2 1];  
polyval(p,[5 7 9])
```

which results in

```
ans =
```

```
86 162 262
```

For another example, see `polyfit`.

See Also

`polyfit`, `polyvalm`

polyvalm

Purpose Matrix polynomial evaluation

Syntax `Y = polyvalm(p,X)`

Description `Y = polyvalm(p,X)` evaluates a polynomial in a matrix sense. This is the same as substituting matrix `X` in the polynomial `p`.

Polynomial `p` is a vector whose elements are the coefficients of a polynomial in descending powers, and `X` must be a square matrix.

Examples The Pascal matrices are formed from Pascal's triangle of binomial coefficients. Here is the Pascal matrix of order 4.

```
X = pascal(4)
X =
     1     1     1     1
     1     2     3     4
     1     3     6    10
     1     4    10    20
```

Its characteristic polynomial can be generated with the `poly` function.

```
p = poly(X)
p =
     1    -29     72    -29     1
```

This represents the polynomial $x^4 - 29x^3 + 72x^2 - 29x + 1$.

Pascal matrices have the curious property that the vector of coefficients of the characteristic polynomial is palindromic; it is the same forward and backward.

Evaluating this polynomial at each element is not very interesting.

```
polyval(p,X)
ans =
     16     16     16     16
     16     15    -140    -563
     16    -140   -2549  -12089
```

```
16      -563  -12089  -43779
```

But evaluating it in a matrix sense is interesting.

```
polyvalm(p,X)
ans =
    0    0    0    0
    0    0    0    0
    0    0    0    0
    0    0    0    0
```

The result is the zero matrix. This is an instance of the Cayley-Hamilton theorem: a matrix satisfies its own characteristic equation.

See Also

`polyfit`, `polyval`

pow2

Purpose Base 2 power and scale floating-point numbers

Syntax
`X = pow2(Y)`
`X = pow2(F,E)`

Description `X = pow2(Y)` returns an array `X` whose elements are 2 raised to the power `Y`.

`X = pow2(F,E)` computes $x = f * 2^e$ for corresponding elements of `F` and `E`. The result is computed quickly by simply adding `E` to the floating-point exponent of `F`. Arguments `F` and `E` are real and integer arrays, respectively.

Remarks This function corresponds to the ANSI C function `ldexp()` and the IEEE floating-point standard function `scalbn()`.

Examples For IEEE arithmetic, the statement `X = pow2(F,E)` yields the values:

F	E	X
1/2	1	1
pi/4	2	pi
-3/4	2	-3
1/2	-51	eps
1-eps/2	1024	realmax
1/2	-1021	realmin

See Also `log2`, `exp`, `hex2num`, `realmax`, `realmin`

The arithmetic operators `^` and `.^`

Purpose Array power

Syntax $Z = X.^Y$

Description $Z = X.^Y$ denotes element-by-element powers. X and Y must have the same dimensions unless one is a scalar. A scalar is expanded to an array of the same size as the other input.

$C = \text{power}(A,B)$ is called for the syntax ' $A.^B$ ' when A or B is an object.

Note that for a negative value X and a non-integer value Y , if the $\text{abs}(Y)$ is less than one, the `power` function returns the complex roots. To obtain the remaining real roots, use the `nthroot` function.

See Also `nthroot`, `realpow`

Purpose Evaluate piecewise polynomial

Syntax `v = ppval(pp,xx)`

Description `v = ppval(pp,xx)` returns the value of the piecewise polynomial f , contained in `pp`, at the entries of `xx`. You can construct `pp` using the functions `interp1`, `pchip`, `spline`, or the spline utility `mkpp`.

`v` is obtained by replacing each entry of `xx` by the value of f there. If f is scalar-valued, `v` is of the same size as `xx`. `xx` may be N-dimensional.

If `pp` was constructed by `pchip`, `spline`, or `mkpp` using the orientation of non-scalar function values specified for those functions, then:

If f is $[D1, \dots, Dr]$ -valued, and `xx` is a vector of length N , then `V` has size $[D1, \dots, Dr, N]$, with `V(:, ..., :, J)` the value of f at `xx(J)`.

If f is $[D1, \dots, Dr]$ -valued, and `xx` has size $[N1, \dots, Ns]$, then `V` has size $[D1, \dots, Dr, N1, \dots, Ns]$, with `V(:, ..., :, J1, ..., Js)` the value of f at `xx(J1, ..., Js)`.

If `pp` was constructed by `interp1` using the orientation of non-scalar function values specified for that function, then:

If f is $[D1, \dots, Dr]$ -valued, and `xx` is a vector of length N , then `V` has size $[N, D1, \dots, Dr]$, with `V(J, :, ..., :)` the value of f at `xx(J)`.

If f is $[D1, \dots, Dr]$ -valued, and `xx` has size $[N1, \dots, Ns]$, then `V` has size $[N1, \dots, Ns, D1, \dots, Dr]$, with `V(J1, ..., Js, :, ..., :)` the value of f at `xx(J1, ..., Js)`.

Examples Compare the results of integrating the function `cos`

```
a = 0; b = 10;
int1 = quad(@cos,a,b)
```

```
int1 =
    -0.5440
```

with the results of integrating the piecewise polynomial `pp` that approximates the cosine function by interpolating the computed values `x` and `y`.

```
x = a:b;
y = cos(x);
pp = spline(x,y);
int2 = quad(@(x)ppval(pp,x),a,b)

int2 =
    -0.5485
```

`int1` provides the integral of the cosine function over the interval `[a,b]`, while `int2` provides the integral over the same interval of the piecewise polynomial `pp`.

See Also

`mkpp`, `spline`, `unmkpp`

prefdir

Purpose Directory containing preferences, history, and layout files

Syntax

```
prefdir
d = prefdir
d = prefdir(1)
```

Description prefdir returns the directory that contains

- Preferences for MATLAB and related products (matlab.prf)
- Command history file (history.m)
- MATLAB shortcuts (shortcuts.xml)
- MATLAB desktop layout files (MATLABDesktop.xml and Your_Saved_LayoutMATLABLayout.xml)
- Other related files

d = prefdir assigns to d the name of the directory containing preferences and related files.

d = prefdir(1) creates a directory for preferences and related files if one does not exist. If the directory does exist, the name is assigned to d.

Remarks

You must have write access to the preferences directory, or MATLAB generates an error in the Command Window when you try to change preferences.

The directory might be in a hidden folder, for example, myname/.matlab/R2009a. How to access hidden folders depends on your platform:

- On Microsoft Windows platforms, in any folder window, select **Tools > Folder Options**. Click the **View** tab, and under **Advanced** settings, select **Show hidden files and folders**. Then you should be able to see the folder returned by prefdir.

- On Apple Macintosh platforms, in the Finder, select **Go -> Go to Folder**. In the resulting dialog box, type the path returned by `prefdir` and press **Enter**.

The preferences directory MATLAB uses depends on the release. The preference directory naming and preference migration practice used from R13 through R14SP2 was changed starting in R14SP3 to address backwards compatibility problems. The differences are relevant primarily if you run multiple versions of MATLAB, and especially if one version is prior to R14SP3:

- For R2009a back through and including R2006a, and R14SP3, MATLAB uses the name of the release for the preference directory. For example, it uses R2009a, R2008b, ... through R14SP3. When you install R2009a, MATLAB migrates the files in the R2008b preferences directory to the R2009a preferences directory. While running R2009a through R14SP3, any changes made to files in those preferences directories (R2009a through R14SP3) are used only in their respective versions. As an example, commands you run in R2009a will *not* appear in the Command History when you run R2008b, and so on. The converse is also true.

Upon startup, MATLAB 7.8 (R2009a) looks for, and if found uses, the R2009a preferences directory. If not found, MATLAB creates an R2009a preferences directory. This happens when the R2009a preferences directory is deleted or does not exist for some other reason. MATLAB then looks for the R2008b preferences directory, and if found, migrates the R2008b preferences to the R2009a preferences. If it does not find the R2008b preferences directory, it uses the default preferences for R2009a. This process also applies when starting MATLAB 7.7 through 7.1.

If you want to use default preferences for R2009a, and do not want MATLAB to migrate preferences from R2008b, the R2009a preferences directory *must exist but be empty* when you start MATLAB. If you want to maintain some of your R2009a customizations, but restore the defaults for others, in the R2009a preferences directory, delete the files for which you want the defaults

to be restored. One file you might want to maintain is `history.m`—for more information about the file, see “Viewing Statements in the Command History Window” in the MATLAB Desktop Tools and Development Environment documentation.

- The R14 through R14SP2 releases all share the R14 preferences directory. While running R14SP1, for example, any changes made to files in the preferences directory, R14, are used when you run R14SP2 and R14. As another example, commands you run in R14 appear in the Command History when you run R14SP2, and the converse is also true. The preferences are not used when you run R14SP3 or later versions because those versions each use their own preferences directories.
- All R13 releases use the R13 preferences directory. While running R13SP1, for example, any changes made to files in the preferences directory, R13, are used when you run R13. As an example, commands you run in R13 will appear in the Command History when you run R13SP1, and the converse is true. The preferences are not used when you run any R14 or later releases because R14 and later releases use different preferences directories, and the converse is true.

Examples

Run

```
prefdir
```

MATLAB returns

```
ans =
```

```
C:\WINNT\Profiles\my_user_name\MATHWORKS\Application Data\MathWorks\MATLAB\R2009a
```

Running `dir` for the directory shows these files and others for MathWorks products:

```
.          history.m
..         matlab.prf
cwdhistory.m  MATLABDesktop.xml
shortcuts.xml MATLAB EditorDesktop.xml
```

In MATLAB, run `cd(prefdir)` to change to that directory.

On Windows platforms, go directly to the preferences directory in Microsoft Windows Explorer by running `winopen(prefdir)`.

See Also

preferences, winopen

“Specifying Options for MATLAB Using Preferences” in the MATLAB Desktop Tools and Development Environment documentation

preferences

Purpose	Open Preferences dialog box
GUI Alternatives	As an alternative to the <code>preferences</code> function, select File > Preferences in the MATLAB desktop or any desktop tool.
Syntax	<code>preferences</code>
Description	<code>preferences</code> displays the Preferences dialog box, from which you can make changes to options for MATLAB and related products.
See Also	<code>prefdir</code> “Specifying Options for MATLAB Using Preferences” in the MATLAB Desktop Tools and Development Environment documentation

Purpose Generate list of prime numbers

Syntax `p = primes(n)`

Description `p = primes(n)` returns a row vector of the prime numbers less than or equal to `n`. A prime number is one that has no factors other than 1 and itself.

Examples `p = primes(37)`

```
p = 2 3 5 7 11 13 17 19 23 29 31 37
```

See Also factor

print, printopt

Purpose Print figure or save to file and configure printer defaults

Contents

“GUI Alternative” on page 2-2854

Syntax

“Description” on page 2-2854

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“See Also” on page 2-2874

GUI Alternative

Select **File > Print** from the figure window to open the Print dialog box and **File > Print Preview** to open the Print Preview GUI. For details, see “How to Print or Export” in the MATLAB Graphics documentation.

Syntax

```
print
print filename
print -ddriver
print -dformat
print -dformat filename
print -smodelname
print -options
print(...)
[pcmd,dev] = printopt
```

Description

`print` and `printopt` produce hard-copy output. All arguments to the `print` command are optional. You can use them in any combination or order.

`print` sends the contents of the current figure, including bitmap representations of any user interface controls, to the printer using the device and system printing command defined by `printopt`.

`print filename` directs the output to the PostScript file designated by `filename`. If `filename` does not include an extension, `print` appends an appropriate extension.

`print -ddriver` prints the figure using the specified printer *driver*, (such as color PostScript). If you omit `-ddriver`, `print` uses the default value stored in `printopt.m`. The table in “Printer Drivers” on page 2-2856 lists all supported device types.

`print -dformat` copies the figure to the system Clipboard (Microsoft Windows platforms only). To be valid, the *format* for this operation must be either `-dmeta` (Windows Enhanced Metafile) or `-dbitmap` (Windows Bitmap).

`print -dformat filename` exports the figure to the specified file using the specified graphics *format* (such as TIFF). The table of “Graphics Format Files” on page 2-2860 lists all supported graphics file formats.

`print -smodelname` prints the current Simulink model *modename*.

`print -options` specifies print options that modify the action of the `print` command. (For example, the `-noui` option suppresses printing of user interface controls.) “Printing Options” on page 2-2864 lists available options.

`print(...)` is the function form of `print`. It enables you to pass variables for any input arguments. This form is useful for passing file names and handles. See Batch Processing for an example.

`[pcmd,dev] = printopt` returns strings containing the current system-dependent printing command and output device. `printopt` is an M-file used by `print` to produce the hard-copy output. You can edit the M-file `printopt.m` to set your default printer type and destination.

`pcmd` and `dev` are platform-dependent strings. `pcmd` contains the command that `print` uses to send a file to the printer. `dev` contains the

print, printopt

printer driver or graphics format option for the `print` command. Their defaults are platform dependent.

Platform	Print Command	Driver or Format
Mac and UNIX	<code>lpr -r</code>	<code>-dps2</code>
Windows	<code>COPY /B %s LPT1:</code>	<code>-dwin</code>

Printer Drivers

The following table shows the more widely used printer drivers supported by MATLAB software. If you do not specify a driver, the default setting shown in the previous table is used. For a list of all supported printer drivers, type `print -d` at the MATLAB prompt. Some things to remember:

- As indicated in “Description” on page 2-2854 the `-d` switch specifies a printer driver or a graphics file format:
 - Specifying a printer driver without a file name or printer name (the `-P` option) sends the output formatted by the specified driver to your default printer, which may not be what you want to do.

Note On Windows systems, when you use the `-P` option to identify a printer to use, if you specify any driver other than `-dwin` or `-dwinc`, MATLAB writes the output to a file with an appropriate extension but does not send it to the printer. You can then copy that file to a printer.

- Specifying a `-dmeta` or a `-dbitmap` graphics format without a file name places the graphic on the system Clipboard, if possible (Windows platforms only).
- Specifying any other graphics format without a file name creates a file in the current directory with a name such as `figureN.fmt`,

where N is 1, 2, 3, ... and *fmt* indicates the format type, for example, eps or png.

- Several drivers come from a product called Ghostscript, which is shipped with MATLAB software. The last column indicates when Ghostscript is used.
- Not all drivers are supported on all platforms. Non support is noted in the first column of the table.
- If you specify a particular printer with the `-P` option and do not specify a driver, a default driver for that printer is selected, either by the operating system or by MATLAB, depending on the platform:
 - On MATLAB, the driver associated with this particular printing device is used.
 - On Macintosh and UNIX platforms, the driver specified in `printopt.m` is used

See Selecting the Printer in the Graphics documentation for more information.

Note The MathWorks™ is planning to leverage existing operating system (OS) support for printer drivers and devices. As a result, the ability to specify certain print devices using the `print -d` command, and certain graphics formats using the `print -d` command and/or the `saveas` command, will be removed in a future release. In the following table, the affected formats have an asterisk (*) next to the `print` command option string. The asterisks provide a link to the Web site which supplies a form for users to give feedback about these changes.

Printer Driver	Print Command Option String	Ghostscript
Canon BubbleJet BJ10e	-dbj10e *	Yes

print, printopt

Printer Driver	Print Command Option String	Ghostscript
Canon BubbleJet BJ200 color	-dbj200 *	Yes
Canon Color BubbleJet BJC-70/BJC-600/BJC-4000	-dbjc600 *	Yes
Canon Color BubbleJet BJC-800	-dbjc800 *	Yes
Epson and compatible 9- or 24-pin dot matrix print drivers	-depson *	Yes
Epson and compatible 9-pin with interleaved lines (triple resolution)	-deps9high *	Yes
Epson LQ-2550 and compatible; color (not supported on HP-700)	-depsonc *	Yes
Fujitsu 3400/2400/1200	-depsonc *	Yes
HP DesignJet 650C color (not supported on Windows)	-ddnj650c *	Yes
HP DeskJet 500	-ddjet500 *	Yes
HP DeskJet 500C (creates black and white output)	-dcdjmono *	Yes
HP DeskJet 500C (with 24 bit/pixel color and high-quality Floyd-Steinberg color dithering) (not supported on Windows)	-dcdjcolor *	Yes

Printer Driver	Print Command Option String	Ghostscript
HP DeskJet 500C/540C color (not supported on Windows)	-dcdj500 *	Yes
HP Deskjet 550C color (not supported on Windows)	-dcdj550 *	Yes
HP DeskJet and DeskJet Plus	-ddeskjet *	Yes
HP LaserJet	-dlaserjet *	Yes
HP LaserJet+	-dljetplus *	Yes
HP LaserJet IIP	-dljet2p *	Yes
HP LaserJet III	-dljet3 *	Yes
HP LaserJet 4, 5L and 5P	-dljet4 *	Yes
HP LaserJet 5 and 6	-dpxlmono *	Yes
HP PaintJet color	-dpaintjet *	Yes
HP PaintJet XL color	-dpjxl *	Yes
HP PaintJet XL color	-dpjetxl *	Yes
HP PaintJet XL300 color (not supported on Windows)	-dpjxl300 *	Yes
HPGL for HP 7475A and other compatible plotters. (Renderer cannot be set to Z-buffer.)	-dhpgl *	No
IBM® 9-pin Proprinter	-dibmpro *	Yes

print, printopt

Printer Driver	Print Command Option String	Ghostscript
PostScript black and white	-dps	No
PostScript color	-dpvc	No
PostScript Level 2 black and white	-dps2	No
PostScript Level 2 color	-dpvc2	No
Windows color (Windows only)	-dwinc	No
Windows monochrome (Windows only)	-dwin	No

Tip Generally, Level 2 PostScript files are smaller and are rendered more quickly when printing than Level 1 PostScript files. However, not all PostScript printers support Level 2, so determine the capabilities of your printer before using those drivers. Level 2 PostScript printing is the default for UNIX platforms. You can change this default by editing the `printopt.m` file. Likewise, if you want color PostScript printing to be the default instead of black-and-white PostScript printing, edit the line in the `printopt.m` file that reads `dev = '-dps2'`; to be `dev = '-dpvc2'`;

Graphics Format Files

To save your figure as a graphics format file, specify a format switch and file name. To set the resolution of the output file for a built-in MATLAB format, use the `-r` switch. (For example, `-r300` sets the output resolution to 300 dots per inch.) The `-r` switch is also supported for Windows Enhanced Metafiles, JPEG, TIFF and PNG files, but is not supported for Ghostscript raster formats. For more information, see “Printing and Exporting without a Display” on page 2-2863 and “Resolution Considerations” on page 2-2866.

Note When you print to a file, the file name must have fewer than 128 characters, including path name. When you print to a file in your current directory, the filename must have fewer than 126 characters, because MATLAB places '.' or '\.' at the beginning of the filename when referring to it.

The following table shows the supported output formats for exporting from figures and the switch settings to use. In some cases, a format is available both as a MATLAB output filter and as a Ghostscript output filter. All formats except for EMF are supported on both PC and UNIX platforms.

Graphics Format	Bitmap or Vector	Print Command Option String	MATLAB or Ghostscript
BMP monochrome BMP	Bitmap	-dbmpmono	Ghostscript
BMP 24-bit BMP	Bitmap	-dbmp16m	Ghostscript
BMP 8-bit (256-color) BMP (this format uses a fixed colormap)	Bitmap	-dbmp256	Ghostscript
BMP 24-bit	Bitmap	-dbmp	MATLAB
EMF	Vector	-dmeta	MATLAB
EPS black and white	Vector	-deps	MATLAB
EPS color	Vector	-depsc	MATLAB
EPS Level 2 black and white	Vector	-deps2	MATLAB
EPS Level 2 color	Vector	-depsc2	MATLAB

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Graphics Format	Bitmap or Vector	Print Command Option String	MATLAB or Ghostscript
HDF 24-bit	Bitmap	-dhdf	MATLAB
ILL (Adobe Illustrator)	Vector	-dill	MATLAB
JPEG 24-bit	Bitmap	-djpeg	MATLAB
PBM (plain format) 1-bit	Bitmap	-dpbm	Ghostscript
PBM (raw format) 1-bit	Bitmap	-dpbmraw	Ghostscript
PCX 1-bit	Bitmap	-dpcxmono	Ghostscript
PCX 24-bit color PCX file format, three 8-bit planes	Bitmap	-dpcx24b	Ghostscript
PCX 8-bit newer color PCX file format (256-color)	Bitmap	-dpcx256	Ghostscript
PCX Older color PCX file format (EGA/VGA, 16-color)	Bitmap	-dpcx16	Ghostscript
PDF Color PDF file format	Vector	-dpdf	Ghostscript
PGM Portable Graymap (plain format)	Bitmap	-dpgm	Ghostscript
PGM Portable Graymap (raw format)	Bitmap	-dpgmraw	Ghostscript

Graphics Format	Bitmap or Vector	Print Command Option String	MATLAB or Ghostscript
PNG 24-bit	Bitmap	-dpng	MATLAB
PPM Portable Pixmap (plain format)	Bitmap	-dppm	Ghostscript
PPM Portable Pixmap (raw format)	Bitmap	-dppmraw	Ghostscript
TIFF 24-bit	Bitmap	-dtiff or -dtiffn	MATLAB
TIFF preview for EPS files	Bitmap	-tiff	

The TIFF image format is supported on all platforms by almost all word processors for importing images. The `-dtiffn` variant writes an uncompressed TIFF. JPEG is a lossy, highly compressed format that is supported on all platforms for image processing and for inclusion into HTML documents on the Web. To create these formats, MATLAB renders the figure using the Z-buffer rendering method and the resulting bitmap is then saved to the specified file.

Printing and Exporting without a Display

On a UNIX platform (including Macintosh), where you can start in MATLAB `nodisplay` mode (`matlab -nodisplay`), you can print using most of the drivers you can use with a display and export to most of the same file formats. The PostScript and Ghostscript devices all function in `nodisplay` mode on UNIX platforms. The graphic devices `-djpeg`, `-dpng`, `-dtiff` (compressed TIFF bitmaps), and `-tiff` (EPS with TIFF preview) work as well, but under `nodisplay` they use Ghostscript to generate output instead of using the drivers built into MATLAB. However, Ghostscript ignores the `-r` option when generating `-djpeg`, `-dpng`, `-dtiff`, and `-tiff` image files. This means that you cannot vary the resolution of image files when running in `nodisplay` mode.

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Naturally, the Windows only `-dwin` and `-dwinc` output formats cannot be used on UNIX or Mac platforms with or without a display.

The same holds true on Windows platforms with the `-noFigureWindows` startup option. The `-dwin`, `-dwinc`, and `-dsetup` options operate as usual under `-noFigureWindows`. However, the `printpreview` GUI does not function in this mode.

The formats which you cannot generate in `nodisplay` mode on UNIX and Mac platforms are:

- `bitmap (-dbitmap)` — Windows bitmap file (except for Simulink models)
- `bmp (-dbmp...)` — Monochrome and color bitmaps
- `hdf (-dhdf)` — Hierarchical Data Format
- `svg (-dsvg)` — Scalable Vector Graphics file (except for Simulink models)
- `tiffn (-dtiffn)` — TIFF image file, no compression

In addition, `uicontrols` do not print or export in `nodisplay` mode.

Printing Options

This table summarizes options that you can specify for `print`. The second column links to tutorials in “Printing and Exporting” in the MATLAB Graphics documentation that provide operational details. Also see “Resolution Considerations” on page 2-2866 for information on controlling output resolution.

Option	Description
<code>-adobecharset</code>	PostScript devices only. Use PostScript default character set encoding. See “Early PostScript 1 Printers”.
<code>-append</code>	PostScript devices only. Append figure to existing PostScript file. See “Settings That Are Driver Specific”.

Option	Description
-cmyk	PostScript devices only. Print with CMYK colors instead of RGB. See “Setting CMYK Color”.
-ddriver	Printing only. Printer driver to use. See “Printer Drivers” on page 2-2856 table.
-dformat	Exporting only. Graphics format to use. See “Graphics Format Files” table.
-dsetup	Windows printing only. Display the (platform-specific) Print Setup dialog. Settings you make in it are saved, but nothing is printed.
-fhandle	Handle of figure to print. Note that you cannot specify both this option and the <i>-swindowtitle</i> option. See “Which Figure Is Printed”.
-loose	PostScript and Ghostscript printing only. Use loose bounding box for PostScript output. See “Producing Uncropped Figures”.
-noui	Suppress printing of user interface controls. See “Excluding User Interface Controls”.
-opengl	Render using the OpenGL algorithm. Note that you cannot specify this method in conjunction with <i>-zbuffer</i> or <i>-painters</i> . See “Selecting a Renderer”.
-painters	Render using the Painter’s algorithm. Note that you cannot specify this method in conjunction with <i>-zbuffer</i> or <i>-opengl</i> . See “Selecting a Renderer”.
-Pprinter	Specify name of printer to use. See “Selecting the Printer”.

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Option	Description
<i>-rnumber</i>	PostScript and built-in raster formats, and Ghostscript vector format only. Specify resolution in dots per inch. Defaults to 90 for Simulink, 150 for figures in image formats and when printing in Z-buffer or OpenGL mode, screen resolution for metafiles, and 864 otherwise. Use <i>-r0</i> to specify screen resolution. For details, see “Resolution Considerations” on page 2-2866 and “Setting the Resolution”.
<i>-swindowtitle</i>	Specify name of Simulink system window to print. Note that you cannot specify both this option and the <i>-fhandle</i> option. See “Which Figure Is Printed”.
<i>-v</i>	Windows printing only. Display the Windows Print dialog box. The <i>v</i> stands for “verbose mode.”
<i>-zbuffer</i>	Render using the Z-buffer algorithm. Note that you cannot specify this method in conjunction with <i>-opengl</i> or <i>-painters</i> . See “Selecting a Renderer”.

Resolution Considerations

Use *-rnumber* to specify the resolution of the generated output. In general, using a higher value will yield higher quality output but at the cost of larger output files. It affects the resolution and output size of all MATLAB built-in *raster* formats (which are identified in column four of the table in “Graphics Format Files” on page 2-2860).

Note Built-in graphics formats are generated directly from MATLAB without conversion through the Ghostscript library. Also, in headless (`nodisplay`) mode, writing to certain image formats is not done by built-in drivers, as it is when a display is being used. These formats are `-djpeg`, `-dtiff`, and `-dpng`. Furthermore, the `-dhdf` and `-dbmp` formats cannot be generated in headless mode (but you can substitute `-dbmp16m` for `-dbmp`). See “Printing and Exporting without a Display” on page 2-2863 for details on printing when not using a display.

Unlike the built-in MATLAB formats, graphic output generated via Ghostscript does not directly obey `-r` option settings. However, the intermediate PostScript file generated by MATLAB as input for the Ghostscript processor is affected by the `-r` setting and thus can indirectly influence the quality of the final Ghostscript generated output.

The effect of the `-r` option on output quality can be subtle at ordinary magnification when using the OpenGL or ZBuffer renderers and writing to one of the MATLAB built-in raster formats, or when generating vector output that contains an embedded raster image (for example, PostScript or PDF). The effect of specifying higher resolution is more apparent when viewing the output at higher magnification or when printed, since a larger `-r` setting provides more data to use when scaling the image.

When generating fully vectorized output (as when using the Painters renderer to output a vector format such as PostScript or PDF), the resolution setting affects the degree of detail of the output; setting resolution higher generates crisper output (but small changes in the resolution may have no observable effect). For example, the gap widths of lines that do not use a solid (‘-’) linestyle can be affected.

Paper Sizes

MATLAB printing supports a number of standard paper sizes. You can select from the following list by setting the `PaperType` property of the figure or selecting a supported paper size from the Print dialog box.

print, printopt

Property Value	Size (Width by Height)
usletter	8.5 by 11 inches
uslegal	8.5 by 14 inches
tabloid	11 by 17 inches
A0	841 by 1189 mm
A1	594 by 841 mm
A2	420 by 594 mm
A3	297 by 420 mm
A4	210 by 297 mm
A5	148 by 210 mm
B0	1029 by 1456 mm
B1	728 by 1028 mm
B2	514 by 728 mm
B3	364 by 514 mm
B4	257 by 364 mm
B5	182 by 257 mm
arch-A	9 by 12 inches
arch-B	12 by 18 inches
arch-C	18 by 24 inches
arch-D	24 by 36 inches
arch-E	36 by 48 inches
A	8.5 by 11 inches
B	11 by 17 inches
C	17 by 22 inches
D	22 by 34 inches
E	34 by 43 inches

Printing Tips

Figures with Resize Functions

The `print` command produces a warning when you print a figure having a callback routine defined for the figure `ResizeFcn`. To avoid the warning, set the figure `PaperPositionMode` property to `auto` or select **Match Figure Screen Size** in the **File > Page Setup** dialog box.

Troubleshooting Microsoft Windows Printing

If you encounter problems such as segmentation violations, general protection faults, or application errors, or the output does not appear as you expect when using Microsoft printer drivers, try the following:

- If your printer is PostScript compatible, print with one of the MATLAB built-in PostScript drivers. There are various PostScript device options that you can use with `print`, which all start with `-dps`.
- The behavior you are experiencing might occur only with certain versions of the print driver. Contact the print driver vendor for information on how to obtain and install a different driver.
- Try printing with one of the MATLAB built-in Ghostscript devices. These devices use Ghostscript to convert PostScript files into other formats, such as HP LaserJet, PCX, Canon BubbleJet, and so on.
- Copy the figure as a Windows Enhanced Metafile using the **Edit > Copy Figure** menu item on the figure window menu or the `print -dmeta` option at the command line. You can then import the file into another application for printing.

You can set copy options in the figure's **File > Preferences > Copying Options** dialog box. The Windows Enhanced Metafile Clipboard format produces a better quality image than Windows Bitmap.

Printing MATLAB GUIs

You can generally obtain better results when printing a figure window that contains MATLAB `uicontrols` by setting these key properties:

print, printopt

- Set the figure `PaperPositionMode` property to `auto`. This ensures that the printed version is the same size as the on-screen version. With `PaperPositionMode` set to `auto` MATLAB, does not resize the figure to fit the current value of the `PaperPosition`. This is particularly important if you have specified a figure `ResizeFcn`, because if MATLAB resizes the figure during the print operation, `ResizeFcn` is automatically called.

To set `PaperPositionMode` on the current figure, use the command:

```
set(gcf, 'PaperPositionMode', 'auto')
```

- Set the figure `InvertHardcopy` property to `off`. By default, MATLAB changes the figure background color of printed output to white, but does not change the color of `uicontrols`. If you have set the background color, for example, to match the gray of the GUI devices, you must set `InvertHardcopy` to `off` to preserve the color scheme.

To set `InvertHardcopy` on the current figure, use the command:

```
set(gcf, 'InvertHardcopy', 'off')
```

- Use a color device if you want lines and text that are in color on the screen to be written to the output file as colored objects. Black and white devices convert colored lines and text to black or white to provide the best contrast with the background and to avoid dithering.
- Use the `print` command's `-loose` option to keep a bounding box from being too tightly wrapped around objects contained in the figure. This is important if you have intentionally used space between `uicontrols` or axes and the edge of the figure and you want to maintain this appearance in the printed output.

If you print or export in `nodisplay` mode, none of the `uicontrols` the figure has will be visible. If you run code that adds `uicontrols` to a figure when the figure is invisible, the controls will not print until the figure is made visible.

Printing Interpolated Shading with PostScript Drivers

You can print MATLAB surface objects (such as graphs created with `surf` or `mesh`) using interpolated colors. However, only patch objects that are composed of triangular faces can be printed using interpolated shading.

Printed output is always interpolated in RGB space, not in the colormap colors. This means that if you are using indexed color and interpolated face coloring, the printed output can look different from what is displayed on screen.

PostScript files generated for interpolated shading contain the color information of the graphics object's vertices and require the printer to perform the interpolation calculations. This can take an excessive amount of time and in some cases, printers might time out before finishing the print job. One solution to this problem is to interpolate the data and generate a greater number of faces, which can then be flat shaded.

To ensure that the printed output matches what you see on the screen, print using the `-zbuffer` option. To obtain higher resolution (for example, to make text look better), use the `-r` option to increase the resolution. There is, however, a tradeoff between the resolution and the size of the created PostScript file, which can be quite large at higher resolutions. The default resolution of 150 dpi generally produces good results. You can reduce the size of the output file by making the figure smaller before printing it and setting the figure `PaperPositionMode` to `auto`, or by just setting the `PaperPosition` property to a smaller size.

Examples

Specifying the Figure to Print

You can print a noncurrent figure by specifying the figure's handle. If a figure has the title "Figure 2", its handle is 2. The syntax is:

```
print -handle
```

This example prints the figure whose handle is 2, regardless of which figure is the current figure:

print, printopt

```
print -f2
```

Note You must use the `-f` option if the figure's handle is hidden (i.e., its `HandleVisibility` property is set to `off`).

This example saves the figure with the handle `-f2` to a PostScript file named `Figure2`, which can be printed later:

```
print -f2 -dps 'Figure2.ps'
```

If the figure uses noninteger handles, use the `figure` command to get its value, and then pass it in as the first argument. For example:

```
h = figure('IntegerHandle','off')
print h -dps2
```

You can also pass a figure handle as a variable to the function form of `print`. For example:

```
h = figure; plot(1:4,5:8)
print(h)
```

This example uses the function form of `print` to enable a file name to be passed in as a variable:

```
filename = 'mydata';
print('-f3', '-dp3c', filename);
```

(Because a file name is specified, the figure will be printed to a file.)

Specifying the Model to Print

To print a noncurrent Simulink model, use the `-s` option with the title of the window. For example, this command prints the Simulink window titled `f14`:

```
print -sf14
```

If the window title includes any spaces, you must call the function form rather than the command form of `print`. For example, this command saves the Simulink window title Thruster Control:

```
print('-sThruster Control')
```

To print the current system, use:

```
print -s
```

For information about issues specific to printing Simulink windows, see the Simulink documentation.

Printing Figures at Screen Size

This example prints a surface plot with interpolated shading. Setting the current figure's (`gcf`) `PaperPositionMode` to `auto` enables you to resize the figure window and print it at the size you see on the screen. See “Printing Options” on page 2-2864 and “Printing Interpolated Shading with PostScript Drivers” on page 2-2871 for information on the `-zbuffer` and `-r200` options.

```
surf(peaks)
shading interp
set(gcf, 'PaperPositionMode', 'auto')
print -dpsc2 -zbuffer -r200
```

For additional details, see “Printing Images” in the MATLAB Graphics documentation.

Batch Processing

You can use the function form of `print` to pass variables containing file names. For example, this for loop uses file names stored in a cell array to create a series of graphs and prints each one with a different file name:

```
fnames = {'file1', 'file2', 'file3'};
for k=1:length(fnames)
```

print, printopt

```
surf(peaks)
print('-dtiff', '-r200', fnames{k})
end
```

Tiff Preview

The command

```
print -depsc -tiff -r300 picture1
```

saves the current figure at 300 dpi, in a color Encapsulated PostScript file named `picture1.eps`. The `-tiff` option creates a 72 dpi TIFF preview, which many word processor applications can display on screen after you import the EPS file. This enables you to view the picture on screen within your word processor and print the document to a PostScript printer using a resolution of 300 dpi.

See Also

`figure`, `hgsave`, `imwrite`, `orient`, `printdlg`, `printopt`, `saveas`

Purpose Print dialog box

Syntax

```
printdlg  
printdlg(fig)  
printdlg('-crossplatform',fig)  
printdlg('-setup',fig)
```

Description

printdlg prints the current figure.

printdlg(fig) creates a modal dialog box from which you can print the figure window identified by the handle fig. Note that uimenu do not print.

printdlg('-crossplatform',fig) displays the standard cross-platform MATLAB printing dialog rather than the built-in printing dialog box for Microsoft Windows computers. Insert this option before the fig argument.

printdlg('-setup',fig) forces the printing dialog to appear in a setup mode. Here one can set the default printing options without actually printing.

Note A modal dialog box prevents the user from interacting with other windows before responding. For more information, see `WindowState` in the MATLAB Figure Properties.

See Also pagesetupdlg, printpreview

Purpose Preview figure to print

Contents

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“See Also” on page 2-2884

GUI Alternative

Use **File > Print Preview** on the figure window menu to access the Print Preview dialog box, described below. For details, see “Using Print Preview” in the MATLAB Graphics documentation.

Syntax

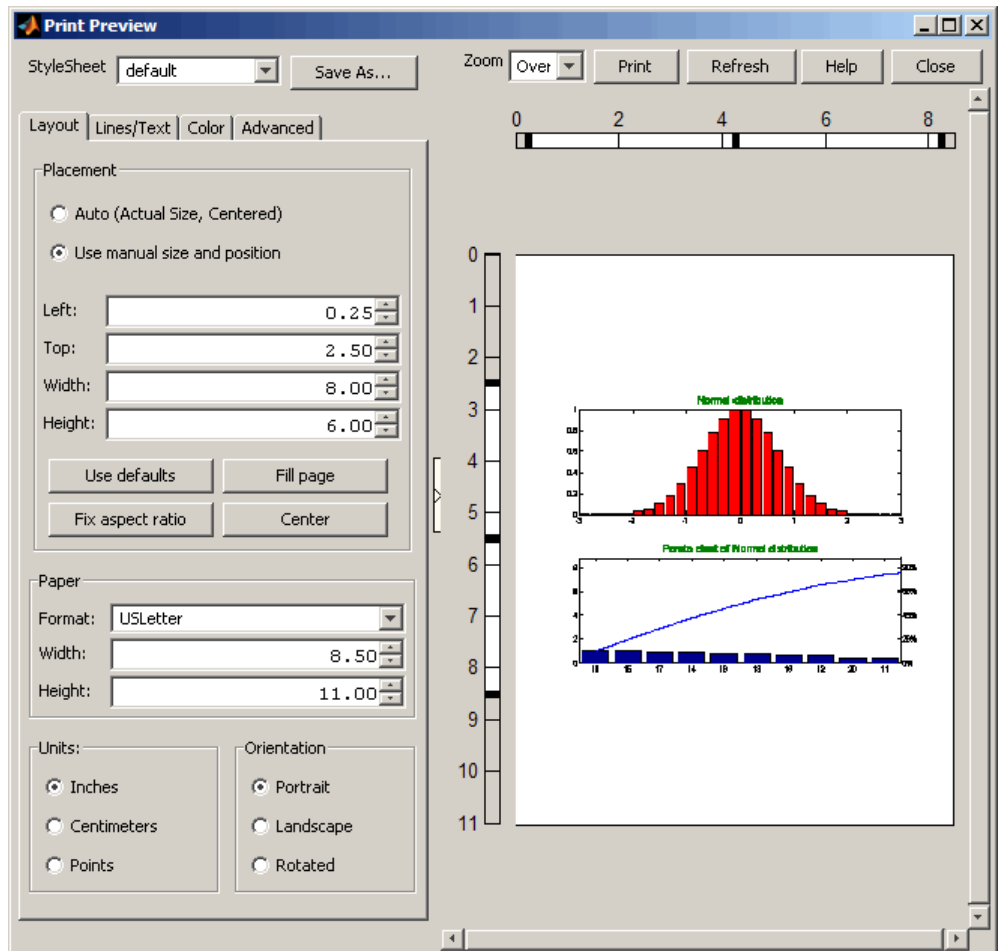
```
printpreview  
printpreview(f)
```

Description

`printpreview` displays a dialog box showing the figure in the currently active figure window as it will print. A scaled version of the figure displays in the right-hand pane of the GUI.

`printpreview(f)` displays a dialog box showing the figure having the handle `f` as it will print.

Use the Print Preview dialog box, shown below, to control the layout and appearance of figures before sending them to a printer or print file. Controls are grouped into four tabbed panes: **Layout**, **Lines/Text**, **Color**, and **Advanced**.



Right Pane Controls

You can position and scale plots on the printed page using the rulers in the right-hand pane of the Print Preview dialog. Use the outer ruler handlebars to change margins. Moving them changes plot proportions. Use the center ruler handlebars to change the position of the plot on the page. Plot proportions do not change, but you can move portions of

the plot off the paper. The buttons on that pane let you refresh the plot, close the dialog (preserving all current settings), print the page immediately, or obtain context-sensitive help. Use the **Zoom** box and scroll bars to view and position page elements more precisely.

The Layout Tab

Use the **Layout** tab, shown above, to control the paper format and placement of the plot on printed pages. The following table summarizes the **Layout** options:

Group	Option	Description
Placement	Auto	Let MATLAB decide placement of plot on page
	Use manual...	Specify position parameters for plot on page
	Top, Left, Width, Height	Standard position parameters in current units
	Use defaults	Revert to default position
	Fill page	Expand figure to fill printable area (see note below)
	Fix aspect ratio	Correct height/width ratio
	Center	Center plot on printed page
Paper	Format	U.S. and ISO® sheet size selector
	Width, Height	Sheet size in current units
Units	Inches	Use inches as units for dimensions and positions
	Centimeters	Use centimeters as units for dimensions and positions
	Points	Use points as units for dimensions and positions
Orientation	Portrait	Upright paper orientation

Group	Option	Description
	Landscape	Sideways paper orientation
	Rotated	Currently the same as Landscape

Note Selecting the **Fill page** option changes the `PaperPosition` property to fill the page, allowing objects in normalized units to expand to fill the space. If an object within the figure has an absolute size, for example a table, it can overflow the page when objects with normalized units expand. To avoid having objects fall off the page, do not use **Fill page** under such circumstances.

The Lines/Text Tab

Use the **Lines/Text** tab, shown below, to control the line weights, font characteristics, and headers for printed pages. The following table summarizes the **Lines/Text** options:

Layout | **Lines/Text** | Color | Advanced

Lines

Line Width Default

Scale By %

Custom points

Min Width Default

Custom

Text

Font Name Default

Custom

Font Size Default

Scale By %

Custom points

Font Weight

Font Angle

Header

Header Text

Font...

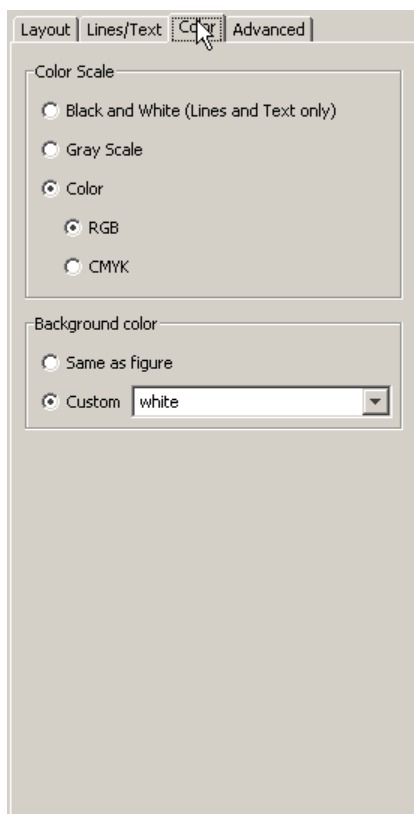
Date Style

Group	Option	Description
Lines	Line Width	Scale all lines by a percentage from 0 upward (100 being no change), print lines at a specified point size, or default line widths used on the plot
	Min Width	Smallest line width (in points) to use when printing; defaults to 0.5 point
Text	Font Name	Select a system font for all text on plot, or default to fonts currently used on the plot

Group	Option	Description
	Font Size	Scale all text by a percentage from 0 upward (100 being no change), print text at a specified point size, or default to this
	Font Weight	Select Normal ... Bold font styling for all text from drop-down menu or default to the font weights used on the plot
	Font Angle	Select Normal, Italic or Oblique font styling for all text from drop-down menu or default to the font angles used on the plot
Header	Header Text	Type the text to appear on the header at the upper left of printed pages, or leave blank for no header
	Date Style	Select a date format to have today's date appear at the upper left of printed pages, or none for no date

The Color Tab

Use the **Color** tab, shown below, to control how colors are printed for lines and backgrounds. The following table summarizes the **Color** options:

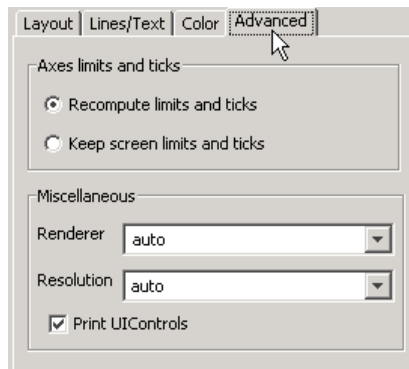


Group	Option	Description
Color Scale	Black and White	Select to print lines and text in black and white, but use color for patches and other objects
	Gray Scale	Convert colors to shades of gray on printed pages

Group	Option	Description
	Color	Print everything in color, matching colors on plot; select RGB (default) or CMYK color model for printing
Background Color	Same as figure	Print the figure's background color as it is
	Custom	Select a color name, or type a colorspec for the background; white (default) implies no background color, even on colored paper.

The Advanced Tab

Use the **Advanced** tab, shown below, to control finer details of printing, such as limits and ticks, renderer, resolution, and the printing of UIControls. The following table summarizes the **Advanced** options:



Group	Option	Description
Axes limits and ticks	Recompute limits and ticks	Redraw x - and y -axes ticks and limits based on printed plot size (default)

Group	Option	Description
Miscellaneous	Keep limits and ticks	Use the x - and y -axes ticks and limits shown on the plot when printing the previewed figure
	Renderer	Select a rendering algorithm for printing: <code>painters</code> , <code>zbuffer</code> , <code>opengl</code> , or <code>auto</code> (default)
	Resolution	Select resolution to print at in dots per inch: 150, 300, 600, or <code>auto</code> (default), or type in any other positive value
	Print UIControls	Print all visible <code>UIControls</code> in the figure (default), or uncheck to exclude them from being printed

See Also

`printdlg`, `pagesetupdlg`

For more information, see [How to Print or Export](#) in the MATLAB Graphics documentation.

Purpose

Product of array elements

Syntax

```
B = prod(A)
B = prod(A,dim)
```

Description

`B = prod(A)` returns the products along different dimensions of an array.

If `A` is a vector, `prod(A)` returns the product of the elements.

If `A` is a matrix, `prod(A)` treats the columns of `A` as vectors, returning a row vector of the products of each column.

If `A` is a multidimensional array, `prod(A)` treats the values along the first non-singleton dimension as vectors, returning an array of row vectors.

`B = prod(A,dim)` takes the products along the dimension of `A` specified by scalar `dim`.

Examples

The magic square of order 3 is

```
M = magic(3)
```

```
M =
     8     1     6
     3     5     7
     4     9     2
```

The product of the elements in each column is

```
prod(M) =
     96     45     84
```

The product of the elements in each row can be obtained by:

```
prod(M,2) =
     48
```

prod

105
72

See Also

cumprod, diff, sum

Purpose	Profile execution time for function
GUI Alternatives	As an alternative to the <code>profile</code> function, select Desktop > Profiler to open the Profiler.
Syntax	<pre>profile on profile -history profile -nohistory profile -history -historysize <i>integer</i> profile -timer <i>clock</i> profile -history -historysize <i>integer</i> -timer <i>clock</i> profile off profile resume profile clear profile viewer S = profile('status') stats = profile('info')</pre>
Description	<p>The <code>profile</code> function helps you debug and optimize M-files by tracking their execution time. For each M-function, M-subfunction, or MEX-function in the file, <code>profile</code> records information about execution time, number of calls, parent functions, child functions, code line hit count, and code line execution time. Some people use <code>profile</code> simply to see the child functions; see also <code>depfun</code> for that purpose. To open the Profiler graphical user interface, use the <code>profile viewer</code> syntax. By default, Profiler time is CPU time. The total time reported by the Profiler is not the same as the time reported using the <code>tic</code> and <code>toc</code> functions or the time you would observe using a stopwatch.</p>

Note If your system uses Intel multi-core chips, you may want to restrict the active number of CPUs to 1 for the most accurate and efficient profiling. See “Intel Multi-Core Processors — Setting for Most Accurate Profiling” for details on how to do this.

`profile on` starts the Profiler, clearing previously recorded profile statistics. Note the following:

- You can specify all, none, or a subset, of the `history`, `historysize` and `timer` options with the `profile on` syntax.
- You can specify options in any order, including before or after `on`.
- If the Profiler is currently on and you specify `profile` with one of the options, MATLAB software returns an error message and the option has no effect. For example, if you specify `profile timer real`, MATLAB returns the following error: The profiler has already been started. `TIMER` cannot be changed.
- To change options, first specify `profile off`, and then specify `profile on` or `profile resume` with new options.

`profile -history` records the exact sequence of function calls. The `profile` function records, by default, up to 1,000,000 function entry and exit events. For more than 1,000,000 events, `profile` continues to record other profile statistics, but not the sequence of calls. To change the number of function entry and exit events that the `profile` function records, use the `historysize` option. By default, the `history` option is not enabled.

`profile -nohistory` disables further recording of the history (exact sequence of function calls). Use the `-nohistory` option after having previously set the `-history` option. All other profiling statistics continue to be collected.

`profile -history -historysize integer` specifies the number of function entry and exit events to record. By default, `historysize` is set to 1,000,000.

`profile -timer clock` specifies the type of time to use. Valid values for `clock` are:

- `'cpu'` — The Profiler uses computer time (the default).
- `'real'` — The Profiler uses wall-clock time.

For example, `cpu` time for the `pause` function is typically small, but `real` time accounts for the actual time paused, and therefore would be larger.

`profile -history -historysize integer -timer clock` specifies all of the options. Any order is acceptable, as is a subset.

`profile off` stops the Profiler.

`profile resume` restarts the Profiler without clearing previously recorded statistics.

`profile clear` clears the statistics recorded by `profile`.

`profile viewer` stops the Profiler and displays the results in the Profiler window. For more information, see [Profiling for Improving Performance in the Desktop Tools and Development Environment documentation](#).

`S = profile('status')` returns a structure containing information about the current status of the Profiler. The table lists the fields in the order that they appear in the structure.

Field	Values	Default Value
ProfilerStatus	'on' or 'off'	off
DetailLevel	'mmex'	'mmex'
Timer	'cpu' or 'real'	'cpu'
HistoryTracking	'on' or 'off'	'off'
HistorySize	integer	1000000

`stats = profile('info')` displays a structure containing the results. Use this function to access the data generated by `profile`. The table lists the fields in the order that they appear in the structure.

Field	Description
FunctionTable	Structure array containing statistics about each function called

Field	Description
FunctionHistory	Array containing function call history
ClockPrecision	Precision of the <code>profile</code> function's time measurement
ClockSpeed	Estimated clock speed of the CPU
Name	Name of the profiler

The `FunctionTable` field is an array of structures, where each structure contains information about one of the functions or subfunctions called during execution. The following table lists these fields in the order that they appear in the structure.

Field	Description
CompleteName	Full path to <code>FunctionName</code> , including subfunctions
FunctionName	Function name; includes subfunctions
FileName	Full path to <code>FunctionName</code> , with file extension, excluding subfunctions
Type	M-functions, MEX-functions, and many other types of functions including M-subfunctions, nested functions, and anonymous functions
NumCalls	Number of times the function was called
TotalTime	Total time spent in the function and its child functions
TotalRecursiveTime	No longer used.
Children	<code>FunctionTable</code> indices to child functions
Parents	<code>FunctionTable</code> indices to parent functions

Field	Description
ExecutedLines	<p>Array containing line-by-line details for the function being profiled.</p> <p>Column 1: Number of the line that executed. If a line was not executed, it does not appear in this matrix.</p> <p>Column 2: Number of times the line was executed</p> <p>Column 3: Total time spent on that line. Note: The sum of Column 3 entries does not necessarily add up to the function's TotalTime.</p>
IsRecursive	BOOLEAN value: Logical 1 (true) if recursive, otherwise logical 0 (false)
PartialData	BOOLEAN value: Logical 1 (true) if function was modified during profiling, for example by being edited or cleared. In that event, data was collected only up until the point when the function was modified.

Examples

Profile and Display Results

This example profiles the MATLAB `magic` command and then displays the results in the Profiler window. The example then retrieves the profile data on which the HTML display is based and uses the `profsave` command to save the profile data in HTML form.

```
profile on
plot(magic(35))
profile viewer
p = profile('info');
profsave(p, 'profile_results')
```

Profile and Save Results

Another way to save profile data is to store it in a MAT-file. This example stores the profile data in a MAT-file, clears the profile data from memory, and then loads the profile data from the MAT-file. This example also shows a way to bring the reloaded profile data into the Profiler graphical interface as live profile data, not as a static HTML page.

```
p = profile('info');
save myprofiledata p
clear p
load myprofiledata
profview(0,p)
```

Profile and Show Results Including History

This example illustrates an effective way to view the results of profiling when the history option is enabled. The history data describes the sequence of functions entered and exited during execution. The `profile` command returns history data in the `FunctionHistory` field of the structure it returns. The history data is a 2-by-n array. The first row contains Boolean values, where 0 means entrance into a function and 1 means exit from a function. The second row identifies the function being entered or exited by its index in the `FunctionTable` field. This example reads the history data and displays it in the MATLAB Command Window.

```
profile on -history
plot(magic(4));
p = profile('info');

for n = 1:size(p.FunctionHistory,2)
    if p.FunctionHistory(1,n)==0
        str = 'entering function: ';
    else
        str = 'exiting function: ';
    end
end
```



```
disp([str p.FunctionTable(p.FunctionHistory(2,n)).FunctionName])  
end
```

See Also

`depdir`, `depfun`, `mlint`, `profsave`

Profiling for Improving Performance in the MATLAB Desktop Tools and Development Environment documentation

“Using the Parallel Profiler” in the Parallel Computing Toolbox documentation

profsave

Purpose Save profile report in HTML format

Syntax `profsave`
`profsave(profinfo)`
`profsave(profinfo,dirname)`

Description `profsave` executes the `profile('info')` function and saves the results in HTML format. `profsave` creates a separate HTML file for each function listed in the `FunctionTable` field of the structure returned by `profile`. By default, `profsave` stores the HTML files in a subdirectory of the current directory named `profile_results`.

`profsave(profinfo)` saves the profiling results, `profinfo`, in HTML format. `profinfo` is a structure of profiling information returned by the `profile('info')` function.

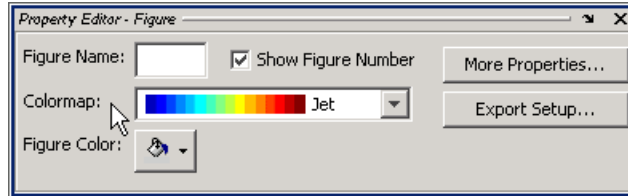
`profsave(profinfo,dirname)` saves the profiling results, `profinfo`, in HTML format. `profsave` creates a separate HTML file for each function listed in the `FunctionTable` field of `profinfo` and stores them in the directory specified by `dirname`.

Examples Run profile and save the results.

```
profile on
plot(magic(5))
profile off
profsave(profile('info'),'myprofile_results')
```

See Also `profile`
Profiling for Improving Performance in the MATLAB Desktop Tools and Development Environment documentation

Purpose Open Property Editor



Syntax
`propedit`
`propedit(handle_list)`

Description `propedit` starts the Property Editor, a graphical user interface to the properties of graphics objects. If no current figure exists, `propedit` will create one.

`propedit(handle_list)` edits the properties for the object (or objects) in `handle_list`.

Starting the Property Editor enables plot editing mode for the figure.

See Also `inspect`, `plottedit`, `propertyeditor`

propedit (COM)

Purpose	Open built-in property page for control
Syntax	<code>h.propedit</code> <code>propedit(h)</code>
Description	<p><code>h.propedit</code> requests the control to display its built-in property page. Note that some controls do not have a built-in property page. For those controls, this command fails.</p> <p><code>propedit(h)</code> is an alternate syntax for the same operation.</p>
Remarks	COM functions are available on Microsoft Windows systems only.
Examples	Create a Microsoft Calendar control and display its property page: <pre>cal = actxcontrol('mscal.calendar', [0 0 500 500]); cal.propedit</pre>
See Also	<code>inspect</code> , <code>get</code> (COM)

Purpose Display class property names

Syntax

```
properties('classname')  
properties(obj)  
p = properties(...)
```

Description `properties('classname')` displays the names of the public properties for the MATLAB class `classname`, including public properties inherited from superclasses.

`properties(obj)` displays the names of the public properties for the class of the object `obj`, where `obj` is an instance of a MATLAB class. `obj` can be either a scalar object or an array of objects. When `obj` is scalar, `properties` also returns dynamic properties.

See “Dynamic Properties — Adding Properties to an Instance” for information on using dynamic properties.

`p = properties(...)` returns the property names in a cell array of strings. Note that you can use the Workspace browser to browse current property values. See “MATLAB Workspace” for more information on using the Workspace browser.

A property is public when its `GetAccess` attributes are set to `public` and its `Hidden` attribute is set to `false` (default values for these attributes). See “Property Attributes” for a complete list of attributes.

You can also use the `fieldnames` function to list property names of MATLAB classes.

Note `properties` is also a keyword used in MATLAB class definition. See `classdef` for more information on class definition keywords.

See “Properties — Storing Class Data” for more information on class properties.

properties

Examples

Retrieve the names of the public properties of class `memmapfile` and store the result in a cell array of strings:

```
p = properties('memmapfile');
p
ans =

    'writable'
    'offset'
    'format'
    'repeat'
    'filename'
```

Construct an instance of the `MException` class and get its properties names:

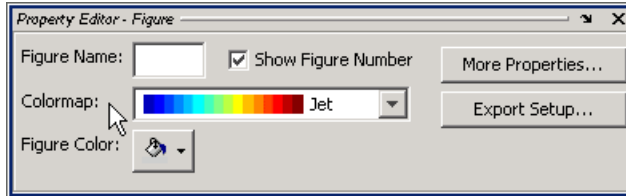
```
me = MException('Msg:ID', 'MsgText');
properties(me)
Properties for class MException:

    identifier
    message
    cause
    stack
```



See Also

`events`, `fieldnames`, `methods`

Purpose Show or hide property editor



GUI Alternatives

Click the larger **Plotting Tools** icon  on the figure toolbar to collectively enable plotting tools, and the smaller icon  to collectively disable them. Open or close the **Property Editor** tool from the figure's **View** menu. For details, see “The Property Editor” in the MATLAB Graphics documentation.

Syntax

```
propertyeditor('on')
propertyeditor('off')
propertyeditor('toggle')
propertyeditor
propertyeditor(figure_handle,...)
```

Description

`propertyeditor('on')` displays the Property Editor on the current figure.

`propertyeditor('off')` hides the Property Editor on the current figure.

`propertyeditor('toggle')` or `propertyeditor` toggles the visibility of the property editor on the current figure.

`propertyeditor(figure_handle,...)` displays or hides the Property Editor on the figure specified by *figure_handle*.

See Also

`plottools`, `plotbrowser`, `figurepalette`, `inspect`

Purpose Psi (polygamma) function

Syntax
Y = psi(X)
Y = psi(k,X)
Y = psi(k0:k1,X)

Description Y = psi(X) evaluates the Ψ function for each element of array X. X must be real and nonnegative. The Ψ function, also known as the digamma function, is the logarithmic derivative of the gamma function

$$\begin{aligned}\psi(x) &= \text{digamma}(x) \\ &= \frac{d(\log(\Gamma(x)))}{dx} \\ &= \frac{d(\Gamma(x))/dx}{\Gamma(x)}\end{aligned}$$

Y = psi(k,X) evaluates the kth derivative of Ψ at the elements of X. psi(0,X) is the digamma function, psi(1,X) is the trigamma function, psi(2,X) is the tetragamma function, etc.

Y = psi(k0:k1,X) evaluates derivatives of order k0 through k1 at X. Y(k,j) is the (k-1+k0)th derivative of Ψ , evaluated at X(j).

Examples

Example 1

Use the psi function to calculate Euler's constant, γ .

```
format long
-psi(1)
ans =
    0.57721566490153

-psi(0,1)
ans =
    0.57721566490153
```


Example 2

The trigamma function of 2, `psi(1,2)`, is the same as $(\pi^2/6) - 1$.

```
format long
psi(1,2)
ans =
    0.64493406684823

pi^2/6 - 1
ans =
    0.64493406684823
```

Example 3

This code produces the first page of Table 6.1 in Abramowitz and Stegun [1].

```
x = (1:.005:1.250)';
[x gamma(x) gammaIn(x) psi(0:1,x)' x-1]
```

Example 4

This code produces a portion of Table 6.2 in [1].

```
psi(2:3,1:.01:2)'
```

See Also

`gamma`, `gammaInc`, `gammaIn`

References

[1] Abramowitz, M. and I. A. Stegun, *Handbook of Mathematical Functions*, Dover Publications, 1965, Sections 6.3 and 6.4.

publish

Purpose	Publish M-file containing cells, saving output to file of specified type
GUI Alternatives	As an alternative to the <code>publish</code> function, use the File > Publish <i>filename</i> menu or File > Publish Configuration for <i>filename</i> items in the Editor.
Syntax	<pre>publish('script') publish('script','format') publish('script',options) publish('function',options)</pre>
Description	<p><code>publish('script')</code> runs the M-file script named <code>script</code> in the base workspace one cell at a time, and saves the code, comments, and results to an HTML output file. The output file is named <code>script.html</code> and is stored, along with other supporting output files, in an <code>html</code> subdirectory in <code>script</code>'s directory.</p> <p><code>publish('script','format')</code> runs the M-file script named <code>script</code>, one cell at a time in the base workspace, and publishes the code, comments, and results to an output file using the specified <code>format</code>. Allowable values for <code>format</code> are <code>html</code> (the default), <code>xml</code>, <code>latex</code> for LaTeX, <code>doc</code> for Microsoft Word documents, and <code>ppt</code> for Microsoft PowerPoint documents. The output file is named <code>script.format</code> and is stored, along with other supporting output files, in an <code>html</code> subdirectory in <code>script</code>'s directory. The <code>doc</code> format requires the Word application, and the <code>ppt</code> format requires PowerPoint application. When publishing to HTML, the M-file code is included at the end of published HTML file as comments, even when the <code>showCode</code> option is set to <code>false</code>. Because it is included as comments, it does not display in a Web browser. Use the <code>grabcode</code> function to extract the code from the HTML file.</p> <p><code>publish('script',options)</code> publishes using the structure <code>options</code>, which can contain any of the fields and corresponding value for each field as shown in Options for <code>publish</code> on page 2-2903. Create and save structures for the options you use regularly. For details, see “Specify Values for the Publish Settings Property Table” in the online documentation for MATLAB software.</p>

`publish('function', options)` publishes an M-file function using the structure `options`. The `codeToEvaluate` field must specify the function input and the file to publish if you set the `evalCode` field to `true`. If you set the `evalCode` field to `false`, it essentially saves the M-file to another format, such as HTML, which allows display with formatting in a Web browser.

Options for publish

Field	Allowable Values
<code>format</code>	'doc', 'html' (default), 'latex', 'ppt', 'xml'
<code>stylesheet</code>	' ' (default), XSL file name (used only when <code>format</code> is <code>html</code> , <code>latex</code> , or <code>xml</code>)
<code>outputDir</code>	' ' (default, a subfolder named <code>html</code>), full path
<code>imageFormat</code>	'png' (default unless <code>format</code> is <code>latex</code>), 'eps2' (default when <code>format</code> is <code>latex</code>), any format supported by <code>print</code> when <code>figureSnapMethod</code> is <code>print</code> , any format supported by <code>imwrite</code> functions when <code>figureSnapMethod</code> is <code>getframe</code> , <code>entireFigureWindow</code> , or <code>entireGUIWindow</code> .
<code>figureSnapMethod</code>	'entireGUIWindow' (default), 'entireFigureWindow', 'print', 'getframe' See the FigureSnap Method Options table for details on the effects of these settings.
<code>useNewFigure</code>	<code>true</code> (default), <code>false</code>
<code>maxHeight</code>	[] (default), any positive integer specifying the maximum height, in pixels, for an image that <code>publish.m</code> generates
<code>maxWidth</code>	[] (default), any positive integer specifying the maximum width, in pixels, for an image that <code>publish.m</code> generates
<code>showCode</code>	<code>true</code> (default), <code>false</code>
<code>evalCode</code>	<code>true</code> (default), <code>false</code>

Options for publish (Continued)

Field	Allowable Values
catchError	true (default, continues publishing and includes the error in the published file), false (displays the error and publishing ends)
codeToEvaluate	M-file you are publishing (default), any valid code
createThumbnail	true (default), false
maxOutputLines	Inf (default), nonnegative integer specifying the maximum number of output lines to publish per M-file cell before truncating the output

FigureSnapMethod Options

To Get Figure Captures with These Appearance Details		Use this FigureSnapMethod Option
Window Decorations	Plot Backgrounds	
Included for dialog boxes; Excluded for figures	Set to white for figures; match screen for dialog boxes.	entireGUIWindow
Excluded for dialog boxes and figures	All set to white	print
Excluded for dialog boxes and figures	All match screen	getframe
Included for dialog boxes and figures	All match screen	entireFigureWindow

Remarks

Be aware that `publish` opens a Figure window and sets the background color to white when publishing begins. It closes this Figure window when publishing ends. If your M-code explicitly creates one or more additional Figure windows, `publish` uses the default background color (gray) unless you specify otherwise. For example, if you publish the following code (using default option settings), the first and second plots publish with a white background and the third plot publishes with a gray background.

```
%% Plot 1
plot(1:10)

%% Plot 2
plot(5:5:25)

%% Plot 3
f = figure;
plot(1:10)
```

Examples

To use the M-Files referenced in the following examples, open the files using the following commands and save each file to a directory to which you have write access. In each example, it is assumed that the directory to which you save the files is `I:/my_matlab_files/my_mfiles`, so you may need to adjust accordingly.

```
edit(fullfile(matlabroot, 'help', 'techdoc', 'matlab_env', 'examples', '
edit(fullfile(matlabroot, 'help', 'techdoc', 'matlab_env', 'examples', ')
```

Publish to HTML Format

To publish the M-file script `I:/mymfiles/sine_wave.m` to HTML, run the following command:

```
publish('I:/my_matlab_files/my_mfiles/sine_wave.m', 'html')
web('I:/my_matlab_files/my_mfiles/html/sine_wave.html')
```

MATLAB runs the file and saves the code, comments, and results to `I:/mymfiles/html/sine_wave.html`. Open that file in the Web browser to view the published output.

Publish to Microsoft Word Format

This example defines the structure `options_doc_nocode`, publishes `sine_wave.m` using the defined options, and displays the resulting document. The resulting report is a Microsoft Word document, `I:/my_doc_files/sine_wave.doc` and includes results, but not the MATLAB code.

```
options_doc_nocode.format='doc'  
options_doc_nocode.outputDir='I:/my_doc_files'  
options_doc_nocode.showCode=false  
publish('I:/my_matlab_files/my_mfiles/sine_wave.m',options_doc_nocode)  
winopen('I:/my_doc_files/sine_wave.doc')
```

Publish Function M-File and Evaluate Code

This examples defines the structure `function_options`, which specifies the value of the input argument to the function, publishes the function `I:/my_matlab_files/my_mfiles/collatz.m`, and displays the resulting HTML document, `I:/my_matlab_files/my_mfiles/html/collatz.html`:

```
function_options.format='html';  
function_options.evalCode=true;  
function_options.codeToEvaluate=[ ...  
    'n=3' char(10) ...  
    'collatz(3)' char(10) ...  
]  
function_options.showCode=true;  
publish('I:/my_matlab_files/my_mfiles/collatz.m',function_options);  
web('I:/my_matlab_files/my_mfiles/html/collatz.html')
```

Publish M-File Script and Capture Window Decorations

This example defines the structure `function_options`, publishes the function `I:/my_matlab_files/my_mfiles/sine_wave.m`, and displays the resulting HTML document, `I:/my_matlab_files/my_mfiles/html/sine_wave.html`:

```
function_options.format='html';  
function_options.figureSnapMethod='entireGUIWindow';  
publish('I:/my_matlab_files/my_mfiles/sine_wave.m',function_options  
web('I:/my_matlab_files/my_mfiles/html/sine_wave.html'))
```

See Also

grabcode, notebook, web, winopen

MATLAB Desktop Tools and Development Environment documentation, specifically:

- “Defining Cells”
- “Publishing M-Files”

PutCharArray

Purpose Store character array in Automation server

Syntax **MATLAB Client**
h.PutCharArray('varname', 'workspace', 'string')
PutCharArray(h, 'varname', 'workspace', 'string')
invoke(h, 'PutCharArray', 'varname', 'workspace', 'string')

Method Signature
PutCharArray([in] BSTR varname, [in] BSTR workspace,
[in] BSTR string)

Microsoft Visual Basic Client
PutCharArray(varname As String, workspace As String,
string As String)

Description PutCharArray stores the character array in string in the specified workspace of the server attached to handle h, assigning to it the variable varname. The workspace argument can be either base or global.

Remarks The character array specified in the string argument can have any dimensions. However, PutCharArray changes the dimensions to a 1-by-n column-wise representation, where n is the number of characters in the array. Executing the following commands in MATLAB illustrates this behavior:

```
h = actxserver('matlab.application');  
chArr = ['abc'; 'def'; 'ghk']  
chArr =  
abc  
def  
ghk  
  
h.PutCharArray('Foo', 'base', chArr)  
tstArr = h.GetCharArray('Foo', 'base')  
tstArr =  
adgbehcfk
```


Server function names, like `PutCharArray`, are case sensitive when using the dot notation syntax shown in the Syntax section.

There is no difference in the operation of the three syntaxes shown above for the MATLAB client.

Examples

Store string `str` in the base workspace of the server using `PutCharArray`.

MATLAB Client

```
h = actxserver('matlab.application');
h.PutCharArray('str', 'base', ...
    'He jests at scars that never felt a wound.')

S = h.GetCharArray('str', 'base')
S =
    He jests at scars that never felt a wound.
```

Visual Basic .NET Client

This example uses the Visual Basic `MsgBox` command to control flow between MATLAB and the Visual Basic Client.

```
Dim Matlab As Object
Try
    Matlab = GetObject(, "matlab.application")
Catch e As Exception
    Matlab = CreateObject("matlab.application")
End Try
MsgBox("MATLAB window created; now open it...")
```

Open the MATLAB window, then click **Ok**.

```
Matlab.PutCharArray("str", "base", _
    "He jests at scars that never felt a wound.")
MsgBox("In MATLAB, type" & vbCrLf _
    & "str")
```

PutCharArray

In the MATLAB window type `str`; MATLAB displays:

```
str =  
He jests at scars that never felt a wound.
```

Click **Ok**.

```
MsgBox("closing MATLAB window...")
```

Click **Ok** to close and terminate MATLAB.

```
Matlab.Quit()
```

See Also

`GetCharArray`, `PutWorkspaceData`, `GetWorkspaceData`, `Execute`

Purpose

Store matrix in Automation server

Syntax**MATLAB Client**

```
h.PutFullMatrix('varname', 'workspace', xreal, ximag)
PutFullMatrix(h, 'varname', 'workspace', xreal, ximag)
invoke(h, 'PutFullMatrix', 'varname', 'workspace',
xreal, ximag)
```

Method Signature

```
PutFullMatrix([in] BSTR varname, [in] BSTR workspace,
[in] SAFEARRAY(double) xreal, [in] SAFEARRAY(double) ximag)
```

Microsoft Visual Basic Client

```
PutFullMatrix([in] varname As String, [in] workspace As String,
[in] xreal As Double, [in] ximag As Double)
```

Description

PutFullMatrix stores a matrix in the specified workspace of the server attached to handle `h`, assigning to it the variable `varname`. Enter the real and imaginary parts of the matrix in the `xreal` and `ximag` input arguments. The workspace argument can be either `base` or `global`.

Remarks

The matrix specified in the `xreal` and `ximag` arguments cannot be scalar, an empty array, or have more than two dimensions.

Server function names, like `PutFullMatrix`, are case sensitive when using the first syntax shown.

There is no difference in the operation of the three syntaxes shown above for the MATLAB client.

For VBScript clients, use the `GetWorkspaceData` and `PutWorkspaceData` functions to pass numeric data to and from the MATLAB workspace. These functions use the variant data type instead of `safearray` which is not supported by VBScript.

PutFullMatrix

Examples

Writing to the Base Workspace Example

Assign a 5-by-5 real matrix to the variable M in the base workspace of the server, and then read it back with GetFullMatrix. The real and imaginary parts are passed in through separate arrays of doubles.

MATLAB Client

```
h = actxserver('matlab.application');
h.PutFullMatrix('M', 'base', rand(5), zeros(5))
% One output returns real, use two for real and imag
xreal = h.GetFullMatrix('M', 'base', zeros(5), zeros(5))
xreal =
    0.9501    0.7621    0.6154    0.4057    0.0579
    0.2311    0.4565    0.7919    0.9355    0.3529
    0.6068    0.0185    0.9218    0.9169    0.8132
    0.4860    0.8214    0.7382    0.4103    0.0099
    0.8913    0.4447    0.1763    0.8936    0.1389
```

Visual Basic .NET Client

```
Dim MatLab As Object
Dim XReal(4, 4) As Double
Dim XImag(4, 4) As Double
Dim ZReal(4, 4) As Double
Dim ZImag(4, 4) As Double
Dim i, j As Integer

For i = 0 To 4
    For j = 0 To 4
        XReal(i, j) = Rnd() * 6
        XImag(i, j) = 0
    Next j
Next i

Matlab = CreateObject("matlab.application")
MatLab.PutFullMatrix("M", "base", XReal, XImag)
MatLab.GetFullMatrix("M", "base", ZReal, ZImag)
```

Writing to the Global Workspace Example

Write a matrix to the global workspace of the server and then examine the server's global workspace from the client.

MATLAB Client

```
h = actxserver('matlab.application');
h.PutFullMatrix('X', 'global', [1 3 5; 2 4 6], ...
                [1 1 1; 1 1 1])
h.invoke('Execute', 'whos global')
ans =
  Name      Size      Bytes  Class
  X         2x3         96  double array (global complex)
Grand total is 6 elements using 96 bytes
```

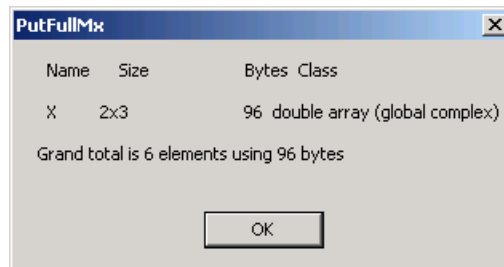
Visual Basic .NET Client

```
Dim MatLab As Object
Dim XReal(1, 2) As Double
Dim XImag(1, 2) As Double
Dim result As String
Dim i, j As Integer

For i = 0 To 1
  For j = 0 To 2
    XReal(i, j) = (j * 2 + 1) + i
    XImag(i, j) = 1
  Next j
Next i

Matlab = CreateObject("matlab.application")
MatLab.PutFullMatrix("X", "global", XReal, XImag)
result = Matlab.Execute("whos global")
MsgBox(result)
```

PutFullMatrix



See Also

GetFullMatrix, PutWorkspaceData, GetWorkspaceDataExecute

Purpose Store data in Automation server workspace

Syntax

MATLAB Client

```
h.PutWorkspaceData('varname', 'workspace', data)
PutWorkspaceData(h, 'varname', 'workspace', data)
invoke(h, 'PutWorkspaceData', 'varname', 'workspace', data)
```

Method Signature

```
PutWorkspaceData([in] BSTR varname, [in] BSTR workspace,
[in] VARIANT data)
```

Microsoft Visual Basic Client

```
PutWorkspaceData(varname As String, workspace As String,
data As Object)
```

Description

PutWorkspaceData stores data in the specified workspace of the server attached to handle h, assigning to it the variable varname. The workspace argument can be either base or global.

Note PutWorkspaceData works on all MATLAB types except sparse arrays, structure arrays, and function handles. Use the Execute method for these data types.

Passing Character Arrays

MATLAB enables you to define 2-D character arrays such as the following:

```
chArr = ['abc'; 'def'; 'ghk']
chArr =
abc
def
ghk

size(chArr)
ans =
     3     3
```

PutWorkspaceData

However, PutWorkspaceData does not preserve the dimensions of character arrays when passing them to a COM server. 2-D arrays are converted to 1-by-n arrays of characters, where n equals the number of characters in the original array plus one newline character for each row in the original array. This means that chArr above is converted to a 1-by-12 array, but the newline characters make it display with three rows in the MATLAB command window. For example:

```
h = actxserver('matlab.application');
h.PutWorkspaceData('Foo', 'base', chArr);
tstArr = h.GetWorkspaceData('Foo', 'base')
tstArr =
abc
def
ghk

size(tstArr)
ans =
     1     12
```

Remarks

You can use PutWorkspaceData in place of PutFullMatrix and PutCharArray to pass numeric and character array data respectively to the server.

Server function names, like PutWorkspaceData, are case sensitive when using the first syntax shown.

There is no difference in the operation of the three syntaxes shown above for the MATLAB client.

The GetWorkspaceData and PutWorkspaceData functions pass numeric data as a variant data type. These functions are especially useful for VBScript clients as VBScript does not support the safearray data type used by GetFullMatrix and PutFullMatrix.

Examples

Create an array in the client and assign it to variable A in the base workspace of the server:

MATLAB Client

```
h = actxserver('matlab.application');  
for i = 0:6  
    data(i+1) = i * 15;  
end  
h.PutWorkspaceData('A', 'base', data)
```

Visual Basic .NET Client

This example uses the Visual Basic MsgBox command to control flow between MATLAB and the Visual Basic Client.

```
Dim Matlab As Object  
Dim data(6) As Double  
Dim i As Integer  
MatLab = CreateObject("matlab.application")  
For i = 0 To 6  
    data(i) = i * 15  
Next i  
MatLab.PutWorkspaceData("A", "base", data)  
MsgBox("In MATLAB, type" & vbCrLf & "A")
```

Open the MATLAB window and type A. MATLAB displays:

```
A =  
    0    15    30    45    60    75    90
```

Click **Ok** to close and terminate MATLAB.

See Also

GetWorkspaceData, PutFullMatrix, GetFullMatrix, PutCharArray, GetCharArrayExecute

See “Introduction” for more examples.

pwd

Purpose

Identify current directory

Graphical Interface

As an alternative to the `pwd` function, you can use the current directory field on the desktop toolbar or the Current Directory browser.

Syntax

```
pwd  
s = pwd
```

Description

`pwd` displays the current working directory.

`s = pwd` returns the current directory to the variable `s`.

On Microsoft Windows platforms, to go directly to the current working directory, use

```
winopen(pwd)
```

See Also

`cd`, `dir`, `fileparts`, `mfilename`, `path`, `what`, `winopen`

“Managing Files and Working with the Current Directory”

Purpose

Quasi-minimal residual method

Syntax

```
x = qmr(A,b)
qmr(A,b,tol)
qmr(A,b,tol,maxit)
qmr(A,b,tol,maxit,M)
qmr(A,b,tol,maxit,M1,M2)
qmr(A,b,tol,maxit,M1,M2,x0)
[x,flag] = qmr(A,b,...)
[x,flag,relres] = qmr(A,b,...)
[x,flag,relres,iter] = qmr(A,b,...)
[x,flag,relres,iter,resvec] = qmr(A,b,...)
```

Description

`x = qmr(A,b)` attempts to solve the system of linear equations $A*x=b$ for x . The n -by- n coefficient matrix A must be square and should be large and sparse. The column vector b must have length n . A can be a function handle `afun` such that `afun(x, 'notransp')` returns $A*x$ and `afun(x, 'transp')` returns $A'*x$. See “Function Handles” in the MATLAB Programming documentation for more information.

“Parametrizing Functions”, in the MATLAB Mathematics documentation, explains how to provide additional parameters to the function `afun`, as well as the preconditioner function `mfun` described below, if necessary.

If `qmr` converges, a message to that effect is displayed. If `qmr` fails to converge after the maximum number of iterations or halts for any reason, a warning message is printed displaying the relative residual $\text{norm}(b-A*x)/\text{norm}(b)$ and the iteration number at which the method stopped or failed.

`qmr(A,b,tol)` specifies the tolerance of the method. If `tol` is `[]`, then `qmr` uses the default, $1e-6$.

`qmr(A,b,tol,maxit)` specifies the maximum number of iterations. If `maxit` is `[]`, then `qmr` uses the default, $\min(n,20)$.

`qmr(A,b,tol,maxit,M)` and `qmr(A,b,tol,maxit,M1,M2)` use preconditioners M or $M = M1*M2$ and effectively solve the system

$\text{inv}(M) * A * x = \text{inv}(M) * b$ for x . If M is $[]$ then `qmr` applies no preconditioner. M can be a function handle `mfun` such that `mfun(x, 'notransp')` returns $M \backslash x$ and `mfun(x, 'transp')` returns $M' \backslash x$.

`qmr(A,b,tol,maxit,M1,M2,x0)` specifies the initial guess. If x_0 is $[]$, then `qmr` uses the default, an all zero vector.

`[x,flag] = qmr(A,b,...)` also returns a convergence flag.

Flag	Convergence
0	<code>qmr</code> converged to the desired tolerance <code>tol</code> within <code>maxit</code> iterations.
1	<code>qmr</code> iterated <code>maxit</code> times but did not converge.
2	Preconditioner M was ill-conditioned.
3	The method stagnated. (Two consecutive iterates were the same.)
4	One of the scalar quantities calculated during <code>qmr</code> became too small or too large to continue computing.

Whenever `flag` is not 0, the solution x returned is that with minimal norm residual computed over all the iterations. No messages are displayed if the `flag` output is specified.

`[x,flag,relres] = qmr(A,b,...)` also returns the relative residual $\text{norm}(b-A*x)/\text{norm}(b)$. If `flag` is 0, `relres` \leq `tol`.

`[x,flag,relres,iter] = qmr(A,b,...)` also returns the iteration number at which x was computed, where $0 \leq \text{iter} \leq \text{maxit}$.

`[x,flag,relres,iter,resvec] = qmr(A,b,...)` also returns a vector of the residual norms at each iteration, including $\text{norm}(b-A*x_0)$.

Examples

Example 1

```
n = 100;  
on = ones(n,1);
```

```

A = spdiags([-2*on 4*on -on],-1:1,n,n);
b = sum(A,2);
tol = 1e-8; maxit = 15;
M1 = spdiags([on/(-2) on],-1:0,n,n);
M2 = spdiags([4*on -on],0:1,n,n);
x = qmr(A,b,tol,maxit,M1,M2);

```

displays the message

```

qmr converged at iteration 9 to a solution...
with relative residual
5.6e-009

```

Example 2

This example replaces the matrix A in Example 1 with a handle to a matrix-vector product function `afun`. The example is contained in an M-file `run_qmr` that

- Calls `qmr` with the function handle `@afun` as its first argument.
- Contains `afun` as a nested function, so that all variables in `run_qmr` are available to `afun`.

The following shows the code for `run_qmr`:

```

function x1 = run_qmr
n = 100;
on = ones(n,1);
A = spdiags([-2*on 4*on -on],-1:1,n,n);
b = sum(A,2);
tol = 1e-8;
maxit = 15;
M1 = spdiags([on/(-2) on],-1:0,n,n);
M2 = spdiags([4*on -on],0:1,n,n);
x1 = qmr(@afun,b,tol,maxit,M1,M2);

function y = afun(x,transp_flag)
    if strcmp(transp_flag,'transp')
        % y = A'*x

```

```
        y = 4 * x;  
        y(1:n-1) = y(1:n-1) - 2 * x(2:n);  
        y(2:n) = y(2:n) - x(1:n-1);  
    elseif strcmp(transp_flag,'notransp') % y = A*x  
        y = 4 * x;  
        y(2:n) = y(2:n) - 2 * x(1:n-1);  
        y(1:n-1) = y(1:n-1) - x(2:n);  
    end  
end  
end  
end
```

When you enter

```
x1=run_qmr;
```

MATLAB software displays the message

```
qmr converged at iteration 9 to a solution with relative residual  
5.6e-009
```

Example 3

```
load west0479;  
A = west0479;  
b = sum(A,2);  
[x,flag] = qmr(A,b)
```

flag is 1 because qmr does not converge to the default tolerance $1e-6$ within the default 20 iterations.

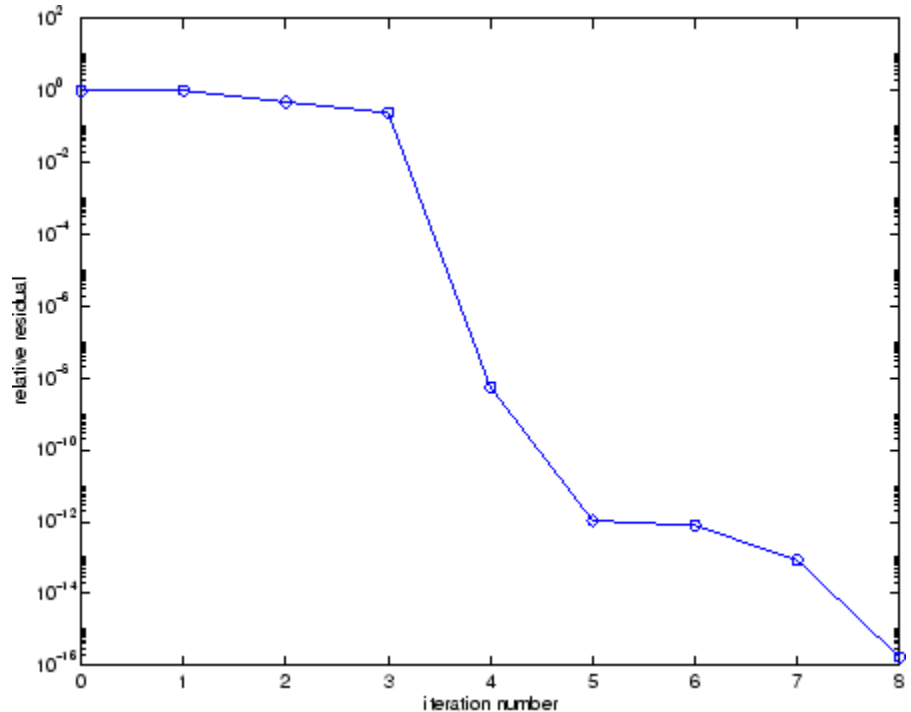
```
[L1,U1] = luinc(A,1e-5);  
[x1,flag1] = qmr(A,b,1e-6,20,L1,U1)
```

flag1 is 2 because the upper triangular U1 has a zero on its diagonal, and qmr fails in the first iteration when it tries to solve a system such as $U1*y = r$ for y using backslash.

```
[L2,U2] = luinc(A,1e-6);  
[x2,flag2,relres2,iter2,resvec2] = qmr(A,b,1e-15,10,L2,U2)
```

flag2 is 0 because qmr converges to the tolerance of $1.6571e-016$ (the value of relres2) at the eighth iteration (the value of iter2) when preconditioned by the incomplete LU factorization with a drop tolerance of $1e-6$. resvec2(1) = norm(b) and resvec2(9) = norm(b-A*x2). You can follow the progress of qmr by plotting the relative residuals at each iteration starting from the initial estimate (iterate number 0).

```
semilogy(0:iter2,resvec2/norm(b),'-o')
xlabel('iteration number')
ylabel('relative residual')
```



See Also

bicg, bicgstab, cgs, gmres, lsqr, luinc, minres, pcg, symmlq,
function_handle (@), mldivide (\)

References

- [1] Barrett, R., M. Berry, T. F. Chan, et al., *Templates for the Solution of Linear Systems: Building Blocks for Iterative Methods*, SIAM, Philadelphia, 1994.
- [2] Freund, Roland W. and Noël M. Nachtigal, "QMR: A quasi-minimal residual method for non-Hermitian linear systems," *SIAM Journal: Numer. Math.* 60, 1991, pp. 315-339.

Purpose

Orthogonal-triangular decomposition

Syntax

$[Q,R] = \text{qr}(A)$ (*full and sparse matrices*)
 $[Q,R] = \text{qr}(A,0)$ (*full and sparse matrices*)
 $[Q,R,E] = \text{qr}(A)$ (*full matrices*)
 $[Q,R,E] = \text{qr}(A,0)$ (*full matrices*)
 $X = \text{qr}(A)$ (*full matrices*)
 $R = \text{qr}(A)$ (*sparse matrices*)
 $[C,R] = \text{qr}(A,B)$ (*sparse matrices*)
 $R = \text{qr}(A,0)$ (*sparse matrices*)
 $[C,R] = \text{qr}(A,B,0)$ (*sparse matrices*)

Description

The `qr` function performs the orthogonal-triangular decomposition of a matrix. This factorization is useful for both square and rectangular matrices. It expresses the matrix as the product of a real complex unitary matrix and an upper triangular matrix.

$[Q,R] = \text{qr}(A)$ produces an upper triangular matrix R of the same dimension as A and a unitary matrix Q so that $A = Q*R$. For sparse matrices, Q is often nearly full. If $[m \ n] = \text{size}(A)$, then Q is m -by- m and R is m -by- n .

$[Q,R] = \text{qr}(A,0)$ produces an “economy-size” decomposition. If $[m \ n] = \text{size}(A)$, and $m > n$, then `qr` computes only the first n columns of Q and R is n -by- n . If $m \leq n$, it is the same as $[Q,R] = \text{qr}(A)$.

$[Q,R,E] = \text{qr}(A)$ for full matrix A , produces a permutation matrix E , an upper triangular matrix R with decreasing diagonal elements, and a unitary matrix Q so that $A*E = Q*R$. The column permutation E is chosen so that $\text{abs}(\text{diag}(R))$ is decreasing.

$[Q,R,E] = \text{qr}(A,0)$ for full matrix A , produces an “economy-size” decomposition in which E is a permutation vector, so that $A(:,E) = Q*R$. The column permutation E is chosen so that $\text{abs}(\text{diag}(R))$ is decreasing.

$X = \text{qr}(A)$ for full matrix A , returns the output of the LAPACK subroutine `DGEQRF` or `ZGEQRF`. `triu(qr(A))` is R .

$R = \text{qr}(A)$ for sparse matrix A , produces only an upper triangular matrix, R . The matrix R provides a Cholesky factorization for the matrix associated with the normal equations,

$$R' * R = A' * A$$

This approach avoids the loss of numerical information inherent in the computation of $A' * A$. It may be preferred to $[Q, R] = \text{qr}(A)$ since Q is always nearly full.

$[C, R] = \text{qr}(A, B)$ for sparse matrix A , applies the orthogonal transformations to B , producing $C = Q' * B$ without computing Q . B and A must have the same number of rows.

$R = \text{qr}(A, 0)$ and $[C, R] = \text{qr}(A, B, 0)$ for sparse matrix A , produce “economy-size” results.

For sparse matrices, the Q-less QR factorization allows the solution of sparse least squares problems

$$\text{minimize} \|Ax - b\|$$

with two steps

$$\begin{aligned} [C, R] &= \text{qr}(A, b) \\ x &= R \setminus C \end{aligned}$$

If A is sparse but not square, MATLAB software uses the two steps above for the linear equation solving backslash operator, i.e., $x = A \setminus b$.

Examples

Example 1

Start with

$$A = \begin{bmatrix} 1 & 2 & 3 \\ 4 & 5 & 6 \\ 7 & 8 & 9 \\ 10 & 11 & 12 \end{bmatrix}$$

This is a rank-deficient matrix; the middle column is the average of the other two columns. The rank deficiency is revealed by the factorization:

$$[Q,R] = \text{qr}(A)$$

Q =

-0.0776	-0.8331	0.5444	0.0605
-0.3105	-0.4512	-0.7709	0.3251
-0.5433	-0.0694	-0.0913	-0.8317
-0.7762	0.3124	0.3178	0.4461

R =

-12.8841	-14.5916	-16.2992
0	-1.0413	-2.0826
0	0	0.0000
0	0	0

The triangular structure of R gives it zeros below the diagonal; the zero on the diagonal in R(3,3) implies that R, and consequently A, does not have full rank.

Example 2

This example uses matrix A from the first example. The QR factorization is used to solve linear systems with more equations than unknowns. For example, let

$$b = [1;3;5;7]$$

The linear system $Ax = b$ represents four equations in only three unknowns. The best solution in a least squares sense is computed by

$$x = A \backslash b$$

which produces

Warning: Rank deficient, rank = 2, tol = 1.4594E-014

```
x =
    0.5000
         0
    0.1667
```

The quantity `tol` is a tolerance used to decide if a diagonal element of `R` is negligible. If `[Q,R,E] = qr(A)`, then

```
tol = max(size(A))*eps*abs(R(1,1))
```

The solution `x` was computed using the factorization and the two steps

```
y = Q' * b;
x = R \ y
```

The computed solution can be checked by forming Ax . This equals b to within roundoff error, which indicates that even though the simultaneous equations $Ax = b$ are overdetermined and rank deficient, they happen to be consistent. There are infinitely many solution vectors `x`; the QR factorization has found just one of them.

Algorithm

Inputs of Type Double

For inputs of type double, `qr` uses the LAPACK routines listed in the following table to compute the QR decomposition.

Syntax	Real	Complex
<code>X = qr(A)</code> <code>X = qr(A,0)</code>	DGEQRF	ZGEQRF
<code>[Q,R] = qr(A)</code> <code>[Q,R] = qr(A,0)</code>	DGEQRF, DORGQR	ZGEQRF, ZUNGQR
<code>[Q,R,e] = qr(A)</code> <code>[Q,R,e] = qr(A,0)</code>	DGEQP3, DORGQR	ZGEQP3, ZUNGQR

Inputs of Type Single

For inputs of type `single`, `qr` uses the LAPACK routines listed in the following table to compute the QR decomposition.

Syntax	Real	Complex
$R = \text{qr}(A)$ $R = \text{qr}(A, 0)$	SGEQRF	CGEQRF
$[Q, R] = \text{qr}(A)$ $[Q, R] = \text{qr}(A, 0)$	SGEQRF, SORGQR	CGEQRF, CUNGQR
$[Q, R, e] = \text{qr}(A)$ $[Q, R, e] = \text{qr}(A, 0)$	SGEQP3, SORGQR	CGEQP3, CUNGQR

See Also

`lu`, `null`, `orth`, `qrdelete`, `qrinsert`, `qrupdate`

The arithmetic operators `\` and `/`

References

[1] Anderson, E., Z. Bai, C. Bischof, S. Blackford, J. Demmel, J. Dongarra, J. Du Croz, A. Greenbaum, S. Hammarling, A. McKenney, and D. Sorensen, *LAPACK User's Guide* (http://www.netlib.org/lapack/lug/lapack_lug.html), Third Edition, SIAM, Philadelphia, 1999.

qrdelete

Purpose Remove column or row from QR factorization

Syntax

```
[Q1,R1] = qrdelete(Q,R,j)
[Q1,R1] = qrdelete(Q,R,j,'col')
[Q1,R1] = qrdelete(Q,R,j,'row')
```

Description

[Q1,R1] = qrdelete(Q,R,j) returns the QR factorization of the matrix A1, where A1 is A with the column A(:,j) removed and [Q,R] = qr(A) is the QR factorization of A.

[Q1,R1] = qrdelete(Q,R,j,'col') is the same as qrdelete(Q,R,j).

[Q1,R1] = qrdelete(Q,R,j,'row') returns the QR factorization of the matrix A1, where A1 is A with the row A(j,:) removed and [Q,R] = qr(A) is the QR factorization of A.

Examples

```
A = magic(5);
[Q,R] = qr(A);
j = 3;
[Q1,R1] = qrdelete(Q,R,j,'row');
```

```
Q1 =
    0.5274    -0.5197   -0.6697   -0.0578
    0.7135     0.6911    0.0158    0.1142
    0.3102   -0.1982    0.4675   -0.8037
    0.3413   -0.4616    0.5768    0.5811
```

```
R1 =
   32.2335   26.0908   19.9482   21.4063   23.3297
         0  -19.7045  -10.9891    0.4318   -1.4873
         0         0   22.7444    5.8357   -3.1977
         0         0         0  -14.5784    3.7796
```

returns a valid QR factorization, although possibly different from

```
A2 = A;
A2(j,:) = [];
[Q2,R2] = qr(A2)
```

```
Q2 =  
-0.5274    0.5197    0.6697   -0.0578  
-0.7135   -0.6911   -0.0158    0.1142  
-0.3102    0.1982   -0.4675   -0.8037  
-0.3413    0.4616   -0.5768    0.5811
```

```
R2 =  
-32.2335  -26.0908  -19.9482  -21.4063  -23.3297  
         0   19.7045   10.9891   -0.4318    1.4873  
         0         0  -22.7444   -5.8357    3.1977  
         0         0         0  -14.5784    3.7796
```

Algorithm

The `qrdelete` function uses a series of Givens rotations to zero out the appropriate elements of the factorization.

See Also

`planerot`, `qr`, `qrinsert`

qrinsert

Purpose Insert column or row into QR factorization

Syntax
[Q1,R1] = qrinsert(Q,R,j,x)
[Q1,R1] = qrinsert(Q,R,j,x,'col')
[Q1,R1] = qrinsert(Q,R,j,x,'row')

Description [Q1,R1] = qrinsert(Q,R,j,x) returns the QR factorization of the matrix A1, where A1 is $A = Q \cdot R$ with the column x inserted before $A(:,j)$. If A has n columns and $j = n+1$, then x is inserted after the last column of A.

[Q1,R1] = qrinsert(Q,R,j,x,'col') is the same as qrinsert(Q,R,j,x).

[Q1,R1] = qrinsert(Q,R,j,x,'row') returns the QR factorization of the matrix A1, where A1 is $A = Q \cdot R$ with an extra row, x, inserted before $A(j,:)$.

Examples

```
A = magic(5);  
[Q,R] = qr(A);  
j = 3;  
x = 1:5;  
[Q1,R1] = qrinsert(Q,R,j,x,'row')
```

```
Q1 =  
    0.5231    0.5039   -0.6750    0.1205    0.0411    0.0225  
    0.7078   -0.6966    0.0190   -0.0788    0.0833   -0.0150  
    0.0308    0.0592    0.0656    0.1169    0.1527   -0.9769  
    0.1231    0.1363    0.3542    0.6222    0.6398    0.2104  
    0.3077    0.1902    0.4100    0.4161   -0.7264   -0.0150  
    0.3385    0.4500    0.4961   -0.6366    0.1761    0.0225
```

```
R1 =  
   32.4962   26.6801   21.4795   23.8182   26.0031  
         0   19.9292   12.4403    2.1340    4.3271  
         0         0   24.4514   11.8132    3.9931  
         0         0         0   20.2382   10.3392
```



```

0      0      0      0  16.1948
0      0      0      0      0

```

returns a valid QR factorization, although possibly different from

```

A2 = [A(1:j-1,:); x; A(j:end,:)];
[Q2,R2] = qr(A2)

```

```

Q2 =
-0.5231    0.5039    0.6750   -0.1205    0.0411    0.0225
-0.7078   -0.6966   -0.0190    0.0788    0.0833   -0.0150
-0.0308    0.0592   -0.0656   -0.1169    0.1527   -0.9769
-0.1231    0.1363   -0.3542   -0.6222    0.6398    0.2104
-0.3077    0.1902   -0.4100   -0.4161   -0.7264   -0.0150
-0.3385    0.4500   -0.4961    0.6366    0.1761    0.0225

```

```

R2 =
-32.4962  -26.6801  -21.4795  -23.8182  -26.0031
         0   19.9292   12.4403    2.1340    4.3271
         0         0  -24.4514  -11.8132   -3.9931
         0         0         0  -20.2382  -10.3392
         0         0         0         0   16.1948
         0         0         0         0         0

```

Algorithm

The `qrinsert` function inserts the values of `x` into the `j`th column (row) of `R`. It then uses a series of Givens rotations to zero out the nonzero elements of `R` on and below the diagonal in the `j`th column (row).

See Also

`planerot`, `qr`, `qrdelete`

qrupdate

Description Rank 1 update to QR factorization

Syntax `[Q1,R1] = qrupdate(Q,R,u,v)`

Description `[Q1,R1] = qrupdate(Q,R,u,v)` when `[Q,R] = qr(A)` is the original QR factorization of A , returns the QR factorization of $A + u*v'$, where u and v are column vectors of appropriate lengths.

Remarks `qrupdate` works only for full matrices.

Examples The matrix

```
mu = sqrt(eps)
```

```
mu =
```

```
1.4901e-08
```

```
A = [ones(1,4); mu*eye(4)];
```

is a well-known example in least squares that indicates the dangers of forming $A'*A$. Instead, we work with the QR factorization – orthonormal Q and upper triangular R .

```
[Q,R] = qr(A);
```

As we expect, R is upper triangular.

```
R =
```

```
-1.0000  -1.0000  -1.0000  -1.0000
         0   0.0000   0.0000   0.0000
         0         0   0.0000   0.0000
         0         0         0   0.0000
         0         0         0         0
```

In this case, the upper triangular entries of R, excluding the first row, are on the order of $\sqrt{\text{eps}}$.

Consider the update vectors

$$u = [-1 \ 0 \ 0 \ 0 \ 0]'; \quad v = \text{ones}(4,1);$$

Instead of computing the rather trivial QR factorization of this rank one update to A from scratch with

$$[QT,RT] = \text{qr}(A + u*v')$$

QT =

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 1 \\ -1 & 0 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 & 0 \\ 0 & 0 & -1 & 0 & 0 \\ 0 & 0 & 0 & -1 & 0 \end{bmatrix}$$

RT =

1.0e-007 *

$$\begin{bmatrix} -0.1490 & 0 & 0 & 0 \\ 0 & -0.1490 & 0 & 0 \\ 0 & 0 & -0.1490 & 0 \\ 0 & 0 & 0 & -0.1490 \\ 0 & 0 & 0 & 0 \end{bmatrix}$$

we may use qrupdate.

$$[Q1,R1] = \text{qrupdate}(Q,R,u,v)$$

Q1 =

$$\begin{bmatrix} -0.0000 & -0.0000 & -0.0000 & -0.0000 & 1.0000 \\ 1.0000 & -0.0000 & -0.0000 & -0.0000 & 0.0000 \end{bmatrix}$$

qrupdate

```
0.0000    1.0000   -0.0000   -0.0000    0.0000
0.0000    0.0000    1.0000   -0.0000    0.0000
-0.0000   -0.0000   -0.0000    1.0000    0.0000
```

R1 =

```
1.0e-007 *
0.1490    0.0000    0.0000    0.0000
0         0.1490    0.0000    0.0000
0         0         0.1490    0.0000
0         0         0         0.1490
0         0         0         0
```

Note that both factorizations are correct, even though they are different.

Algorithm

qrupdate uses the algorithm in section 12.5.1 of the third edition of *Matrix Computations* by Golub and van Loan. qrupdate is useful since, if we take $N = \max(m, n)$, then computing the new QR factorization from scratch is roughly an $O(N^3)$ algorithm, while simply updating the existing factors in this way is an $O(N^2)$ algorithm.

References

[1] Golub, Gene H. and Charles Van Loan, *Matrix Computations*, Third Edition, Johns Hopkins University Press, Baltimore, 1996

See Also

cholupdate, qr

Purpose

Numerically evaluate integral, adaptive Simpson quadrature

Syntax

```
q = quad(fun,a,b)
q = quad(fun,a,b,tol)
q = quad(fun,a,b,tol,trace)
[q,fcnt] = quad(...)
```

Description

Quadrature is a numerical method used to find the area under the graph of a function, that is, to compute a definite integral.

$$q = \int_a^b f(x) dx$$

`q = quad(fun,a,b)` tries to approximate the integral of function `fun` from `a` to `b` to within an error of `1e-6` using recursive adaptive Simpson quadrature. `fun` is a function handle. See “Function Handles” in the MATLAB Programming documentation for more information. Limits `a` and `b` must be finite. The function `y = fun(x)` should accept a vector argument `x` and return a vector result `y`, the integrand evaluated at each element of `x`.

“Parametrizing Functions”, in the MATLAB Mathematics documentation, explains how to provide additional parameters to the function `fun`, if necessary.

`q = quad(fun,a,b,tol)` uses an absolute error tolerance `tol` instead of the default which is `1.0e-6`. Larger values of `tol` result in fewer function evaluations and faster computation, but less accurate results. In MATLAB version 5.3 and earlier, the `quad` function used a less reliable algorithm and a default relative tolerance of `1.0e-3`.

`q = quad(fun,a,b,tol,trace)` with non-zero `trace` shows the values of `[fcnt a b-a Q]` during the recursion.

`[q,fcnt] = quad(...)` returns the number of function evaluations.

The function `quadl` may be more efficient with high accuracies and smooth integrands.

The list below contains information to help you determine which quadrature function in MATLAB to use:

- The `quad` function may be most efficient for low accuracies with nonsmooth integrands.
- The `quadl` function may be more efficient than `quad` at higher accuracies with smooth integrands.
- The `quadgk` function may be most efficient for high accuracies and oscillatory integrands. It supports infinite intervals and can handle moderate singularities at the endpoints. It also supports contour integration along piecewise linear paths.
- The `quadv` function vectorizes `quad` for an array-valued `fun`.
- If the interval is infinite, $[a, \text{Inf})$, then for the integral of `fun(x)` to exist, `fun(x)` must decay as `x` approaches infinity, and `quadgk` requires it to decay rapidly. Special methods should be used for oscillatory functions on infinite intervals, but `quadgk` can be used if `fun(x)` decays fast enough.
- The `quadgk` function will integrate functions that are singular at finite endpoints if the singularities are not too strong. For example, it will integrate functions that behave at an endpoint `c` like $\log|x-c|$ or $|x-c|^p$ for $p \geq -1/2$. If the function is singular at points inside (a,b) , write the integral as a sum of integrals over subintervals with the singular points as endpoints, compute them with `quadgk`, and add the results.

Example

To compute the integral

$$\int_0^2 \frac{1}{x^3 - 2x - 5} dx$$

write an M-file function `myfun` that computes the integrand:

```
function y = myfun(x)
y = 1./(x.^3-2*x-5);
```

Then pass @myfun, a function handle to myfun, to quad, along with the limits of integration, 0 to 2:

```
Q = quad(@myfun,0,2)

Q =

    -0.4605
```

Alternatively, you can pass the integrand to quad as an anonymous function handle F:

```
F = @(x)1./(x.^3-2*x-5);
Q = quad(F,0,2);
```

Algorithm

quad implements a low order method using an adaptive recursive Simpson's rule.

Diagnostics

quad may issue one of the following warnings:

'Minimum step size reached' indicates that the recursive interval subdivision has produced a subinterval whose length is on the order of roundoff error in the length of the original interval. A nonintegrable singularity is possible.

'Maximum function count exceeded' indicates that the integrand has been evaluated more than 10,000 times. A nonintegrable singularity is likely.

'Infinite or Not-a-Number function value encountered' indicates a floating point overflow or division by zero during the evaluation of the integrand in the interior of the interval.

See Also

quad2d, dblquad, quadgk, quadl, quadv, trapz, triplequad, function_handle (@), "Anonymous Functions"

References

[1] Gander, W. and W. Gautschi, "Adaptive Quadrature – Revisited," BIT, Vol. 40, 2000, pp. 84-101. This document is also available at <http://www.inf.ethz.ch/personal/gander>.

quad2d

Purpose Numerically evaluate double integral over planar region

Syntax
`q = quad2d(fun,a,b,c,d)`
`[q,errbnd] = quad2d(...)`
`q = quad2d(fun,a,b,c,d,param1,val1,param2,val2,...)`

Description `q = quad2d(fun,a,b,c,d)` approximates the integral of `fun(x,y)` over the planar region $a \leq x \leq b$ and $c(x) \leq y \leq d(x)$. `fun` is a function handle, `c` and `d` may each be a scalar or a function handle. All input functions must be vectorized. The function `Z=fun(X,Y)` must accept 2-D matrices `X` and `Y` of the same size and return a matrix `Z` of corresponding values. The functions `ymin=c(X)` and `ymax=d(X)` must accept matrices and return matrices of the same size with corresponding values.

`[q,errbnd] = quad2d(...)`. `errbnd` is an approximate upper bound on the absolute error, $|Q - I|$, where `I` denotes the exact value of the integral.

`q = quad2d(fun,a,b,c,d,param1,val1,param2,val2,...)` performs the integration as above with specified values of optional parameters:

<code>AbsTol</code>	absolute error tolerance
<code>RelTol</code>	relative error tolerance

`quad2d` attempts to satisfy $ERRBND \leq \max(AbsTol, RelTol * |Q|)$. This is absolute error control when $|Q|$ is sufficiently small and relative error control when $|Q|$ is larger. A default tolerance value is used when a tolerance is not specified. The default value of `AbsTol` is $1e-5$. The default value of `RelTol` is $100 * \text{eps}(\text{class}(Q))$. This is also the minimum value of `RelTol`. Smaller `RelTol` values are automatically increased to the default value.

<code>MaxFunEvals</code>	Maximum allowed number of evaluations of <code>fun</code> reached.
--------------------------	--

The `MaxFunEvals` parameter limits the number of vectorized calls to `fun`. The default is 2000.

<code>FailurePlot</code>	Generate a plot if <code>MaxFunEvals</code> is reached.
--------------------------	---

Setting `FailurePlot` to `true` generates a graphical representation of the regions needing further refinement when `MaxFunEvals` is reached. No plot is generated if the integration succeeds before reaching `MaxFunEvals`. These (generally) 4-sided regions are mapped to rectangles internally. Clusters of small regions indicate the areas of difficulty. The default is `false`.

<code>Singular</code>	Problem may have boundary singularities
-----------------------	---

With `Singular` set to `true`, `quad2d` will employ transformations to weaken boundary singularities for better performance. The default is `true`. Setting `Singular` to `false` will turn these transformations off, which may provide a performance benefit on some smooth problems.

Examples

Example 1

Integrate $y \sin(x) + x \cos(y)$ over $\pi \leq x \leq 2\pi$, $0 \leq y \leq \pi$. The true value of the integral is $-\pi^2$.

```
Q = quad2d(@(x,y) y.*sin(x)+x.*cos(y),pi,2*pi,0,pi)
```

Example 2

Integrate $[(x+y)^{1/2}(1+x+y)^2]^{-1}$ over the triangle $0 \leq x \leq 1$ and $0 \leq y \leq 1-x$. The integrand is infinite at $(0,0)$. The true value of the integral is $\pi/4 - 1/2$.

```
fun = @(x,y) 1./((sqrt(x + y) .* (1 + x + y).^2 )
```

In Cartesian coordinates:

```
ymax = @(x) 1 - x;
```

quad2d

```
Q = quad2d(fun,0,1,0,ymax)
```

In polar coordinates:

```
polarfun = @(theta,r) fun(r.*cos(theta),r.*sin(theta)).*r;  
rmax = @(theta) 1./(sin(theta) + cos(theta));  
Q = quad2d(polarfun,0,pi/2,0,rmax)
```

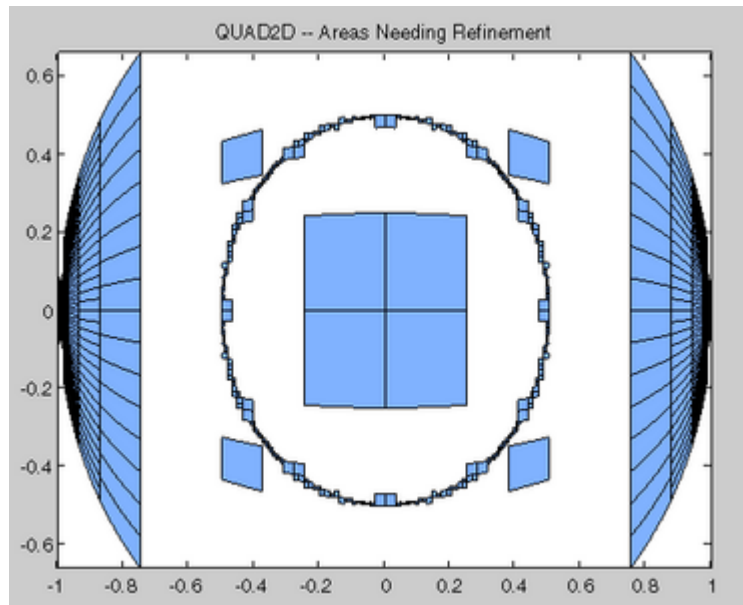
Limitations

quad2d begins by mapping the region of integration to a rectangle. Consequently, it may have trouble integrating over a region that does not have four sides or has a side that cannot be mapped smoothly to a straight line. If the integration is unsuccessful, some helpful tactics are leaving `Singular` set to its default value of `true`, changing between Cartesian and polar coordinates, or breaking the region of integration into pieces and adding the results of integration over the pieces.

For example:

```
fun = @(x,y)abs(x.^2 + y.^2 - 0.25);  
c = @(x)-sqrt(1 - x.^2);  
d = @(x)sqrt(1 - x.^2);  
quad2d(fun,-1,1,c,d,'AbsTol',1e-8,...  
    'FailurePlot',true,'Singular',false)  
Warning: Reached the maximum number of function ...  
    evaluations (2000). The result fails the ...  
    global error test.
```

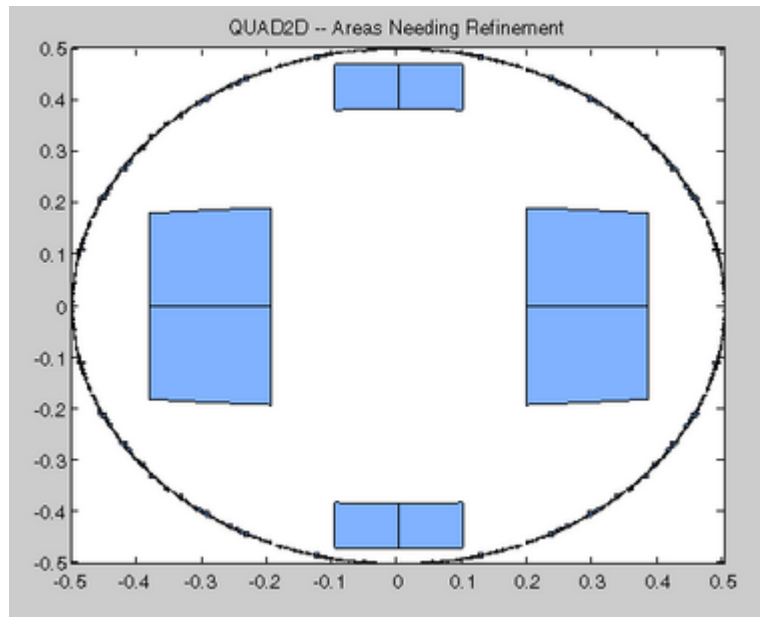
The failure plot shows two areas of difficulty, near the points $(-1,0)$ and $(1,0)$ and near the circle $x^2 + y^2 = 0.25$:



Changing the value of `Singular` to `true` will cope with the geometric singularities at $(-1,0)$ and $(1,0)$. The larger shaded areas may need refinement but are probably not areas of difficulty.

```
Q = quad2d(fun,-1,1,c,d,'AbsTol',1e-8, ...
           'FailurePlot',true,'Singular',true)
Warning: Reached the maximum number of function ...
         evaluations (2000). The result passes the ...
         global error test.
```

quad2d



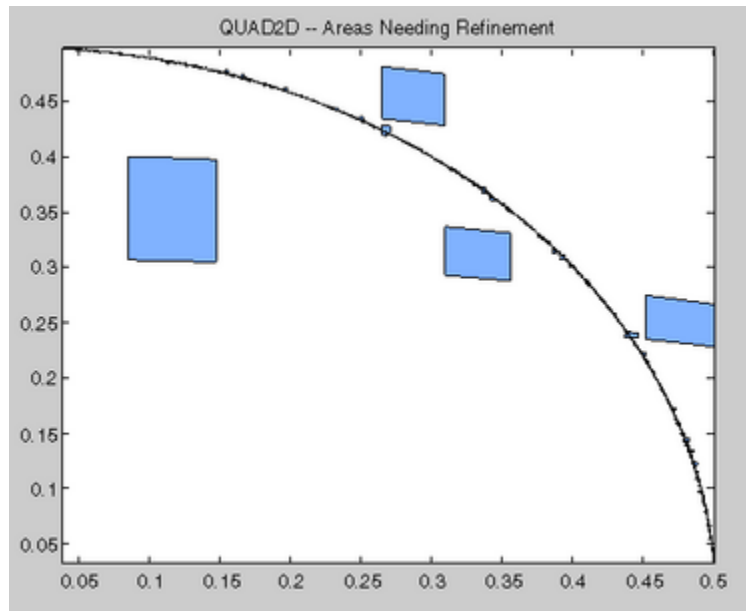
From here you can take advantage of symmetry:

```
Q = 4*quad2d(fun,0,1,0,d,'Abstol',1e-8,...  
             'Singular',true, 'FailurePlot',true)
```

However, the code is still working very hard near the singularity. It may not be able to provide higher accuracy:

```
Q = 4*quad2d(fun,0,1,0,d,'Abstol',1e-10,...  
             'Singular',true,'FailurePlot',true)
```

```
Warning: Reached the maximum number of function ...  
evaluations (2000). The result passes the ...  
global error test.
```



At higher accuracy, a change in coordinates may work better.

```
polarfun = @(theta,r) fun(r.*cos(theta),r.*sin(theta)).*r;
Q = 4*quad2d(polarfun,0,pi/2,0,1,'AbsTol',1e-10)
```

It is best to put the singularity on the boundary by splitting the region of integration into two parts:

```
Q1 = 4*quad2d(polarfun,0,pi/2,0,0.5,'AbsTol',5e-11);
Q2 = 4*quad2d(polarfun,0,pi/2,0.5,1,'AbsTol',5e-11);
Q = Q1 + Q2
```

References

[1] L.F. Shampine “Vectorized Adaptive Quadrature in MATLAB,” *Journal of Computational and Applied Mathematics*, 211, 2008, pp.131–140.

See Also

dblquad, quad, quad1, quadv, quadgk, triplequad, function_handle (@), “Anonymous Functions”

quadgk

Purpose Numerically evaluate integral, adaptive Gauss-Kronrod quadrature

Syntax
`q = quadgk(fun,a,b)`
`[q,errbnd] = quadgk(fun,a,b,tol)`
`[q,errbnd] = quadgk(fun,a,b,param1,val1,param2,val2,...)`

Description `q = quadgk(fun,a,b)` attempts to approximate the integral of a scalar-valued function `fun` from `a` to `b` using high-order global adaptive quadrature and default error tolerances. The function `y = fun(x)` should accept a vector argument `x` and return a vector result `y`. The integrand evaluated at each element of `x`. `fun` must be a function handle. See “Function Handles” in the MATLAB Programming documentation for more information. Limits `a` and `b` can be `-Inf` or `Inf`. If both are finite, they can be complex. If at least one is complex, the integral is approximated over a straight line path from `a` to `b` in the complex plane.

“Parametrizing Functions”, in the MATLAB Mathematics documentation, explains how to provide additional parameters to the function `fun`, if necessary.

`[q,errbnd] = quadgk(fun,a,b,tol)` returns an approximate bound on the absolute error, $|Q - I|$, where `I` denotes the exact value of the integral.

`[q,errbnd] = quadgk(fun,a,b,param1,val1,param2,val2,...)` performs the integration with specified values of optional parameters. The available parameters are

Parameter	Description	
'AbsTol'	<p>Absolute error tolerance.</p> <p>The default value of 'AbsTol' is 1.e-10 (double), 1.e-5 (single).</p>	<p>quadgk attempts to satisfy $err_{bnd} \leq \max(AbsTol, RelTol * Q)$. This is absolute error control when Q is sufficiently small and relative error control when Q is larger.</p>
'RelTol'	<p>Relative error tolerance.</p> <p>The default value of 'RelTol' is 1.e-6 (double), 1.e-4 (single).</p>	<p>For pure absolute error control use 'AbsTol' > 0 and 'RelTol' = 0. For pure relative error control use 'AbsTol' = 0. Except when using pure absolute error control, the minimum relative tolerance is 'RelTol' >= 100*eps(class(Q)).</p>

Parameter	Description	
'Waypoints'	Vector of integration waypoints.	<p>If $\text{fun}(x)$ has discontinuities in the interval of integration, the locations should be supplied as a <code>Waypoints</code> vector. When <code>a</code>, <code>b</code>, and the waypoints are all real, only the waypoints between <code>a</code> and <code>b</code> are used, and they are used in sorted order. Note that waypoints are not intended for singularities in $\text{fun}(x)$. Singular points should be handled by making them endpoints of separate integrations and adding the results.</p> <p>If <code>a</code>, <code>b</code>, or any entry of the waypoints vector is complex, the integration is performed over a sequence of straight line paths in the complex plane, from <code>a</code> to the first waypoint, from the first waypoint to the second, and so forth, and finally from the last waypoint to <code>b</code>.</p>
'MaxIntervalCount'	<p>Maximum number of intervals allowed.</p> <p>The default value is 650.</p>	<p>The <code>'MaxIntervalCount'</code> parameter limits the number of intervals that <code>quadgk</code> uses at any one time after the first iteration. A warning is issued if <code>quadgk</code> returns early because of this limit. Routinely increasing this value is not recommended, but</p>

The list below contains information to help you determine which quadrature function in MATLAB to use:

- The `quad` function may be most efficient for low accuracies with nonsmooth integrands.
- The `quadl` function may be more efficient than `quad` at higher accuracies with smooth integrands.
- The `quadgk` function may be most efficient for high accuracies and oscillatory integrands. It supports infinite intervals and can handle moderate singularities at the endpoints. It also supports contour integration along piecewise linear paths.
- The `quadv` function vectorizes `quad` for an array-valued `fun`.
- If the interval is infinite, $[a, \text{Inf})$, then for the integral of `fun(x)` to exist, `fun(x)` must decay as `x` approaches infinity, and `quadgk` requires it to decay rapidly. Special methods should be used for oscillatory functions on infinite intervals, but `quadgk` can be used if `fun(x)` decays fast enough.
- The `quadgk` function will integrate functions that are singular at finite endpoints if the singularities are not too strong. For example, it will integrate functions that behave at an endpoint `c` like $\log|x-c|$ or $|x-c|^p$ for $p \geq -1/2$. If the function is singular at points inside (a,b) , write the integral as a sum of integrals over subintervals with the singular points as endpoints, compute them with `quadgk`, and add the results.

Examples

Integrand with a singularity at an integration end point

Write an M-file function `myfun` that computes the integrand:

```
function y = myfun(x)
y = exp(x).*log(x);
```

Then pass `@myfun`, a function handle to `myfun`, to `quadgk`, along with the limits of integration, 0 to 1:

quadgk

```
Q = quadgk(@myfun,0,1)
```

```
Q =
```

```
-1.3179
```

Alternatively, you can pass the integrand to `quadgk` as an anonymous function handle `F`:

```
F = @(x)exp(x).*log(x);
```

```
Q = quadgk(F,0,1);
```

Oscillatory integrand on a semi-infinite interval

Integrate over a semi-infinite interval with specified tolerances, and return the approximate error bound:

```
[q,errbnd] = quadgk(@(x)x.^5.*exp(-x).*sin(x),0,inf,'RelTol',1e-8,'AbsTol',1e-10)
```

```
q =
```

```
-15.0000
```

```
errbnd =
```

```
9.4386e-009
```

Contour integration around a pole

Use `Waypoints` to integrate around a pole using a piecewise linear contour:

```
Q = quadgk(@(z)1./(2*z - 1),-1-i,-1-i,'Waypoints',[1-i,1+i,-1+i])
```

```
Q =
```

```
0.0000 + 3.1416i
```

Algorithm

quadgk implements adaptive quadrature based on a Gauss-Kronrod pair (15th and 7th order formulas).

Diagnostics

quadgk may issue one of the following warnings:

'Minimum step size reached' indicates that interval subdivision has produced a subinterval whose length is on the order of roundoff error in the length of the original interval. A nonintegrable singularity is possible.

'Reached the limit on the maximum number of intervals in use' indicates that the integration was terminated before meeting the tolerance requirements and that continuing the integration would require more than `MaxIntervalCount` subintervals. The integral may not exist, or it may be difficult to approximate numerically. Increasing `MaxIntervalCount` usually does not help unless the tolerance requirements were nearly met when the integration was previously terminated.

'Infinite or Not-a-Number function value encountered' indicates a floating point overflow or division by zero during the evaluation of the integrand in the interior of the interval.

References

[1] L.F. Shampine “Vectorized Adaptive Quadrature in MATLAB,” *Journal of Computational and Applied Mathematics*, 211, 2008, pp.131–140.

See Also

quad2d, dblquad, quad, quadl, quadv, triplequad, function_handle (@), “Anonymous Functions”

quadl

Purpose Numerically evaluate integral, adaptive Lobatto quadrature

Syntax

```
q = quadl(fun,a,b)
q = quadl(fun,a,b,tol)
quadl(fun,a,b,tol,trace)
[q,fcnt] = quadl(...)
```

Description `q = quadl(fun,a,b)` approximates the integral of function `fun` from `a` to `b`, to within an error of 10^{-6} using recursive adaptive Lobatto quadrature. `fun` is a function handle. See “Function Handles” in the MATLAB Programming documentation for more information. `fun` accepts a vector `x` and returns a vector `y`, the function `fun` evaluated at each element of `x`. Limits `a` and `b` must be finite.

“Parametrizing Functions”, in the MATLAB Mathematics documentation, explains how to provide additional parameters to the function `fun`, if necessary.

`q = quadl(fun,a,b,tol)` uses an absolute error tolerance of `tol` instead of the default, which is $1.0e-6$. Larger values of `tol` result in fewer function evaluations and faster computation, but less accurate results.

`quadl(fun,a,b,tol,trace)` with non-zero `trace` shows the values of `[fcnt a b-a q]` during the recursion.

`[q,fcnt] = quadl(...)` returns the number of function evaluations.

Use array operators `.*`, `./` and `.^` in the definition of `fun` so that it can be evaluated with a vector argument.

The function `quad` may be more efficient with low accuracies or nonsmooth integrands.

The list below contains information to help you determine which quadrature function in MATLAB to use:

- The `quad` function may be most efficient for low accuracies with nonsmooth integrands.

- The quadl function may be more efficient than quad at higher accuracies with smooth integrands.
- The quadgk function may be most efficient for high accuracies and oscillatory integrands. It supports infinite intervals and can handle moderate singularities at the endpoints. It also supports contour integration along piecewise linear paths.
- The quadv function vectorizes quad for an array-valued fun.
- If the interval is infinite, $[a, \text{Inf})$, then for the integral of $\text{fun}(x)$ to exist, $\text{fun}(x)$ must decay as x approaches infinity, and quadgk requires it to decay rapidly. Special methods should be used for oscillatory functions on infinite intervals, but quadgk can be used if $\text{fun}(x)$ decays fast enough.
- The quadgk function will integrate functions that are singular at finite endpoints if the singularities are not too strong. For example, it will integrate functions that behave at an endpoint c like $\log|x-c|$ or $|x-c|^p$ for $p \geq -1/2$. If the function is singular at points inside (a,b) , write the integral as a sum of integrals over subintervals with the singular points as endpoints, compute them with quadgk, and add the results.

Examples

Pass M-file function handle @myfun to quadl:

```
Q = quadl(@myfun,0,2);
```

where the M-file myfun.m is

```
function y = myfun(x)
y = 1./(x.^3-2*x-5);
```

Pass anonymous function handle F to quadl:

```
F = @(x) 1./(x.^3-2*x-5);
Q = quadl(F,0,2);
```

Algorithm

quadl implements a high order method using an adaptive Gauss/Lobatto quadrature rule.

quadl

Diagnostics

quadl may issue one of the following warnings:

'Minimum step size reached' indicates that the recursive interval subdivision has produced a subinterval whose length is on the order of roundoff error in the length of the original interval. A nonintegrable singularity is possible.

'Maximum function count exceeded' indicates that the integrand has been evaluated more than 10,000 times. A nonintegrable singularity is likely.

'Infinite or Not-a-Number function value encountered' indicates a floating point overflow or division by zero during the evaluation of the integrand in the interior of the interval.

See Also

quad2d, dblquad, quad, quadgk, triplequad, function_handle (@), "Anonymous Functions"

References

[1] Gander, W. and W. Gautschi, "Adaptive Quadrature – Revisited," BIT, Vol. 40, 2000, pp. 84-101. This document is also available at <http://www.inf.ethz.ch/personal/gander>.

Purpose

Vectorized quadrature

Syntax

```
Q = quadv(fun,a,b)
Q = quadv(fun,a,b,tol)
Q = quadv(fun,a,b,tol,trace)
[Q,fcnt] = quadv(...)
```

Description

`Q = quadv(fun,a,b)` approximates the integral of the complex array-valued function `fun` from `a` to `b` to within an error of $1.e-6$ using recursive adaptive Simpson quadrature. `fun` is a function handle. See “Function Handles” in the MATLAB Programming documentation for more information. The function `Y = fun(x)` should accept a scalar argument `x` and return an array result `Y`, whose components are the integrands evaluated at `x`. Limits `a` and `b` must be finite.

“Parametrizing Functions”, in the MATLAB Mathematics documentation, explains how to provide addition parameters to the function `fun`, if necessary.

`Q = quadv(fun,a,b,tol)` uses the absolute error tolerance `tol` for all the integrals instead of the default, which is $1.e-6$.

Note The same tolerance is used for all components, so the results obtained with `quadv` are usually not the same as those obtained with `quad` on the individual components.

`Q = quadv(fun,a,b,tol,trace)` with non-zero `trace` shows the values of `[fcnt a b-a Q(1)]` during the recursion.

`[Q,fcnt] = quadv(...)` returns the number of function evaluations.

The list below contains information to help you determine which quadrature function in MATLAB to use:

- The `quad` function may be most efficient for low accuracies with nonsmooth integrands.

- The `quadl` function may be more efficient than `quad` at higher accuracies with smooth integrands.
- The `quadgk` function may be most efficient for high accuracies and oscillatory integrands. It supports infinite intervals and can handle moderate singularities at the endpoints. It also supports contour integration along piecewise linear paths.
- The `quadv` function vectorizes `quad` for an array-valued fun.
- If the interval is infinite, $[a, \text{Inf})$, then for the integral of $\text{fun}(x)$ to exist, $\text{fun}(x)$ must decay as x approaches infinity, and `quadgk` requires it to decay rapidly. Special methods should be used for oscillatory functions on infinite intervals, but `quadgk` can be used if $\text{fun}(x)$ decays fast enough.
- The `quadgk` function will integrate functions that are singular at finite endpoints if the singularities are not too strong. For example, it will integrate functions that behave at an endpoint c like $\log|x-c|$ or $|x-c|^p$ for $p \geq -1/2$. If the function is singular at points inside (a,b) , write the integral as a sum of integrals over subintervals with the singular points as endpoints, compute them with `quadgk`, and add the results.

Example

For the parameterized array-valued function `myarrayfun`, defined by

```
function Y = myarrayfun(x,n)
Y = 1./((1:n)+x);
```

the following command integrates `myarrayfun`, for the parameter value $n = 10$ between $a = 0$ and $b = 1$:

```
Qv = quadv(@(x)myarrayfun(x,10),0,1);
```

The resulting array `Qv` has 10 elements estimating $Q(k) = \log((k+1)/(k))$, for $k = 1:10$.

The entries in `Qv` are slightly different than if you compute the integrals using `quad` in a loop:


```
for k = 1:10
    Qs(k) = quadv(@(x)myscalarfun(x,k),0,1);
end
```

where `myscalarfun` is:

```
function y = myscalarfun(x,k)
y = 1./(k+x);
```

See Also

`quad`, `quad2d`, `quadgk`, `quadl`, `dblquad`, `triplequad`, `function_handle`
(@)

questdlg

Purpose Create and open question dialog box

Syntax

```
button = questdlg('qstring')
button = questdlg('qstring','title')
button = questdlg('qstring','title',default)
button = questdlg('qstring','title','str1','str2',default)
button = questdlg('qstring','title','str1','str2','str3',
    default)
button = questdlg('qstring','title', ..., options)
```

Description `button = questdlg('qstring')` displays a modal dialog box presenting the question 'qstring'. The dialog has three default buttons, **Yes**, **No**, and **Cancel**. If the user presses one of these three buttons, `button` is set to the name of the button pressed. If the user presses the close button on the dialog without making a choice, `button` is set to the empty string. If the user presses the **Return** key, `button` is set to 'Yes'. 'qstring' is a cell array or a string that automatically wraps to fit within the dialog box.

Note A modal dialog box prevents the user from interacting with other windows before responding. For more information, see `WindowState` in the MATLAB Figure Properties.

`button = questdlg('qstring','title')` displays a question dialog with 'title' displayed in the dialog's title bar.

`button = questdlg('qstring','title',default)` specifies which push button is the default in the event that the **Return** key is pressed. '*default*' must be 'Yes', 'No', or 'Cancel'.

`button = questdlg('qstring','title','str1','str2',default)` creates a question dialog box with two push buttons labeled 'str1' and 'str2'. *default* specifies the default button selection and must be 'str1' or 'str2'.

```
button =
questdlg('qstring','title','str1','str2','str3',default)
creates a question dialog box with three push buttons labeled 'str1',
'str2', and 'str3'. default specifies the default button selection and
must be 'str1', 'str2', or 'str3'.
```

When *default* is specified, but is not set to one of the button names, pressing the **Enter** key displays a warning and the dialog remains open.

```
button = questdlg('qstring','title', ..., options) replaces
the string default with a structure, options. The structure specifies
which button string is the default answer, and whether to use TeX to
interpret the question string, qstring. Button strings and dialog titles
cannot use TeX interpretation. The options structure must include the
fields Default and Interpreter, both strings. It can include other
fields, but questdlg does not use them. You can set Interpreter to
'none' or 'tex'. If the Default field does not contain a valid button
name, a command window warning is issued and the dialog box does
not respond to pressing the Enter key.
```

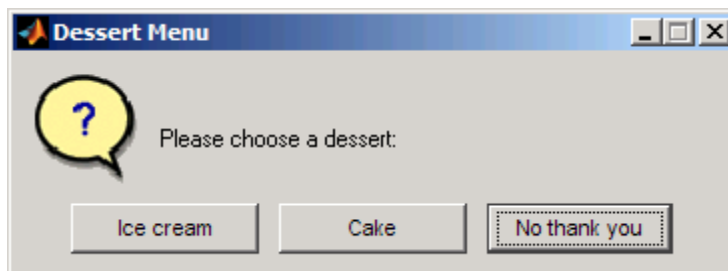
Examples

Example 1

Create a dialog that requests a dessert preference and encode the resulting choice as an integer.

```
% Construct a questdlg with three options
choice = questdlg('Please choose a dessert:', ...
'Dessert Menu', ...
'Ice cream','Cake','No thank you','No thank you');
% Handle response
switch choice
case 'Ice cream'
    disp([choice ' coming right up.'])
    dessert = 1;
    break
case 'Cake'
    disp([choice ' coming right up.'])
    dessert = 2;
    break
```

```
        case 'No thank you'  
            disp('I'll bring you your check.')  
            dessert = 0;  
        end
```

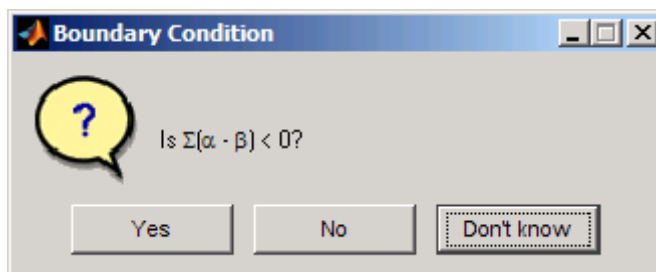


The case statements can contain white space but are case-sensitive.

Example 2

Specify an options structure to use the TeX interpreter to format a question.

```
options.Interpreter = 'tex';  
% Include the desired Default answer  
options.Default = 'Don't know';  
% Create a TeX string for the question  
qstring = 'Is  $\Sigma(\alpha - \beta) < 0$ ?';  
choice = questdlg(qstring,'Boundary Condition',...  
    'Yes','No','Don't know',options)
```

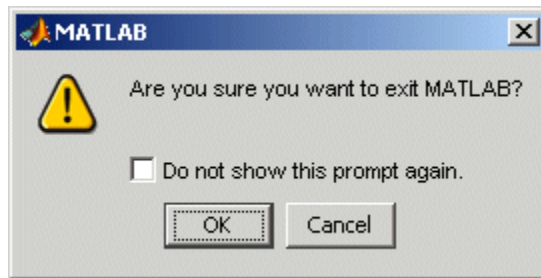


See Also

dialog, errordlg, helpdlg, inputdlg, listdlg, msgbox, warndlg
figure, textwrap, uiwait, uiresume
Predefined Dialog Boxes for related functions

quit

Purpose	Terminate MATLAB program
GUI Alternatives	As an alternative to the quit function, use the Close box or select File > Exit MATLAB in the MATLAB desktop.
Syntax	<code>quit</code> <code>quit cancel</code> <code>quit force</code>
Description	<p><code>quit</code> displays a confirmation dialog box if the confirm upon quitting preference is selected, and if confirmed or if the confirmation preference is not selected, terminates MATLAB after running <code>finish.m</code>, if <code>finish.m</code> exists. The workspace is not automatically saved by <code>quit</code>. To save the workspace or perform other actions when quitting, create a <code>finish.m</code> file to perform those actions. For example, you can display a custom dialog box to confirm quitting using a <code>finish.m</code> file—see the following examples for details. If an error occurs while <code>finish.m</code> is running, <code>quit</code> is canceled so that you can correct your <code>finish.m</code> file without losing your workspace.</p> <p><code>quit cancel</code> is for use in <code>finish.m</code> and cancels quitting. It has no effect anywhere else.</p> <p><code>quit force</code> bypasses <code>finish.m</code> and terminates MATLAB. Use this to override <code>finish.m</code>, for example, if an errant <code>finish.m</code> will not let you quit.</p>
Remarks	<p>When using Handle Graphics objects in <code>finish.m</code>, use <code>uiwait</code>, <code>waitfor</code>, or <code>drawnow</code> so that figures are visible. See the reference pages for these functions for more information.</p> <p>If you want MATLAB to display the following confirmation dialog box after running <code>quit</code>, select File > Preferences > General > Confirmation Dialogs. Then select the check box for Confirm before exiting MATLAB, and click OK.</p>



Examples

Two sample `finish.m` files are included with MATLAB. Use them to help you create your own `finish.m`, or rename one of the files to `finish.m` to use it.

- `finishesav.m`—Saves the workspace to a MAT-file when MATLAB quits.
- `finishdlg.m`—Displays a dialog allowing you to cancel quitting; it uses `quit cancel` and contains the following code:

```
button = questdlg('Ready to quit?', ...
    'Exit Dialog','Yes','No','No');
switch button
    case 'Yes',
        disp('Exiting MATLAB');
        %Save variables to matlab.mat
        save
    case 'No',
        quit cancel;
end
```

See Also

`exit`, `finish`, `save`, `startup`

Quit (COM)

Purpose Terminate MATLAB Automation server

Syntax

MATLAB Client
h.Quit
Quit(h)
invoke(h, 'Quit')

Method Signature
void Quit(void)

Microsoft Visual Basic Client
Quit

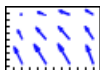
Description Quit terminates the MATLAB server session attached to handle h.

Remarks Server function names, like Quit, are case sensitive when using the first syntax shown.


There is no difference in the operation of the three syntaxes shown above for the MATLAB client.

COM functions are available on Microsoft Windows systems only.

Purpose Quiver or velocity plot



GUI Alternatives

To graph selected variables, use the Plot Selector  in the Workspace Browser, or use the Figure Palette Plot Catalog. Manipulate graphs in *plot edit* mode with the Property Editor. For details, see Plotting Tools — Interactive Plotting in the MATLAB Graphics documentation and Creating Graphics from the Workspace Browser in the MATLAB Desktop Tools documentation.

Syntax

```
quiver(x,y,u,v)
quiver(u,v)
quiver(...,scale)
quiver(...,LineStyle)
quiver(...,LineStyle,'filled')
quiver(axes_handle,...)
h = quiver(...)
hlines = quiver('v6',...)
```

Description

A quiver plot displays velocity vectors as arrows with components (u,v) at the points (x,y) .

For example, the first vector is defined by components $u(1),v(1)$ and is displayed at the point $x(1),y(1)$.

`quiver(x,y,u,v)` plots vectors as arrows at the coordinates specified in each corresponding pair of elements in x and y . The matrices x , y , u , and v must all be the same size and contain corresponding position and velocity components. However, x and y can also be vectors, as explained in the next section. By default, the arrows are scaled to just not overlap, but you can scale them to be longer or shorter if you want.

Expanding x- and y-Coordinates

MATLAB expands x and y if they are not matrices. This expansion is equivalent to calling `meshgrid` to generate matrices from vectors:

```
[x,y] = meshgrid(x,y);  
quiver(x,y,u,v)
```


In this case, the following must be true:

`length(x) = n` and `length(y) = m`, where `[m,n] = size(u) = size(v)`.

The vector `x` corresponds to the columns of `u` and `v`, and vector `y` corresponds to the rows of `u` and `v`.

`quiver(u,v)` draws vectors specified by `u` and `v` at equally spaced points in the x - y plane.

`quiver(...,scale)` automatically scales the arrows to fit within the grid and then stretches them by the factor `scale`. `scale = 2` doubles their relative length, and `scale = 0.5` halves the length. Use `scale = 0` to plot the velocity vectors without automatic scaling. You can also tune the length of arrows after they have been drawn by choosing the **Plot**

Edit  tool, selecting the `quivergroup` object, opening the Property Editor, and adjusting the **Length** slider.

`quiver(...,LineStyle)` specifies line style, marker symbol, and color using any valid `LineStyle`. `quiver` draws the markers at the origin of the vectors.

`quiver(...,LineStyle, 'filled')` fills markers specified by `LineStyle`.

`quiver(axes_handle,...)` plots into the axes with the handle `axes_handle` instead of into the current axes (`gca`).

`h = quiver(...)` returns the handle to the `quivergroup` object.

Backward-Compatible Version

`hlines = quiver('v6',...)` returns the handles of line objects instead of `quivergroup` objects for compatibility with MATLAB 6.5 and earlier.

Note The v6 option enables users of Version 7.x of MATLAB to create FIG-files that previous versions can open. It is obsolete and will be removed in a future version of MATLAB.

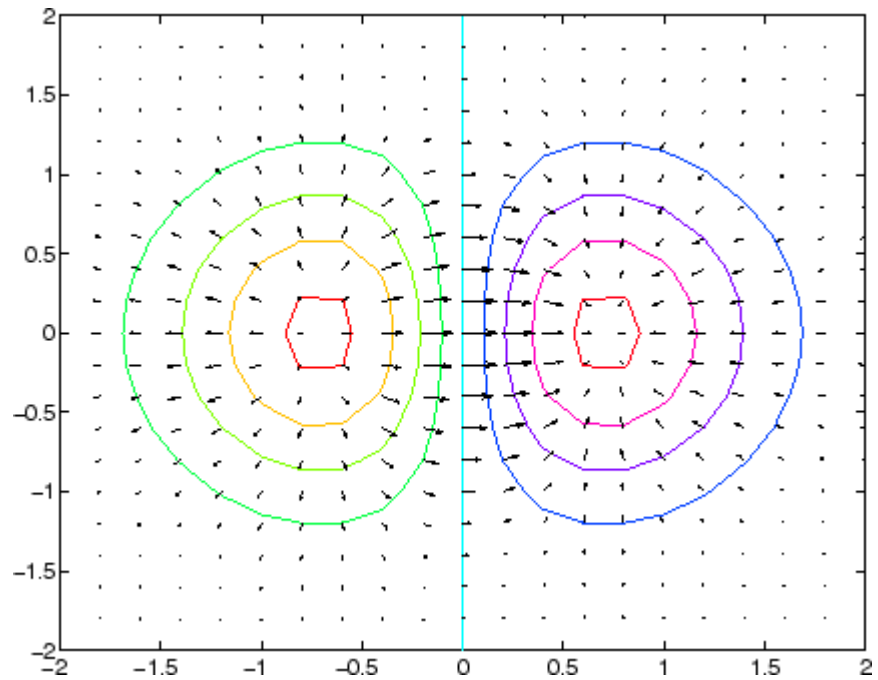
See Plot Objects and Backward Compatibility for more information.

Examples

Showing the Gradient with Quiver Plots

Plot the gradient field of the function $z = xe^{(-x^2 - y^2)}$:

```
[X,Y] = meshgrid(-2:.2:2);  
Z = X.*exp(-X.^2 - Y.^2);  
[DX,DY] = gradient(Z, .2, .2);  
contour(X,Y,Z)  
hold on  
quiver(X,Y,DX,DY)  
colormap hsv  
hold off
```



See Also

`contour`, `LineSpec`, `plot`, `quiver3`

“Direction and Velocity Plots” on page 1-96 for related functions


Two-Dimensional Quiver Plots for more examples

Quivergroup Properties for property descriptions

Purpose 3-D quiver or velocity plot



GUI Alternatives

To graph selected variables, use the Plot Selector  in the Workspace Browser, or use the Figure Palette Plot Catalog. Manipulate graphs in *plot edit* mode with the Property Editor. For details, see Plotting Tools — Interactive Plotting in the MATLAB Graphics documentation and Creating Graphics from the Workspace Browser in the MATLAB Desktop Tools documentation.

Syntax

```
quiver3(x,y,z,u,v,w)
quiver3(z,u,v,w)
quiver3(...,scale)
quiver3(...,LineStyle)
quiver3(...,LineStyle,'filled')
quiver3(axes_handle,...)
h = quiver3(...)
```

Description

A three-dimensional quiver plot displays vectors with components (u,v,w) at the points (x,y,z) , where u,v,w,x,y , and z all have real (non-complex) values.

`quiver3(x,y,z,u,v,w)` plots vectors with components (u,v,w) at the points (x,y,z) . The matrices x,y,z,u,v,w must all be the same size and contain the corresponding position and vector components.

`quiver3(z,u,v,w)` plots the vectors at the equally spaced surface points specified by matrix z . `quiver3` automatically scales the vectors based on the distance between them to prevent them from overlapping.

`quiver3(...,scale)` automatically scales the vectors to prevent them from overlapping, and then multiplies them by `scale`. `scale = 2` doubles their relative length, and `scale = 0.5` halves them. Use `scale = 0` to plot the vectors without the automatic scaling.

quiver3

`quiver3(...,LineStyle)` specifies line type and color using any valid `LineStyle`.

`quiver3(...,LineStyle,'filled')` fills markers specified by `LineStyle`.

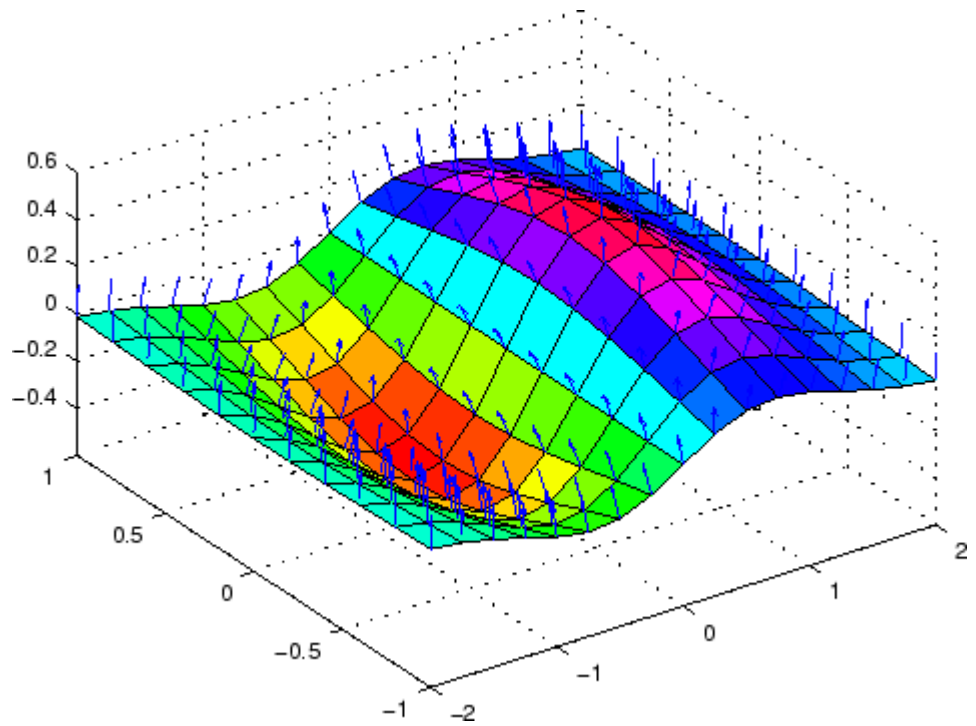
`quiver3(axes_handle,...)` plots into the axes with the handle `axes_handle` instead of into the current axes (`gca`).

`h = quiver3(...)` returns a vector of line handles.

Examples

Plot the surface normals of the function $z = xe^{(-x^2-y^2)}$.

```
[X,Y] = meshgrid(-2:0.25:2,-1:0.2:1);
Z = X.* exp(-X.^2 - Y.^2);
[U,V,W] = surfnorm(X,Y,Z);
quiver3(X,Y,Z,U,V,W,0.5);
hold on
surf(X,Y,Z);
colormap hsv
view(-35,45)
axis ([-2 2 -1 1 -.6 .6])
hold off
```

**See Also**

axis, contour, LineSpec, plot, plot3, quiver, surfnorm, view
“Direction and Velocity Plots” on page 1-96 for related functions
Three-Dimensional Quiver Plots for more examples

Quivergroup Properties

Purpose Define quivergroup properties

Modifying Properties You can set and query graphics object properties using the `set` and `get` commands or the Property Editor (`propertyeditor`).

Note that you cannot define default properties for `areaseries` objects.

See Plot Objects for more information on quivergroup objects.

Quivergroup Property Descriptions This section provides a description of properties. Curly braces `{ }` enclose default values.

Annotation
hg.Annotation object Read Only

Control the display of quivergroup objects in legends. The Annotation property enables you to specify whether this quivergroup object is represented in a figure legend.

Querying the Annotation property returns the handle of an `hg.Annotation` object. The `hg.Annotation` object has a property called `LegendInformation`, which contains an `hg.LegendEntry` object.

Once you have obtained the `hg.LegendEntry` object, you can set its `IconDisplayStyle` property to control whether the quivergroup object is displayed in a figure legend:

IconDisplayStyle Value	Purpose
on	Include the quivergroup object in a legend as one entry, but not its children objects
off	Do not include the quivergroup or its children in a legend (default)
children	Include only the children of the quivergroup as separate entries in the legend

Setting the IconDisplayStyle Property

These commands set the `IconDisplayStyle` of a graphics object with handle `hobj` to `children`, which causes each child object to have an entry in the legend:

```
hAnnotation = get(hobj, 'Annotation');  
hLegendEntry = get(hAnnotation, 'LegendInformation');  
set(hLegendEntry, 'IconDisplayStyle', 'children')
```

Using the IconDisplayStyle Property

See “Controlling Legends” for more information and examples.

AutoScale

{on} | off

Autoscale arrow length. Based on average spacing in the x and y directions, `AutoScale` scales the arrow length to fit within the grid-defined coordinate data and keeps the arrows from overlapping. After autoscaling, quiver applies the `AutoScaleFactor` to the arrow length.

AutoScaleFactor

scalar (default = 0.9)

User-specified scale factor. When `AutoScale` is on, the quiver function applies this user-specified autoscale factor to the arrow length. A value of 2 doubles the length of the arrows; 0.5 halves the length.

BeingDeleted

on | {off} Read Only

This object is being deleted. The `BeingDeleted` property provides a mechanism that you can use to determine if objects are in the process of being deleted. MATLAB sets the `BeingDeleted` property to on when the object’s delete function callback is called

Quivergroup Properties

(see the `DeleteFcn` property). It remains set to `on` while the delete function executes, after which the object no longer exists.

For example, an object's delete function might call other functions that act on a number of different objects. These functions might not need to perform actions on objects if the objects are going to be deleted, and therefore, can check the object's `BeingDeleted` property before acting.

BusyAction
cancel | {queue}

Callback routine interruption. The `BusyAction` property enables you to control how MATLAB handles events that potentially interrupt executing callbacks. If there is a callback function executing, callbacks invoked subsequently always attempt to interrupt it.

If the `Interruptible` property of the object whose callback is executing is set to `on` (the default), then interruption occurs at the next point where the event queue is processed. If the `Interruptible` property is `off`, the `BusyAction` property (of the object owning the executing callback) determines how MATLAB handles the event. The choices are

- `cancel` — Discard the event that attempted to execute a second callback routine.
- `queue` — Queue the event that attempted to execute a second callback routine until the current callback finishes.

ButtonDownFcn
string or function handle

Button press callback function. A callback that executes whenever you press a mouse button while the pointer is over this object, but not over another graphics object. See the `HitTestArea` property for information about selecting objects of this type.

See the figure's `SelectionMode` property to determine if modifier keys were also pressed.

This property can be

- A string that is a valid MATLAB expression
- The name of an M-file
- A function handle

Set this property to a function handle that references the callback. The expressions execute in the MATLAB workspace.

See “Function Handle Callbacks” for information on how to use function handles to define the callbacks.

Children

array of graphics object handles

Children of this object. The handle of a patch object that is the child of this object (whether visible or not).

Note that if a child object's `HandleVisibility` property is set to `callback` or `off`, its handle does not show up in this object's `Children` property unless you set the root `ShowHiddenHandles` property to `on`:

```
set(0, 'ShowHiddenHandles', 'on')
```

Clipping

{on} | off

Clipping mode. MATLAB clips graphs to the axes plot box by default. If you set `Clipping` to `off`, portions of graphs can be displayed outside the axes plot box. This can occur if you create a plot object, set `hold` to `on`, freeze axis scaling (`axis manual`), and then create a larger plot object.

Quivergroup Properties

Color

ColorSpec

Color of the object. A three-element RGB vector or one of the MATLAB predefined names, specifying the object's color.

See the ColorSpec reference page for more information on specifying color.

CreateFcn

string or function handle

Callback routine executed during object creation. This property defines a callback that executes when MATLAB creates an object. You must specify the callback during the creation of the object. For example,

```
area(y, 'CreateFcn', @CallbackFcn)
```

where @CallbackFcn is a function handle that references the callback function.

MATLAB executes this routine after setting all other object properties. Setting this property on an existing object has no effect.

The handle of the object whose CreateFcn is being executed is accessible only through the root CallbackObject property, which you can query using gcbo.

See “Function Handle Callbacks” for information on how to use function handles to define the callback function.

DeleteFcn

string or function handle

Callback executed during object deletion. A callback that executes when this object is deleted (e.g., this might happen when you issue

a `delete` command on the object, its parent axes, or the figure containing it). MATLAB executes the callback before destroying the object's properties so the callback routine can query these values.

The handle of the object whose `DeleteFcn` is being executed is accessible only through the root `CallbackObject` property, which can be queried using `gcbo`.

See “Function Handle Callbacks” for information on how to use function handles to define the callback function.

See the `BeingDeleted` property for related information.

`DisplayName`

string (default is empty string)

String used by legend for this quivergroup object. The legend function uses the string defined by the `DisplayName` property to label this quivergroup object in the legend.

- If you specify string arguments with the legend function, `DisplayName` is set to this quivergroup object's corresponding string and that string is used for the legend.
- If `DisplayName` is empty, legend creates a string of the form, `['data' n]`, where `n` is the number assigned to the object based on its location in the list of legend entries. However, legend does not set `DisplayName` to this string.
- If you edit the string directly in an existing legend, `DisplayName` is set to the edited string.
- If you specify a string for the `DisplayName` property and create the legend using the figure toolbar, then MATLAB uses the string defined by `DisplayName`.
- To add programmatically a legend that uses the `DisplayName` string, call `legend` with the `toggle` or `show` option.

Quivergroup Properties

See “Controlling Legends” for more examples.

EraseMode

{normal} | none | xor | background

Erase mode. This property controls the technique MATLAB uses to draw and erase objects and their children. Alternative erase modes are useful for creating animated sequences, where control of the way individual objects are redrawn is necessary to improve performance and obtain the desired effect.

- **normal** — Redraw the affected region of the display, performing the three-dimensional analysis necessary to ensure that all objects are rendered correctly. This mode produces the most accurate picture, but is the slowest. The other modes are faster, but do not perform a complete redraw and are therefore less accurate.
- **none** — Do not erase objects when they are moved or destroyed. While the objects are still visible on the screen after erasing with EraseMode none, you cannot print these objects because MATLAB stores no information about their former locations.
- **xor** — Draw and erase the object by performing an exclusive OR (XOR) with each pixel index of the screen behind it. Erasing the object does not damage the color of the objects behind it. However, the color of the erased object depends on the color of the screen behind it and it is correctly colored only when it is over the axes background color (or the figure background color if the axes Color property is set to none). That is, it isn’t erased correctly if there are objects behind it.
- **background** — Erase the graphics objects by redrawing them in the axes background color, (or the figure background color if the axes Color property is set to none). This damages other graphics objects that are behind the erased object, but the erased object is always properly colored.

Printing with Nonnormal Erase Modes

MATLAB always prints figures as if the `EraseMode` of all objects is `normal`. This means graphics objects created with `EraseMode` set to `none`, `xor`, or `background` can look different on screen than on paper. On screen, MATLAB can mathematically combine layers of colors (e.g., performing an XOR on a pixel color with that of the pixel behind it) and ignore three-dimensional sorting to obtain greater rendering speed. However, these techniques are not applied to the printed output.

Set the axes background color with the axes `Color` property. Set the figure background color with the figure `Color` property.

You can use the MATLAB `getframe` command or other screen capture applications to create an image of a figure containing nonnormal mode objects.

`HandleVisibility`

`{on} | callback | off`

Control access to object's handle by command-line users and GUIs. This property determines when an object's handle is visible in its parent's list of children. `HandleVisibility` is useful for preventing command-line users from accidentally accessing objects that you need to protect for some reason.

- `on` — Handles are always visible when `HandleVisibility` is `on`.
- `callback` — Setting `HandleVisibility` to `callback` causes handles to be visible from within callback routines or functions invoked by callback routines, but not from within functions invoked from the command line. This provides a means to protect GUIs from command-line users, while allowing callback routines to have access to object handles.
- `off` — Setting `HandleVisibility` to `off` makes handles invisible at all times. This might be necessary when a callback invokes a function that might potentially damage the GUI (such as evaluating a user-typed string) and so temporarily hides its own handles during the execution of that function.

Quivergroup Properties

Functions Affected by Handle Visibility

When a handle is not visible in its parent's list of children, it cannot be returned by functions that obtain handles by searching the object hierarchy or querying handle properties. This includes `get`, `findobj`, `gca`, `gcf`, `gco`, `newplot`, `cla`, `clf`, and `close`.

Properties Affected by Handle Visibility

When a handle's visibility is restricted using `callback` or `off`, the object's handle does not appear in its parent's `Children` property, figures do not appear in the root's `CurrentFigure` property, objects do not appear in the root's `CallbackObject` property or in the figure's `CurrentObject` property, and axes do not appear in their parent's `CurrentAxes` property.

Overriding Handle Visibility

You can set the root `ShowHiddenHandles` property to `on` to make all handles visible regardless of their `HandleVisibility` settings (this does not affect the values of the `HandleVisibility` properties). See also `findall`.

Handle Validity

Handles that are hidden are still valid. If you know an object's handle, you can `set` and `get` its properties and pass it to any function that operates on handles.

Note If you change one data source property to a variable that contains data of a different dimension, you might cause the function to generate a warning and not render the graph until you have changed all data source properties to appropriate values.

HitTest

{on} | off

Selectable by mouse click. HitTest determines whether this object can become the current object (as returned by the `gco` command and the figure `CurrentObject` property) as a result of a mouse click on the objects that compose the area graph. If HitTest is off, clicking this object selects the object below it (which is usually the axes containing it).

HitTestArea

on | {off}

Select the object by clicking lines or area of extent. This property enables you to select plot objects in two ways:

- Select by clicking lines or markers (default).
- Select by clicking anywhere in the extent of the plot.

When HitTestArea is off, you must click the object's lines or markers (excluding the baseline, if any) to select the object. When HitTestArea is on, you can select this object by clicking anywhere within the extent of the plot (i.e., anywhere within a rectangle that encloses it).

Interruptible

{on} | off

Callback routine interruption mode. The Interruptible property controls whether an object's callback can be interrupted by callbacks invoked subsequently.

Only callbacks defined for the `ButtonDownFcn` property are affected by the Interruptible property. MATLAB checks for events that can interrupt a callback only when it encounters a `drawnow`, `figure`, `getframe`, or `pause` command in the routine. See the `BusyAction` property for related information.

Quivergroup Properties

Setting `Interruptible` to on allows any graphics object's callback to interrupt callback routines originating from a bar property. Note that MATLAB does not save the state of variables or the display (e.g., the handle returned by the `gca` or `gcf` command) when an interruption occurs.

LineStyle

{-} | - | : | -. | none

Line style. This property specifies the line style of the object. Available line styles are shown in the following table.

Specifier String	Line Style
-	Solid line (default)
--	Dashed line
:	Dotted line
-. .	Dash-dot line
none	No line

You can use `LineStyle none` when you want to place a marker at each point but do not want the points connected with a line (see the `Marker` property).

LineWidth

scalar

The width of linear objects and edges of filled areas. Specify this value in points (1 point = $\frac{1}{72}$ inch). The default `LineWidth` is 0.5 points.

Marker

character (see table)

Marker symbol. The `Marker` property specifies the type of markers that are displayed at plot vertices. You can set values for the

Marker property independently from the `LineStyle` property. Supported markers include those shown in the following table.

Marker Specifier	Description
+	Plus sign
o	Circle
*	Asterisk
.	Point
x	Cross
s	Square
d	Diamond
^	Upward-pointing triangle
v	Downward-pointing triangle
>	Right-pointing triangle
<	Left-pointing triangle
p	Five-pointed star (pentagram)
h	Six-pointed star (hexagram)
none	No marker (default)

`MarkerEdgeColor`

`ColorSpec` | none | {auto}

Marker edge color. The color of the marker or the edge color for filled markers (circle, square, diamond, pentagram, hexagram, and the four triangles). `ColorSpec` defines the color to use. `none` specifies no color, which makes nonfilled markers invisible. `auto` sets `MarkerEdgeColor` to the same color as the `Color` property.

`MarkerFaceColor`

`ColorSpec` | {none} | auto

Quivergroup Properties

Marker face color. The fill color for markers that are closed shapes (circle, square, diamond, pentagram, hexagram, and the four triangles). ColorSpec defines the color to use. none makes the interior of the marker transparent, allowing the background to show through. auto sets the fill color to the axes color, or to the figure color if the axes Color property is set to none (which is the factory default for axes objects).

MarkerSize
size in points

Marker size. A scalar specifying the size of the marker in points. The default value for MarkerSize is 6 points (1 point = 1/72 inch). Note that MATLAB draws the point marker (specified by the ' .' symbol) at one-third the specified size.

MaxHeadSize
scalar (default = 0.2)

Maximum size of arrowhead. A value determining the maximum size of the arrowhead relative to the length of the arrow.

Parent
handle of parent axes, hggroup, or hgtransform

Parent of this object. This property contains the handle of the object's parent. The parent is normally the axes, hggroup, or hgtransform object that contains the object.

See “Objects That Can Contain Other Objects” for more information on parenting graphics objects.

Selected
on | {off}

Is object selected? When you set this property to on, MATLAB displays selection "handles" at the corners and midpoints if the SelectionHighlight property is also on (the default). You can, for example, define the ButtonDownFcn callback to set this

property to on, thereby indicating that this particular object is selected. This property is also set to on when an object is manually selected in plot edit mode.

SelectionHighlight
{on} | off

Objects are highlighted when selected. When the Selected property is on, MATLAB indicates the selected state by drawing four edge handles and four corner handles. When SelectionHighlight is off, MATLAB does not draw the handles except when in plot edit mode and objects are selected manually.

ShowArrowHead
{on} | off

Display arrowheads on vectors. When this property is on, MATLAB draws arrowheads on the vectors displayed by quiver. When you set this property to off, quiver draws the vectors as lines without arrowheads.

Tag
string

User-specified object label. The Tag property provides a means to identify graphics objects with a user-specified label. This is particularly useful when you are constructing interactive graphics programs that would otherwise need to define object handles as global variables or pass them as arguments between callbacks. You can define Tag as any string.

For example, you might create an areaseries object and set the Tag property.

```
t = area(Y, 'Tag', 'area1')
```

When you want to access objects of a given type, you can use findobj to find the object's handle. The following statement changes the FaceColor property of the object whose Tag is area1.

Quivergroup Properties

```
set(findobj('Tag','area1'),'FaceColor','red')
```

Type

string (read only)

Type of graphics object. This property contains a string that identifies the class of the graphics object. For stem objects, `Type` is `'hggrouop'`. This statement finds all the `hggrouop` objects in the current axes.

```
t = findobj(gca,'Type','hggrouop');
```

UIContextMenu

handle of a `uicontextmenu` object

Associate a context menu with this object. Assign this property the handle of a `uicontextmenu` object created in the object's parent figure. Use the `uicontextmenu` function to create the context menu. MATLAB displays the context menu whenever you right-click over the object.

UserData

array

User-specified data. This property can be any data you want to associate with this object (including cell arrays and structures). The object does not set values for this property, but you can access it using the `set` and `get` functions.

Visible

{on} | off

Visibility of this object and its children. By default, a new object's visibility is on. This means all children of the object are visible unless the child object's `Visible` property is set to `off`. Setting an object's `Visible` property to `off` prevents the object from being displayed. However, the object still exists and you can set and query its properties.

UData

matrix

One dimension of 2-D or 3-D vector components. UData, VData, and WData, together specify the components of the vectors displayed as arrows in the quiver graph. For example, the first vector is defined by components `UData(1)`, `VData(1)`, `WData(1)`.

UDataSource

string (MATLAB variable)

Link UData to MATLAB variable. Set this property to a MATLAB variable that, by default, is evaluated in the base workspace to generate the UData.

MATLAB reevaluates this property only when you set it. Therefore, a change to workspace variables appearing in an expression does not change UData.

You can use the `refreshdata` function to force an update of the object's data. `refreshdata` also enables you to specify that the data source variable be evaluated in the workspace of a function from which you call `refreshdata`.

See the `refreshdata` reference page for more information.

Note If you change one data source property to return data of a different dimension, you might cause the function to generate a warning and not render the graph until you have changed all data source properties to appropriate values.

VData

matrix

Quivergroup Properties

One dimension of 2-D or 3-D vector components. UData, VData and WData (for 3-D) together specify the components of the vectors displayed as arrows in the quiver graph. For example, the first vector is defined by components UData(1),VData(1),WData(1).

VDataSource
string (MATLAB variable)

Link VData to MATLAB variable. Set this property to a MATLAB variable that, by default, is evaluated in the base workspace to generate the VData.

MATLAB reevaluates this property only when you set it. Therefore, a change to workspace variables appearing in an expression does not change VData.

You can use the refreshdata function to force an update of the object's data. refreshdata also enables you to specify that the data source variable be evaluated in the workspace of a function from which you call refreshdata.

See the refreshdata reference page for more information.

Note If you change one data source property to return data of a different dimension, you might cause the function to generate a warning and not render the graph until you have changed all data source properties to appropriate values.

WData
matrix

One dimension of 2-D or 3-D vector components. UData, VData and WData (for 3-D) together specify the components of the vectors displayed as arrows in the quiver graph. For example, the first vector is defined by components UData(1),VData(1),WData(1).

WDataSource

string (MATLAB variable)

Link WData to MATLAB variable. Set this property to a MATLAB variable that, by default, is evaluated in the base workspace to generate the WData.

MATLAB reevaluates this property only when you set it. Therefore, a change to workspace variables appearing in an expression does not change WData.

You can use the `refreshdata` function to force an update of the object's data. `refreshdata` also enables you to specify that the data source variable be evaluated in the workspace of a function from which you call `refreshdata`.

See the `refreshdata` reference page for more information.

Note If you change one data source property to return data of a different dimension, you might cause the function to generate a warning and not render the graph until you have changed all data source properties to appropriate values.

XData

vector or matrix

X-axis coordinates of arrows. The `quiver` function draws an individual arrow at each *x*-axis location in the XData array. XData can be either a matrix equal in size to all other data properties or for 2-D, a vector equal in length to the number of columns in UData or VData. That is, `length(XData) == size(UData,2)`.

If you do not specify XData (i.e., the input argument X), the `quiver` function uses the indices of UData to create the quiver graph. See the XDataMode property for related information.

Quivergroup Properties

XDataMode

{auto} | manual

Use automatic or user-specified x-axis values. If you specify XData (by setting the XData property or specifying the input argument X), the quiver function sets this property to manual.

If you set XDataMode to auto after having specified XData, the quiver function resets the x tick-mark labels to the indices of the U, V, and W data, overwriting any previous values.

XDataSource

string (MATLAB variable)

Link XData to MATLAB variable. Set this property to a MATLAB variable that is evaluated in the base workspace to generate the XData.

MATLAB reevaluates this property only when you set it. Therefore, a change to workspace variables appearing in an expression does not change XData.

You can use the refreshdata function to force an update of the object's data. refreshdata also enables you to specify that the data source variable be evaluated in the workspace of a function from which you call refreshdata.

See the refreshdata reference page for more information.

Note If you change one data source property to a variable that contains data of a different dimension, you might cause the function to generate a warning and not render the graph until you have changed all data source properties to appropriate values.

YData

vector or matrix

Y-axis coordinates of arrows. The quiver function draws an individual arrow at each *y*-axis location in the YData array. YData can be either a matrix equal in size to all other data properties or for 2-D, a vector equal in length to the number of rows in UData or VData. That is, `length(YData) == size(UData,1)`.

If you do not specify YData (i.e., the input argument Y), the quiver function uses the indices of VData to create the quiver graph. See the YDataMode property for related information.

The input argument *y* in the quiver function calling syntax assigns values to YData.

YDataMode

{auto} | manual

Use automatic or user-specified y-axis values. If you specify YData (by setting the YData property or specifying the input argument Y), MATLAB sets this property to manual.

If you set YDataMode to auto after having specified YData, MATLAB resets the *y* tick-mark labels to the indices of the U, V, and W data, overwriting any previous values.

YDataSource

string (MATLAB variable)

Link YData to MATLAB variable. Set this property to a MATLAB variable that is evaluated in the base workspace to generate the YData.

MATLAB reevaluates this property only when you set it. Therefore, a change to workspace variables appearing in an expression does not change YData.

Quivergroup Properties

You can use the `refreshdata` function to force an update of the object's data. `refreshdata` also enables you to specify that the data source variable be evaluated in the workspace of a function from which you call `refreshdata`.

See the `refreshdata` reference page for more information.

Note If you change one data source property to a variable that contains data of a different dimension, you might cause the function to generate a warning and not render the graph until you have changed all data source properties to appropriate values.

ZData

vector or matrix

Z-axis coordinates of arrows. The `quiver` function draws an individual arrow at each *z*-axis location in the `ZData` array. `ZData` must be a matrix equal in size to `XData` and `YData`.

The input argument `z` in the `quiver3` function calling syntax assigns values to `ZData`.

Purpose

QZ factorization for generalized eigenvalues

Syntax

```
[AA, BB, Q, Z] = qz(A, B)
[AA, BB, Q, Z, V, W] = qz(A, B)
qz(A, B, flag)
```

Description

The qz function gives access to intermediate results in the computation of generalized eigenvalues.

`[AA, BB, Q, Z] = qz(A, B)` for square matrices A and B , produces upper quasitriangular matrices AA and BB , and unitary matrices Q and Z such that $Q^*A^*Z = AA$, and $Q^*B^*Z = BB$. For complex matrices, AA and BB are triangular.

`[AA, BB, Q, Z, V, W] = qz(A, B)` also produces matrices V and W whose columns are generalized eigenvectors.

`qz(A, B, flag)` for real matrices A and B , produces one of two decompositions depending on the value of `flag`:

'complex'	Produces a possibly complex decomposition with a triangular AA . For compatibility with earlier versions, 'complex' is the default.
'real'	Produces a real decomposition with a quasitriangular AA , containing 1-by-1 and 2-by-2 blocks on its diagonal.

If AA is triangular, the diagonal elements of AA and BB , $\alpha = \text{diag}(AA)$ and $\beta = \text{diag}(BB)$, are the generalized eigenvalues that satisfy

$$A^*V*\beta = B^*V*\alpha$$

$$\beta^*W'^*A = \alpha^*W'^*B$$

The eigenvalues produced by

$$\lambda = \text{eig}(A, B)$$

are the ratios of the α s and β s.

$$\lambda = \alpha./\beta$$

If AA is not triangular, it is necessary to further reduce the 2-by-2 blocks to obtain the eigenvalues of the full system.

Algorithm

For full matrices A and B , qz uses the LAPACK routines listed in the following table.

	A and B Real	A or B Complex
A and B double	DGGES, DTGEVC (if you request the fifth output V)	ZGGES, ZTGEVC (if you request the fifth output V)
A or B single	SGGES, STGEVC (if you request the fifth output V)	CGGES, CTGEVC (if you request the fifth output V)

See Also

eig

References

[1] Anderson, E., Z. Bai, C. Bischof, S. Blackford, J. Demmel, J. Dongarra, J. Du Croz, A. Greenbaum, S. Hammarling, A. McKenney, and D. Sorensen, *LAPACK User's Guide* (http://www.netlib.org/lapack/lug/lapack_lug.html), Third Edition, SIAM, Philadelphia, 1999.

Purpose

Uniformly distributed pseudorandom numbers

Syntax

```
r = rand(n)
rand(m,n)
rand([m,n])
rand(m,n,p,...)
rand([m,n,p,...])
rand
rand(size(A))
r = rand(..., 'double')
r = rand(..., 'single')
```

Description

`r = rand(n)` returns an n -by- n matrix containing pseudorandom values drawn from the standard uniform distribution on the open interval $(0,1)$. `rand(m,n)` or `rand([m,n])` returns an m -by- n matrix. `rand(m,n,p,...)` or `rand([m,n,p,...])` returns an m -by- n -by- p -by-... array. `rand` returns a scalar. `rand(size(A))` returns an array the same size as `A`. `r = rand(..., 'double')` or `r = rand(..., 'single')` returns an array of uniform values of the specified class.

Note Note: The size inputs `m`, `n`, `p`, ... should be nonnegative integers. Negative integers are treated as 0.

The sequence of numbers produced by `rand` is determined by the internal state of the uniform pseudorandom number generator that underlies `rand`, `randi`, and `randn`. The default random number stream properties can be set using `@RandStream` methods. See `@RandStream` for details about controlling the default stream.

Resetting the default stream to the same fixed state allows computations to be repeated. Setting the stream to different states leads to unique computations, however, it does not improve any statistical properties. Since the random number generator is initialized to the same state every time MATLAB software starts up, `rand`, `randn`, and `randi` will

rand

generate the same sequence of numbers in each session until the state is changed.

Note In versions of MATLAB prior to 7.7, you controlled the internal state of the random number stream used by `rand` by calling `rand` directly with the `'seed'`, `'state'`, or `'twister'` keywords. That syntax is still supported for backwards compatibility, but is deprecated. For version 7.7, use the default stream as described in the `@RandStream` reference documentation.

Examples

Generate values from the uniform distribution on the interval $[a, b]$.

```
r = a + (b-a).*rand(100,1);
```

Replace the default stream at MATLAB startup, using a stream whose seed is based on `clock`, so that `rand` will return different values in different MATLAB sessions. It is usually not desirable to do this more than once per MATLAB session.

```
RandStream.setDefaultStream  
    (RandStream('mt19937ar','seed',sum(100*clock)));  
rand(1,5)
```

Save the current state of the default stream, generate 5 values, restore the state, and repeat the sequence.

```
defaultStream = RandStream.getDefaultStream;  
savedState = defaultStream.State;  
u1 = rand(1,5)  
defaultStream.State = savedState;  
u2 = rand(1,5) % contains exactly the same values as u1
```

See Also

`randi`, `randn`, `@RandStream`, `rand` (`RandStream`), `getDefaultStream` (`RandStream`), `sprand`, `sprandn`, `randperm`

Purpose Uniformly distributed random numbers

Class @RandStream

Syntax

```
r = rand(s,n)
rand(s,m,n)
rand(s,[m,n])
rand(s,m,n,p,...)
rand(s,[m,n,p,...])
rand(s)
rand(s,size(A))
r = rand(..., 'double')
r = rand(..., 'single')
```

Description

`r = rand(s,n)` returns an n -by- n matrix containing pseudorandom values drawn from the standard uniform distribution on the open interval (0,1). The values are drawn from the random stream `s`. `rand(s,m,n)` or `rand(s,[m,n])` returns an m -by- n matrix. `rand(s,m,n,p,...)` or `rand(s,[m,n,p,...])` returns an m -by- n -by- p -by-... array. `rand(s)` returns a scalar. `rand(s,size(A))` returns an array the same size as `A`.

`r = rand(..., 'double')` or `r = rand(..., 'single')` returns an array of uniform values of the specified class.

Note The size inputs `m`, `n`, `p`, ... should be nonnegative integers. Negative integers are treated as 0.

The sequence of numbers produced by `rand` is determined by the internal state of the random number stream `s`. Resetting that stream to the same fixed state allows computations to be repeated. Setting the stream to different states leads to unique computations, however, it does not improve any statistical properties.

rand (RandStream)

See Also

rand, @RandStream, randi (RandStream), randn (RandStream),
randperm (RandStream)

Purpose

Uniformly distributed pseudorandom integers

Syntax

```
randi(imax)
r = randi(imax,n)
randi(imax,m,n)
randi(imax,[m,n])
randi(imax,m,n,p,...)
randi(imax,[m,n,p,...])
randi(imax,size(A))
r = randi([imin,imax],...)
r = randi(..., classname)
```

Description

`randi(imax)` returns a random integer on the interval `1:imax`. `r = randi(imax,n)` returns an `n`-by-`n` matrix containing pseudorandom integer values drawn from the discrete uniform distribution on `1:imax`. `randi(imax,m,n)` or `randi(imax,[m,n])` returns an `m`-by-`n` matrix. `randi(imax,m,n,p,...)` or `randi(imax,[m,n,p,...])` returns an `m`-by-`n`-by-`p`-by-... array. `randi(imax,size(A))` returns an array the same size as `A`.

`r = randi([imin,imax],...)` returns an array containing integer values drawn from the discrete uniform distribution on `imin:imax`.

`r = randi(..., classname)` returns an array of integer values of class `classname`. `classname` does not support 64-bit integers.

Note Note: The size inputs `m`, `n`, `p`, ... should be nonnegative integers. Negative integers are treated as 0.

The sequence of numbers produced by `randi` is determined by the internal state of the uniform pseudorandom number generator that underlies `rand`, `randi`, and `randn`. `randi` uses one uniform value from that default stream to generate each integer value. Control the default stream using its properties and methods. See `@RandStream` for details about the default stream.

Resetting the default stream to the same fixed state allows computations to be repeated. Setting the stream to different states leads to unique computations, however, it does not improve any statistical properties. Since the random number generator is initialized to the same state every time MATLAB software starts up, `rand`, `randn`, and `randi` will generate the same sequence of numbers in each session until the state is changed.

Examples

Generate integer values from the uniform distribution on the set 1:10.

```
r = randi(10,100,1);
```

Generate an integer array of integers drawn uniformly from 1:10.

```
r = randi(10,100,1,'uint32');
```

Generate integer values drawn uniformly from -10:10.

```
r = randi([-10 10],100,1);
```

Replace the default stream at MATLAB startup, using a stream whose seed is based on `clock`, so that `randi` will return different values in different MATLAB sessions. It is usually not desirable to do this more than once per MATLAB session.

```
RandStream.setDefaultStream  
    (RandStream('mt19937ar','seed',sum(100*clock)));  
randi(100,1,5)
```

Save the current state of the default stream, generate 5 integer values, restore the state, and repeat the sequence.

```
defaultStream = RandStream.getDefaultStream;  
savedState = defaultStream.State;  
i1 = randi(10,1,5)  
defaultStream.State = savedState;  
i2 = randi(10,1,5) %contains exactly the same values as i1
```

See Also

rand, randn, @RandStream, randi (RandStream), getDefaultStream (RandStream)

randi (RandStream)

Purpose Uniformly distributed pseudorandom integers

Class @RandStream

Syntax

```
r = randi(s,imax,n)
randi(s,imax,m,n)
randi(s,imax,[m,n])
randi(s,imax,m,n,p,...)
randi(s,imax,[m,n,p,...])
randi(s,imax)
randi(s,imax,size(A))
r = randi(s,[imin,imax],...)
r = randi(..., classname)
```

Description

`r = randi(s,imax,n)` returns an n -by- n matrix containing pseudorandom integer values drawn from the discrete uniform distribution on $1:imax$. `randi` draws those values from the random stream `s`. `randi(s,imax,m,n)` or `randi(s,imax,[m,n])` returns an m -by- n matrix. `randi(s,imax,m,n,p,...)` or `randi(s,imax,[m,n,p,...])` returns an m -by- n -by- p -by-... array. `randi(s,imax)` returns a scalar. `randi(s,imax,size(A))` returns an array the same size as `A`.

`r = randi(s,[imin,imax],...)` returns an array containing integer values drawn from the discrete uniform distribution on $imin:imax$.

`r = randi(..., classname)` returns an array of integer values of class `classname`. `classname` does not support 64-bit integers.

Note The size inputs `m`, `n`, `p`, ... should be nonnegative integers. Negative integers are treated as 0.

The sequence of numbers produced by `randi` is determined by the internal state of the random stream `s`. `randi` uses one uniform value from `s` to generate each integer value. Resetting `s` to the same fixed

state allows computations to be repeated. Setting the stream to different states leads to unique computations, however, it does not improve any statistical properties.

See Also

rand, @RandStream, rand (RandStream), randn (RandStream),
randperm (RandStream)

randn

Purpose Normally distributed pseudorandom numbers

Syntax

```
r = randn(n)
randn(m,n)
randn([m,n])
randn(m,n,p,...)
randn([m,n,p,...])
randn(size(A))
r = randn(..., 'double')
r = randn(..., 'single')
```

Description `r = randn(n)` returns an n-by-n matrix containing pseudorandom values drawn from the standard normal distribution. `randn(m,n)` or `randn([m,n])` returns an m-by-n matrix. `randn(m,n,p,...)` or `randn([m,n,p,...])` returns an m-by-n-by-p-by-... array. `randn` returns a scalar. `randn(size(A))` returns an array the same size as A.

`r = randn(..., 'double')` or `r = randn(..., 'single')` returns an array of normal values of the specified class.

Note The size inputs `m`, `n`, `p`, ... should be nonnegative integers. Negative integers are treated as 0.

The sequence of numbers produced by `randn` is determined by the internal state of the uniform pseudorandom number generator that underlies `rand`, `randi`, and `randn`. `randn` uses one or more uniform values from that default stream to generate each normal value. Control the default stream using its properties and methods. See `@RandStream` for details about the default stream.

Resetting the default stream to the same fixed state allows computations to be repeated. Setting the stream to different states leads to unique computations, however, it does not improve any statistical properties. Since the random number generator is initialized to the same state every time MATLAB software starts up, `rand`, `randn`, and `randi` will

generate the same sequence of numbers in each session until the state is changed.

Note In versions of MATLAB prior to 7.7, you controlled the internal state of the random number stream used by `randn` by calling `randn` directly with the `'seed'` or `'state'` keywords. That syntax is still supported for backwards compatibility, but is deprecated. For version 7.7, use the default stream as described in the `@RandStream` reference documentation.

Examples

Generate values from a normal distribution with mean 1 and standard deviation 2.

```
r = 1 + 2.*randn(100,1);
```

Generate values from a bivariate normal distribution with specified mean vector and covariance matrix.

```
mu = [1 2];  
Sigma = [1 .5; .5 2]; R = chol(Sigma);  
z = repmat(mu,100,1) + randn(100,2)*R;
```

Replace the default stream at MATLAB startup, using a stream whose seed is based on `clock`, so that `randn` will return different values in different MATLAB sessions. It is usually not desirable to do this more than once per MATLAB session.

```
RandStream.setDefaultStream  
    (RandStream('mt19937ar', 'seed', sum(100*clock)));  
randn(1,5)
```

Save the current state of the default stream, generate 5 values, restore the state, and repeat the sequence.

```
defaultStream = RandStream.getDefaultStream;  
savedState = defaultStream.State;
```

randn

```
z1 = randn(1,5)
defaultStream.State = savedState;
z2 = randn(1,5) % contains exactly the same values as z1
```

See Also

rand, randi, @RandStream, randn (RandStream), getDefaultStream (RandStream)

Purpose Normally distributed pseudorandom numbers

Class @RandStream

Syntax

```
randn(s,m,n)
randn(s,[m,n])
randn(s,m,n,p,...)
randn(s,[m,n,p,...])
randn(s)
randn(s,size(A))
r = randn(..., 'double')
r = randn(..., 'single')
```

Description

`r = randn(s,n)` returns an n -by- n matrix containing pseudorandom values drawn from the standard normal distribution. `randn` draws those values from the random stream `s`. `randn(s,m,n)` or `randn(s,[m,n])` returns an m -by- n matrix. `randn(s,m,n,p,...)` or `randn(s,[m,n,p,...])` returns an m -by- n -by- p -by-... array. `randn(s)` returns a scalar. `randn(s,size(A))` returns an array the same size as `A`.

`r = randn(..., 'double')` or `r = randn(..., 'single')` returns an array of uniform values of the specified class.

Note The size inputs `m`, `n`, `p`, ... should be nonnegative integers. Negative integers are treated as 0.

The sequence of numbers produced by `randn` is determined by the internal state of the random stream `s`. `randn` uses one or more uniform values from `s` to generate each normal value. Resetting that stream to the same fixed state allows computations to be repeated. Setting the stream to different states leads to unique computations, however, it does not improve any statistical properties.

See Also `randn`, `@RandStream`, `rand` (RandStream), `randi` (RandStream)

randperm

Purpose Random permutation

Syntax `p = randperm(n)`

Description `p = randperm(n)` returns a random permutation of the integers `1:n`.

Remarks The `randperm` function calls `rand` and therefore changes the state of the default random number stream.

Examples `randperm(6)` might be the vector

```
[3 2 6 4 1 5]
```

or it might be some other permutation of `1:6`.

See Also `permute`

Class @RandStream

Syntax randperm(s,n)

Description randperm(s,n) generates a random permutation of the integers from 1 to n. For example, randperm(s,6) might be [2 4 5 6 1 3]. randperm(s,n) uses random values drawn from the random number stream s.

See Also permute, @RandStream

RandStream

Purpose Random number stream

Constructor RandStream (RandStream)

Description Pseudorandom numbers in MATLAB come from one or more random number streams. The simplest way to generate arrays of random numbers is to use `rand`, `randn`, or `randi`. These functions all rely on the same stream of uniform random numbers, known as the default stream. You can create other stream objects that act separately from the default stream, and you can use their `rand`, `randi`, or `randn` methods to generate arrays of random numbers. You can also create a random number stream and make it the default stream.

To create a single random number stream, use either the `RandStream` constructor or the `RandStream.create` factory method. To create multiple independent random number streams, use `RandStream.create`.

`stream = RandStream.getDefaultStream` returns the default random number stream, that is, the one currently used by the `rand`, `randi`, and `randn` functions.

`prevstream = RandStream.setDefaultStream(stream)` returns the current default stream, and designates the random number stream `stream` as the new default to be used by the `rand`, `randi`, and `randn` functions.

A random number stream `s` has properties that control its behavior. Access or assign to a property using `p= s.Property` or `s.Property = p`. The following table lists defined properties:

Properties

Property	Description
Type	(Read-only) Generator algorithm used by the stream. The list of possible generators is given by <code>RandStream.list</code> .

Property	Description
Seed	(Read-only) Seed value used to create the stream.
NumStreams	(Read-only) Number of streams in the group in which the current stream was created.
StreamIndex	(Read-only) Index of the current stream from among the group of streams with which it was created.
State	Internal state of the generator. You should not depend on the format of this property. The value you assign to <code>S.State</code> must be a value read from <code>S.State</code> previously.
Substream	Index of the substream to which the stream is currently set. The default is 1. Multiple substreams are not supported by all generator types; the multiplicative lagged Fibonacci generator (<code>m1fg6331_64</code>) and combined multiple recursive generator (<code>mrg32k3a</code>) support multiple streams.
RandnAlg	Algorithm used by <code>randn(s, ...)</code> to generate normal pseudorandom values. Possible values are 'Ziggurat', 'Polar', or 'Inversion'.

RandStream

Property	Description
Antithetic	Logical value indicating whether S generates antithetic pseudorandom values. For uniform values, these are the usual values subtracted from 1. The default is false.
FullPrecision	Logical value indicating whether S generates values using its full precision. Some generators can create pseudorandom values faster, but with fewer random bits, if FullPrecision is false. The default is true.

Methods

Method	Description
RandStream	Create a random number stream
create	Create multiple independent random number streams
get	Get the properties of a random stream object
list	List available random number generator algorithms
getDefaultStream	Get the default random number stream
setDefaultStream	Set the default random number stream
reset	Reset a stream to its initial internal state

Method	Description
rand	Pseudorandom numbers from a uniform distribution
randn	Pseudorandom numbers from a standard normal distribution
randi	Pseudorandom integers from a uniform discrete distribution
randperm	Random permutation of a set of values

See Also

rand, randn, randi, rand (RandStream), randn (RandStream), randi (RandStream)

RandStream (RandStream)

Purpose Random number stream

Class @RandStream

Syntax
`s = RandStream('gentype')`
`[...] = RandStream('gentype', 'param1', val1, 'param2', val2, ...)`

Description `s = RandStream('gentype')` creates a random number stream that uses the uniform pseudorandom number generator algorithm specified by `gentype`. `[...] = RandStream('gentype', 'param1', val1, 'param2', val2, ...)` allows you to specify optional parameter name/value pairs to control creation of the stream. Options for `gentype` are given by `RandStream.list`.

Parameters are for `RandStream` are:

Parameter	Description
Seed	Nonnegative scalar integer with which to initialize all streams. Default is 0. Seeds must be an integer between 0 and .
RandnAlg	Algorithm used by <code>randn(s, ...)</code> to generate normal pseudorandom values. Possible values are 'Ziggurat', 'Polar', or 'Inversion'.

Examples Construct a random stream object using the combined multiple recursive generator and generate 5 uniformly distributed values from that stream.

```
stream=RandStream('mrg32k3a');  
rand(stream,1,5)
```

Construct a random stream object using the multiplicative lagged Fibonacci generator and generate 5 normally distributed values using the polar algorithm.

```
stream=RandStream('mlfg6331_64','RandnAlg','Polar');  
randn(stream,1,5)
```

See Also

@RandStream, rand (RandStream), randn (RandStream), randi (RandStream), getDefaultStream (RandStream)

rank

Purpose Rank of matrix

Syntax `k = rank(A)`
`k = rank(A,tol)`

Description The rank function provides an estimate of the number of linearly independent rows or columns of a full matrix.

`k = rank(A)` returns the number of singular values of A that are larger than the default tolerance, `max(size(A))*eps(norm(A))`.

`k = rank(A,tol)` returns the number of singular values of A that are larger than `tol`.

Remark Use `sprank` to determine the structural rank of a sparse matrix.

Algorithm There are a number of ways to compute the rank of a matrix. MATLAB software uses the method based on the singular value decomposition, or SVD. The SVD algorithm is the most time consuming, but also the most reliable.

The rank algorithm is

```
s = svd(A);  
tol = max(size(A))*eps(max(s));  
r = sum(s > tol);
```

See Also `sprank`

References [1] Anderson, E., Z. Bai, C. Bischof, S. Blackford, J. Demmel, J. Dongarra, J. Du Croz, A. Greenbaum, S. Hammarling, A. McKenney, and D. Sorensen, *LAPACK User's Guide* (http://www.netlib.org/lapack/lug/lapack_lug.html), Third Edition, SIAM, Philadelphia, 1999.

Purpose Rational fraction approximation

Syntax

```
[N,D] = rat(X)
[N,D] = rat(X,tol)
rat(X)
S = rats(X,strlen)
S = rats(X)
```

Description Even though all floating-point numbers are rational numbers, it is sometimes desirable to approximate them by simple rational numbers, which are fractions whose numerator and denominator are small integers. The `rat` function attempts to do this. Rational approximations are generated by truncating continued fraction expansions. The `rats` function calls `rat`, and returns strings.

`[N,D] = rat(X)` returns arrays `N` and `D` so that `N./D` approximates `X` to within the default tolerance, `1.e-6*norm(X(:),1)`.

`[N,D] = rat(X,tol)` returns `N./D` approximating `X` to within `tol`.

`rat(X)`, with no output arguments, simply displays the continued fraction.

`S = rats(X,strlen)` returns a string containing simple rational approximations to the elements of `X`. Asterisks are used for elements that cannot be printed in the allotted space, but are not negligible compared to the other elements in `X`. `strlen` is the length of each string element returned by the `rats` function. The default is `strlen = 13`, which allows 6 elements in 78 spaces.

`S = rats(X)` returns the same results as those printed by MATLAB with `format rat`.

Examples Ordinarily, the statement

```
s = 1 - 1/2 + 1/3 - 1/4 + 1/5 - 1/6 + 1/7
```

produces

```
s =
```

rat, rats

```
0.7595
```

However, with

```
format rat
```

or with

```
rats(s)
```

the printed result is

```
s =  
319/420
```

This is a simple rational number. Its denominator is 420, the least common multiple of the denominators of the terms involved in the original expression. Even though the quantity s is stored internally as a binary floating-point number, the desired rational form can be reconstructed.

To see how the rational approximation is generated, the statement `rat(s)` produces

```
1 + 1/(-4 + 1/(-6 + 1/(-3 + 1/(-5))))
```

And the statement

```
[n,d] = rat(s)
```

produces

```
n = 319, d = 420
```

The mathematical quantity π is certainly not a rational number, but the MATLAB quantity `pi` that approximates it is a rational number. `pi` is the ratio of a large integer and 2^{52} :

```
14148475504056880/4503599627370496
```

However, this is not a simple rational number. The value printed for pi with `format rat`, or with `rats(pi)`, is

355/113

This approximation was known in Euclid's time. Its decimal representation is

3.14159292035398

and so it agrees with pi to seven significant figures. The statement

`rat(pi)`

produces

3 + 1/(7 + 1/(16))

This shows how the 355/113 was obtained. The less accurate, but more familiar approximation 22/7 is obtained from the first two terms of this continued fraction.

Algorithm

The `rat(X)` function approximates each element of X by a continued fraction of the form

$$\frac{n}{d} = d_1 + \frac{1}{d_2 + \frac{1}{\left(d_3 + \dots + \frac{1}{d_k}\right)}}$$

The d s are obtained by repeatedly picking off the integer part and then taking the reciprocal of the fractional part. The accuracy of the approximation increases exponentially with the number of terms and is worst when $X = \text{sqrt}(2)$. For $x = \text{sqrt}(2)$, the error with k terms is about $2.68 * (.173)^k$, so each additional term increases the accuracy by less than one decimal digit. It takes 21 terms to get full floating-point accuracy.

rat, rats

See Also

format

Purpose	Create rubberband box for area selection
Syntax	<pre>rbbox rbbox(initialRect) rbbox(initialRect, fixedPoint) rbbox(initialRect, fixedPoint, stepSize) finalRect = rbbox(...)</pre>
Description	<p><code>rbbox</code> initializes and tracks a rubberband box in the current figure. It sets the initial rectangular size of the box to 0, anchors the box at the figure's <code>CurrentPoint</code>, and begins tracking from this point.</p> <p><code>rbbox(initialRect)</code> specifies the initial location and size of the rubberband box as <code>[x y width height]</code>, where <code>x</code> and <code>y</code> define the lower left corner, and <code>width</code> and <code>height</code> define the size. <code>initialRect</code> is in the units specified by the current figure's <code>Units</code> property, and measured from the lower left corner of the figure window. The corner of the box closest to the pointer position follows the pointer until <code>rbbox</code> receives a button-up event.</p> <p><code>rbbox(initialRect, fixedPoint)</code> specifies the corner of the box that remains fixed. All arguments are in the units specified by the current figure's <code>Units</code> property, and measured from the lower left corner of the figure window. <code>fixedPoint</code> is a two-element vector, <code>[x y]</code>. The tracking point is the corner diametrically opposite the anchored corner defined by <code>fixedPoint</code>.</p> <p><code>rbbox(initialRect, fixedPoint, stepSize)</code> specifies how frequently the rubberband box is updated. When the tracking point exceeds <code>stepSize</code> figure units, <code>rbbox</code> redraws the rubberband box. The default <code>stepSize</code> is 1.</p> <p><code>finalRect = rbbox(...)</code> returns a four-element vector, <code>[x y width height]</code>, where <code>x</code> and <code>y</code> are the <code>x</code> and <code>y</code> components of the lower left corner of the box, and <code>width</code> and <code>height</code> are the dimensions of the box.</p>
Remarks	<code>rbbox</code> is useful for defining and resizing a rectangular region:

- For box definition, `initialRect` is `[x y 0 0]`, where `(x,y)` is the figure's `CurrentPoint`.
- For box resizing, `initialRect` defines the rectangular region that you resize (e.g., a legend). `fixedPoint` is the corner diametrically opposite the tracking point.

`rbbox` returns immediately if a button is not currently pressed. Therefore, you use `rbbox` with `waitforbuttonpress` so that the mouse button is down when `rbbox` is called. `rbbox` returns when you release the mouse button.

Examples

Assuming the current view is `view(2)`, use the current axes' `CurrentPoint` property to determine the extent of the rectangle in dataspace units:

```
k = waitforbuttonpress;
point1 = get(gca, 'CurrentPoint');    % button down detected
finalRect = rbbox;                   % return figure units
point2 = get(gca, 'CurrentPoint');    % button up detected
point1 = point1(1,1:2);              % extract x and y
point2 = point2(1,1:2);
p1 = min(point1,point2);              % calculate locations
offset = abs(point1-point2);          % and dimensions
x = [p1(1) p1(1)+offset(1) p1(1)+offset(1) p1(1) p1(1)];
y = [p1(2) p1(2) p1(2)+offset(2) p1(2)+offset(2) p1(2)];
hold on
axis manual
plot(x,y)                             % redraw in dataspace units
```

See Also

`axis`, `dragrect`, `waitforbuttonpress`

“View Control” on page 1-106 for related functions

Purpose Matrix reciprocal condition number estimate

Syntax `c = rcond(A)`

Description `c = rcond(A)` returns an estimate for the reciprocal of the condition of A in 1-norm using the LAPACK condition estimator. If A is well conditioned, `rcond(A)` is near 1.0. If A is badly conditioned, `rcond(A)` is near 0.0. Compared to `cond`, `rcond` is a more efficient, but less reliable, method of estimating the condition of a matrix.

Algorithm For full matrices A , `rcond` uses the LAPACK routines listed in the following table to compute the estimate of the reciprocal condition number.

	Real	Complex
A double	DLANGE, DGETRF, DGECON	ZLANGE, ZGETRF, ZGECON
A single	SLANGE, SGETRF, SGECON	CLANGE, CGETRF, CGECON

See Also `cond`, `condest`, `norm`, `normest`, `rank`, `svd`

References [1] Anderson, E., Z. Bai, C. Bischof, S. Blackford, J. Demmel, J. Dongarra, J. Du Croz, A. Greenbaum, S. Hammarling, A. McKenney, and D. Sorensen, *LAPACK User's Guide* (http://www.netlib.org/lapack/lug/lapack_lug.html), Third Edition, SIAM, Philadelphia, 1999.

read

Purpose Read video frame data from multimedia reader object

Syntax
`video = read(obj)`
`video = read(obj, index)`

Description `video = read(obj)` reads in video frames from the associated file. `video` is an H-by-W-by-B-by-F matrix where H is the image frame height, W is the image frame width, B is the number of bands in the image (e.g., 3 for RGB), and F is the number of frames read in. The default behavior is to read in all frames unless an index is specified. The type of data returned is always UINT8 data representing RGB24 video frames.

`video = read(obj, index)` performs the same operation, but reads only the frame(s) specified by `index`, where the first frame number is 1. `index` can be a single index, or a two-element array representing an index range of the video stream.

For example, read only the first frame:

```
video = read(obj, 1);
```

Read the first 10 frames:

```
video = read(obj, [1 10]);
```

You can use `Inf` to represent the last frame in the file:

```
video = read(obj, Inf);
```

Read from frame 50 through the end of the file:

```
video = read(obj, [50 Inf]);
```

If an invalid `index` is specified, the MATLAB software throws an error.

Examples Construct a multimedia reader object associated with file `xylophone.mpg` and with the user tag property set to `'myreader1'`.

```
readerobj = mmreader('xylophone.mpg', 'tag', 'myreader1');
```

Read in all video frames from the file.

```
vidFrames = read(readerobj);
```

Determine the number of frames in the file.

```
numFrames = get(readerobj, 'NumberOfFrames');
```

Create a MATLAB movie struct from the video frames.

```
for k = 1 : numFrames
    mov(k).cdata = vidFrames(:,:,k);
    mov(k).colormap = [];
end
```

Create a figure.

```
hf = figure;
```

Resize the figure based on the video's width and height.

```
set(hf, 'position', [150 150 readerobj.Width readerobj.Height])
```

Play back the movie once at the video's frame rate.

```
movie(hf, mov, 1, readerobj.FrameRate);
```

See Also

get, mmreader, movie, set

readasync

Purpose

Read data asynchronously from device

Syntax

```
readasync(obj)  
readasync(obj, size)
```

Description

`readasync(obj)` initiates an asynchronous read operation on the serial port object, `obj`.

`readasync(obj, size)` asynchronously reads, at most, the number of bytes given by `size`. If `size` is greater than the difference between the `InputBufferSize` property value and the `BytesAvailable` property value, an error is returned.

Remarks

Before you can read data, you must connect `obj` to the device with the `fopen` function. A connected serial port object has a `Status` property value of `open`. An error is returned if you attempt to perform a read operation while `obj` is not connected to the device.

You should use `readasync` only when you configure the `ReadAsyncMode` property to `manual`. `readasync` is ignored if used when `ReadAsyncMode` is `continuous`.

The `TransferStatus` property indicates if an asynchronous read or write operation is in progress. You can write data while an asynchronous read is in progress because serial ports have separate read and write pins. You can stop asynchronous read and write operations with the `stopasync` function.

You can monitor the amount of data stored in the input buffer with the `BytesAvailable` property. Additionally, you can use the `BytesAvailableFcn` property to execute an M-file callback function when the terminator or the specified amount of data is read.

Rules for Completing an Asynchronous Read Operation

An asynchronous read operation with `readasync` completes when one of these conditions is met:

- The terminator specified by the `Terminator` property is read.

- The time specified by the Timeout property passes.
- The specified number of bytes is read.
- The input buffer is filled (if size is not specified).

Because `readasync` checks for the terminator, this function can be slow. To increase speed, you might want to configure `ReadAsyncMode` to `continuous` and continuously return data to the input buffer as soon as it is available from the device.

Example

This example creates the serial port object `s` on a Windows platform. It connects `s` to a Tektronix TDS 210 oscilloscope, configures `s` to read data asynchronously only if `readasync` is issued, and configures the instrument to return the peak-to-peak value of the signal on channel 1.

```
s = serial('COM1');
fopen(s)
s.ReadAsyncMode = 'manual';
fprintf(s, 'Measurement:Meas1:Source CH1')
fprintf(s, 'Measurement:Meas1:Type Pk2Pk')
fprintf(s, 'Measurement:Meas1:Value?')
```

Begin reading data asynchronously from the instrument using `readasync`. When the read operation is complete, return the data to the MATLAB workspace using `fscanf`.

```
readasync(s)
s.BytesAvailable
ans =
    15
out = fscanf(s)
out =
2.0399999619E0
fclose(s)
```

readasync

See Also

Functions

fopen, stopasync

Properties

BytesAvailable, BytesAvailableFcn, ReadAsyncMode, Status, TransferStatus

Purpose Real part of complex number

Syntax `X = real(Z)`

Description `X = real(Z)` returns the real part of the elements of the complex array `Z`.

Examples `real(2+3*i)` is 2.

See Also `abs`, `angle`, `conj`, `i`, `j`, `imag`

reallog

Purpose Natural logarithm for nonnegative real arrays

Syntax `Y = reallog(X)`

Description `Y = reallog(X)` returns the natural logarithm of each element in array `X`. Array `X` must contain only nonnegative real numbers. The size of `Y` is the same as the size of `X`.

Examples

```
M = magic(4)
```

```
M =
```

16	2	3	13
5	11	10	8
9	7	6	12
4	14	15	1

```
reallog(M)
```

```
ans =
```

2.7726	0.6931	1.0986	2.5649
1.6094	2.3979	2.3026	2.0794
2.1972	1.9459	1.7918	2.4849
1.3863	2.6391	2.7081	0

See Also `log`, `realpow`, `realsqrt`

Purpose	Largest positive floating-point number
Syntax	<code>n = realmax</code>
Description	<p><code>n = realmax</code> returns the largest floating-point number representable on your computer. Anything larger overflows.</p> <p><code>realmax('double')</code> is the same as <code>realmax</code> with no arguments.</p> <p><code>realmax('single')</code> is the largest single precision floating point number representable on your computer. Anything larger overflows to <code>single(Inf)</code>.</p>
Examples	<code>realmax</code> is one bit less than 2^{1024} or about <code>1.7977e+308</code> .
Algorithm	<p>The <code>realmax</code> function is equivalent to <code>pow2(2-eps,maxexp)</code>, where <code>maxexp</code> is the largest possible floating-point exponent.</p> <p>Execute type <code>realmax</code> to see <code>maxexp</code> for various computers.</p>
See Also	<code>eps</code> , <code>realmin</code> , <code>intmax</code>

realmin

Purpose Smallest positive normalized floating-point number

Syntax `n = realmin`

Description `n = realmin` returns the smallest positive normalized floating-point number on your computer. Anything smaller underflows or is an IEEE “denormal.”

`REALMIN('double')` is the same as `REALMIN` with no arguments.

`REALMIN('single')` is the smallest positive normalized single precision floating point number on your computer.

Examples `realmin` is $2^{(-1022)}$ or about $2.2251e-308$.

Algorithm The `realmin` function is equivalent to `pow2(1,minexp)` where `minexp` is the smallest possible floating-point exponent.

Execute type `realmin` to see `minexp` for various computers.

See Also `eps`, `realmax`, `intmin`

Purpose Array power for real-only output

Syntax `Z = realpow(X,Y)`

Description `Z = realpow(X,Y)` raises each element of array `X` to the power of its corresponding element in array `Y`. Arrays `X` and `Y` must be the same size. The range of `realpow` is the set of all real numbers, i.e., all elements of the output array `Z` must be real.

Examples

```
X = -2*ones(3,3)
```

```
X =  
    -2    -2    -2  
    -2    -2    -2  
    -2    -2    -2
```

```
Y = pascal(3)
```

```
ans =  
     1     1     1  
     1     2     3  
     1     3     6
```

```
realpow(X,Y)
```

```
ans =  
    -2    -2    -2  
    -2     4    -8  
    -2    -8   64
```

See Also `reallog`, `realsqrt`, `.`[^] (array power operator)

realsqrt

Purpose Square root for nonnegative real arrays

Syntax `Y = realsqrt(X)`

Description `Y = realsqrt(X)` returns the square root of each element of array `X`. Array `X` must contain only nonnegative real numbers. The size of `Y` is the same as the size of `X`.

Examples

```
M = magic(4)
```

```
M =  
    16     2     3    13  
     5    11    10     8  
     9     7     6    12  
     4    14    15     1
```

```
realsqrt(M)
```

```
ans =  
    4.0000    1.4142    1.7321    3.6056  
    2.2361    3.3166    3.1623    2.8284  
    3.0000    2.6458    2.4495    3.4641  
    2.0000    3.7417    3.8730    1.0000
```

See Also `reallog`, `realpow`, `sqrt`, `sqrtm`

Purpose	Record data and event information to file
Syntax	<code>record(obj)</code> <code>record(obj, 'switch')</code>
Description	<code>record(obj)</code> toggles the recording state for the serial port object, <code>obj</code> . <code>record(obj, 'switch')</code> initiates or terminates recording for <code>obj</code> . <code>switch</code> can be <code>on</code> or <code>off</code> . If <code>switch</code> is <code>on</code> , recording is initiated. If <code>switch</code> is <code>off</code> , recording is terminated.
Remarks	<p>Before you can record information to disk, <code>obj</code> must be connected to the device with the <code>fopen</code> function. A connected serial port object has a <code>Status</code> property value of <code>open</code>. An error is returned if you attempt to record information while <code>obj</code> is not connected to the device. Each serial port object must record information to a separate file. Recording is automatically terminated when <code>obj</code> is disconnected from the device with <code>fclose</code>.</p> <p>The <code>RecordName</code> and <code>RecordMode</code> properties are read-only while <code>obj</code> is recording, and must be configured before using <code>record</code>.</p> <p>For a detailed description of the record file format and the properties associated with recording data and event information to a file, refer to Debugging: Recording Information to Disk.</p>
Example	<p>This example creates the serial port object <code>s</code> on a Windows platform. It connects <code>s</code> to the device, configures <code>s</code> to record information to a file, writes and reads text data, and then disconnects <code>s</code> from the device.</p>

```
s = serial('COM1');
fopen(s)
s.RecordDetail = 'verbose';
s.RecordName = 'MySerialFile.txt';
record(s, 'on')
fprintf(s, '*IDN?')
out = fscanf(s);
record(s, 'off')
```

record

`fclose(s)`

See Also

Functions

`fclose`, `fopen`

Properties

`RecordDetail`, `RecordMode`, `RecordName`, `RecordStatus`, `Status`

Purpose Create 2-D rectangle object

Syntax

```
rectangle  
rectangle('Position',[x,y,w,h])  
rectangle(...,'Curvature',[x,y])  
h = rectangle(...)
```

Description rectangle draws a rectangle with Position [0,0,1,1] and Curvature [0,0] (i.e., no curvature).

rectangle('Position',[x,y,w,h]) draws the rectangle from the point x,y and having a width of w and a height of h. Specify values in axes data units.

Note that, to display a rectangle in the specified proportions, you need to set the axes data aspect ratio so that one unit is of equal length along both the x and y axes. You can do this with the command `axis equal` or `aspect([1,1,1])`.

rectangle(...,'Curvature',[x,y]) specifies the curvature of the rectangle sides, enabling it to vary from a rectangle to an ellipse. The horizontal curvature x is the fraction of width of the rectangle that is curved along the top and bottom edges. The vertical curvature y is the fraction of the height of the rectangle that is curved along the left and right edges.

The values of x and y can range from 0 (no curvature) to 1 (maximum curvature). A value of [0,0] creates a rectangle with square sides. A value of [1,1] creates an ellipse. If you specify only one value for Curvature, then the same length (in axes data units) is curved along both horizontal and vertical sides. The amount of curvature is determined by the shorter dimension.

h = rectangle(...) returns the handle of the rectangle object created.

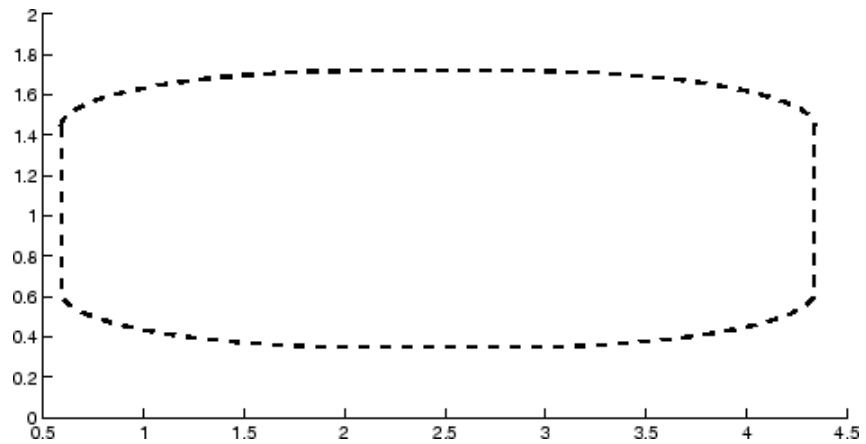
Remarks Rectangle objects are 2-D and can be drawn in an axes only if the view is [0 90] (i.e., `view(2)`). Rectangles are children of axes and are defined in coordinates of the axes data.

rectangle

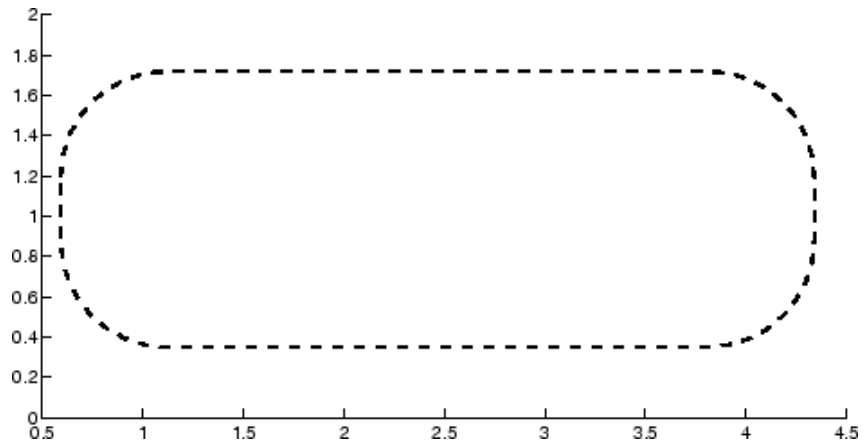
Examples

This example sets the data aspect ratio to `[1,1,1]` so that the rectangle is displayed in the specified proportions (`daspect`). Note that the horizontal and vertical curvature can be different. Also, note the effects of using a single value for `Curvature`.

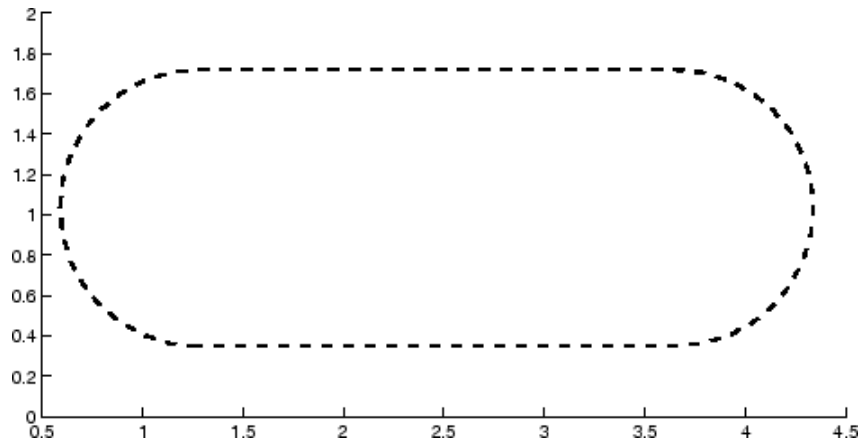
```
rectangle('Position',[0.59,0.35,3.75,1.37],...  
         'Curvature',[0.8,0.4],...  
         'LineWidth',2,'LineStyle','--')  
daspect([1,1,1])
```



Specifying a single value of `[0.4]` for `Curvature` produces



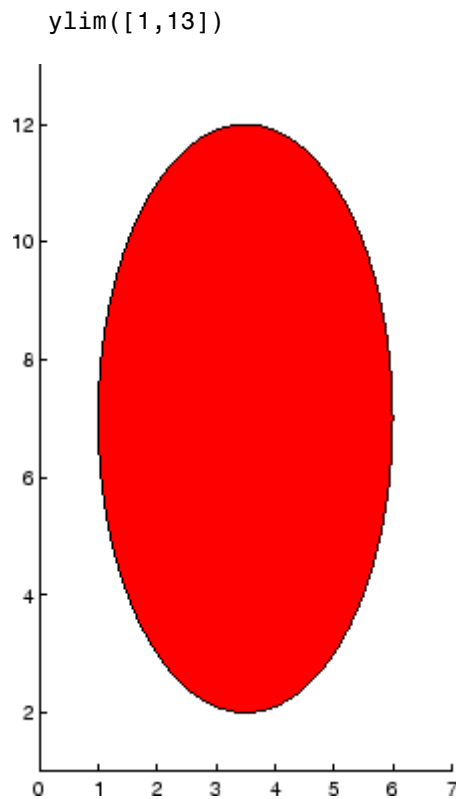
A Curvature of [1] produces a rectangle with the shortest side completely round:



This example creates an ellipse and colors the face red.

```
rectangle('Position',[1,2,5,10],'Curvature',[1,1],...  
         'FaceColor','r')  
daspect([1,1,1])  
xlim([0,7])
```

rectangle



Setting Default Properties

You can set default rectangle properties on the axes, figure, and root object levels:

```
set(0, 'DefaultRectangleProperty', PropertyValue...)  
set(gcf, 'DefaultRectangleProperty', PropertyValue...)  
set(gca, 'DefaultRectangleProperty', PropertyValue...)
```

where *Property* is the name of the rectangle property whose default value you want to set and *PropertyValue* is the value you are specifying. Use `set` and `get` to access the surface properties.

See Also

line, patch

“Object Creation” on page 1-101 for related functions

See the `annotation` function for information about the `rectangle` annotation object.

`Rectangle` Properties for property descriptions

Rectangle Properties

Purpose

Define rectangle properties

Modifying Properties

You can set and query graphics object properties in two ways:

- “The Property Editor” is an interactive tool that enables you to see and change object property values.
- The set and get commands enable you to set and query the values of properties.

To change the default values of properties, see “Setting Default Property Values”.

See “Core Graphics Objects” for general information about this type of object.

Rectangle Property Descriptions

This section lists property names along with the type of values each accepts. Curly braces { } enclose default values.

Annotation

hg.Annotation object Read Only

Control the display of rectangle objects in legends. The Annotation property enables you to specify whether this rectangle object is represented in a figure legend.

Querying the Annotation property returns the handle of an hg.Annotation object. The hg.Annotation object has a property called LegendInformation, which contains an hg.LegendEntry object.

Once you have obtained the hg.LegendEntry object, you can set its IconDisplayStyle property to control whether the rectangle object is displayed in a figure legend:

IconDisplayStyle Value	Purpose
on	Represent this rectangle object in a legend (default)
off	Do not include this rectangle object in a legend
children	Same as on because rectangle objects do not have children

Setting the **IconDisplayStyle** property

These commands set the **IconDisplayStyle** of a graphics object with handle `hobj` to `off`:

```
hAnnotation = get(hobj, 'Annotation');  
hLegendEntry = get(hAnnotation, 'LegendInformation');  
set(hLegendEntry, 'IconDisplayStyle', 'off')
```

Using the **IconDisplayStyle** property

See “Controlling Legends” for more information and examples.

BeingDeleted

on | {off} read only

This object is being deleted. The **BeingDeleted** property provides a mechanism that you can use to determine if objects are in the process of being deleted. The MATLAB software sets the **BeingDeleted** property to `on` when the object’s delete function callback is called (see the **DeleteFcn** property). It remains set to `on` while the delete function executes, after which the object no longer exists.

For example, an object’s delete function might call other functions that act on a number of different objects. These functions may not need to perform actions on objects that are going to be deleted,

Rectangle Properties

and therefore, can check the object's `BeingDeleted` property before acting.

`BusyAction`
cancel | {queue}

Callback routine interruption. The `BusyAction` property enables you to control how MATLAB handles events that potentially interrupt executing callback routines. If there is a callback routine executing, callback routines invoked subsequently always attempt to interrupt it. If the `Interruptible` property of the object whose callback is executing is set to on (the default), then interruption occurs at the next point where the event queue is processed. If the `Interruptible` property is off, the `BusyAction` property (of the object owning the executing callback) determines how MATLAB handles the event. The choices are

- `cancel` — Discard the event that attempted to execute a second callback routine.
- `queue` — Queue the event that attempted to execute a second callback routine until the current callback finishes.

`ButtonDownFcn`
function handle, cell array containing function handle and additional arguments, or string (not recommended)

Button press callback function. A callback function that executes whenever you press a mouse button while the pointer is over the rectangle object.

See the figure's `SelectionType` property to determine if modifier keys were also pressed.

Set this property to a function handle that references the callback. The function must define at least two input arguments (handle of object associated with the button down event and an event structure, which is empty for this property)


```
function button_down(src,evnt)
% src - the object that is the source of the event
% evnt - empty for this property
    sel_typ = get(gcf,'SelectionType')
    switch sel_typ
        case 'normal'
            disp('User clicked left-mouse button')
            set(src,'Selected','on')
        case 'extend'
            disp('User did a shift-click')
            set(src,'Selected','on')
        case 'alt'
            disp('User did a control-click')
            set(src,'Selected','on')
            set(src,'SelectionHighlight','off')
    end
end
```

Suppose `h` is the handle of a rectangle object and that the `button_down` function is on your MATLAB path. The following statement assigns the function above to the `ButtonDownFcn`:

```
set(h,'ButtonDownFcn',@button_down)
```

See “Function Handle Callbacks” for information on how to use function handles to define the callback function.

Children

vector of handles

The empty matrix; rectangle objects have no children.

Clipping

{on} | off

Clipping mode. MATLAB clips rectangles to the axes plot box by default. If you set `Clipping` to `off`, rectangles are displayed outside the axes plot box. This can occur if you create a rectangle,

Rectangle Properties

set hold to on, freeze axis scaling (axis set to manual), and then create a larger rectangle.

CreateFcn

function handle, cell array containing function handle and additional arguments, or string (not recommended)

Callback function executed during object creation. This property defines a callback function that executes when MATLAB creates a rectangle object. You must define this property as a default value for rectangles or in a call to the `rectangle` function to create a new rectangle object. For example, the statement

```
set(0, 'DefaultRectangleCreateFcn', @rect_create)
```

defines a default value for the rectangle `CreateFcn` property on the root level that sets the axes `DataAspectRatio` whenever you create a rectangle object. The callback function must be on your MATLAB path when you execute the above statement.

```
function rect_create(src, evnt)
% src - the object that is the source of the event
% evnt - empty for this property
    axh = get(src, 'Parent');
    set(axh, 'DataAspectRatio', [1,1,1])
end
```

MATLAB executes this function after setting all rectangle properties. Setting this property on an existing rectangle object has no effect. The function must define at least two input arguments (handle of object created and an event structure, which is empty for this property).

The handle of the object whose `CreateFcn` is being executed is passed by MATLAB as the first argument to the callback function and is also accessible through the root `CallbackObject` property, which you can query using `gcbo`.

See “Function Handle Callbacks” for information on how to use function handles to define the callback function.

Curvature

one- or two-element vector [x,y]

Amount of horizontal and vertical curvature. This property specifies the curvature of the rectangle sides, which enables the shape of the rectangle to vary from rectangular to ellipsoidal. The horizontal curvature x is the fraction of width of the rectangle that is curved along the top and bottom edges. The vertical curvature y is the fraction of the height of the rectangle that is curved along the left and right edges.

The values of x and y can range from 0 (no curvature) to 1 (maximum curvature). A value of [0,0] creates a rectangle with square sides. A value of [1,1] creates an ellipse. If you specify only one value for Curvature, then the same length (in axes data units) is curved along both horizontal and vertical sides. The amount of curvature is determined by the shorter dimension.

DeleteFcn

function handle, cell array containing function handle and additional arguments, or string (not recommended)

Delete rectangle callback function. A callback function that executes when you delete the rectangle object (e.g., when you issue a delete command or clear the axes cla or figure clf). For example, the following function displays object property data before the object is deleted.

```
function delete_fcn(src,evnt)
% src - the object that is the source of the event
% evnt - empty for this property
    obj_tp = get(src,'Type');
    disp([obj_tp, ' object deleted'])
    disp('Its user data is:')
    disp(get(src,'UserData'))
```

Rectangle Properties

end

MATLAB executes the function before deleting the object's properties so these values are available to the callback function. The function must define at least two input arguments (handle of object being deleted and an event structure, which is empty for this property)

The handle of the object whose `DeleteFcn` is being executed is passed by MATLAB as the first argument to the callback function and is also accessible through the root `CallbackObject` property, which you can query using `gcbo`.

See “Function Handle Callbacks” for information on how to use function handles to define the callback function.

DisplayName

string (default is empty string)

String used by legend for this rectangle object. The `legend` function uses the string defined by the `DisplayName` property to label this rectangle object in the legend.

- If you specify string arguments with the `legend` function, `DisplayName` is set to this rectangle object's corresponding string and that string is used for the legend.
- If `DisplayName` is empty, `legend` creates a string of the form, `['data' n]`, where n is the number assigned to the object based on its location in the list of legend entries. However, `legend` does not set `DisplayName` to this string.
- If you edit the string directly in an existing legend, `DisplayName` is set to the edited string.
- If you specify a string for the `DisplayName` property and create the legend using the figure toolbar, then MATLAB uses the string defined by `DisplayName`.

- To add programmatically a legend that uses the `DisplayName` string, call `legend` with the `toggle` or `show` option.

See “Controlling Legends” for more examples.

`EdgeColor`
{ColorSpec} | none

Color of the rectangle edges. This property specifies the color of the rectangle edges as a color or specifies that no edges be drawn.

`EraseMode`
{normal} | none | xor | background

Erase mode. This property controls the technique MATLAB uses to draw and erase rectangle objects. Alternative erase modes are useful for creating animated sequences, where control of the way individual objects are redrawn is necessary to improve performance and obtain the desired effect.

- `normal` (the default) — Redraw the affected region of the display, performing the three-dimensional analysis necessary to ensure that all objects are rendered correctly. This mode produces the most accurate picture, but is the slowest. The other modes are faster, but do not perform a complete redraw and are therefore less accurate.
- `none` — Do not erase the rectangle when it is moved or destroyed. While the object is still visible on the screen after erasing with `EraseMode none`, you cannot print it because MATLAB stores no information about its former location.
- `xor` — Draw and erase the rectangle by performing an exclusive OR (XOR) with the color of the screen beneath it. This mode does not damage the color of the objects beneath the rectangle. However, the rectangle’s color depends on the color of whatever is beneath it on the display.
- `background` — Erase the rectangle by drawing it in the axes background `Color`, or the figure background `Color` if the axes

Rectangle Properties

Color is set to none. This damages objects that are behind the erased rectangle, but rectangles are always properly colored.

Printing with Nonnormal Erase Modes

MATLAB always prints figures as if the `EraseMode` of all objects is `normal`. This means graphics objects created with `EraseMode` set to `none`, `xor`, or `background` can look different on screen than on paper. On screen, MATLAB can mathematically combine layers of colors (e.g., performing an XOR of a pixel color with that of the pixel behind it) and ignore three-dimensional sorting to obtain greater rendering speed. However, these techniques are not applied to the printed output.

You can use the MATLAB `getframe` command or other screen capture application to create an image of a figure containing nonnormal mode objects.

FaceColor

ColorSpec | {none}

Color of rectangle face. This property specifies the color of the rectangle face, which is not colored by default.

HandleVisibility

{on} | callback | off

Control access to object's handle by command-line users and GUIs. This property determines when an object's handle is visible in its parent's list of children. `HandleVisibility` is useful for preventing command-line users from accidentally drawing into or deleting a figure that contains only user interface devices (such as a dialog box).

Handles are always visible when `HandleVisibility` is on.

Setting `HandleVisibility` to `callback` causes handles to be visible from within callback routines or functions invoked by callback routines, but not from within functions invoked from

the command line. This provides a means to protect GUIs from command-line users, while allowing callback routines to have complete access to object handles.

Setting `HandleVisibility` to `off` makes handles invisible at all times. This may be necessary when a callback routine invokes a function that might potentially damage the GUI (such as evaluating a user-typed string), and so temporarily hides its own handles during the execution of that function.

When a handle is not visible in its parent's list of children, it cannot be returned by functions that obtain handles by searching the object hierarchy or querying handle properties. This includes `get`, `findobj`, `gca`, `gcf`, `gco`, `newplot`, `cla`, `clf`, and `close`.

When a handle's visibility is restricted using `callback` or `off`, the object's handle does not appear in its parent's `Children` property, figures do not appear in the root's `CurrentFigure` property, objects do not appear in the root's `CallbackObject` property or in the figure's `CurrentObject` property, and axes do not appear in their parent's `CurrentAxes` property.

You can set the `Root ShowHiddenHandles` property to `on` to make all handles visible regardless of their `HandleVisibility` settings (this does not affect the values of the `HandleVisibility` properties).

Handles that are hidden are still valid. If you know an object's handle, you can `set` and `get` its properties and pass it to any function that operates on handles.

`HitTest`
{on} | off

Selectable by mouse click. `HitTest` determines if the rectangle can become the current object (as returned by the `gco` command and the figure `CurrentObject` property) as a result of a mouse click on

Rectangle Properties

the rectangle. If `HitTest` is `off`, clicking the rectangle selects the object below it (which may be the axes containing it).

Interruptible
{on} | off

Callback routine interruption mode. The `Interruptible` property controls whether a rectangle callback routine can be interrupted by subsequently invoked callback routines. Only callback routines defined for the `ButtonDownFcn` are affected by the `Interruptible` property. MATLAB checks for events that can interrupt a callback routine only when it encounters a `drawnow`, `figure`, `getframe`, or `pause` command in the routine.

LineStyle
{-} | - | : | -. | none

Line style of rectangle edge. This property specifies the line style of the edges. The available line styles are

Symbol	Line Style
-	Solid line (default)
--	Dashed line
:	Dotted line
-.	Dash-dot line
none	No line

LineWidth
scalar

The width of the rectangle edge line. Specify this value in points (1 point = $1/72$ inch). The default `LineWidth` is 0.5 points.

Parent
handle of axes, `hgroup`, or `hgtransform`

Parent of rectangle object. This property contains the handle of the rectangle object's parent. The parent of a rectangle object is the axes, hgggroup, or hgtransform object that contains it.

See “Objects That Can Contain Other Objects” for more information on parenting graphics objects.

Position

four-element vector [x,y,width,height]

Location and size of rectangle. This property specifies the location and size of the rectangle in the data units of the axes. The point defined by x, y specifies one corner of the rectangle, and width and height define the size in units along the x-and y-axes respectively.

Selected

on | off

Is object selected? When this property is on MATLAB displays selection handles if the SelectionHighlight property is also on. You can, for example, define the ButtonDownFcn to set this property, allowing users to select the object with the mouse.

SelectionHighlight

{on} | off

Objects are highlighted when selected. When the Selected property is on, MATLAB indicates the selected state by drawing handles at each vertex. When SelectionHighlight is off, MATLAB does not draw the handles.

Tag

string

User-specified object label. The Tag property provides a means to identify graphics objects with a user-specified label. This is particularly useful when you are constructing interactive graphics programs that would otherwise need to define object handles as

Rectangle Properties

global variables or pass them as arguments between callback routines. You can define `Tag` as any string.

Type

string (read only)

Class of graphics object. For rectangle objects, `Type` is always the string `'rectangle'`.

UIContextMenu

handle of a `uicontextmenu` object

Associate a context menu with the rectangle. Assign this property the handle of a `uicontextmenu` object created in the same figure as the rectangle. Use the `uicontextmenu` function to create the context menu. MATLAB displays the context menu whenever you right-click over the rectangle.

UserData

matrix

User-specified data. Any data you want to associate with the rectangle object. MATLAB does not use this data, but you can access it using the `set` and `get` commands.

Visible

{on} | off

Rectangle visibility. By default, all rectangles are visible. When set to `off`, the rectangle is not visible, but still exists, and you can `get` and `set` its properties.

Purpose Rectangle intersection area

Syntax `area = rectint(A,B)`

Description `area = rectint(A,B)` returns the area of intersection of the rectangles specified by position vectors `A` and `B`.

If `A` and `B` each specify one rectangle, the output `area` is a scalar.

`A` and `B` can also be matrices, where each row is a position vector. `area` is then a matrix giving the intersection of all rectangles specified by `A` with all the rectangles specified by `B`. That is, if `A` is `n-by-4` and `B` is `m-by-4`, then `area` is an `n-by-m` matrix where `area(i,j)` is the intersection area of the rectangles specified by the `i`th row of `A` and the `j`th row of `B`.

Note A position vector is a four-element vector `[x,y,width,height]`, where the point defined by `x` and `y` specifies one corner of the rectangle, and `width` and `height` define the size in units along the `x` and `y` axes respectively.

See Also `polyarea`

recycle

Purpose Set option to move deleted files to recycle folder

Syntax
S = recycle
S = recycle state
S = recycle('state')

Description S = recycle returns a character array S that shows the current state of the file recycling option in the MATLAB application. This state can be either on or off. When file recycling is on, MATLAB moves all files that you delete with the `delete` function to either the recycle bin on Microsoft Windows or Apple Macintosh platforms, or to a temporary directory on UNIX²⁴ platforms. (To locate this directory on UNIX platforms, see the Remarks section below.) When file recycling is off, any files you delete are actually removed from the system. The default recycle state is off. You can turn on recycling for all of your MATLAB sessions using preferences. Select **File > Preferences > General**, and for **Default behavior of the delete function**, select **Move files to the Recycle Bin**. For more information, click the **Help** button in General Preferences.

S = recycle state sets the recycle option for MATLAB to the specified state, either on or off. Return value S shows the previous recycle state.

S = recycle('state') is the function format.

Remarks On UNIX platforms, you can locate the system temporary directory by entering the MATLAB function `tempdir`. The recycle directory is a subdirectory of this temporary directory, and is named according to the format

```
MATLAB_Files_<day>-<mo>-<yr>_<hr>_<min>_<sec>
```

For example, files recycled on a UNIX platform at 2:09:28 in the afternoon of November 9, 2007 are copied to a directory named

24. UNIX is a registered trademark of The Open Group in the United States and other countries.

```
/tmp/MATLAB_Files_09-Nov-2007_14_09_28
```

You can recycle files that are stored on your local computer system, but not files that you access over a network connection. On Windows platforms, when you use the `delete` function on files accessed over a network, MATLAB removes the file entirely, regardless of the recycle state.

Examples

Start from a state where file recycling has been turned off. Check the current recycle state:

```
recycle
ans =
    off
```

Turn file recycling on. Delete a file and verify that it is transferred to the recycle bin or temporary folder:

```
recycle on;
delete myfile.txt
```

See Also

`delete`, `dir`, `ls`, `fileparts`, `mkdir`, `rmdir`

“Managing Files and Working with the Current Directory”

reducepatch

Purpose Reduce number of patch faces

Syntax

```
nfv = reducepatch(p,r)
nfv = reducepatch(fv,r)
nfv = reducepatch(p) or nfv = reducepatch(fv)
reducepatch(...,'fast')
reducepatch(...,'verbose')
nfv = reducepatch(f,v,r)
[nf,nv] = reducepatch(...)
```

Description `reducepatch(p,r)` reduces the number of faces of the patch identified by handle `p`, while attempting to preserve the overall shape of the original object. The MATLAB software interprets the reduction factor `r` in one of two ways depending on its value:

- If `r` is less than 1, `r` is interpreted as a fraction of the original number of faces. For example, if you specify `r` as 0.2, then the number of faces is reduced to 20% of the number in the original patch.
- If `r` is greater than or equal to 1, then `r` is the target number of faces. For example, if you specify `r` as 400, then the number of faces is reduced until there are 400 faces remaining.

`nfv = reducepatch(p,r)` returns the reduced set of faces and vertices but does not set the `Faces` and `Vertices` properties of patch `p`. The struct `nfv` contains the faces and vertices after reduction.

`nfv = reducepatch(fv,r)` performs the reduction on the faces and vertices in the struct `fv`.

`nfv = reducepatch(p)` or `nfv = reducepatch(fv)` uses a reduction value of 0.5.

`reducepatch(...,'fast')` assumes the vertices are unique and does not compute shared vertices.

`reducepatch(...,'verbose')` prints progress messages to the command window as the computation progresses.

`nfv = reducepatch(f,v,r)` performs the reduction on the faces in `f` and the vertices in `v`.

`[nf,nv] = reducepatch(...)` returns the faces and vertices in the arrays `nf` and `nv`.

Remarks

If the patch contains nonshared vertices, MATLAB computes shared vertices before reducing the number of faces. If the faces of the patch are not triangles, MATLAB triangulates the faces before reduction. The faces returned are always defined as triangles.

The number of output triangles may not be exactly the number specified with the reduction factor argument (`r`), particularly if the faces of the original patch are not triangles.

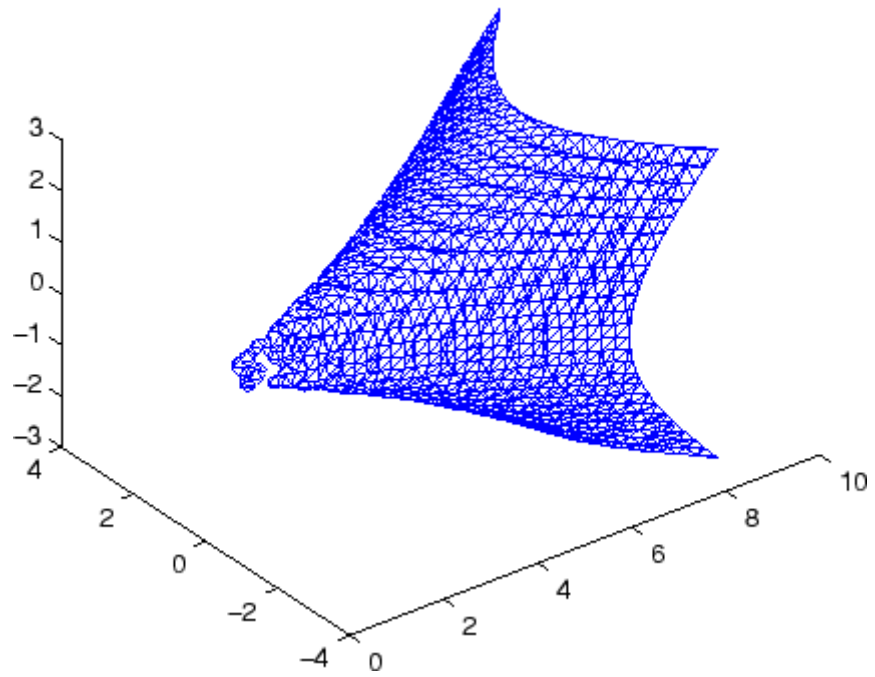
Examples

This example illustrates the effect of reducing the number of faces to only 15% of the original value.

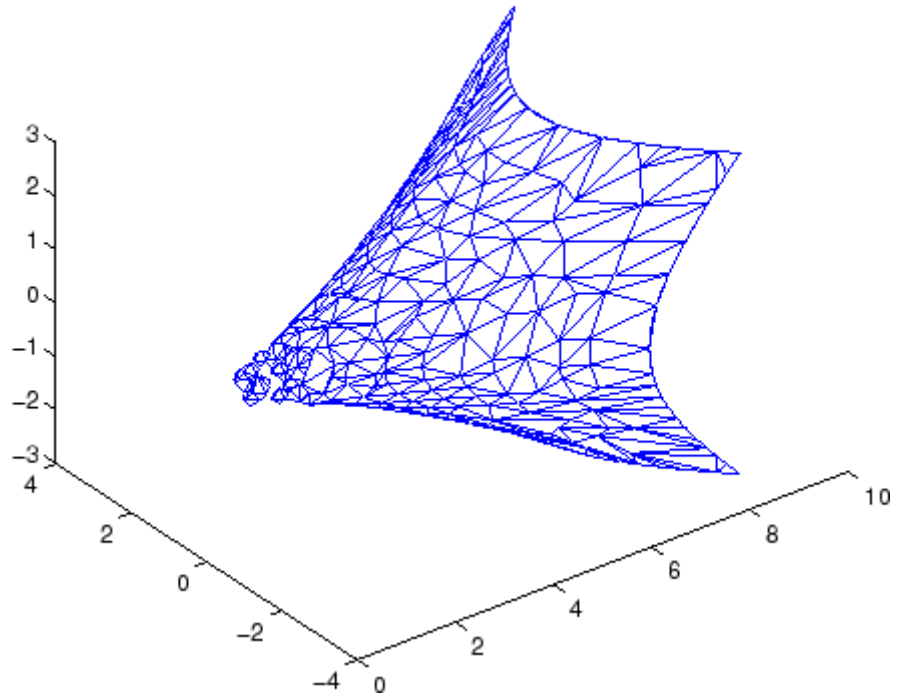
```
[x,y,z,v] = flow;
p = patch(isosurface(x,y,z,v,-3));
set(p,'facecolor','w','EdgeColor','b');
daspect([1,1,1])
view(3)
figure;
h = axes;
p2 = copyobj(p,h);
reducepatch(p2,0.15)
daspect([1,1,1])
view(3)
```

reducepatch

Before Reduction



After Reduction to 15% of Original Number of Faces



See Also

`isosurface`, `isocaps`, `isonormals`, `smooth3`, `subvolume`, `reducevolume`
“Volume Visualization” on page 1-108 for related functions
Vector Field Displayed with Cone Plots for another example

reducevolume

Purpose Reduce number of elements in volume data set

Syntax
`[nx,ny,nz,nv] = reducevolume(X,Y,Z,V,[Rx,Ry,Rz])`
`[nx,ny,nz,nv] = reducevolume(V,[Rx,Ry,Rz])`
`nv = reducevolume(...)`

Description `[nx,ny,nz,nv] = reducevolume(X,Y,Z,V,[Rx,Ry,Rz])` reduces the number of elements in the volume by retaining every R_x^{th} element in the x direction, every R_y^{th} element in the y direction, and every R_z^{th} element in the z direction. If a scalar R is used to indicate the amount or reduction instead of a three-element vector, the MATLAB software assumes the reduction to be `[R R R]`.

The arrays X , Y , and Z define the coordinates for the volume V . The reduced volume is returned in nv , and the coordinates of the reduced volume are returned in nx , ny , and nz .

`[nx,ny,nz,nv] = reducevolume(V,[Rx,Ry,Rz])` assumes the arrays X , Y , and Z are defined as `[X,Y,Z] = meshgrid(1:n,1:m,1:p)`, where `[m,n,p] = size(V)`.

`nv = reducevolume(...)` returns only the reduced volume.

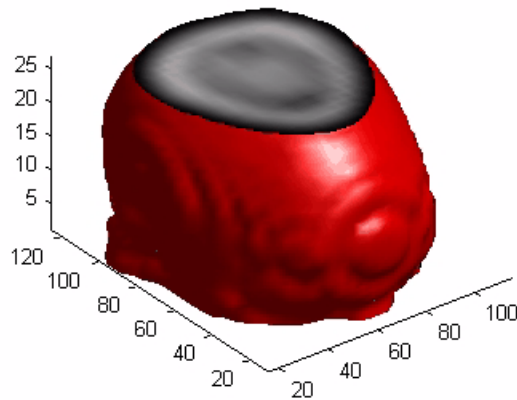
Examples

This example uses a data set that is a collection of MRI slices of a human skull. This data is processed in a variety of ways:

- The 4-D array is squeezed (`squeeze`) into three dimensions and then reduced (`reducevolume`) so that what remains is every fourth element in the x and y directions and every element in the z direction.
- The reduced data is smoothed (`smooth3`).
- The outline of the skull is an isosurface generated as a patch (`p1`) whose vertex normals are recalculated to improve the appearance when lighting is applied (`patch`, `isosurface`, `isonormals`).
- A second patch (`p2`) with an interpolated face color draws the end caps (`FaceColor`, `isocaps`).
- The view of the object is set (`view`, `axis`, `daspect`).

- A 100-element grayscale colormap provides coloring for the end caps (colormap).
- Adding a light to the right of the camera illuminates the object (camlight, lighting).

```
load mri
D = squeeze(D);
[x,y,z,D] = reducevolume(D,[4,4,1]);
D = smooth3(D);
p1 = patch(isosurface(x,y,z,D, 5,'verbose'),...
    'FaceColor','red','EdgeColor','none');
isonormals(x,y,z,D,p1);
p2 = patch(isocaps(x,y,z,D, 5),...
    'FaceColor','interp','EdgeColor','none');
view(3); axis tight; daspect([1,1,.4])
colormap(gray(100))
camlight; lighting gouraud
```



See Also

isosurface, isocaps, isonormals, smooth3, subvolume, reducepatch

reducevolume

“Volume Visualization” on page 1-108 for related functions

Purpose	Redraw current figure
Syntax	<code>refresh</code> <code>refresh(h)</code>
Description	<code>refresh</code> erases and redraws the current figure. <code>refresh(h)</code> redraws the figure identified by <code>h</code> .
See Also	“Figure Windows” on page 1-102 for related functions

refreshdata

Purpose Refresh data in graph when data source is specified

Syntax

```
refreshdata
refreshdata(figure_handle)
refreshdata(object_handles)
refreshdata(object_handles, 'workspace')
```

Description `refreshdata` evaluates any data source properties (XDataSource, YDataSource, or ZDataSource) on all objects in graphs in the current figure. If the specified data source has changed, the MATLAB software updates the graph to reflect this change.

Note that the variable assigned to the data source property must be in the base workspace.

`refreshdata(figure_handle)` refreshes the data of the objects in the specified figure.

`refreshdata(object_handles)` refreshes the data of the objects specified in `object_handles` or the children of those objects. Therefore, `object_handles` can contain figure, axes, or plot object handles.

`refreshdata(object_handles, 'workspace')` enables you to specify whether the data source properties are evaluated in the base workspace or the workspace of the function in which `refreshdata` was called. `workspace` is a string that can be

- `base` — Evaluate the data source properties in the base workspace.
- `caller` — Evaluate the data source properties in the workspace of the function that called `refreshdata`.

Remarks The Linked Plots feature (see documentation for `linked`) sets up data sources for graphs and synchronizes them with the workspace variables they display. When you use this feature, you do not also need to call `refreshdata`, as it is essentially automatically triggered every time a data source changes.

If you are not using the Linked Plots feature, you need to set the `XDataSource`, `YDataSource`, and/or `ZDataSource` properties of a graph in order to use `refreshdata`. You can do that programmatically, as shown in the examples below, or use the Property Editor, one of the plotting tools. In the Property Editor, select the graph (e.g., a lineseries object) and type in (or select from the drop-down choices) the name(s) of the workspace variable(s) from which you want the plot to refresh, in the fields labelled **X Data Source**, **Y Data Source**, and/or **Z Data Source**. The call to `refreshdata` causes the graph to update.

Examples

Plot a sine wave, identify data sources, and then modify its `YDataSource`:

```
x = 0:.1:8;
y = sin(x);
h = plot(x,y)
set(h,'YDataSource','y')
set(h,'XDataSource','x')
y = sin(x.^3);
refreshdata
```

Create a surface plot, identify a `ZDataSource` for it, and change the data to a different size.

```
Z = peaks(5);
h = surf(Z)
set(h,'ZDataSource','Z')
pause(3)
Z = peaks(25);
refreshdata
```

See Also

The `[X,Y,Z]DataSource` properties of plot objects.

regexp, regexpi

Purpose Match regular expression

Syntax

```
regexp('str', 'expr')  
[start_idx, end_idx, extents, matches, tokens, names,  
    splits] = regexp('str', 'expr')  
[v1, v2, ...] = regexp('str', 'expr', q1, q2, ...)  
[v1 v2 ...] = regexp('str', 'expr', ..., options)
```

Each of these syntaxes applies to both `regexp` and `regexpi`. The `regexp` function is case sensitive in matching regular expressions to a string, and `regexpi` is case insensitive.

Description The following descriptions apply to both `regexp` and `regexpi`:

`regexp('str', 'expr')` returns a row vector containing the starting index of each substring of `str` that matches the regular expression string `expr`. If no matches are found, `regexp` returns an empty array. The `str` and `expr` arguments can also be cell arrays of strings. See “Regular Expressions” in the MATLAB Programming Fundamentals documentation for more information.

To specify more than one string to parse or more than one expression to match, see the guidelines listed below under “Multiple Strings or Expressions” on page 2-3073.

`[start_idx, end_idx, extents, matches, tokens, names, splits] = regexp('str', 'expr')` returns up to six values, one for each output variable you specify, and in the default order (as shown in the table below).

Note The `str` and `expr` inputs are required and must be entered as the first and second arguments, respectively. Any other input arguments (all are described below) are optional and can be entered following the two required inputs in any order.

`[v1, v2, ...] = regexp('str', 'expr', q1, q2, ...)` returns up to six values, one for each output variable you specify, and ordered according to the order of the qualifier arguments, q1, q2, etc.

Return Values for Regular Expressions

Default Order	Description	Qualifier
1	Row vector containing the starting index of each substring of <code>str</code> that matches <code>expr</code> .	start
2	Row vector containing the ending index of each substring of <code>str</code> that matches <code>expr</code> .	end
3	Cell array containing the starting and ending indices of each substring of <code>str</code> that matches a token in <code>expr</code> . (This is a double array when used with 'once'.)	tokenExtents
4	Cell array containing the text of each substring of <code>str</code> that matches <code>expr</code> . (This is a string when used with 'once'.)	match
5	Cell array of cell arrays of strings containing the text of each token captured by <code>regexp</code> . (This is a cell array of strings when used with 'once'.)	tokens
6	Structure array containing the name and text of each <i>named</i> token captured by <code>regexp</code> . If there are no named tokens in <code>expr</code> , <code>regexp</code> returns a structure array with no fields. Field names of the returned structure are set to the token names, and field values are the text of those tokens. Named tokens are generated by the expression <code>(?<tokenname>)</code> .	names
7	Cell array containing those parts of the input string that are delimited by substrings returned when using the <code>regexp</code> 'match' option.	split

Tip When using the `split` option, `regexp` always returns one more string than it does with the `match` option. Also, you can always put the original input string back together from the substrings obtained from both `split` and `match`. See “Example 4 — Splitting the Input String” on page 2-3074.

`[v1 v2 ...] = regexp('str', 'expr', ..., options)` calls `regexp` with one or more of the nondefault options listed in the following table. These options must follow `str` and `expr` in the input argument list.

Option	Description
<code>mode</code>	See the section on “Modes” on page 2-3070 below.
<code>'once'</code>	Return only the first match found.
<code>'warnings'</code>	Display any hidden warning messages issued by MATLAB during the execution of the command. This option only enables warnings for the one command being executed. See “Example 11 — Displaying Parsing Warnings” on page 2-3080.

Modes

You can specify one or more of the following modes with the `regexp`, `regexpi`, and `regexprep` functions. You can enable or disable any of these modes using the mode specifier keyword (e.g., `'lineanchors'`) or the mode flag (e.g., `(?m)`). Both are shown in the tables that follow. Use the keyword to enable or disable the mode for the entire string being parsed. Use the flag to both enable and disable the mode for selected pieces of the string.

Case-Sensitivity Mode

Use the Case-Sensitivity mode to control whether or not MATLAB considers letter case when matching an expression to a string. “Example 7 — Using the Case-Sensitive Mode” on page 2-3077 illustrates this mode.

Mode Keyword	Flag	Description
'matchcase'	(?-i)	Letter case must match when matching patterns to a string. (The default for regexp).
'ignorecase'	(?i)	Do not consider letter case when matching patterns to a string. (The default for regexpi).

Dot Matching Mode

Use the Dot Matching mode to control whether or not MATLAB includes the newline (`\n`) character when matching the dot (`.`) metacharacter in a regular expression. “Example 8 — Using the Dot Matching Mode” on page 2-3078 illustrates the Dot Matching mode.

Mode Keyword	Flag	Description
'dotall'	(?s)	Match dot (<code>.</code>) in the pattern string with any character. (This is the default).
'dotexceptnewline'	(?-s)	Match dot in the pattern with any character that is not a newline.

Anchor Type Mode

Use the Anchor Type mode to control whether MATLAB considers the `^` and `$` metacharacters to represent the beginning and end of a string or the beginning and end of a line. “Example 9 — Using the Anchor Type Mode” on page 2-3078 illustrates the Anchor mode.

regexp, regexpi

Mode Keyword	Flag	Description
'stringanchors'	(?-m)	Match the ^ and \$ metacharacters at the beginning and end of a string. (This is the default).
'lineanchors'	(?m)	Match the ^ and \$ metacharacters at the beginning and end of a line.

Spacing Mode

Use the Spacing mode to control how MATLAB interprets space characters and comments within the parsing string. Note that spacing mode applies to the parsing string (the second input argument that contains the metacharacters (e.g., \w) and not the string being parsed. “Example 10 — Using the Spacing Mode” on page 2-3079 illustrates the Spacing mode.

Mode Keyword	Flag	Description
'literalspacing'	(?-x)	Parse space characters and comments (the # character and any text to the right of it) in the same way as any other characters in the string. (This is the default).
'freespacing'	(?x)	Ignore spaces and comments when parsing the string. (You must use '\ ' and '\#' to match space and # characters.)

Remarks

See “Regular Expressions” in the MATLAB Programming Fundamentals documentation for a listing of all regular expression elements supported by MATLAB.

Multiple Strings or Expressions

Either the `str` or `expr` argument, or both, can be a cell array of strings, according to the following guidelines:

- If `str` is a cell array of strings, then each of the `regexp` outputs is a cell array having the same dimensions as `str`.
- If `str` is a single string but `expr` is a cell array of strings, then each of the `regexp` outputs is a cell array having the same dimensions as `expr`.
- If both `str` and `expr` are cell arrays of strings, these two cell arrays must contain the same number of elements.

Examples

Example 1 – Matching a Simple Pattern

Return a row vector of indices that match words that start with `c`, end with `t`, and contain one or more vowels between them. Make the matches insensitive to letter case (by using `regexpi`):

```
str = 'bat cat can car COAT court cut ct CAT-scan';
regexpi(str, 'c[aeiou]+t')
ans =
     5     17     28     35
```

Example 2 – Parsing Multiple Input Strings

Return a cell array of row vectors of indices that match capital letters and white spaces in the cell array of strings `str`:

```
str = {'Madrid, Spain' 'Romeo and Juliet' 'MATLAB is great'};
s1 = regexp(str, '[A-Z]');
s2 = regexp(str, '\s');
```

Capital letters, '[A-Z]', were found at these `str` indices:

```
s1{:}
ans =
     1     9
ans =
```

regexp, regexpi

```
      1    11
ans =
      1    2    3    4    5    6
```

Space characters, '\s', were found at these str indices:

```
s2{:}
ans =
      8
ans =
      6    10
ans =
      7    10
```

Example 3 – Selecting Return Values

Return the text and the starting and ending indices of words containing the letter x:

```
str = 'regexp helps you relax';
[m s e] = regexp(str, '\w*x\w*', 'match', 'start', 'end')
m =
    'regexp'    'relax'
s =
      1    18
e =
      6    22
```

Example 4 – Splitting the Input String

Find the substrings delimited by the ^ character:

```
s1 = ['Use REGEXP to split ^this string into ' ...
      'several ^individual pieces'];

s2 = regexp(s1, '\^', 'split');

s2(:)
ans =
    'Use REGEXP to split '
```

```
'this string into several '
'individual pieces'
```

The `split` option returns those parts of the input string that are not returned when using the `'match'` option. Note that when you match the beginning or ending characters in a string (as is done in this example), the first (or last) return value is always an empty string:

```
str = 'She sells sea shells by the seashore.';

[matchstr splitstr] = regexp(str, '[Ss]h.', 'match', ...
                             'split')

matchstr =
    'She'    'she'    'sho'
splitstr =
    ''      ' sells sea '    'lls by the sea'    're.'
```

For any string that has been split, you can reassemble the pieces into the initial string using the command

```
j = [splitstr; [matchstr {''}]]; [j{:}]

ans =
    She sells sea shells by the seashore.
```

Example 5 – Using Tokens

Search a string for opening and closing HTML tags. Use the expression `<(\w+)` to find the opening tag (e.g., `<tagname'`) and to create a token for it. Use the expression `</\1>` to find another occurrence of the same token, but formatted as a closing tag (e.g., `</tagname>'`):

```
str = ['if <code>A</code> == x<sup>2</sup>, ' ...
      '<em>disp(x)</em>']
str =
if <code>A</code> == x<sup>2</sup>, <em>disp(x)</em>

expr = '<(\w+).*?>.*?</\1>';
```

regexp, regexpi

```
[tok mat] = regexp(str, expr, 'tokens', 'match');

tok{:}
ans =
    'code'
ans =
    'sup'
ans =
    'em'

mat{:}
ans =
    <code>A</code>
ans =
    <sup>2</sup>
ans =
    <em>disp(x)</em>
```

See “Tokens” in the MATLAB Programming Fundamentals documentation for information on using tokens.

Example 6 – Using Named Capture

Enter a string containing two names, the first and last names being in a different order:

```
str = sprintf('John Davis\nRogers, James')
str =
    John Davis
    Rogers, James
```

Create an expression that generates first and last name tokens, assigning the names `first` and `last` to the tokens. Call `regexp` to get the text and names of each token found:

```
expr = ...
    '(?<first>\w+)\s+(?<last>\w+)|(?<last>\w+)\s+(?<first>\w+)';

[tokens names] = regexp(str, expr, 'tokens', 'names');
```


Examine the `tokens` cell array that was returned. The first and last name tokens appear in the order in which they were generated: first name–last name, then last name–first name:

```
tokens{:}
ans =
    'John'    'Davis'
ans =
    'Rogers'    'James'
```

Now examine the `names` structure that was returned. First and last names appear in a more usable order:

```
names(:,1)
ans =
    first: 'John'
    last:  'Davis'

names(:,2)
ans =
    first: 'James'
    last:  'Rogers'
```

Example 7 – Using the Case-Sensitive Mode

Given a string that has both uppercase and lowercase letters,

```
str = 'A string with UPPERCASE and lowercase text.';
```

Use the `regexp` default mode (case-sensitive) to locate only the lowercase instance of the word `case`:

```
regexp(str, 'case', 'match')
ans =
    'case'
```

Now disable case-sensitive matching to find both instances of `case`:

```
regexp(str, 'case', 'ignorecase', 'match')
ans =
```

regexp, regexpi

```
'CASE'      'case'
```

Match 5 letters that are followed by 'CASE'. Use the (?-i) flag to turn on case-sensitivity for the first match and (?i) to turn it off for the second:

```
M = regexp(str, {'(?-i)\w{5}(?=CASE)', ...  
                '(?i)\w{5}(?=CASE)'} , 'match');
```

```
M{:}  
ans =  
    'UPPER'  
ans =  
    'UPPER'    'lower'
```

Example 8 – Using the Dot Matching Mode

Parse the following string that contains a newline (\n) character:

```
str = sprintf('abc\ndef')  
str =  
abc  
def
```

When you use the default mode, `dotall`, MATLAB includes the newline in the characters matched:

```
regexp(str, '.', 'match')  
ans =  
    'a'    'b'    'c'    [1x1 char]    'd'    'e'    'f'
```

When you use the `dotexceptnewline` mode, MATLAB skips the newline character:

```
regexp(str, '.', 'match', 'dotexceptnewline')  
ans =  
    'a'    'b'    'c'    'd'    'e'    'f'
```

Example 9 – Using the Anchor Type Mode

Given the following two-line string,

```
str = sprintf('%s\n%s', 'Here is the first line', ...
              'followed by the second line')
str =
    Here is the first line
    followed by the second line
```

In `stringanchors` mode, MATLAB interprets the `$` metacharacter as an end-of-string specifier, and thus finds the last two words of the entire *string*:

```
regexp(str, '\w+\W\w+$', 'match', 'stringanchors')
ans =
    'second line'
```

While in `lineanchors` mode, MATLAB interprets `$` as an end-of-line specifier, and finds the last two words of each *line*:

```
regexp(str, '\w+\W\w+$', 'match', 'lineanchors')
ans =
    'first line'    'second line'
```

Example 10 – Using the Spacing Mode

Create a file called `regexp_str.txt` containing the following text.

```
(?x)  # turn on freespacing.

# This pattern matches a string with a repeated letter.

\w*   # First, match any number of preceding word characters.

(     # Mark a token.
.     # Match a character of any type.
)     # Finish capturing said token.
\1    # Backreference to match what token #1 matched.

\w*   # Finally, match the remainder of the word.
```

regexp, regexpi

Because the first line enables freespacing mode, MATLAB ignores all spaces and comments that appear in the file. Here is the string to parse:

```
str = ['Looking for words with letters that ' ...  
      'appear twice in succession.'];
```

Use the pattern expression read from the file to find those words that have consecutive matching letters:

```
patt = fileread('regexp_str.txt');  
regexp(str, patt, 'match')  
ans =  
      'Looking'      'letters'      'appear'      'succession'
```

Example 11 – Displaying Parsing Warnings

To help debug problems in parsing a string with `regexp`, `regexpi`, or `regexprep`, use the `'warnings'` option to view all warning messages:

```
regexp('$.', '[a-]', 'warnings')  
Warning: Unbound range.  
[a-]  
|
```

See Also

`regexprep`, `regexprtranslate`, `strfind`, `findstr`, `strmatch`, `strcmp`, `strcmpi`, `strncmp`, `strncmpi`

Purpose Replace string using regular expression

Syntax `s = regexprep('str', 'expr', 'repstr')`
`s = regexprep('str', 'expr', 'repstr', options)`

Description `s = regexprep('str', 'expr', 'repstr')` replaces all occurrences of the regular expression `expr` in string `str` with the string `repstr`. The new string is returned in `s`. If no matches are found, return string `s` is the same as input string `str`. You can use character representations (e.g., `'\t'` for tab, or `'\n'` for newline) in replacement string `repstr`. See “Regular Expressions” in the MATLAB Programming Fundamentals documentation for more information.

If `str` is a cell array of strings, then the `regexprep` return value `s` is always a cell array of strings having the same dimensions as `str`.

To specify more than one expression to match or more than one replacement string, see the guidelines listed below under “Multiple Expressions or Replacement Strings” on page 2-3082.

You can capture parts of the input string as tokens and then reuse them in the replacement string. Specify the parts of the string to capture using the `(...)` operator. Specify the tokens to use in the replacement string using the operators `$1`, `$2`, `$N` to reference the first, second, and `N`th tokens captured. (See “Tokens” and the example “Using Tokens in a Replacement String” in the MATLAB Programming Fundamentals documentation for information on using tokens.)

`s = regexprep('str', 'expr', 'repstr', options)` By default, `regexprep` replaces all matches and is case sensitive. You can use one or more of the following options with `regexprep`.

Option	Description
<code>mode</code>	See <code>mode</code> descriptions on the <code>regexp</code> reference page.
<code>N</code>	Replace only the <code>N</code> th occurrence of <code>expr</code> in <code>str</code> .
<code>'once'</code>	Replace only the first occurrence of <code>expr</code> in <code>str</code> .

Option	Description
'ignorecase'	Ignore case when matching and when replacing.
'preserveCase'	Ignore case when matching (as with 'ignorecase'), but override the case of replace characters with the case of corresponding characters in str when replacing.
'warnings'	Display any hidden warning messages issued by MATLAB during the execution of the command. This option only enables warnings for the one command being executed.

Remarks

See “Regular Expressions” in the MATLAB Programming Fundamentals documentation for a listing of all regular expression metacharacters supported by MATLAB.

Multiple Expressions or Replacement Strings

In the case of multiple expressions and/or replacement strings, `regexprep` attempts to make all matches and replacements. The first match is against the initial input string. Successive matches are against the string resulting from the previous replacement.

The `expr` and `repstr` inputs follow these rules:

- If `expr` is a cell array of strings and `repstr` is a single string, `regexprep` uses the same replacement string on each expression in `expr`.
- If `expr` is a single string and `repstr` is a cell array of N strings, `regexprep` attempts to make N matches and replacements.
- If both `expr` and `repstr` are cell arrays of strings, then `expr` and `repstr` must contain the same number of elements, and `regexprep` pairs each `repstr` element with its matching element in `expr`.

Examples

Example 1 – Making a Case-Sensitive Replacement

Perform a case-sensitive replacement on words starting with `m` and ending with `y`:

```
str = 'My flowers may bloom in May';
pat = 'm(\w*)y';
regexprep(str, pat, 'April')
ans =
    My flowers April bloom in May
```

Replace all words starting with `m` and ending with `y`, regardless of case, but maintain the original case in the replacement strings:

```
regexprep(str, pat, 'April', 'preserveCase')
ans =
    April flowers april bloom in April
```

Example 2 – Using Tokens In the Replacement String

Replace all variations of the words 'walk up' using the letters following walk as a token. In the replacement string

```
str = 'I walk up, they walked up, we are walking up.';
pat = 'walk(\w*) up';
regexprep(str, pat, 'ascend$1')
ans =
    I ascend, they ascended, we are ascending.
```

Example 3 – Operating on Multiple Strings

This example operates on a cell array of strings. It searches for consecutive matching letters (e.g., 'oo') and uses a common replacement value ('--') for all matches. The function returns a cell array of strings having the same dimensions as the input cell array:

```
str = {
    'Whose woods these are I think I know.' ; ...
    'His house is in the village though;' ; ...
    'He will not see me stopping here' ; ...
    'To watch his woods fill up with snow.'};
```

regexprep

```
a = regexprep(str, '(.)\1', '--', 'ignorecase')
a =
    'Whose w--ds these are I think I know.'
    'His house is in the vi--age though;'
    'He wi-- not s-- me sto--ing here'
    'To watch his w--ds fi-- up with snow.'
```

See Also

regexp, regexpi, regexprtranslate, strfind, findstr, strmatch,
strcmp, strcmpi, strncmp, strncmpi

Purpose Translate string into regular expression

Syntax `s2 = regexptranslate(type, s1)`

Description `s2 = regexptranslate(type, s1)` translates string `s1` into a regular expression string `s2` that you can then use as input into one of the MATLAB regular expression functions such as `regexp`. The `type` input can be either one of the following strings that define the type of translation to be performed. See “Regular Expressions” in the MATLAB Programming Fundamentals documentation for more information.

Type	Description
'escape'	Translate all special characters (e.g., '\$', '.', '?', '[') in string <code>s1</code> so that they are treated as literal characters when used in the <code>regexp</code> and <code>regexprep</code> functions. The translation inserts an escape character ('\') before each special character in <code>s1</code> . Return the new string in <code>s2</code> .
'wildcard'	Translate all wildcard and '.' characters in string <code>s1</code> so that they are treated as literal wildcards and periods when used in the <code>regexp</code> and <code>regexprep</code> functions. The translation replaces all instances of '*' with '.', all instances of '?' with '.', and all instances of '.' with '\.'. Return the new string in <code>s2</code> .

Examples

Example 1 – Using the 'escape' Option

Because `regexp` interprets the sequence '\n' as a newline character, it cannot locate the two consecutive characters '\ ' and 'n' in this string:

```
str = 'The sequence \n generates a new line';
pat = '\n';

regexp(str, pat)
ans =
     []
```

regexptranslate

To have `regexp` interpret the expression `expr` as the characters ``\`` and ``n``, first translate the expression using `regexptranslate`:

```
pat2 = regexptranslate('escape', pat)
pat2 =
    \n

regexp(str, pat2)
ans =
    14
```

Example 2 – Using 'escape' In a Replacement String

Replace the word 'walk' with 'ascend' in this string, treating the characters '\$1' as a token designator:

```
str = 'I walk up, they walked up, we are walking up.';
pat = 'walk(\w*) up';

regprep(str, pat, 'ascend$1')
ans =
    I ascend, they ascended, we are ascending.
```

Make another replacement on the same string, this time treating the '\$1' as literal characters:

```
regprep(str, pat, regexptranslate('escape', 'ascend$1'))
ans =
    I ascend$1, they ascend$1, we are ascend$1.
```

Example 3 – Using the 'wildcard' Option

Given the following string of filenames, pick out just the MAT-files. Use `regexptranslate` to interpret the '*' wildcard as '\w+' instead of as a regular expression quantifier:

```
files = ['test1.mat, myfile.mat, newfile.txt, ' ...
        'jan30.mat, table3.xls'];
regexp(str, regexptranslate('wildcard', '*.mat'), 'match')
ans =
```

```
'test1.mat' 'myfile.mat' 'jan30.mat'
```

To see the translation, you can type

```
regexptranslate('wildcard', '*.mat')  
ans =  
  \w+\.mat
```

See Also

regexp, regexpi, regexprep

registerevent

Purpose Register event handler for COM object event at run-time

Syntax `h.registerevent(event_handler)`
`registerevent(h, event_handler)`

Description `h.registerevent(event_handler)` registers certain event handler routines with their corresponding events. Once an event is registered, the object responds to the occurrence of that event by invoking its event handler routine. The `event_handler` argument can be either a string that specifies the name of the event handler function, or a function handle that maps to that function. Strings used in the `event_handler` argument are not case sensitive.

`registerevent(h, event_handler)` is an alternate syntax for the same operation.

You can either register events at the time you create the control (using `actxcontrol`), or register them dynamically at any time after the control has been created (using `registerevent`). The `event_handler` argument specifies both events and event handlers (see “Writing Event Handlers” in the External Interfaces documentation).

Remarks COM functions are available on Microsoft Windows systems only.

Examples Register Events Using Function Name Example

Create an `mwsamp` control and list all events associated with the control:

```
f = figure ('position', [100 200 200 200]);  
h = actxcontrol ('mwsamp.mwsampctrl.2', [0 0 200 200], f);  
  
h.events
```

MATLAB software displays (output is formatted):

```
Click = void Click()  
Db1Click = void Db1Click()  
MouseDown = void MouseDown(int16 Button, int16 Shift,
```

```
Variant x, Variant y)
Event_Args = void Event_Args(int16 typeshort,
    int32 typelong, double typedouble, string typestring,
    bool typebool)
```

Register all events with the same event handler routine, `sampev`. Use `eventlisteners` to see the event handler used by each event:

```
h.registerevent('sampev');
h.eventlisteners
```

MATLAB displays:

```
ans =
    'Click'          'sampev'
    'Db1Click'      'sampev'
    'MouseDown'     'sampev'
    'Event_Args'    'sampev'
```

Unregister these events. Now register the `Click` and `Db1Click` events with the event handlers `myclick` and `my2click`, respectively. Note that the strings in the argument list are not case sensitive.

```
h.unregisterallevnts;
h.registerevent({'click' 'myclick'; ...
    'dblclick' 'my2click'});
h.eventlisteners
```

MATLAB displays:

```
ans =
    'click'          'myclick'
    'dblclick'      'my2click'
```

Register Events Using Function Handle Example

Register all events with the same event handler routine, `sampev`, but use a function handle (`@sampev`) instead of the function name:

registerevent

```
h = actxcontrol('mwsamp.mwsampctrl.2', [0 0 200 200]);
registerevent(h, @sampev);
```

Register Workbook Events Example

Create a Microsoft Excel Workbook object.

```
myApp = actxserver('Excel.Application');
wbs = myApp.Workbooks;
wb = wbs.Add;
```

Register all events with the same event handler routine, `AllEventHandler`.

```
wb.registerevent('AllEventHandler')
wb.eventlisteners
```

The MATLAB displays the list of all Workbook events, registered with `AllEventHandler`.

```
ans =
    'Open'                'AllEventHandler'
    'Activate'            'AllEventHandler'
    'Deactivate'          'AllEventHandler'
    'BeforeClose'         'AllEventHandler'
    .
    .
```

See Also

`events` (COM), `eventlisteners`, `unregisterevent`, `unregisterallevnts`, `isevent`

Purpose Refresh function and file system path caches

Syntax

```
rehash
rehash path
rehash toolbox
rehash pathreset
rehash toolboxreset
rehash toolboxcache
```

Description rehash with no arguments updates the MATLAB list of known files and classes for directories on the search path that are not in *matlabroot*/toolbox. It compares the timestamps for loaded functions against their timestamps on disk. It clears loaded functions if the files on disk are newer. All of this normally happens each time MATLAB displays the Command Window prompt. Use rehash with no arguments only when you run an M-file that updates a second M-file, and the calling file needs to reuse the updated version of the second M-file before the calling file has finished running.

rehash **path** performs the same updates as rehash, but uses a different technique for detecting the files and directories that require updates. Run rehash path only if you receive a warning during MATLAB startup notifying you that MATLAB could not tell if a directory has changed, and you encounter problems with MATLAB not using the most current versions of your M-files.

rehash **toolbox** performs the same updates as rehash path, except it updates the list of known files and classes for *all* directories on the search path, including those in *matlabroot*/toolbox. Run rehash toolbox when you change, add, or remove files in *matlabroot*/toolbox during a session. Typically, you should not make changes to files and directories in *matlabroot*/toolbox.

rehash **pathreset** performs the same updates as rehash **path**, and also ensures the known files and classes list follows precedence rules for shadowed functions.

rehash

`rehash toolboxreset` performs the same updates as `rehash toolbox`, and also ensures the known files and classes list follows precedence rules for shadowed functions.

`rehash toolboxcache` performs the same updates as `rehash toolbox`, and also updates the cache file. This is the equivalent of clicking the **Update Toolbox Path Cache** button in the General Preferences dialog box.

See Also

`addpath`, `clear`, `matlabroot`, `path`, `rmpath`

“Toolbox Path Caching in the MATLAB Program” and “Search Path” in the MATLAB Desktop Tools and Development Environment documentation

Purpose	Release COM interface
Syntax	<code>h.release</code> <code>release(h)</code>
Description	<p><code>h.release</code> releases the interface and all resources used by the interface. Each interface handle must be released when you are finished manipulating its properties and invoking its methods. Once an interface has been released, it is no longer valid. Subsequent operations on the MATLAB object that represents that interface will result in errors.</p> <p><code>release(h)</code> is an alternate syntax for the same operation.</p>

Note Releasing the interface does not delete the control itself (see `delete`), since other interfaces on that object may still be active. See Releasing Interfaces in the External Interfaces documentation for more information.

Remarks COM functions are available on Microsoft Windows systems only.

Examples Create a Microsoft Calendar application. Then create a `TitleFont` interface and use it to change the appearance of the font of the calendar's title:

```
f = figure('position',[300 300 500 500]);
cal = actxcontrol('mscal.calendar', [0 0 500 500], f);

TFont = cal.TitleFont;
TFont.Name = 'Viva BoldExtraExtended';
TFont.Bold = 0;
```

When you're finished working with the title font, release the `TitleFont` interface:

```
TFont.release;
```

Now create a `GridFont` interface and use it to modify the size of the calendar's date numerals:

```
GFont = cal.GridFont;  
GFont.Size = 16;
```

When you're done, delete the `cal` object and the figure window:

```
cal.delete;  
delete(f);  
clear f;
```

See Also

`delete (COM)`, `save (COM)`, `load (COM)`, `actxcontrol`, `actxserver`

Purpose Equality and sorting of handle objects

Syntax

```
TF = eq(H1,H2)
TF = ne(H1,H2)
TF = lt(H1,H2)
TF = le(H1,H2)
TF = gt(H1,H2)
TF = ge(H1,H2)
```

Description

```
TF = eq(H1,H2)
TF = ne(H1,H2)
TF = lt(H1,H2)
TF = le(H1,H2)
TF = gt(H1,H2)
TF = ge(H1,H2)
```

For each pair of input arrays (H1 and H2), a logical array of the same size is returned in which each element is an element-wise equality or comparison test result. These methods perform scalar expansion in the same way as the MATLAB built-in functions. See `relationaloperators` for more information.

You can make the following assumptions about the result of a handle comparison:

- The same two handles always compare as equal and the repeated comparison of any two handles always yields the same result in the same MATLAB session.
- Different handles are always not-equal.
- The order of handle values is purely arbitrary and has no connection to the state of the handle objects being compared.
- If the input arrays belong to different classes (including the case where one input array belongs to a non-handle class such as `double`) then the comparison is always false.

relationaloperators (handle)

- If a comparison is made between a handle object and an object of a dominant class, the method of the dominant class is invoked. You should generally test only like objects because a dominant class might not define one of these methods.
- An error occurs if the input arrays are not the same size and neither is scalar.

See Also

handle, meta.class

Purpose	Remainder after division
Syntax	$R = \text{rem}(X, Y)$
Description	<p>$R = \text{rem}(X, Y)$ if $Y \neq 0$, returns $X - n \cdot Y$ where $n = \text{fix}(X./Y)$. If Y is not an integer and the quotient $X./Y$ is within roundoff error of an integer, then n is that integer. The inputs X and Y must be real arrays of the same size, or real scalars.</p> <p>The following are true by convention:</p> <ul style="list-style-type: none">• $\text{rem}(X, 0)$ is NaN• $\text{rem}(X, X)$ for $X \neq 0$ is 0• $\text{rem}(X, Y)$ for $X \neq Y$ and $Y \neq 0$ has the same sign as X.
Remarks	<p>$\text{mod}(X, Y)$ for $X \neq Y$ and $Y \neq 0$ has the same sign as Y.</p> <p>$\text{rem}(X, Y)$ and $\text{mod}(X, Y)$ are equal if X and Y have the same sign, but differ by Y if X and Y have different signs.</p> <p>The <code>rem</code> function returns a result that is between 0 and $\text{sign}(X) \cdot \text{abs}(Y)$. If Y is zero, <code>rem</code> returns NaN.</p>
See Also	<code>mod</code>

remove (Map)

Purpose Remove key-value pairs from `containers.Map`

Syntax `remove(M, keys)`

Description `remove(M, keys)` erases all specified keys, and the values associated with them, from Map object `M`. `keys` can be a scalar key or a cell array of keys.

Using `remove` changes the count of the elements in the map.

Read more about Map Containers in the MATLAB Programming Fundamentals documentation.

Examples Create a Map object containing the names of several US states and the capital city of each:

```
US_Capitals = containers.Map( ...  
    {'Arizona', 'Nebraska', 'Nevada', 'New York', ...  
    'Georgia', 'Alaska', 'Vermont', 'Oregon'}, ...  
    {'Phoenix', 'Lincoln', 'Carson City', 'Albany', ...  
    'Atlanta', 'Juneau', 'Montpelier', 'Salem'});
```

After checking how many keys there are in the `US_Capitals` map, remove the key-value pair with key name `Oregon` from it:

```
US_Capitals.Count  
ans =  
    8  
  
remove(US_Capitals, 'Oregon');  
  
US_Capitals.Count  
ans =  
    7
```

Remove three more key-value pairs from the map:

```
remove(US_Capitals, {'Nebraska', 'Nevada', 'New York'});
US_Capitals.Count
ans =
    4
```

See Also

containers.Map, keys(Map), values(Map), size(Map),
length(Map) isKey(Map), handle

removets

Purpose Remove timeseries objects from tscollection object

Syntax `tsc = removets(tsc,Name)`

Description `tsc = removets(tsc,Name)` removes one or more timeseries objects with the name specified in Name from the tscollection object tsc. Name can either be a string or a cell array of strings.

Examples The following example shows how to remove a time series from a tscollection.

1 Create two timeseries objects, ts1 and ts2.

```
ts1=timeseries([1.1 2.9 3.7 4.0 3.0],1:5,'name','acceleration');  
ts2=timeseries([3.2 4.2 6.2 8.5 1.1],1:5,'name','speed');
```

2 Create a tscollection object tsc, which includes ts1 and ts2.

```
tsc=tscollection({ts1 ts2});
```

3 To view the members of tsc, type the following at the MATLAB prompt:

```
tsc
```

The response is

```
Time Series Collection Object: unnamed
```

```
Time vector characteristics
```

```
Start time          1 seconds  
End time            5 seconds
```

```
Member Time Series Objects:
```



```
acceleration
speed
```

The members of `tsc` are listed by name at the bottom: `acceleration` and `speed`. These are the `Name` properties of `ts1` and `ts2`, respectively.

- 4** Remove `ts2` from `tsc`.

```
tsc=removets(tsc,'speed');
```

- 5** To view the current members of `tsc`, type the following at the MATLAB prompt:

```
tsc
```

The response is

```
Time Series Collection Object: unnamed
```

```
Time vector characteristics
```

```
Start time          1 seconds
End time            5 seconds
```

```
Member Time Series Objects:
acceleration
```

The remaining member of `tsc` is `acceleration`. The timeseries `speed` has been removed.

See Also

`addts`, `tscollection`

rename

Purpose Rename file on FTP server

Syntax `rename(f, 'oldname', 'newname')`

Description `rename(f, 'oldname', 'newname')` changes the name of the file `oldname` to `newname` in the current directory of the FTP server `f`, where `f` was created using `ftp`.

Examples Connect to server `testsite`, view the contents, and change the name of `testfile.m` to `showresults.m`.

```
test=ftp('ftp.testsite.com');
dir(test)
.          ..          testfile.m
rename(test, 'testfile.m', 'showresults.m')
dir(test)
.          ..          showresults.m
```

See Also `dir (ftp)`, `delete (ftp)`, `ftp`, `mget`, `mput`

Purpose

Replicate and tile array

Syntax

```
B = repmat(A,m,n)
B = repmat(A,[m n])
B = repmat(A,[m n p...])
```

Description

`B = repmat(A,m,n)` creates a large matrix `B` consisting of an `m`-by-`n` tiling of copies of `A`. The size of `B` is `[size(A,1)*m, (size(A,2)*n)]`. The statement `repmat(A,n)` creates an `n`-by-`n` tiling.

`B = repmat(A,[m n])` accomplishes the same result as `repmat(A,m,n)`.

`B = repmat(A,[m n p...])` produces a multidimensional array `B` composed of copies of `A`. The size of `B` is `[size(A,1)*m, size(A,2)*n, size(A,3)*p, ...]`.

Remarks

`repmat(A,m,n)`, when `A` is a scalar, produces an `m`-by-`n` matrix filled with `A`'s value and having `A`'s class. For certain values, you can achieve the same results using other functions, as shown by the following examples:

- `repmat(NaN,m,n)` returns the same result as `NaN(m,n)`.
- `repmat(single(inf),m,n)` is the same as `inf(m,n,'single')`.
- `repmat(int8(0),m,n)` is the same as `zeros(m,n,'int8')`.
- `repmat(uint32(1),m,n)` is the same as `ones(m,n,'uint32')`.
- `repmat(eps,m,n)` is the same as `eps(ones(m,n))`.

Examples

In this example, `repmat` replicates 12 copies of the second-order identity matrix, resulting in a “checkerboard” pattern.

```
B = repmat(eye(2),3,4)
```

```
B =
     1     0     1     0     1     0     1     0
     0     1     0     1     0     1     0     1
     1     0     1     0     1     0     1     0
```

repmat

```
0  1  0  1  0  1  0  1
1  0  1  0  1  0  1  0
0  1  0  1  0  1  0  1
```

The statement `N = repmat(NaN,[2 3])` creates a 2-by-3 matrix of NaNs.

See Also

`bsxfun`, `NaN`, `Inf`, `ones`, `zeros`

Purpose Select or interpolate timeseries data using new time vector

Syntax

```
ts = resample(ts,Time)
ts = resample(ts,Time,interp_method)
ts = resample(ts,Time,interp_method,code)
```

Description

`ts = resample(ts,Time)` resamples the timeseries object `ts` using the new `Time` vector. When `ts` uses date strings and `Time` is numeric, `Time` is treated as specified relative to the `ts.TimeInfo.StartDate` property and in the same units that `ts` uses. The `resample` operation uses the default interpolation method, which you can view by using the `getinterpmethod(ts)` syntax.

`ts = resample(ts,Time,interp_method)` resamples the timeseries object `ts` using the interpolation method given by the string `interp_method`. Valid interpolation methods include 'linear' and 'zoh' (zero-order hold).

`ts = resample(ts,Time,interp_method,code)` resamples the timeseries object `ts` using the interpolation method given by the string `interp_method`. The integer `code` is a user-defined Quality code for resampling, applied to all samples.

Examples The following example shows how to resample a timeseries object.

1 Create a timeseries object.

```
ts=timeseries([1.1 2.9 3.7 4.0 3.0],1:5,'Name','speed');
```

2 Transpose `ts` to make the data columnwise.

```
ts=transpose(ts)
```

The display in the MATLAB Command Window is

```
Time Series Object: speed
```

```
Time vector characteristics
```

resample (timeseries)

```
Length          5
Start time      1 seconds
End time        5 seconds
```

Data characteristics

```
Interpolation method  linear
Size                  [5 1]
Data type              double
```

Time	Data	Quality
1	1.1	
2	2.9	
3	3.7	
4	4	
5	3	

Note that the interpolation method is set to `linear`, by default.

3 Resample `ts` using its default interpolation method.

```
res_ts=resample(ts,[1 1.5 3.5 4.5 4.9])
```

The resampled time series displays as follows:

```
Time Series Object: speed
```

Time vector characteristics

```
Length          5
Start time      1 seconds
End time        4.900000e+000 seconds
```

Data characteristics

Interpolation method	linear
Size	[5 1]
Data type	double

Time	Data	Quality
1	1.1	
1.5	2	
3.5	3.85	
4.5	3.5	
4.9	3.1	

See Also

`getinterpmethod`, `setinterpmethod`, `synchronize`, `timeseries`

resample (tscollection)

Purpose Select or interpolate data in `tscollection` using new time vector

Syntax

```
tsc = resample(tsc,Time)
tsc = resample(tsc,Time,interp_method)
tsc = resample(tsc,Time,interp_method,code)
```

Description `tsc = resample(tsc,Time)` resamples the `tscollection` object `tsc` on the new `Time` vector. When `tsc` uses date strings and `Time` is numeric, `Time` is treated as numerical specified relative to the `tsc.TimeInfo.StartDate` property and in the same units that `tsc` uses. The `resample` method uses the default interpolation method for each time series member.

`tsc = resample(tsc,Time,interp_method)` resamples the `tscollection` object `tsc` using the interpolation method given by the string `interp_method`. Valid interpolation methods include 'linear' and 'zoh' (zero-order hold).

`tsc = resample(tsc,Time,interp_method,code)` resamples the `tscollection` object `tsc` using the interpolation method given by the string `interp_method`. The integer `code` is a user-defined quality code for resampling, applied to all samples.

Examples The following example shows how to resample a `tscollection` that consists of two `timeseries` members.

1 Create two `timeseries` objects.

```
ts1=timeseries([1.1 2.9 3.7 4.0 3.0],1:5,'name','acceleration');
ts2=timeseries([3.2 4.2 6.2 8.5 1.1],1:5,'name','speed');
```

2 Create a `tscollection` `tsc`.

```
tsc=tscollection({ts1 ts2});
```

The time vector of the collection `tsc` is `[1:5]`, which is the same as for `ts1` and `ts2` (individually).

- 3** Get the interpolation method for acceleration by typing

```
tsc.acceleration
```

MATLAB responds with

```
Time Series Object: acceleration
```

```
Time vector characteristics
```

```
Length           5
Start time       1 seconds
End time         5 seconds
```

```
Data characteristics
```

```
Interpolation method linear
Size               [1 1 5]
Data type          double
```

- 4** Set the interpolation method for speed to zero-order hold by typing

```
setinterpmethod(tsc.speed, 'zoh')
```

MATLAB responds with

```
Time Series Object: acceleration
```

```
Time vector characteristics
```

```
Length           5
Start time       1 seconds
End time         5 seconds
```

resample (tscollection)

Data characteristics

Interpolation method	zoh
Size	[1 1 5]
Data type	double

- 5 Resample the time-series collection `tsc` by individually resampling each time-series member of the collection and using its interpolation method.

```
res_tsc=resample(tsc,[1 1.5 3.5 4.5 4.9])
```

See Also

`getinterpmethod`, `setinterpmethod`, `tscollection`

Purpose	Reset graphics object properties to their defaults
Syntax	<code>reset(h)</code>
Description	<p><code>reset(h)</code> resets all properties having factory defaults on the object identified by <code>h</code>. To see the list of factory defaults, use the statement</p> <pre>get(0, 'factory')</pre> <p>If <code>h</code> is a figure, the MATLAB software does not reset <code>Position</code>, <code>Units</code>, <code>WindowStyle</code>, or <code>PaperUnits</code>. If <code>h</code> is an axes, MATLAB does not reset <code>Position</code> and <code>Units</code>.</p>
Examples	<p><code>reset(gca)</code> resets the properties of the current axes.</p> <p><code>reset(gcf)</code> resets the properties of the current figure.</p>
See Also	<p><code>cla</code>, <code>clf</code>, <code>gca</code>, <code>gcf</code>, <code>hold</code></p> <p>“Object Manipulation” on page 1-107 for related functions</p>

reset (RandStream)

Purpose Reset random stream

Class @RandStream

Syntax reset(s)
reset(s,seed)

Description reset(s) resets the generator for the random stream s to its initial internal state. This is similar to clearing s and recreating it using RandStream('type',...), except reset does not set the stream's RandnAlg, Antithetic, and FullPrecision properties to their original values.

reset(s,seed) resets the generator for the random stream s to the initial internal state corresponding to the seed seed. Resetting a stream's seed can invalidate independence with other streams.

Note Resetting a stream should be used primarily for reproducing results.

Examples

1 Create a random stream object.

```
s=RandStream('mt19937ar')
```

2 Make it the default stream.

```
RandStream.setDefaultStream(s)
```

3 Reset the stream object you just created and generate 5 uniform random values using the rand method.

```
rand(s,1,5)
```

```
ans =
```

```
0.3631    0.4048    0.1490    0.9438    0.1247
```

4 Reset the stream.

```
reset(s)
```

5 Generate the same 5 random values from the default stream.

```
rand(s,1,5)
```

```
ans =
```

```
    0.3631    0.4048    0.1490    0.9438    0.1247
```

See Also

@RandStream

reshape

Purpose

Reshape array

Syntax

```
B = reshape(A,m,n)
B = reshape(A,m,n,p,...)
B = reshape(A,[m n p ...])
B = reshape(A,...,[],...)
B = reshape(A,siz)
```

Description

`B = reshape(A,m,n)` returns the m -by- n matrix `B` whose elements are taken column-wise from `A`. An error results if `A` does not have $m*n$ elements.

`B = reshape(A,m,n,p,...)` or `B = reshape(A,[m n p ...])` returns an n -dimensional array with the same elements as `A` but reshaped to have the size m -by- n -by- p -by- \dots . The product of the specified dimensions, $m*n*p*\dots$, must be the same as `prod(size(A))`.

`B = reshape(A,...,[],...)` calculates the length of the dimension represented by the placeholder `[]`, such that the product of the dimensions equals `prod(size(A))`. The value of `prod(size(A))` must be evenly divisible by the product of the specified dimensions. You can use only one occurrence of `[]`.

`B = reshape(A,siz)` returns an n -dimensional array with the same elements as `A`, but reshaped to `siz`, a vector representing the dimensions of the reshaped array. The quantity `prod(siz)` must be the same as `prod(size(A))`.

Examples

Reshape a 3-by-4 matrix into a 2-by-6 matrix.

```
A =
    1     4     7    10
    2     5     8    11
    3     6     9    12
```

```
B = reshape(A,2,6)
```

```
B =
```

```
    1   3   5   7   9  11
    2   4   6   8  10  12
B = reshape(A,2,[])
```

```
B =
    1   3   5   7   9  11
    2   4   6   8  10  12
```

See Also

`shiftdim`, `squeeze`, `circshift`, `permute`

The colon operator :

residue

Purpose Convert between partial fraction expansion and polynomial coefficients

Syntax
[r,p,k] = residue(b,a)
[b,a] = residue(r,p,k)

Description The residue function converts a quotient of polynomials to pole-residue representation, and back again.

[r,p,k] = residue(b,a) finds the residues, poles, and direct term of a partial fraction expansion of the ratio of two polynomials, $b(s)$ and $a(s)$, of the form

$$\frac{b(s)}{a(s)} = \frac{b_1s^m + b_2s^{m-1} + b_3s^{m-2} + \dots + b_{m+1}}{a_1s^n + a_2s^{n-1} + a_3s^{n-2} + \dots + a_{n+1}}$$

where b_j and a_j are the j th elements of the input vectors b and a .

[b,a] = residue(r,p,k) converts the partial fraction expansion back to the polynomials with coefficients in b and a .

Definition If there are no multiple roots, then

$$\frac{b(s)}{a(s)} = \frac{r_1}{s-p_1} + \frac{r_2}{s-p_2} + \dots + \frac{r_n}{s-p_n} + k(s)$$

The number of poles n is

$$n = \text{length}(a) - 1 = \text{length}(r) = \text{length}(p)$$

The direct term coefficient vector is empty if $\text{length}(b) < \text{length}(a)$; otherwise

$$\text{length}(k) = \text{length}(b) - \text{length}(a) + 1$$

If $p(j) = \dots = p(j+m-1)$ is a pole of multiplicity m , then the expansion includes terms of the form

$$\frac{r_j}{s-p_j} + \frac{r_{j+1}}{(s-p_j)^2} + \dots + \frac{r_{j+m-1}}{(s-p_j)^m}$$

Arguments

b, a	Vectors that specify the coefficients of the polynomials in descending powers of s
r	Column vector of residues
p	Column vector of poles
k	Row vector of direct terms

Algorithm

It first obtains the poles with `roots`. Next, if the fraction is nonproper, the direct term `k` is found using `deconv`, which performs polynomial long division. Finally, the residues are determined by evaluating the polynomial with individual roots removed. For repeated roots, `resi2` computes the residues at the repeated root locations.

Limitations

Numerically, the partial fraction expansion of a ratio of polynomials represents an ill-posed problem. If the denominator polynomial, $a(s)$, is near a polynomial with multiple roots, then small changes in the data, including roundoff errors, can make arbitrarily large changes in the resulting poles and residues. Problem formulations making use of state-space or zero-pole representations are preferable.

Examples

If the ratio of two polynomials is expressed as

$$\frac{b(s)}{a(s)} = \frac{5s^3 + 3s^2 - 2s + 7}{-4s^3 + 8s + 3}$$

then

$$\begin{aligned} b &= [5 \ 3 \ -2 \ 7] \\ a &= [-4 \ 0 \ 8 \ 3] \end{aligned}$$

residue

and you can calculate the partial fraction expansion as

$$[r, p, k] = \text{residue}(b,a)$$

$$r = \begin{array}{l} -1.4167 \\ -0.6653 \\ 1.3320 \end{array}$$

$$p = \begin{array}{l} 1.5737 \\ -1.1644 \\ -0.4093 \end{array}$$

$$k = \begin{array}{l} -1.2500 \end{array}$$

Now, convert the partial fraction expansion back to polynomial coefficients.

$$[b,a] = \text{residue}(r,p,k)$$

$$b = \begin{array}{cccc} -1.2500 & -0.7500 & 0.5000 & -1.7500 \end{array}$$

$$a = \begin{array}{cccc} 1.0000 & -0.0000 & -2.0000 & -0.7500 \end{array}$$

The result can be expressed as

$$\frac{b(s)}{a(s)} = \frac{-1.25s^3 - 0.75s^2 + 0.50s - 1.75}{s^3 - 2.00s - 0.75}$$

Note that the result is normalized for the leading coefficient in the denominator.

See Also

deconv, poly, roots

References

[1] Oppenheim, A.V. and R.W. Schaffer, *Digital Signal Processing*, Prentice-Hall, 1975, p. 56.

restoredefaultpath

Purpose Restore default search path

Syntax restoredefaultpath
restoredefaultpath; matlabrc

Description restoredefaultpath sets the search path to include only installed products from The MathWorks. Run restoredefaultpath if you are having problems with the search path. If restoredefaultpath seems to correct the problem, run savepath. Start the MATLAB program again to be sure the problem does not reappear.

restoredefaultpath; matlabrc sets the search path to include only installed products from The MathWorks and corrects path problems encountered during startup. Run restoredefaultpath; matlabrc if you are having problems with the search path and if restoredefaultpath by itself does not correct the problem. After the problem seems to be resolved, run savepath. Start MATLAB again to be sure the problem does not reappear.

See Also addpath, path, rmpath, savepath

Search Path in the MATLAB Desktop Tools and Development Environment documentation

Purpose Reissue error

Syntax rethrow(err)

Description rethrow(err) reissues the error specified by err. The currently running M-file terminates and control returns to the keyboard (or to any enclosing catch block). The err argument must be a MATLAB structure containing at least one of the following fields.

Fieldname	Description
message	Text of the error message
identifier	Message identifier of the error message
stack	Information about the error from the program stack

See "Message Identifiers" in the MATLAB documentation for more information on the syntax and usage of message identifiers.

A convenient way to get a valid err structure for the last error issued is by using the lasterror function.

Remarks The err input can contain the field stack, identical in format to the output of the dbstack command. If the stack field is present, the stack of the rethrown error will be set to that value. Otherwise, the stack will be set to the line at which the rethrow occurs.

Examples rethrow is usually used in conjunction with try-catch statements to reissue an error from a catch block after performing catch-related operations. For example,

```
try
    do_something
catch
    do_cleanup
    rethrow(lasterror)
end
```

rethrow

See Also

`error`, `lasterror`, `try`, `catch`, `dbstop`

Purpose Reissue existing exception

Syntax rethrow(ME)

Description rethrow(ME) terminates the currently running function, reissues an exception that is based on MException object ME that has been caught within a try-catch block, and returns control to the keyboard or to any enclosing catch block.

rethrow differs from the throw and throwAsCaller methods in that it does not modify the stack field. Call stack information in the ME object is kept as it was when the exception was first thrown.

rethrow can only issue a previously caught exception. If an exception that was not previously thrown is passed to the rethrow method, the MATLAB software generates a new exception.

You might use rethrow from the catch part of a try-catch block, for example, after performing some required cleanup tasks following an error.

Examples

This variation of the MATLAB surf function catches an error in the input arguments, gives the user the opportunity to correct the error, and rethrows the error if the user does not use that opportunity:

```
function surf2(varargin)
try
    surf(varargin{:})
catch ME
    ME.message      % Display the error.
    % Give user another try to enter input arguments.
    newargs = input('\nEnter argument list: ','s');
    if ~isempty(newargs)
        surf(eval(newargs));
    else
        % If no response from user, rethrow the error.
        rethrow(ME);
    end
end
```

rethrow (MException)

```
end
```

When asked to correct the error, the user presses **Enter**. MATLAB rethrows the original error:

```
surf2
ans =
Not enough input arguments.

Enter argument list:
??? Error using ==> surf at 54
Not enough input arguments.

Error in ==> surf2 at 3
    surf(varargin{:});
```

This time, the user enters valid input and MATLAB successfully displays the output plot:

```
surf2
ans =
Not enough input arguments.

Enter argument list: peaks(30)
```

See Also

`try`, `catch`, `error`, `assert`, `MException`, `throw(MException)`, `throwAsCaller(MException)`, `addCause(MException)`, `getReport(MException)`, `disp(MException)`, `isequal(MException)`, `eq(MException)`, `ne(MException)`, `last(MException)`

Purpose Return to invoking function

Syntax return

Description return causes a normal return to the invoking function or to the keyboard. It also terminates keyboard mode.

Examples If the determinant function were an M-file, it might use a return statement in handling the special case of an empty matrix, as follows:

```
function d = det(A)
%DET det(A) is the determinant of A.
if isempty(A)
    d = 1;
    return
else
    ...
end
```

See Also break, continue, disp, end, error, for, if, keyboard, switch, while

rgb2hsv

Purpose Convert RGB colormap to HSV colormap

Syntax
`cmap = rgb2hsv(M)`
`hsv_image = rgb2hsv(rgb_image)`

Description `cmap = rgb2hsv(M)` converts an RGB colormap `M` to an HSV colormap `cmap`. Both colormaps are *m*-by-3 matrices. The elements of both colormaps are in the range 0 to 1.

The columns of the input matrix `M` represent intensities of red, green, and blue, respectively. The columns of the output matrix `cmap` represent hue, saturation, and value, respectively.

`hsv_image = rgb2hsv(rgb_image)` converts the RGB image to the equivalent HSV image. RGB is an *m*-by-*n*-by-3 image array whose three planes contain the red, green, and blue components for the image. HSV is returned as an *m*-by-*n*-by-3 image array whose three planes contain the hue, saturation, and value components for the image.

See Also `brighten`, `colormap`, `hsv2rgb`, `rgbplot`
“Color Operations” on page 1-105 for related functions

Purpose

Convert RGB image to indexed image

Syntax

```
[X,map] = rgb2ind( RGB, n)
X = rgb2ind( RGB, map)
[X,map] = rgb2ind( RGB, tol)
[...] = rgb2ind(..., dither_option)
```

Description

rgb2ind converts RGB images to indexed images using one of these methods:

- Uniform quantization
- Minimum variance quantization
- Colormap approximation

For all these methods, rgb2ind also dithers the image unless you specify 'nodither' for dither_option.

`[X,map] = rgb2ind(RGB, n)` converts the RGB image to an indexed image `X` using minimum variance quantization. `map` contains at most `n` colors. `n` must be less than or equal to 65,536.

`X = rgb2ind(RGB, map)` converts the RGB image to an indexed image `X` with colormap `map` by matching colors in `RGB` with the nearest color in the colormap `map`. `size(map, 1)` must be less than or equal to 65,536.

`[X,map] = rgb2ind(RGB, tol)` converts the RGB image to an indexed image `X` using uniform quantization. `map` contains at most $(\text{floor}(1/\text{tol})+1)^3$ colors. `tol` must be between 0.0 and 1.0.

`[...] = rgb2ind(..., dither_option)` enables or disables dithering. `dither_option` is a string that can have one of these values.

'dither' (default)	dithers, if necessary, to achieve better color resolution at the expense of spatial resolution.
'nodither'	maps each color in the original image to the closest color in the new map. No dithering is performed.

Note The values in the resultant image X are indexes into the colormap map and cannot be used in mathematical processing, such as filtering operations.

Class Support

The input image can be of class `uint8`, `uint16`, `single`, or `double`. If the length of map is less than or equal to 256, the output image is of class `uint8`. Otherwise, the output image is of class `uint16`.

Remarks

If you specify `tol`, `rgb2ind` uses uniform quantization to convert the image. This method involves cutting the RGB color cube into smaller cubes of length `tol`. For example, if you specify a `tol` of 0.1, the edges of the cubes are one-tenth the length of the RGB cube. The total number of small cubes is:

$$n = (\text{floor}(1/\text{tol})+1)^3$$

Each cube represents a single color in the output image. Therefore, the maximum length of the colormap is `n`. `rgb2ind` removes any colors that don't appear in the input image, so the actual colormap can be much smaller than `n`.

If you specify `n`, `rgb2ind` uses minimum variance quantization. This method involves cutting the RGB color cube into smaller boxes (not necessarily cubes) of different sizes, depending on how the colors are distributed in the image. If the input image actually uses fewer colors than the number you specify, the output colormap is also smaller.

If you specify `map`, `rgb2ind` uses colormap mapping, which involves finding the colors in `map` that best match the colors in the RGB image.

Examples

```
RGB = imread('peppers.png');  
[X,map] = rgb2ind(RGB,128);  
figure, imshow(X,map)
```



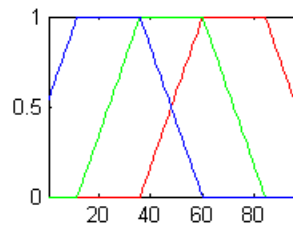
See Also

`cmunique`, `dither`, `imapprox`, `ind2rgb`

rgbplot

Purpose

Plot colormap



Syntax

```
rgbplot(cmap)
```

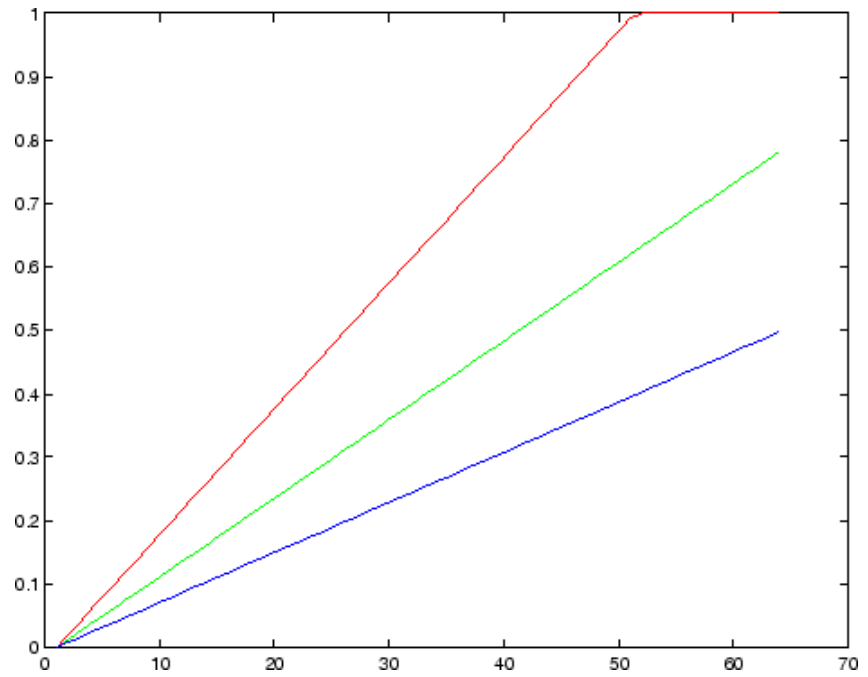
Description

`rgbplot(cmap)` plots the three columns of `cmap`, where `cmap` is an m -by-3 colormap matrix. `rgbplot` draws the first column in red, the second in green, and the third in blue.

Examples

Plot the RGB values of the copper colormap.

```
rgbplot(copper)
```



See Also

`colormap`

“Color Operations” on page 1-105 for related functions


ribbon

Purpose

Ribbon plot



GUI Alternatives

To graph selected variables, use the Plot Selector  in the Workspace Browser, or use the Figure Palette Plot Catalog. Manipulate graphs in *plot edit* mode with the Property Editor. For details, see [Plotting Tools — Interactive Plotting in the MATLAB Graphics documentation](#) and [Creating Graphics from the Workspace Browser in the MATLAB Desktop Tools documentation](#).

Syntax

```
ribbon(Y)
ribbon(X,Y)
ribbon(X,Y,width)
ribbon(axes_handle,...)
h = ribbon(...)
```

Description

`ribbon(Y)` plots the columns of `Y` as undulating three-dimensional ribbons of uniform width using `X = 1:size(Y,1)`. Ribbons advance along the *x*-axis centered on tick marks at unit intervals, three-quarters of a unit in width. Ribbons are assigned colors from the current colormap in sequence from minimum *X* to maximum *X* (the `axes colororder` property, used by `plot` and `plot3`, does not apply to ribbon or other surface plots).

`ribbon(X,Y)` plots *X* versus the columns of *Y* as three-dimensional strips. *X* and *Y* are vectors of the same size or matrices of the same size. Additionally, *X* can be a row or a column vector, and *Y* a matrix with `length(X)` rows. `ribbon(X,Y)` is the same as `plot(X,Y)` except that the columns of *Y* are plotted as separated ribbons in 3-D. The *y* and *z*-axes of `ribbon(X,Y)` correspond to the *x* and *y*-axes of `plot(X,Y)`.

`ribbon(X,Y,width)` specifies the width of the ribbons. The default is 0.75. If `width = 1`, the ribbons touch, leaving no space between them when viewed down the *z*-axis. If `width > 1`, ribbons overlap and can intersect.

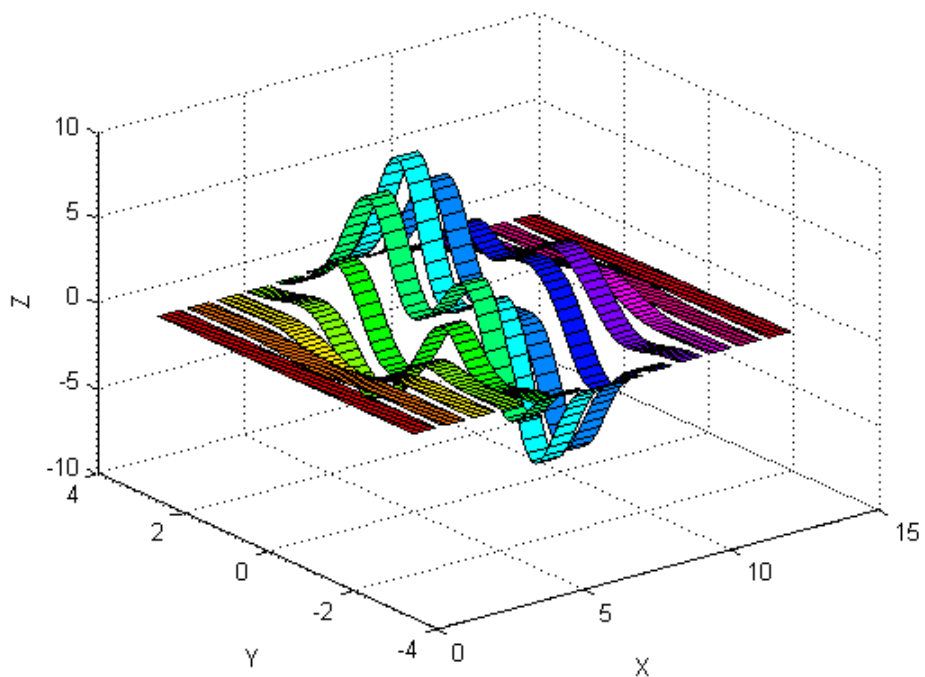
`ribbon(axes_handle,...)` plots into the axes with handle `axes_handle` instead of the current axes (`gca`).

`h = ribbon(...)` returns a vector of handles to surface graphics objects. `ribbon` returns one handle per strip.

Examples

Create a ribbon plot of the peaks function.

```
[x,y] = meshgrid(-3:.5:3,-3:.1:3);  
z = peaks(x,y);  
ribbon(y,z)  
xlabel('X')  
ylabel('Y')  
zlabel('Z')  
colormap hsv
```



ribbon

See Also

plot, plot3, surface, waterfall

“Polygons and Surfaces” on page 1-97 for related functions

Purpose Remove application-defined data

Syntax `rmappdata(h,name)`

Description `rmappdata(h,name)` removes the application-defined data `name` from the object specified by handle `h`.

Remarks Application data is data that is meaningful to or defined by your application which you attach to a figure or any GUI component (other than ActiveX controls) through its `AppData` property. Only Handle Graphics MATLAB objects use this property.

See Also `getappdata`, `isappdata`, `setappdata`

rmdir

Purpose

Remove directory

Graphical Interface

As an alternative to the `rmdir` function, use the delete feature in the Current Directory browser.

Syntax

```
rmdir('dirname')
rmdir('dirname','s')
[status, message, messageid] = rmdir('dirname','s')
```

Description

`rmdir('dirname')` removes the directory `dirname` from the current directory. If the directory is not empty, you must use the `s` argument. If `dirname` is not in the current directory, specify the relative path to the current directory or the full path for `dirname`.

`rmdir('dirname','s')` removes the directory `dirname` and its contents from the current directory. This removes all subdirectories and files in the current directory regardless of their write permissions.

`[status, message, messageid] = rmdir('dirname','s')` removes the directory `dirname` and its contents from the current directory, returning the status, a message, and the MATLAB error message ID (see `error` and `lasterror`). Here, `status` is 1 for success and is 0 for error, and `message`, `messageid`, and the `s` input argument are optional.

Remarks

When attempting to remove multiple directories, either by including a wildcard in the directory name or by specifying the `'s'` flag in the `rmdir` command, MATLAB throws an error if it is unable to remove all directories to which the command applies. The error message contains a listing of those directories and files that MATLAB could not remove.

Examples

Remove Empty Directory

To remove `myfiles` from the current directory, where `myfiles` is empty, type

```
rmdir('myfiles')
```

If the current directory is `matlabr13/work`, and `myfiles` is in `d:/matlabr13/work/project/`, use the relative path to `myfiles`:

```
rmdir('project/myfiles')
```

or the full path to `myfiles`:

```
rmdir('d:/matlabr13/work/project/myfiles')
```

Remove Directory and All Contents

To remove `myfiles`, its subdirectories, and all files in the directories, assuming `myfiles` is in the current directory, type

```
rmdir('myfiles','s')
```

Remove Directory and Return Results

To remove `myfiles` from the current directory, type

```
[stat, mess, id]=rmdir('myfiles')
```

MATLAB returns

```
stat =  
    0
```

```
mess =
```

```
The directory is not empty.
```

```
id =
```

```
MATLAB:RMDIR:OSError
```

indicating the directory `myfiles` is not empty.

To remove `myfiles` and its contents, run

```
[stat, mess]=rmdir('myfiles','s')
```

and MATLAB returns

rmmdir

```
stat =  
    1  
  
mess =  
    ''
```

indicating myfiles and its contents have been removed.

See Also

cd, copyfile, delete, dir, error, fileattrib, filebrowser,
lasterror, mkdir, movefile

“Managing Files and Working with the Current Directory”

Purpose Remove directory on FTP server

Syntax `rmdir(f, 'dirname')`

Description `rmdir(f, 'dirname')` removes the directory `dirname` from the current directory of the FTP server `f`, where `f` was created using `ftp`.

Examples Connect to server `testsite`, view the contents of `testdir`, and remove the directory `newdir` from the directory `testdir`.

```
test=ftp('ftp.testsite.com');
cd(test, 'testdir');
dir(test)
.          ..          newdir
dir(test, 'newdir')
.          ..
rmdir(test, 'newdir');
dir(test, 'testdir')
.          ..
```

See Also `cd (ftp)`, `delete (ftp)`, `dir (ftp)`, `ftp`, `mkdir (ftp)`

rmfield

Purpose Remove fields from structure

Syntax
`s = rmfield(s, 'fieldname')`
`s = rmfield(s, fields)`

Description `s = rmfield(s, 'fieldname')` removes the specified field from the structure array `s`.

`s = rmfield(s, fields)` removes more than one field at a time. `fields` is a character array of field names or cell array of strings.

See Also `fieldnames`, `setfield`, `getfield`, `isfield`, `orderfields`, dynamic field names

Purpose	Remove directories from search path
GUI Alternatives	As an alternative to the <code>rmpath</code> function, use the Set Path dialog box.
Syntax	<code>rmpath('directory')</code> <code>rmpath directory</code>
Description	<code>rmpath('directory')</code> removes the specified directory from the current MATLAB search path . Use the full pathname for <code>directory</code> . <code>rmpath directory</code> is the command form of the syntax.
Examples	Remove <code>/usr/local/matlab/mytools</code> from the search path. <pre>rmpath /usr/local/matlab/mytools</pre>
See Also	<code>addpath</code> , <code>cd</code> , <code>dir</code> , <code>genpath</code> , <code>matlabroot</code> , <code>partialpath</code> , <code>path</code> , <code>pathsep</code> , <code>pathtool</code> , <code>rehash</code> , <code>restoredefaultpath</code> , <code>savepath</code> , <code>userpath</code> , <code>what</code> Search Path in the MATLAB Desktop Tools and Development Environment documentation

rmpref

Purpose

Remove preference

Syntax

```
rmpref('group','pref')  
rmpref('group',{'pref1','pref2',... 'prefn'})  
rmpref('group')
```

Description

`rmpref('group','pref')` removes the preference specified by `group` and `pref`. It is an error to remove a preference that does not exist.

`rmpref('group',{'pref1','pref2',... 'prefn'})` removes each preference specified in the cell array of preference names. It is an error if any of the preferences do not exist.

`rmpref('group')` removes all the preferences for the specified group. It is an error to remove a group that does not exist.

Examples

```
addpref('mytoolbox','version','1.0')  
rmpref('mytoolbox')
```

See Also

`addpref`, `getpref`, `ispref`, `setpref`, `uigetpref`, `uisetpref`

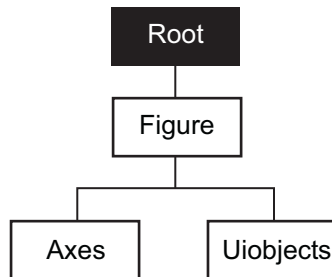
Purpose Root

Description The root is a graphics object that corresponds to the computer screen. There is only one root object and it has no parent. The children of the root object are figures.

The root object exists when you start MATLAB; you never have to create it and you cannot destroy it. Use `set` and `get` to access the root properties.

See Also diary, echo, figure, format, gcf, get, set

Object Hierarchy



Root Properties

Purpose

Root properties

Modifying Properties

You can set and query graphics object properties in two ways:

- The “The Property Editor” is an interactive tool that enables you to see and change object property values.
- The set and get commands enable you to set and query the values of properties.

To change the default values of properties, see “Setting Default Property Values”.

Root Properties

This section lists property names along with the type of values each accepts. Curly braces {} enclose default values.

BusyAction

cancel | {queue}

Not used by the root object.

ButtonDownFcn

string

Not used by the root object.

CallbackObject

handle (read only)

Handle of current callback's object. This property contains the handle of the object whose callback routine is currently executing. If no callback routines are executing, this property contains the empty matrix []. See also the gco command.

Children

vector of handles

Handles of child objects. A vector containing the handles of all nonhidden figure objects (see HandleVisibility for more

information). You can change the order of the handles and thereby change the stacking order of the figures on the display.

Clipping

{on} | off

Clipping has no effect on the root object.

CommandWindowSize

[columns rows]

Current size of command window. This property contains the size of the MATLAB command window in a two-element vector. The first element is the number of columns wide and the second element is the number of rows tall.

CreateFcn

The root does not use this property.

CurrentFigure

figure handle

Handle of the current figure window, which is the one most recently created, clicked in, or made current with the statement

```
figure(h)
```

which restacks the figure to the top of the screen, or

```
set(0, 'CurrentFigure', h)
```

which does not restack the figures. In these statements, h is the handle of an existing figure. If there are no figure objects,

```
get(0, 'CurrentFigure')
```

returns the empty matrix. Note, however, that `gcf` always returns a figure handle, and creates one if there are no figure objects.

DeleteFcn

string

Root Properties

This property is not used, because you cannot delete the root object.

Diary

on | {off}

Diary file mode. When this property is on, MATLAB maintains a file (whose name is specified by the `DiaryFile` property) that saves a copy of all keyboard input and most of the resulting output. See also the `diary` command.

DiaryFile

string

Diary filename. The name of the diary file. The default name is `diary`.

Echo

on | {off}

Script echoing mode. When `Echo` is on, MATLAB displays each line of a script file as it executes. See also the `echo` command.

ErrorMessage

string

Text of last error message. This property contains the last error message issued by MATLAB.

FixedWidthFontName

font name

Fixed-width font to use for axes, text, and uicontrols whose `FontName` is set to `FixedWidth`. MATLAB uses the font name specified for this property as the value for axes, text, and uicontrol `FontName` properties when their `FontName` property is set to `FixedWidth`. Specifying the font name with this property eliminates the need to hardcode font names in MATLAB applications and thereby enables these applications to run

without modification in locales where non-ASCII character sets are required. In these cases, MATLAB attempts to set the value of `FixedWidthFontName` to the correct value for a given locale.

MATLAB application developers should not change this property, but should create axes, text, and uicontrols with `FontName` properties set to `FixedWidth` when they want to use a fixed-width font for these objects.

MATLAB end users can set this property if they do not want to use the preselected value. In locales where Latin-based characters are used, `Courier` is the default.

Format

`short` | `{shortE}` | `long` | `longE` | `bank` |
`hex` | `+` | `rat`

Output format mode. This property sets the format used to display numbers. See also the `format` command.

- `short` — Fixed-point format with 5 digits
- `shortE` — Floating-point format with 5 digits
- `shortG` — Fixed- or floating-point format displaying as many significant figures as possible with 5 digits
- `long` — Scaled fixed-point format with 15 digits
- `longE` — Floating-point format with 15 digits
- `longG` — Fixed- or floating-point format displaying as many significant figures as possible with 15 digits
- `bank` — Fixed-format of dollars and cents
- `hex` — Hexadecimal format
- `+` — Displays + and – symbols
- `rat` — Approximation by ratio of small integers

Root Properties

FormatSpacing
compact | {loose}

Output format spacing (see also `format` command).

- compact — Suppress extra line feeds for more compact display.
- loose — Display extra line feeds for a more readable display.

HandleVisibility
{on} | callback | off

This property is not useful on the root object.

HitTest
{on} | off

This property is not useful on the root object.

Interruptible
{on} | off

This property is not useful on the root object.

Language
string

System environment setting.

MonitorPosition
[x y width height;x y width height]

Width and height of primary and secondary monitors, in pixels.

This property contains the width and height of each monitor connected to your computer. The x and y values for the primary monitor are 0, 0 and the width and height of the monitor are specified in pixels.

The secondary monitor position is specified as

x = primary monitor width + 1


```
y = primary monitor height + 1
```

Querying the value of the figure `MonitorPosition` on a multiheaded system returns the position for each monitor on a separate line.

```
v = get(0, 'MonitorPosition')
v =
    x y width height % Primary monitor
    x y width height % Secondary monitor
```

The value of the `ScreenSize` property is inconsistent when using multiple monitors. If you want specific and consistent values, use the `MonitorPosition` property.

Parent

handle

Handle of parent object. This property always contains the empty matrix, because the root object has no parent.

PointerLocation

[x,y]

Current location of pointer. A vector containing the x - and y -coordinates of the pointer position, measured from the lower left corner of the screen. You can move the pointer by changing the values of this property. The `Units` property determines the units of this measurement.

This property always contains the current pointer location, even if the pointer is not in a MATLAB window. A callback routine querying the `PointerLocation` can get a value different from the location of the pointer when the callback was triggered. This difference results from delays in callback execution caused by competition for system resources.

Root Properties

On Macintosh platforms, you cannot change the pointer location using the `set` command.

`PointerWindow`
handle (read only)

Handle of window containing the pointer. MATLAB sets this property to the handle of the figure window containing the pointer. If the pointer is not in a MATLAB window, the value of this property is 0. A callback routine querying the `PointerWindow` can get the wrong window handle if you move the pointer to another window before the callback executes. This error results from delays in callback execution caused by competition for system resources.

`RecursionLimit`
integer

Number of nested M-file calls. This property sets a limit to the number of nested calls to M-files MATLAB will make before stopping (or potentially running out of memory). By default the value is set to a large value. Setting this property to a smaller value (something like 150, for example) should prevent MATLAB from running out of memory and will instead cause MATLAB to issue an error when the limit is reached.

`ScreenDepth`
bits per pixel

Screen depth. The depth of the display bitmap (i.e., the number of bits per pixel). The maximum number of simultaneously displayed colors on the current graphics device is 2 raised to this power.

`ScreenDepth` supersedes the `BlackAndWhite` property. To override automatic hardware checking, set this property to 1. This value causes MATLAB to assume the display is monochrome. This is useful if MATLAB is running on color hardware but is

being displayed on a monochrome terminal. Such a situation can cause MATLAB to determine erroneously that the display is color.

ScreenPixelsPerInch
Display resolution

DPI setting for your display. This property contains the setting of your display resolution specified in your system preferences.

ScreenSize
four-element rectangle vector (read only)

Screen size. A four-element vector,

[left,bottom,width,height]

that defines the display size. `left` and `bottom` are 0 for all Units except `pixels`, in which case `left` and `bottom` are 1. `width` and `height` are the screen dimensions in units specified by the Units property.

Determining Screen Size

Note that the screen size in absolute units (e.g., inches) is determined by dividing the number of pixels in width and height by the screen DPI (see the `ScreenPixelPerInch` property). This value is approximate and might not represent the actual size of the screen.

Note that the `ScreenSize` property is static. Its values are read only at MATLAB startup and not updated if system display settings change. Also, the values returned might not represent the usable screen size for application developers due to the presence of other GUIs, such as the Microsoft Windows task bar.

Selected
on | off

This property has no effect on the root level.

Root Properties

SelectionHighlight
{on} | off

This property has no effect on the root level.

ShowHiddenHandles
on | {off}

Show or hide handles marked as hidden. When set to on, this property disables handle hiding and exposes all object handles regardless of the setting of an object's `HandleVisibility` property. When set to off, all objects so marked remain hidden within the graphics hierarchy.

Tag
string

User-specified object label. The `Tag` property provides a means to identify graphics objects with a user-specified label. While it is not necessary to identify the root object with a tag (since its handle is always 0), you can use this property to store any string value that you can later retrieve using `set`.

Type
string (read only)

Class of graphics object. For the root object, `Type` is always 'root'.

UIContextMenu
handle

This property has no effect on the root level.

Units

{pixels} | normalized | inches | centimeters
| points | characters

Unit of measurement. This property specifies the units MATLAB uses to interpret size and location data. All units are measured from the lower left corner of the screen. Normalized units map the lower left corner of the screen to (0,0) and the upper right corner to (1.0,1.0). inches, centimeters, and points are absolute units (one point equals 1/72 of an inch). Characters are units defined by characters from the default system font; the width of one unit is the width of the letter x, the height of one character is the distance between the baselines of two lines of text.

This property affects the `PointerLocation` and `ScreenSize` properties. If you change the value of `Units`, it is good practice to return it to its default value after completing your operation, so as not to affect other functions that assume `Units` is set to the default value.

`UserData`
matrix

User-specified data. This property can be any data you want to associate with the root object. MATLAB does not use this property, but you can access it using the `set` and `get` functions.

`Visible`
{on} | off

Object visibility. This property has no effect on the root object.

roots

Purpose	Polynomial roots
Syntax	<code>r = roots(c)</code>
Description	<p><code>r = roots(c)</code> returns a column vector whose elements are the roots of the polynomial <code>c</code>.</p> <p>Row vector <code>c</code> contains the coefficients of a polynomial, ordered in descending powers. If <code>c</code> has <code>n+1</code> components, the polynomial it represents is $c_1s^n + \dots + c_n s + c_{n+1}$.</p>
Remarks	<p>Note the relationship of this function to <code>p = poly(r)</code>, which returns a row vector whose elements are the coefficients of the polynomial. For vectors, <code>roots</code> and <code>poly</code> are inverse functions of each other, up to ordering, scaling, and roundoff error.</p>
Examples	<p>The polynomial $s^3 - 6s^2 - 72s - 27$ is represented in MATLAB software as</p> <pre>p = [1 -6 -72 -27]</pre> <p>The roots of this polynomial are returned in a column vector by</p> <pre>r = roots(p)</pre> <pre>r = 12.1229 -5.7345 -0.3884</pre>
Algorithm	<p>The algorithm simply involves computing the eigenvalues of the companion matrix:</p> <pre>A = diag(ones(n-1,1),-1); A(1,:) = -c(2:n+1)./c(1); eig(A)</pre>

It is possible to prove that the results produced are the exact eigenvalues of a matrix within roundoff error of the companion matrix A , but this does not mean that they are the exact roots of a polynomial with coefficients within roundoff error of those in c .


See Also

fzero, poly, residue

Purpose Angle histogram plot



GUI Alternatives

To graph selected variables, use the Plot Selector  in the Workspace Browser, or use the Figure Palette Plot Catalog. Manipulate graphs in *plot edit* mode with the Property Editor. For details, see Plotting Tools — Interactive Plotting in the MATLAB Graphics documentation and Creating Graphics from the Workspace Browser in the MATLAB Desktop Tools documentation.

Syntax

```
rose(theta)
rose(theta,x)
rose(theta,nbins)
rose(axes_handle,...)
h = rose(...)
[tout,rout] = rose(...)
```

Description

`rose(theta)` creates an angle histogram, which is a polar plot showing the distribution of values grouped according to their numeric range, showing the distribution of `theta` in 20 angle bins or less. The vector `theta`, expressed in radians, determines the angle of each bin from the origin. The length of each bin reflects the number of elements in `theta` that fall within a group, which ranges from 0 to the greatest number of elements deposited in any one bin.

`rose(theta,x)` uses the vector `x` to specify the number and the locations of bins. `length(x)` is the number of bins and the values of `x` specify the center angle of each bin. For example, if `x` is a five-element vector, `rose` distributes the elements of `theta` in five bins centered at the specified `x` values.

`rose(theta,nbins)` plots `nbins` equally spaced bins in the range `[0, 2*pi]`. The default is 20.

`rose(axes_handle,...)` plots into the axes with handle `axes_handle` instead of the current axes (`gca`).

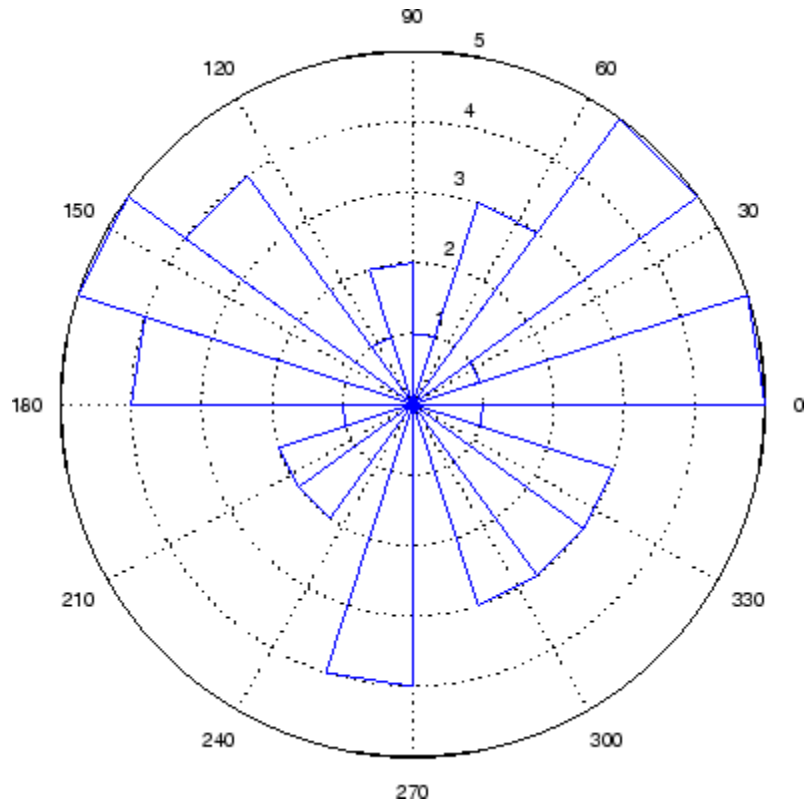
`h = rose(...)` returns the handles of the line objects used to create the graph.

`[tout,rout] = rose(...)` returns the vectors `tout` and `rout` so `polar(tout,rout)` generates the histogram for the data. This syntax does not generate a plot.

Example

Create a rose plot showing the distribution of 50 random numbers.

```
theta = 2*pi*rand(1,50);  
rose(theta)
```



See Also

compass, feather, hist, line, polar

“Histograms” on page 1-97 for related functions

Histograms in Polar Coordinates for another example

Purpose Classic symmetric eigenvalue test problem

Syntax A = rosser

Description A = rosser returns the Rosser matrix. This matrix was a challenge for many matrix eigenvalue algorithms. But LAPACK's DSYEV routine used in MATLAB software has no trouble with it. The matrix is 8-by-8 with integer elements. It has:

- A double eigenvalue
- Three nearly equal eigenvalues
- Dominant eigenvalues of opposite sign
- A zero eigenvalue
- A small, nonzero eigenvalue

Examples

```
rosser
```

```
ans =
```

```

611  196 -192  407   -8  -52  -49   29
196  899  113 -192  -71  -43   -8  -44
-192  113  899  196   61   49    8   52
407 -192  196  611    8   44   59  -23
  -8  -71   61    8  411 -599  208  208
-52 -43   49   44 -599  411  208  208
-49  -8    8   59  208  208   99 -911
  29 -44   52  -23  208  208 -911   99
```

rot90

Purpose Rotate matrix 90 degrees

Syntax $B = \text{rot90}(A)$
 $B = \text{rot90}(A, k)$

Description $B = \text{rot90}(A)$ rotates matrix A counterclockwise by 90 degrees.
 $B = \text{rot90}(A, k)$ rotates matrix A counterclockwise by $k \cdot 90$ degrees, where k is an integer.

Examples The matrix

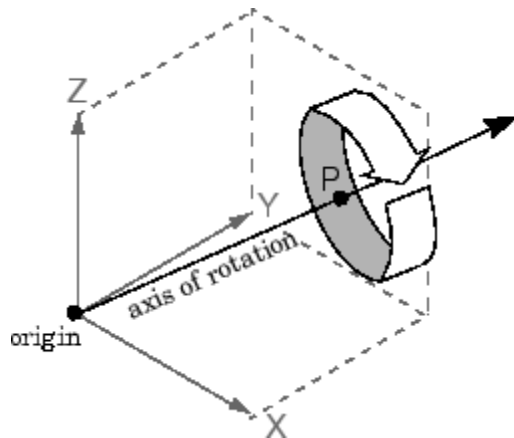
```
X =  
    1    2    3  
    4    5    6  
    7    8    9
```

rotated by 90 degrees is

```
Y = rot90(X)  
Y =  
    3    6    9  
    2    5    8  
    1    4    7
```

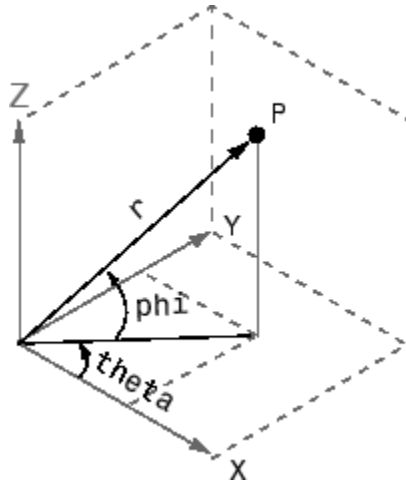
See Also `flipdim`, `fliplr`, `flipud`

- Purpose** Rotate object in specified direction
- Syntax** `rotate(h,direction,alpha)`
`rotate(...,origin)`
- Description** The rotate function rotates a graphics object in three-dimensional space, according to the right-hand rule.
- `rotate(h,direction,alpha)` rotates the graphics object `h` by `alpha` degrees. `direction` is a two- or three-element vector that describes the axis of rotation in conjunction with the origin.
- `rotate(...,origin)` specifies the origin of the axis of rotation as a three-element vector. The default origin is the center of the plot box.
- Remarks** The graphics object you want rotated must be a child of the same axes. The object's data is modified by the rotation transformation. This is in contrast to `view` and `rotate3d`, which only modify the viewpoint.
- The axis of rotation is defined by an origin and a point P relative to the origin. P is expressed as the spherical coordinates `[theta phi]` or as Cartesian coordinates.



rotate

The two-element form for `direction` specifies the axis direction using the spherical coordinates `[theta phi]`. `theta` is the angle in the x - y plane counterclockwise from the positive x -axis. `phi` is the elevation of the direction vector from the x - y plane.



The three-element form for `direction` specifies the axis direction using Cartesian coordinates. The direction vector is the vector from the origin to (X,Y,Z) .

Examples

Rotate a graphics object 180° about the x -axis.

```
h = surf(peaks(20));  
rotate(h,[1 0 0],180)
```

Rotate a surface graphics object 45° about its center in the z direction.

```
h = surf(peaks(20));  
zdir = [0 0 1];  
center = [10 10 0];  
rotate(h,zdir,45,center)
```

Remarks

rotate changes the Xdata, Ydata, and Zdata properties of the appropriate graphics object.

See Also

rotate3d, sph2cart, view


The axes CameraPosition, CameraTarget, CameraUpVector, CameraViewAngle

“Object Manipulation” on page 1-107 for related functions

rotate3d

Purpose Rotate 3-D view using mouse

GUI Alternatives

Use the Rotate3D tool  on the figure toolbar to enable and disable rotate3D mode on a plot, or select **Rotate 3D** from the figure's **Tools** menu. For details, see “Rotate 3D — Interactive Rotation of 3-D Views” in the MATLAB Graphics documentation.

Syntax

```
rotate3d on
rotate3d off
rotate3d
rotate3d(figure_handle,...)
rotate3d(axes_handle,...)
h = rotate3d(figure_handle)
```

Description

`rotate3d on` enables mouse-base rotation on all axes within the current figure.

`rotate3d off` disables interactive axes rotation in the current figure.

`rotate3d` toggles interactive axes rotation in the current figure.

`rotate3d(figure_handle,...)` enables rotation within the specified figure instead of the current figure.

`rotate3d(axes_handle,...)` enables rotation only in the specified axes.

`h = rotate3d(figure_handle)` returns a `rotate3d mode object` for `figure_handle` for you to customize the mode's behavior.

Using Rotate Mode Objects

You access the following properties of rotate mode objects via `get` and modify some of them using `set`.

- `FigureHandle` `<handle>` — The associated figure handle, a read-only property that cannot be set
- `Enable` `'on' | 'off'` — Specifies whether this figure mode is currently enabled on the figure

- *RotateStyle* 'orbit' | 'box' — Sets the method of rotation
'orbit' rotates the entire axes; 'box' rotates a plot-box outline of the axes.

Rotate3D Mode Callbacks

You can program the following callbacks for rotate3d mode operations.

- *ButtonDownFilter* <function_handle> — Function to intercept ButtonDown events

The application can inhibit the rotate operation under circumstances the programmer defines, depending on what the callback returns. The input function handle should reference a function with two implicit arguments (similar to handle callbacks):

```
function [res] = myfunction(obj,event_obj)
% obj          handle to the object that has been clicked on
% event_obj    handle to event data object (empty in this release)
% res [output] logical flag to determine whether the rotate
                operation should take place or the 'ButtonDownFcn'
                property of the object should take precedence
```

- *ActionPreCallback* <function_handle> — Function to execute before rotating

Set this callback to listen to when a rotate operation will start. The input function handle should reference a function with two implicit arguments (similar to Handle Graphics object callbacks):

```
function myfunction(obj,event_obj)
% obj          handle to the figure that has been clicked on
% event_obj    object containing struct of event data
```

The event data has the following field:

Axes	The handle of the axes that is being panned
------	---

- `ActionPostCallback` <function_handle> — Function to execute after rotating

Set this callback to listen to when a rotate operation has finished. The input function handle should reference a function with two implicit arguments (similar to Handle Graphics object callbacks):

```
function myfunction(obj,event_obj)
% obj          handle to the figure that has been clicked on
% event_obj    object containing struct of event data (same as the
%              event data of the 'ActionPreCallback' callback)
```

Rotate3D Mode Utility Functions

The following functions in pan mode query and set certain of its properties.

- `flags = isAllowAxesRotate(h,axes)` — Function querying permission to rotate axes

Calling the function `isAllowAxesRotate` on the `rotate3d` object, `h`, with a vector of axes handles, `axes`, as input will return a logical array of the same dimension as the axes handle vector which indicate whether a rotate operation is permitted on the axes objects.

- `setAllowAxesRotate(h,axes,flag)` — Function to set permission to pan axes

Calling the function `setAllowAxesRotate` on the `rotate3d` object, `h`, with a vector of axes handles, `axes`, and a logical scalar, `flag`, will either allow or disallow a rotate operation on the axes objects.

Examples

Example 1

Simple 3-D rotation

```
surf(peaks);
rotate3d on
% rotate the plot using the mouse pointer.
```

Example 2

Rotate the plot using the "Plot Box" rotate style:

```
surf(peaks);
h = rotate3d;
set(h,'RotateStyle','box','Enable','on');
% Rotate the plot.
```

Example 3

Create two axes as subplots and then prevent one from rotating:

```
ax1 = subplot(1,2,1);
surf(peaks);
h = rotate3d;
ax2 = subplot(1,2,2);
surf(membrane);
setAllowAxesRotate(h,ax2,false);
% rotate the plots.
```

Example 4

Create a `ButtonDown` callback for rotate mode objects to trigger. Copy the following code to a new M-file, execute it, and observe rotation behavior:

```
function demo
% Allow a line to have its own 'ButtonDownFcn' callback.
hLine = plot(rand(1,10));
set(hLine,'ButtonDownFcn','disp(''This executes'')');
set(hLine,'Tag','DoNotIgnore');
h = rotate3d;
set(h,'ButtonDownFilter',@mycallback);
set(h,'Enable','on');
% mouse-click on the line
%
```

rotate3d

```
function [flag] = mycallback(obj,event_obj)
% If the tag of the object is 'DoNotIgnore', then return true.
objTag = get(obj,'Tag');
if strcmpi(objTag,'DoNotIgnore')
    flag = true;
else
    flag = false;
end
```

Example 5

Create callbacks for pre- and post-buttonDown events for rotate3D mode objects to trigger. Copy the following code to a new M-file, execute it, and observe rotation behavior:

```
function demo
% Listen to rotate events
surf(peaks);
h = rotate3d;
set(h,'ActionPreCallback',@myprecallback);
set(h,'ActionPostCallback',@mypostcallback);
set(h,'Enable','on');
%
function myprecallback(obj,evd)
disp('A rotation is about to occur.');
```

```
%
function mypostcallback(obj,evd)
newView = round(get(evd.Axes,'View'));
msgbox(sprintf('The new view is [%d %d].',newView));
```

Remarks

When enabled, rotate3d provides continuous rotation of axes and the objects it contains through mouse movement. A numeric readout appears in the lower left corner of the figure during rotation, showing the current azimuth and elevation of the axes. Releasing the mouse button removes the animated box and the readout. This differs from the camorbit function in that while the rotate3d tool modifies the View property of the axes, the camorbit function fixes the aspect ratio

and modifies the `CameraTarget`, `CameraPosition` and `CameraUpVector` properties of the axes. See [Axes Properties](#) for more information.

You can also enable 3-D rotation from the figure **Tools** menu or the figure toolbar.

You can create a `rotate3D` mode object once and use it to customize the behavior of different axes, as example 3 illustrates. You can also change its callback functions on the fly.

Note Do not change figure callbacks within an interactive mode. While a mode is active (when panning, zooming, etc.), you will receive a warning if you attempt to change any of the figure's callbacks and the operation will not succeed. The one exception to this rule is the figure `WindowButtonMotionFcn` callback, which can be changed from within a mode. Therefore, if you are creating a GUI that updates a figure's callbacks, the GUI should some keep track of which interactive mode is active, if any, before attempting to do this.

When you assign different 3-D rotation behaviors to different subplot axes via a mode object and then link them using the `linkaxes` function, the behavior of the axes you manipulate with the mouse will carry over to the linked axes, regardless of the behavior you previously set for the other axes.

See Also

`camorbit`, `pan`, `rotate`, `view`, `zoom`

[Object Manipulation](#) for related functions

[Axes Properties](#) for related properties

round

Purpose Round to nearest integer

Syntax $Y = \text{round}(X)$

Description $Y = \text{round}(X)$ rounds the elements of X to the nearest integers. For complex X , the imaginary and real parts are rounded independently.

Examples

```
a = [-1.9, -0.2, 3.4, 5.6, 7.0, 2.4+3.6i]
```

```
a =
```

```
Columns 1 through 4
```

```
-1.9000      -0.2000      3.4000      5.6000
```

```
Columns 5 through 6
```

```
7.0000      2.4000 + 3.6000i
```

```
round(a)
```

```
ans =
```

```
Columns 1 through 4
```

```
-2.0000      0      3.0000      6.0000
```

```
Columns 5 through 6
```

```
7.0000      2.0000 + 4.0000i
```

See Also

ceil, fix, floor

Purpose

Reduced row echelon form

Syntax

```
R = rref(A)
[R, jb] = rref(A)
[R, jb] = rref(A, tol)
```

Description

`R = rref(A)` produces the reduced row echelon form of `A` using Gauss Jordan elimination with partial pivoting. A default tolerance of $(\max(\text{size}(A)) * \text{eps} * \text{norm}(A, \text{inf}))$ tests for negligible column elements.

`[R, jb] = rref(A)` also returns a vector `jb` such that:

- `r = length(jb)` is this algorithm's idea of the rank of `A`.
- `x(jb)` are the pivot variables in a linear system $Ax = b$.
- `A(:, jb)` is a basis for the range of `A`.
- `R(1:r, jb)` is the `r`-by-`r` identity matrix.

`[R, jb] = rref(A, tol)` uses the given tolerance in the rank tests.

Roundoff errors may cause this algorithm to compute a different value for the rank than `rank`, `orth` and `null`.

Examples

Use `rref` on a rank-deficient magic square:

```
A = magic(4), R = rref(A)
```

```
A =
    16     2     3    13
     5    11    10     8
     9     7     6    12
     4    14    15     1
```

```
R =
     1     0     0     1
     0     1     0     3
```

rref

$$\begin{array}{cccc} 0 & 0 & 1 & -3 \\ 0 & 0 & 0 & 0 \end{array}$$

See Also [inv](#), [lu](#), [rank](#)

Purpose Convert real Schur form to complex Schur form

Syntax `[U,T] = rsf2csf(U,T)`

Description The *complex Schur form* of a matrix is upper triangular with the eigenvalues of the matrix on the diagonal. The *real Schur form* has the real eigenvalues on the diagonal and the complex eigenvalues in 2-by-2 blocks on the diagonal.

`[U,T] = rsf2csf(U,T)` converts the real Schur form to the complex form.

Arguments `U` and `T` represent the unitary and Schur forms of a matrix `A`, respectively, that satisfy the relationships: $A = U^*T^*U'$ and $U' * U = \text{eye}(\text{size}(A))$. See `schur` for details.

Examples

Given matrix `A`,

```

1     1     1     3
1     2     1     1
1     1     3     1
-2    1     1     4

```

with the eigenvalues

```

4.8121    1.9202 + 1.4742i    1.9202 + 1.4742i    1.3474

```

Generating the Schur form of `A` and converting to the complex Schur form

```

[u,t] = schur(A);
[U,T] = rsf2csf(u,t)

```

yields a triangular matrix `T` whose diagonal (underlined here for readability) consists of the eigenvalues of `A`.

```

U =

```

-0.4916	-0.2756 - 0.4411i	0.2133 + 0.5699i	-0.3428
-0.4980	-0.1012 + 0.2163i	-0.1046 + 0.2093i	0.8001
-0.6751	0.1842 + 0.3860i	-0.1867 - 0.3808i	-0.4260
-0.2337	0.2635 - 0.6481i	0.3134 - 0.5448i	0.2466

T =

4.8121	-0.9697 + 1.0778i	-0.5212 + 2.0051i	-1.0067
0	1.9202 + 1.4742i	2.3355	0.1117 + 1.6547i
0	0	1.9202 - 1.4742i	0.8002 + 0.2310i
0	0	0	1.3474

See Also

schur

Purpose Run script that is not on current path

Syntax `run scriptname`

Description `run scriptname` runs the MATLAB script specified by `scriptname`. If `scriptname` contains the full pathname to the script file, then `run` changes the current directory to be the one in which the script file resides, executes the script, and sets the current directory back to what it was. The script is run within the caller's workspace.

`run` is a convenience function that runs scripts that are not currently on the path. Typically, you just type the name of a script at the MATLAB prompt to execute it. This works when the script is on your path. Use the `cd` or `addpath` function to make a script executable by entering the script name alone.

See Also `cd`, `addpath`

Purpose

Save workspace variables to disk

Graphical Interface

As an alternative to the `save` function, select **Save Workspace As** from the **File** menu in the MATLAB desktop, or use the Workspace browser.

Syntax

```
save
save filename
save filename content
save filename options
save filename content options
save('filename', 'var1', 'var2', ...)
```

Description

`save` stores all variables from the current MATLAB workspace in a MATLAB formatted file (MAT-file) named `matlab.mat` that resides in the current working directory. Use the `load` function to retrieve data stored in MAT-files. By default, MAT-files are double-precision, binary files. You can create a MAT-file on one machine and then load it on another machine using a different floating-point format, and retaining as much accuracy and range as the different formats allow. MAT-files can also be manipulated by other programs external to MATLAB.

`save filename` stores all variables in the current workspace in the file `filename`. If you do not specify an extension to the filename, MATLAB uses `.mat`. The file must be writable. To save to another directory, use a full pathname for the `filename`.

`save filename content` stores only those variables specified by `content` in file `filename`. If `filename` is not specified, MATLAB stores the data in a file called `matlab.mat`. See the following table.

Values for <i>content</i>	Description
<code>varlist</code>	Save only those variables that are in <code>varlist</code> . You can use the <code>*</code> wildcard to save only those variables that match the specified pattern. For example, <code>save('A*')</code> saves all variables that start with <code>A</code> .

Values for <i>content</i>	Description
-regexp <i>explist</i>	Save those variables that match any of the regular expressions in <i>explist</i> . See the Remarks section below.
-struct <i>s</i>	Save as individual variables all fields of the scalar structure <i>s</i> .
-struct <i>s fieldlist</i>	Save as individual variables only the specified fields of structure <i>s</i> .

In this table, the terms *varlist*, *explist*, and *fieldlist* refer to one or more variable names, regular expressions, or structure field names separated by either spaces or commas, depending on whether you are using the MATLAB command or function format. See the examples below:

Command format:

```
save myfile.mat firstname lastname
```

Function format:

```
save('myfile.mat', 'firstname', 'lastname')
```

`save filename options` stores all variables from the MATLAB workspace in file *filename* according to one or more of the following options. If *filename* is not specified, MATLAB stores the data in a file called `matlab.mat`.

Values for <i>options</i>	Description
-append	Add new variables to those already stored in an existing MAT-file.

Values for <i>options</i>	Description
<i>-format</i>	Save using the specified binary or ASCII format. See the section on, “MAT-File Format Options” on page 2-3178, below.
<i>-version</i>	Save in a format that can be loaded into an earlier version of MATLAB. See the section on “Version Compatibility Options” on page 2-3178, below.

`save filename content options` stores only those variables specified by *content* in file *filename*, also applying the specified *options*. If *filename* is not specified, MATLAB stores the data in a file called `matlab.mat`.

`save('filename', 'var1', 'var2', ...)` is the function form of the syntax.

MAT-File Format Options

The following table lists the valid *MAT-file format* options.

<i>MAT-file format</i> Options	How Data Is Stored
<i>-ascii</i>	Save data in 8-digit ASCII format.
<i>-ascii -tabs</i>	Save data in 8-digit ASCII format delimited with tabs.
<i>-ascii -double</i>	Save data in 16-digit ASCII format.
<i>-ascii -double -tabs</i>	Save data in 16-digit ASCII format delimited with tabs.
<i>-mat</i>	Binary MAT-file form (default).

Version Compatibility Options

The following table lists version compatibility options. These options enable you to save your workspace data to a MAT-file that can then be loaded into an earlier version of MATLAB software. The resulting

MAT-file supports only those data items and features that were available in this earlier version of MATLAB. (See the second table below for what is supported in each version.)

version Option	Use When Running ...	To Save a MAT-File That You Can Load In ...
-v7.3	Version 7.3 or later	Version 7.3 or later
-v7	Version 7.3 or later	Versions 7.0 through 7.2 (or later)
-v6	Version 7 or later	Versions 5 and 6 (or later)
-v4	Version 5 or later	Versions 1 through 4 (or later)

The default version option is the value specified in the **Preferences** dialog box. Select **File > Preferences** in the Command Window, click **General**, and then **MAT-Files** to view or change the default.

The next table shows what data items and features are supported in different versions of MATLAB. You can use this information to determine which of the version compatibility options shown above to use.

MATLAB Versions	Data Items or Features Supported
4 and earlier	Support for 2D double, character, and sparse
5 and 6	Version 4 capability plus support for ND arrays, structs, and cells
7.0 through 7.2	Version 6 capability plus support for data compression and Unicode character encoding
7.3 and later	Version 7.2 capability plus support for data items greater than or equal to 2GB

Remarks

When using the `-regexp` switch, `save` considers all variables in the argument list, with the exception of the optional filename and structure name variables, to be regular expressions. The filename, if specified, is always the first argument in the argument list, provided that this argument is a variable name. The structure name, if specified, is always the first argument following the `-struct` keyword, provided that the argument list includes that keyword.

When working on 64-bit platforms, you can have data items in your workspace that occupy more than 2 GB. To save data of this size, you must use the HDF5-based version of the MATLAB MAT-file. Use the `v7.3` option to do this:

```
save -v7.3 myfile v1 v2
```

If you are running MATLAB on a 64-bit computer system and you attempt to save a variable that is too large for a version 7 (or earlier) MAT-file, that is, you save without using the `-v7.3` option, MATLAB skips that variable during the save operation and issues a warning message to that effect.

If you are running MATLAB on a 32-bit computer system and attempt to load a variable from a `-v7.3` MAT-file that is too large to fit in 32-bit address space, MATLAB skips that variable and issues a warning message to that effect.

MAT-files saved with compression and Unicode encoding cannot be loaded into versions of MATLAB prior to MATLAB Version 7.0. If you save data to a MAT-file that you intend to load using MATLAB Version 6 or earlier, you must specify the `-v6` option when saving. This disables compression and Unicode encoding for that particular save operation.

If you want to save to a file that you can then load into a Version 4 MATLAB session, you must use the `-v4` option when saving. When you use this option, variables that are incompatible with MATLAB Version 4 are not saved to the MAT-file. For example, ND arrays, structs, cells, etc. cannot be saved to a MATLAB Version 4 MAT-file. Also, variables with names that are longer than 19 characters cannot be saved to a MATLAB Version 4 MAT-file.

For information on any of the following topics related to saving to MAT-files, see “Exporting Data to MAT-Files” in the MATLAB Programming Fundamentals documentation:

- Appending variables to an existing MAT-file
- Compressing data in the MAT-file
- Saving in ASCII format
- Saving in MATLAB Version 4 format
- Saving with Unicode character encoding
- Data storage requirements
- Saving from external programs

For information on saving figures, see the documentation for `hgsave` and `saveas`. For information on exporting figures to other graphics formats, see the documentation for `print`.

Examples

Example 1

Save all variables from the workspace in binary MAT-file `test.mat`:

```
save test.mat
```

Example 2

Save variables `p` and `q` in binary MAT-file `test.mat`.

In this example, the file name is stored in a variable, `savefile`. You must call `save` using the function syntax of the command if you intend to reference the file name through a variable.

```
savefile = 'test.mat';  
p = rand(1, 10);  
q = ones(10);  
save(savefile, 'p', 'q')
```

Example 3

Save the values of variables `vol` and `temp` in ASCII format to a file named `june10`:

```
save('d:\mymfiles\june10','vol','temp','-ASCII')
```

Example 4

Save the fields of structure `s1` as individual variables rather than as an entire structure.

```
s1.a = 12.7; s1.b = {'abc', [4 5; 6 7]}; s1.c = 'Hello!';  
save newstruct.mat -struct s1;  
clear
```

Check what was saved to `newstruct.mat`:

```
whos -file newstruct.mat
```

Name	Size	Bytes	Class
a	1x1	8	double array
b	1x2	158	cell array
c	1x6	12	char array

Grand total is 16 elements using 178 bytes

Read only the `b` field into the MATLAB workspace.

```
str = load('newstruct.mat', 'b')  
str =  
    b: {'abc' [2x2 double]}
```

Example 5

Using regular expressions, save in MAT-file `mydata.mat` those variables with names that begin with `Mon`, `Tue`, or `Wed`:

```
save('mydata', '-regexp', '^Mon|^Tue|^Wed');
```

Here is another way of doing the same thing. In this case, there are three separate expression arguments:

```
save('mydata', '-regexp', '^Mon', '^Tue', '^Wed');
```

Example 6

Save a 3000-by-3000 matrix uncompressed to file `c1.mat`, and compressed to file `c2.mat`. The compressed file uses about one quarter the disk space required to store the uncompressed data:

```
x = ones(3000);
y = uint32(rand(3000) * 100);

save -v6 c1 x y      % Save without compression
save -v7 c2 x y      % Save with compression

d1 = dir('c1.mat');
d2 = dir('c2.mat');

d1.bytes
ans =
    45000240      % Size of the uncompressed data in bytes.
d2.bytes
ans =
    11985283      % Size of the compressed data in bytes.

d2.bytes/d1.bytes
ans =
    0.2663      % Ratio of compressed to uncompressed
```

See Also

`load`, `clear`, `diary`, `fileformats`, `fprintf`, `fwrite`, `genvarname`, `who`, `whos`, `workspace`, `regexp`

save (COM)

Purpose Serialize control object to file

Syntax `h.save('filename')`
`save(h, 'filename')`

Description `h.save('filename')` saves the COM control object, `h`, to the file specified in the string, `filename`.
`save(h, 'filename')` is an alternate syntax for the same operation.

Note The COM save function is only supported for controls at this time.

Remarks COM functions are available on Microsoft Windows systems only.

Examples Create an `mwsamp` control and save its original state to the file `mwsample`:

```
f = figure('position', [100 200 200 200]);  
h = actxcontrol('mwsamp.mwsampctrl.2', [0 0 200 200], f);  
h.save('mwsample')
```

Now, alter the figure by changing its label and the radius of the circle:

```
h.Label = 'Circle';  
h.Radius = 50;  
h.Redraw;
```

Using the `load` function, you can restore the control to its original state:

```
h.load('mwsample');  
h.get
```

MATLAB displays the original values:

```
ans =  
    Label: 'Label'  
    Radius: 20
```

See Also load (COM), actxcontrol, actxserver, release, delete (COM)

serial.save

Purpose Save serial port objects and variables to MAT-file

Syntax
`save filename`
`save filename obj1 obj2...`

Description `save filename` saves all MATLAB variables to the MAT-file `filename`. If an extension is not specified for `filename`, then the `.mat` extension is used.

`save filename obj1 obj2...` saves the serial port objects `obj1 obj2...` to the MAT-file `filename`.

Remarks You can use `save` in the functional form as well as the command form shown above. When using the functional form, you must specify the filename and serial port objects as strings. For example, to save the serial port object `s` to the file `MySerial.mat` on a Windows platform

```
s = serial('COM1');  
save('MySerial','s')
```

Any data that is associated with the serial port object is not automatically stored in the MAT-file. For example, suppose there is data in the input buffer for `obj`. To save that data to a MAT-file, you must bring it into the MATLAB workspace using one of the synchronous read functions, and then save to the MAT-file using a separate variable name. You can also save data to a text file with the `record` function.

You return objects and variables to the MATLAB workspace with the `load` command. Values for read-only properties are restored to their default values upon loading. For example, the `Status` property is restored to `closed`. To determine if a property is read-only, examine its reference pages.

Example This example illustrates how to use the command and functional form of `save` on a Windows platform.

```
s = serial('COM1');  
set(s,'BaudRate',2400,'StopBits',1)
```

```
save MySerial1 s
set(s, 'BytesAvailableFcn', @mycallback)
save('MySerial2', 's')
```

See Also

Functions

load, record

Properties

Status

Purpose Save figure or Simulink block diagram using specified format

GUI Alternative Use **File > Save As** on the figure window menu to access the Save As dialog, in which you can select a graphics format. For details, see “Exporting in a Specific Graphics Format” in the MATLAB Graphics documentation. Sizes of files written to image formats by this GUI and by `saveas` can differ due to disparate resolution settings.

Syntax
`saveas(h, 'filename.ext')`
`saveas(h, 'filename', 'format')`

Description `saveas(h, 'filename.ext')` saves the figure or Simulink block diagram with the handle `h` to the file `filename.ext`. The format of the file is determined by the extension, `ext`. Allowable values for `ext` are listed in this table.

You can pass the handle of any Handle Graphics object to `saveas`, which then saves the parent figure to the object you specified should `h` not be a figure handle. This means that `saveas` cannot save a subplot without also saving all subplots in its parent figure.

ext Value	Format
ai	Adobe® Illustrator ‘88
bmp	Windows bitmap
emf	Enhanced metafile
eps	EPS Level 1
fig	MATLAB figure (invalid for Simulink block diagrams)
jpg	JPEG image (invalid for Simulink block diagrams)
m	MATLAB M-file (invalid for Simulink block diagrams)
pbm	Portable bitmap

ext Value	Format
pcx	Paintbrush 24-bit
pdf	Portable Document Format
pgm	Portable Graymap
png	Portable Network Graphics
ppm	Portable Pixmap
tif	TIFF image, compressed

`saveas(h, 'filename', 'format')` saves the figure or Simulink block diagram with the handle `h` to the file called `filename` using the specified `format`. The filename can have an extension, but the extension is not used to define the file format. If no extension is specified, the standard extension corresponding to the specified format is automatically appended to the filename.

Allowable values for `format` are the extensions in the table above and the device drivers and graphic formats supported by `print`. The drivers and graphic formats supported by `print` include additional file formats not listed in the table above. When using a `print` device type to specify format for `saveas`, do not prefix it with `-d`.

Remarks

You can use `open` to open files saved using `saveas` with an `m` or `fig` extension. Other `saveas` and `print` formats are not supported by `open`. Both the **Save As** and **Export Setup** dialog boxes that you access from a figure's **File** menu use `saveas` with the `format` argument, and support all device and file types listed above.

Note Whenever you specify a format for saving a figure with the **Save As** menu item, that file format is used again the next time you save that figure or a new one. If you do not want to save in the previously-used format, use **Save As** and be sure to set the **Save as type** drop-down menu to the kind of file you want to write. However, saving a figure with the `saveas` function and a format does not change the **Save as type** setting in the GUI.

If you want to control the size or resolution of figures saved in image (bit-mapped) formats, such as BMP or JPG, use the `print` command and specify dots-per-inch resolution with the `r` switch.

Examples

Example 1: Specify File Extension

Save the current figure that you annotated using the Plot Editor to a file named `pred_pre` using the MATLAB `fig` format. This allows you to open the file `pred_pre.fig` at a later time and continue editing it with the Plot Editor.

```
saveas(gcf, 'pred_pre.fig')
```

Example 2: Specify File Format but No Extension

Save the current figure, using Adobe Illustrator format, to the file `logo`. Use the `ai` extension from the above table to specify the format. The file created is `logo.ai`.

```
saveas(gcf, 'logo', 'ai')
```

This is the same as using the Adobe Illustrator format from the `print devices` table, which is `-dill`; use `doc print` or `help print` to see the table for print device types. The file created is `logo.ai`. MATLAB automatically appends the `ai` extension for an Illustrator format file because no extension was specified.

```
saveas(gcf, 'logo', 'ill')
```

Example 3: Specify File Format and Extension

Save the current figure to the file `star.eps` using the Level 2 Color PostScript format. If you use `doc print` or `help print`, you can see from the table for print device types that the device type for this format is `-dpsc2`. The file created is `star.eps`.

```
saveas(gcf,'star.eps','psc2')
```

In another example, save the current Simulink block diagram to the file `trans.tiff` using the TIFF format with no compression. From the table for print device types, you can see that the device type for this format is `-dtiffn`. The file created is `trans.tiff`.

```
saveas(gcf,'trans.tiff','tiffn')
```

See Also

`hgsave`, `open`, `print`

“Printing” on page 1-99 for related functions

Simulink users, see also `save_system`

saveobj

Purpose Modify how save function saves objects

Syntax B = saveobj(A)

Description B = saveobj(A) is called by the MATLAB save function when object A is saved to a MAT-file. This call executes the object's saveobj method, if such a method exists. The returned value B is written to the MAT-file by save. If you define a saveobj method for your class, you should define a loadobj method to take the appropriate action with the class is loaded.

Define a saveobj method to modify the object before the save operation. For example, you might define a saveobj method that saves all property data in a struct. Your loadobj method then would reconstruct the object from the data in the struct.

Remarks MATLAB does not call the superclass saveobj methods of an object when you save it. However, you should call the superclass saveobj method from the subclass implementation of saveobj. For example, the mySub class calls its superclass saveobj method with the following syntax:

```
classdef mySub < super
    methods
        function sobj = saveobj(obj)
            % Call superclass saveobj method
            sobj = saveobj@super(obj);
            % Perform subclass save operations
            ...
        end
    ...
end
...
end
...
end
```

Subclasses should always define a saveobj method if their superclass defines a saveobj method. See “The Save and Load Process” for more information.

MATLAB invokes `saveobj` separately for each object saved.

Examples

The following example shows a `saveobj` method that determines if an object has already been assigned an account number from a previous `save` operation. If not, `saveobj` calls the object's `getAccountNumber` method to obtain an account number and assigns it to the `AccountNumber` property. The value returned by `saveobj` (`b`) is saved to the MAT-file.

```
function b = saveobj(a)
    if isempty(a.AccountNumber)
        a.AccountNumber = getAccountNumber(a);
    end
    b = a;
end
```

See Also

`save`, `load`, `loadobj`

savepath

Purpose

Save current search path

GUI Alternatives

As an alternative to the `savepath` function, use the Set Path dialog box.

Syntax

```
savepath  
savepath directory/pathdef.m
```

Description

`savepath` saves the current search path for the MATLAB program so you can use it in a future session. MATLAB saves the search path to the `pathdef.m` file from which it created the search path at startup. If there is a `pathdef.m` file located in the current directory, `savepath` saves the current search path to it instead of the search path it created at startup. Consider using `savepath` in your `finish.m` file to automatically save the search path when you exit MATLAB.

`savepath directory/pathdef.m` saves the current search path to `pathdef.m` located in `directory`. Use this form of the syntax if you want an alternative to the standard path for use in a future session. If you do not specify `directory`, MATLAB saves `pathdef.m` in the current directory. `directory` can be a relative or absolute path. If you want to use the saved path in a future session, make `directory` be the startup directory for MATLAB.

Examples

The statement

```
savepath I:\my_matlab_files\pathdef.m
```

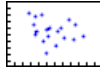
saves the current search path to `pathdef.m`, located in `I:\my_matlab_files`.

See Also


`addpath`, `cd`, `dir`, `finish`, `genpath`, `matlabroot`, `partialpath`, `pathsep`, `pathtool`, `rehash`, `restoredefaultpath`, `rmpath`, `startup`, `userpath`, `what`

Search Path and “Startup Directory for the MATLAB Program” in the MATLAB Desktop Tools and Development Environment documentation

Purpose Scatter plot



GUI Alternatives

To graph selected variables, use the Plot Selector  in the Workspace Browser, or use the Figure Palette Plot Catalog. Manipulate graphs in *plot edit* mode with the Property Editor. For details, see Plotting Tools — Interactive Plotting in the MATLAB Graphics documentation and Creating Graphics from the Workspace Browser in the MATLAB Desktop Tools documentation.

Syntax

```
scatter(X,Y,S,C)
scatter(X,Y)
scatter(X,Y,S)
scatter(...,markertype)
scatter(...,'filled')
scatter(...,'PropertyName',propertyvalue)
scatter(axes_handles,...)
h = scatter(...)
hpatch = scatter('v6',...)
```

Description

`scatter(X,Y,S,C)` displays colored circles at the locations specified by the vectors `X` and `Y` (which must be the same size).

`S` determines the area of each marker (specified in `points^2`). `S` can be a vector the same length as `X` and `Y` or a scalar. If `S` is a scalar, MATLAB draws all the markers the same size. If `S` is empty, the default size is used.

`C` determines the color of each marker. When `C` is a vector the same length as `X` and `Y`, the values in `C` are linearly mapped to the colors in the current colormap. When `C` is a 1-by-3 matrix, it specifies the colors of the markers as RGB values. If you have 3 points in the scatter plot and wish to have the colors be indices into the colormap, `C` should be a 3-by-1 matrix. `C` can also be a color string (see `ColorSpec` for a list of color string specifiers).

scatter

`scatter(X,Y)` draws the markers in the default size and color.

`scatter(X,Y,S)` draws the markers at the specified sizes (S) with a single color. This type of graph is also known as a bubble plot.

`scatter(...,markertype)` uses the marker type specified instead of 'o' (see `LineStyleSpec` for a list of marker specifiers).

`scatter(..., 'filled')` fills the markers.

`scatter(..., 'PropertyName', propertyvalue)` creates the scatter graph, applying the specified property settings. See `scattergroup` properties for a description of properties.

`scatter(axes_handles,...)` plots into the axes object with handle `axes_handle` instead of the current axes object (`gca`).

`h = scatter(...)` returns the handle of the `scattergroup` object created.

Backward-Compatible Version

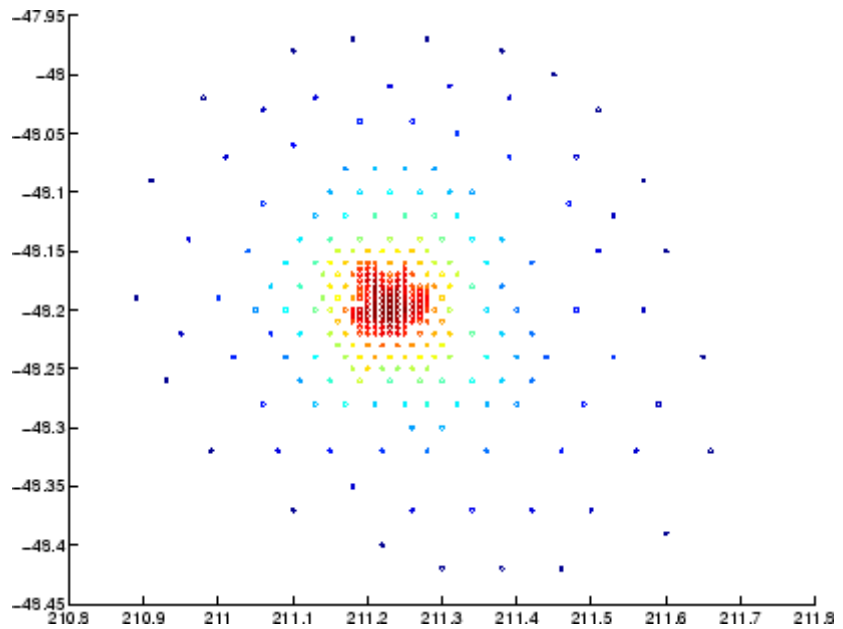
`hpatch = scatter('v6',...)` returns the handles to the patch objects created by `scatter` (see `Patch Properties` for a list of properties you can specify using the object handles and `set`).

Note The `v6` option enables users of Version 7.x of MATLAB to create FIG-files that previous versions can open. It is obsolete and will be removed in a future version of MATLAB.

See `Plot Objects and Backward Compatibility` for more information.

Example

```
load seamount
scatter(x,y,5,z)
```


**See Also**

`scatter3`, `plot3`

“Scatter/Bubble Plots” on page 1-98 for related functions

See “Triangulations and Scattered Data” for related information.

See `Scattergroup` Properties for property descriptions.


scatter3

Purpose

3-D scatter plot



GUI Alternatives

To graph selected variables, use the Plot Selector  in the Workspace Browser, or use the Figure Palette Plot Catalog. Manipulate graphs in *plot edit* mode with the Property Editor. For details, see [Plotting Tools — Interactive Plotting in the MATLAB Graphics documentation](#) and [Creating Graphics from the Workspace Browser in the MATLAB Desktop Tools documentation](#).

Syntax

```
scatter3(X,Y,Z,S,C)
scatter3(X,Y,Z)
scatter3(X,Y,Z,S)
scatter3(...,markertype)
scatter3(...,'filled')
scatter3(...,'PropertyName',propertyvalue)
h = scatter3(...)
hpatch = scatter3('v6',...)
```

Description

`scatter3(X,Y,Z,S,C)` displays colored circles at the locations specified by the vectors X , Y , and Z (which must all be the same size).

S determines the size of each marker (specified in points). S can be a vector the same length as X , Y , and Z or a scalar. If S is a scalar, MATLAB draws all the markers the same size.

C determines the color of each marker. When C is a vector the same length as X and Y , the values in C are linearly mapped to the colors in the current colormap. When C is a 1-by-3 matrix, it specifies the colors of the markers as RGB values. If you have 3 points in the scatter plot and wish to have the colors be indices into the colormap, C should be a 3-by-1 matrix. C can also be a color string (see [ColorSpec](#) for a list of color string specifiers).

`scatter3(X,Y,Z)` draws the markers in the default size and color.

`scatter3(X,Y,Z,S)` draws markers at the specified sizes (S) in a single color.

`scatter3(...,markertype)` uses the marker type specified instead of 'o' (see `LineStyle` for a list of marker specifiers).

`scatter3(...,'filled')` fills the markers.

`scatter3(...,'PropertyName',propertyvalue)` creates the scatter graph, applying the specified property settings. See `scattergroup` properties for a description of properties.

`h = scatter3(...)` returns handles to the `scattergroup` objects created by `scatter3`. See `Scattergroup Properties` for property descriptions.

Backward-Compatible Version

`hpatch = scatter3('v6',...)` returns the handles to the patch objects created by `scatter3` (see `Patch` for a list of properties you can specify using the object handles and `set`).

Note The v6 option enables users of Version 7.x of MATLAB to create FIG-files that previous versions can open. It is obsolete and will be removed in a future version of MATLAB.

See `Plot Objects and Backward Compatibility` for more information.

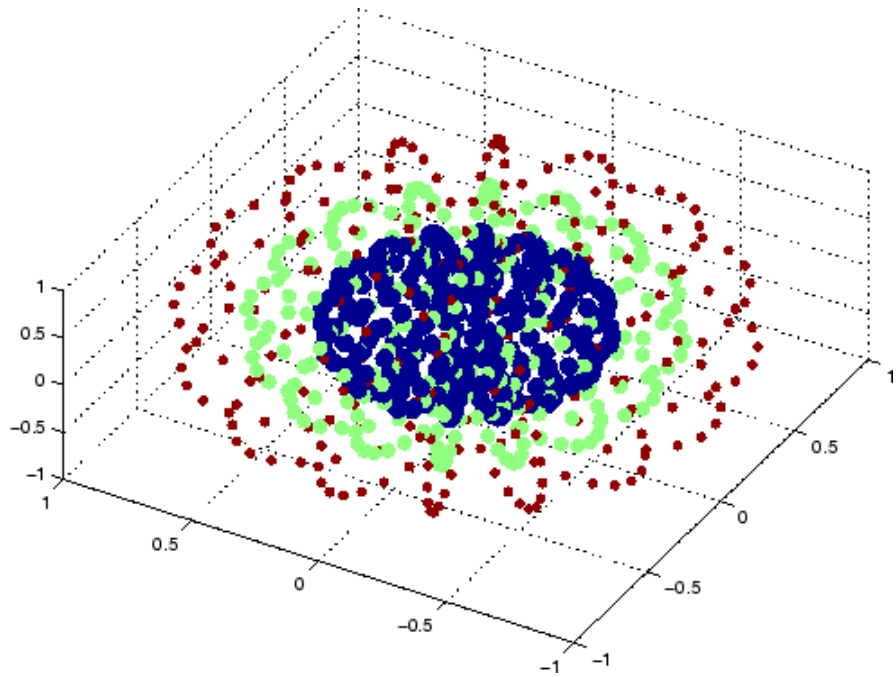
Remarks

Use `plot3` for single color, single marker size 3-D scatter plots.

Examples

```
[x,y,z] = sphere(16);
X = [x(:)*.5 x(:)*.75 x(:)];
Y = [y(:)*.5 y(:)*.75 y(:)];
Z = [z(:)*.5 z(:)*.75 z(:)];
S = repmat([1 .75 .5]*10,prod(size(x)),1);
C = repmat([1 2 3],prod(size(x)),1);
scatter3(X(:),Y(:),Z(:),S(:),C(:),'filled'), view(-60,60)
```

scatter3



See Also

`scatter`, `plot3`

See `Scattergroup` Properties for property descriptions

“Scatter/Bubble Plots” on page 1-98 for related functions

Purpose

Define scattergroup properties

Modifying Properties

You can set and query graphics object properties using the `set` and `get` commands or the Property Editor (`propertyeditor`).

Note that you cannot define default property values for scattergroup objects.

See Plot Objects for information on scattergroup objects.

Scattergroup Property Descriptions

This section provides a description of properties. Curly braces `{ }` enclose default values.

Annotation

`hg.Annotation` object Read Only

Control the display of scattergroup objects in legends. The Annotation property enables you to specify whether this scattergroup object is represented in a figure legend.

Querying the Annotation property returns the handle of an `hg.Annotation` object. The `hg.Annotation` object has a property called `LegendInformation`, which contains an `hg.LegendEntry` object.

Once you have obtained the `hg.LegendEntry` object, you can set its `IconDisplayStyle` property to control whether the scattergroup object is displayed in a figure legend:

IconDisplayStyle Value	Purpose
on	Include the scattergroup object in a legend as one entry, but not its children objects

Scattergroup Properties

IconDisplayStyle Value	Purpose
off	Do not include the scattergroup or its children in a legend (default)
children	Include only the children of the scattergroup as separate entries in the legend

Setting the IconDisplayStyle Property

These commands set the `IconDisplayStyle` of a graphics object with handle `hobj` to `children`, which causes each child object to have an entry in the legend:

```
hAnnotation = get(hobj, 'Annotation');  
hLegendEntry = get(hAnnotation, 'LegendInformation');  
set(hLegendEntry, 'IconDisplayStyle', 'children')
```

Using the IconDisplayStyle Property

See “Controlling Legends” for more information and examples.

BeingDeleted
on | {off} Read Only

This object is being deleted. The `BeingDeleted` property provides a mechanism that you can use to determine if objects are in the process of being deleted. MATLAB sets the `BeingDeleted` property to `on` when the object’s delete function callback is called (see the `DeleteFcn` property). It remains set to `on` while the delete function executes, after which the object no longer exists.

For example, an object’s delete function might call other functions that act on a number of different objects. These functions might not need to perform actions on objects if the objects are going to be deleted, and therefore, can check the object’s `BeingDeleted` property before acting.

BusyAction

cancel | {queue}

Callback routine interruption. The `BusyAction` property enables you to control how MATLAB handles events that potentially interrupt executing callbacks. If there is a callback function executing, callbacks invoked subsequently always attempt to interrupt it.

If the `Interruptible` property of the object whose callback is executing is set to `on` (the default), then interruption occurs at the next point where the event queue is processed. If the `Interruptible` property is `off`, the `BusyAction` property (of the object owning the executing callback) determines how MATLAB handles the event. The choices are

- `cancel` — Discard the event that attempted to execute a second callback routine.
- `queue` — Queue the event that attempted to execute a second callback routine until the current callback finishes.

ButtonDownFcn

string or function handle

Button press callback function. A callback that executes whenever you press a mouse button while the pointer is over this object, but not over another graphics object. See the `HitTestArea` property for information about selecting objects of this type.

See the figure's `SelectionType` property to determine if modifier keys were also pressed.

This property can be

- A string that is a valid MATLAB expression
- The name of an M-file

Scattergroup Properties

- A function handle

Set this property to a function handle that references the callback. The expressions execute in the MATLAB workspace.

See “Function Handle Callbacks” for information on how to use function handles to define the callbacks.

CData

vector, m-by-3 matrix, ColorSpec

Color of markers. When CData is a vector the same length as XData and YData, the values in CData are linearly mapped to the colors in the current colormap. When CData is a length(XData)-by-3 matrix, it specifies the colors of the markers as RGB values.

CDataSource

string (MATLAB variable)

Link YData to MATLAB variable. Set this property to a MATLAB variable that, by default, is evaluated in the base workspace to generate the CData.

MATLAB reevaluates this property only when you set it. Therefore, a change to workspace variables appearing in an expression does not change CData.

You can use the `refreshdata` function to force an update of the object's data. `refreshdata` also enables you to specify that the data source variable be evaluated in the workspace of a function from which you call `refreshdata`.

See the `refreshdata` reference page for more information.

Note If you change one data source property to a variable that contains data of a different dimension, you might cause the function to generate a warning and not render the graph until you have changed all data source properties to appropriate values.

Children

array of graphics object handles

Children of this object. The handle of a patch object that is the child of this object (whether visible or not).

Note that if a child object's `HandleVisibility` property is set to `callback` or `off`, its handle does not show up in this object's `Children` property unless you set the root `ShowHiddenHandles` property to `on`:

```
set(0, 'ShowHiddenHandles', 'on')
```

Clipping

{on} | off

Clipping mode. MATLAB clips graphs to the axes plot box by default. If you set `Clipping` to `off`, portions of graphs can be displayed outside the axes plot box. This can occur if you create a plot object, set `hold` to `on`, freeze axis scaling (`axis manual`), and then create a larger plot object.

CreateFcn

string or function handle

Callback routine executed during object creation. This property defines a callback that executes when MATLAB creates an object. You must specify the callback during the creation of the object. For example,

```
area(y, 'CreateFcn', @CallbackFcn)
```

Scattergroup Properties

where `@CallbackFcn` is a function handle that references the callback function.

MATLAB executes this routine after setting all other object properties. Setting this property on an existing object has no effect.

The handle of the object whose `CreateFcn` is being executed is accessible only through the root `CallbackObject` property, which you can query using `gcbo`.

See “Function Handle Callbacks” for information on how to use function handles to define the callback function.

DeleteFcn

string or function handle

Callback executed during object deletion. A callback that executes when this object is deleted (e.g., this might happen when you issue a `delete` command on the object, its parent axes, or the figure containing it). MATLAB executes the callback before destroying the object’s properties so the callback routine can query these values.

The handle of the object whose `DeleteFcn` is being executed is accessible only through the root `CallbackObject` property, which can be queried using `gcbo`.

See “Function Handle Callbacks” for information on how to use function handles to define the callback function.

See the `BeingDeleted` property for related information.

DisplayName

string (default is empty string)

String used by legend for this scattergroup object. The legend function uses the string defined by the `DisplayName` property to label this scattergroup object in the legend.

- If you specify string arguments with the legend function, `DisplayName` is set to this scattergroup object's corresponding string and that string is used for the legend.
- If `DisplayName` is empty, legend creates a string of the form, `['data' n]`, where *n* is the number assigned to the object based on its location in the list of legend entries. However, legend does not set `DisplayName` to this string.
- If you edit the string directly in an existing legend, `DisplayName` is set to the edited string.
- If you specify a string for the `DisplayName` property and create the legend using the figure toolbar, then MATLAB uses the string defined by `DisplayName`.
- To add programmatically a legend that uses the `DisplayName` string, call legend with the `toggle` or `show` option.

See “Controlling Legends” for more examples.

EraseMode

`{normal} | none | xor | background`

Erase mode. This property controls the technique MATLAB uses to draw and erase objects and their children. Alternative erase modes are useful for creating animated sequences, where control of the way individual objects are redrawn is necessary to improve performance and obtain the desired effect.

- `normal` — Redraw the affected region of the display, performing the three-dimensional analysis necessary to ensure that all objects are rendered correctly. This mode produces the most accurate picture, but is the slowest. The other modes are faster, but do not perform a complete redraw and are therefore less accurate.

Scattergroup Properties

- **none** — Do not erase objects when they are moved or destroyed. While the objects are still visible on the screen after erasing with `EraseMode none`, you cannot print these objects because MATLAB stores no information about their former locations.
- **xor** — Draw and erase the object by performing an exclusive OR (XOR) with each pixel index of the screen behind it. Erasing the object does not damage the color of the objects behind it. However, the color of the erased object depends on the color of the screen behind it and it is correctly colored only when it is over the axes background color (or the figure background color if the axes `Color` property is set to `none`). That is, it isn't erased correctly if there are objects behind it.
- **background** — Erase the graphics objects by redrawing them in the axes background color, (or the figure background color if the axes `Color` property is set to `none`). This damages other graphics objects that are behind the erased object, but the erased object is always properly colored.

Printing with Nonnormal Erase Modes

MATLAB always prints figures as if the `EraseMode` of all objects is `normal`. This means graphics objects created with `EraseMode` set to `none`, `xor`, or `background` can look different on screen than on paper. On screen, MATLAB can mathematically combine layers of colors (e.g., performing an XOR on a pixel color with that of the pixel behind it) and ignore three-dimensional sorting to obtain greater rendering speed. However, these techniques are not applied to the printed output.

Set the axes background color with the axes `Color` property. Set the figure background color with the figure `Color` property.

You can use the MATLAB `getframe` command or other screen capture applications to create an image of a figure containing nonnormal mode objects.

HandleVisibility

{on} | callback | off

Control access to object's handle by command-line users and GUIs. This property determines when an object's handle is visible in its parent's list of children. `HandleVisibility` is useful for preventing command-line users from accidentally accessing objects that you need to protect for some reason.

- `on` — Handles are always visible when `HandleVisibility` is `on`.
- `callback` — Setting `HandleVisibility` to `callback` causes handles to be visible from within callback routines or functions invoked by callback routines, but not from within functions invoked from the command line. This provides a means to protect GUIs from command-line users, while allowing callback routines to have access to object handles.
- `off` — Setting `HandleVisibility` to `off` makes handles invisible at all times. This might be necessary when a callback invokes a function that might potentially damage the GUI (such as evaluating a user-typed string) and so temporarily hides its own handles during the execution of that function.

Functions Affected by Handle Visibility

When a handle is not visible in its parent's list of children, it cannot be returned by functions that obtain handles by searching the object hierarchy or querying handle properties. This includes `get`, `findobj`, `gca`, `gcf`, `gco`, `newplot`, `cla`, `clf`, and `close`.

Properties Affected by Handle Visibility

When a handle's visibility is restricted using `callback` or `off`, the object's handle does not appear in its parent's `Children` property, figures do not appear in the root's `CurrentFigure` property, objects do not appear in the root's `CallbackObject` property or in

Scattergroup Properties

the figure's `CurrentObject` property, and axes do not appear in their parent's `CurrentAxes` property.

Overriding Handle Visibility

You can set the root `ShowHiddenHandles` property to `on` to make all handles visible regardless of their `HandleVisibility` settings (this does not affect the values of the `HandleVisibility` properties). See also `findall`.

Handle Validity

Handles that are hidden are still valid. If you know an object's handle, you can `set` and `get` its properties and pass it to any function that operates on handles.

Note If you change one data source property to a variable that contains data of a different dimension, you might cause the function to generate a warning and not render the graph until you have changed all data source properties to appropriate values.

`HitTest`
`{on} | off`

Selectable by mouse click. `HitTest` determines whether this object can become the current object (as returned by the `gco` command and the figure `CurrentObject` property) as a result of a mouse click on the objects that compose the area graph. If `HitTest` is `off`, clicking this object selects the object below it (which is usually the axes containing it).

`HitTestArea`
`on | {off}`

Select the object by clicking lines or area of extent. This property enables you to select plot objects in two ways:

- Select by clicking lines or markers (default).
- Select by clicking anywhere in the extent of the plot.

When `HitTestArea` is off, you must click the object's lines or markers (excluding the baseline, if any) to select the object. When `HitTestArea` is on, you can select this object by clicking anywhere within the extent of the plot (i.e., anywhere within a rectangle that encloses it).

Interruptible

{on} | off

Callback routine interruption mode. The `Interruptible` property controls whether an object's callback can be interrupted by callbacks invoked subsequently.

Only callbacks defined for the `ButtonDownFcn` property are affected by the `Interruptible` property. MATLAB checks for events that can interrupt a callback only when it encounters a `drawnow`, `figure`, `getframe`, or `pause` command in the routine. See the `BusyAction` property for related information.

Setting `Interruptible` to on allows any graphics object's callback to interrupt callback routines originating from a bar property. Note that MATLAB does not save the state of variables or the display (e.g., the handle returned by the `gca` or `gcf` command) when an interruption occurs.

LineWidth

scalar

The width of linear objects and edges of filled areas. Specify this value in points (1 point = $\frac{1}{72}$ inch). The default `LineWidth` is 0.5 points.

Scattergroup Properties

Marker

character (see table)

Marker symbol. The Marker property specifies the type of markers that are displayed at plot vertices. You can set values for the Marker property independently from the LineStyle property. Supported markers include those shown in the following table.

Marker Specifier	Description
+	Plus sign
o	Circle
*	Asterisk
.	Point
x	Cross
s	Square
d	Diamond
^	Upward-pointing triangle
v	Downward-pointing triangle
>	Right-pointing triangle
<	Left-pointing triangle
p	Five-pointed star (pentagram)
h	Six-pointed star (hexagram)
none	No marker (default)

MarkerEdgeColor

ColorSpec | none | {auto}

Marker edge color. The color of the marker or the edge color for filled markers (circle, square, diamond, pentagram, hexagram, and the four triangles). ColorSpec defines the color to use. none

specifies no color, which makes nonfilled markers invisible. `auto` sets `MarkerEdgeColor` to the same color as the `CData` property.

MarkerFaceColor

ColorSpec | {none} | auto

Marker face color. The fill color for markers that are closed shapes (circle, square, diamond, pentagram, hexagram, and the four triangles). `ColorSpec` defines the color to use. `none` makes the interior of the marker transparent, allowing the background to show through. `auto` sets the fill color to the axes color, or to the figure color if the axes `Color` property is set to `none` (which is the factory default for axes objects).

Parent

handle of parent axes, `hggroup`, or `hgtransform`

Parent of this object. This property contains the handle of the object's parent. The parent is normally the axes, `hggroup`, or `hgtransform` object that contains the object.

See “Objects That Can Contain Other Objects” for more information on parenting graphics objects.

Selected

on | {off}

Is object selected? When you set this property to `on`, MATLAB displays selection "handles" at the corners and midpoints if the `SelectionHighlight` property is also `on` (the default). You can, for example, define the `ButtonDownFcn` callback to set this property to `on`, thereby indicating that this particular object is selected. This property is also set to `on` when an object is manually selected in plot edit mode.

SelectionHighlight

{on} | off

Scattergroup Properties

Objects are highlighted when selected. When the `Selected` property is on, MATLAB indicates the selected state by drawing four edge handles and four corner handles. When `SelectionHighlight` is off, MATLAB does not draw the handles except when in plot edit mode and objects are selected manually.

SizeData

square points

Size of markers in square points. This property specifies the area of the marker in the scatter graph in units of points. Since there are 72 points to one inch, to specify a marker that has an area of one square inch you would use a value of 72^2 .

Tag

string

User-specified object label. The `Tag` property provides a means to identify graphics objects with a user-specified label. This is particularly useful when you are constructing interactive graphics programs that would otherwise need to define object handles as global variables or pass them as arguments between callbacks. You can define `Tag` as any string.

For example, you might create an `areaseries` object and set the `Tag` property.

```
t = area(Y, 'Tag', 'area1')
```

When you want to access objects of a given type, you can use `findobj` to find the object's handle. The following statement changes the `FaceColor` property of the object whose `Tag` is `area1`.

```
set(findobj('Tag', 'area1'), 'FaceColor', 'red')
```

Type

string (read only)

Type of graphics object. This property contains a string that identifies the class of the graphics object. For stemseries objects, Type is 'hggroup'. The following statement finds all the hggroup objects in the current axes.

```
t = findobj(gca,'Type','hggroup');
```

UIContextMenu

handle of a uicontextmenu object

Associate a context menu with this object. Assign this property the handle of a uicontextmenu object created in the object's parent figure. Use the uicontextmenu function to create the context menu. MATLAB displays the context menu whenever you right-click over the object.

UserData

array

User-specified data. This property can be any data you want to associate with this object (including cell arrays and structures). The object does not set values for this property, but you can access it using the set and get functions.

Visible

{on} | off

Visibility of this object and its children. By default, a new object's visibility is on. This means all children of the object are visible unless the child object's Visible property is set to off. Setting an object's Visible property to off prevents the object from being displayed. However, the object still exists and you can set and query its properties.

XData

array

X-coordinates of scatter markers. The scatter function draws individual markers at each x-axis location in the XData array.

Scattergroup Properties

The input argument `x` in the `scatter` function calling syntax assigns values to `XData`.

`XDataSource`
string (MATLAB variable)

Link XData to MATLAB variable. Set this property to a MATLAB variable that is evaluated in the base workspace to generate the `XData`.

MATLAB reevaluates this property only when you set it. Therefore, a change to workspace variables appearing in an expression does not change `XData`.

You can use the `refreshdata` function to force an update of the object's data. `refreshdata` also enables you to specify that the data source variable be evaluated in the workspace of a function from which you call `refreshdata`.

See the `refreshdata` reference page for more information.

Note If you change one data source property to a variable that contains data of a different dimension, you might cause the function to generate a warning and not render the graph until you have changed all data source properties to appropriate values.

`YData`
scalar, vector, or matrix

Y-coordinates of scatter markers. The `scatter` function draws individual markers at each *y*-axis location in the `YData` array.

The input argument `y` in the `scatter` function calling syntax assigns values to `YData`.

YDataSource

string (MATLAB variable)

Link YData to MATLAB variable. Set this property to a MATLAB variable that is evaluated in the base workspace to generate the YData.

MATLAB reevaluates this property only when you set it. Therefore, a change to workspace variables appearing in an expression does not change YData.

You can use the `refreshdata` function to force an update of the object's data. `refreshdata` also enables you to specify that the data source variable be evaluated in the workspace of a function from which you call `refreshdata`.

See the `refreshdata` reference page for more information.

Note If you change one data source property to a variable that contains data of a different dimension, you might cause the function to generate a warning and not render the graph until you have changed all data source properties to appropriate values.

ZData

vector of coordinates

Z-coordinates. A vector defining the *z*-coordinates for the graph. XData and YData must be the same length and have the same number of rows.

ZDataSource

string (MATLAB variable)

Scattergroup Properties

Link ZData to MATLAB variable. Set this property to a MATLAB variable that is evaluated in the base workspace to generate the ZData.

MATLAB reevaluates this property only when you set it. Therefore, a change to workspace variables appearing in an expression does not change ZData.

You can use the `refreshdata` function to force an update of the object's data. `refreshdata` also enables you to specify that the data source variable be evaluated in the workspace of a function from which you call `refreshdata`.

See the `refreshdata` reference page for more information.

Note If you change one data source property to a variable that contains data of a different dimension, you might cause the function to generate a warning and not render the graph until you have changed all data source properties to appropriate values.

Purpose

Schur decomposition

Syntax

```
T = schur(A)
T = schur(A, flag)
[U, T] = schur(A, ...)
```

Description

The `schur` command computes the Schur form of a matrix.

`T = schur(A)` returns the Schur matrix `T`.

`T = schur(A, flag)` for real matrix `A`, returns a Schur matrix `T` in one of two forms depending on the value of `flag`:

'complex'	<code>T</code> is triangular and is complex if <code>A</code> has complex eigenvalues.
'real'	<code>T</code> has the real eigenvalues on the diagonal and the complex eigenvalues in 2-by-2 blocks on the diagonal. 'real' is the default.

If `A` is complex, `schur` returns the complex Schur form in matrix `T`. The complex Schur form is upper triangular with the eigenvalues of `A` on the diagonal.

The function `rsf2csf` converts the real Schur form to the complex Schur form.

`[U, T] = schur(A, ...)` also returns a unitary matrix `U` so that $A = U^*T^*U'$ and $U' * U = \text{eye}(\text{size}(A))$.

Examples

`H` is a 3-by-3 eigenvalue test matrix:

```
H = [ -149   -50   -154
       537   180   546
       -27    -9   -25 ]
```

Its Schur form is

```
schur(H)
```

```
ans =  
  1.0000   -7.1119  -815.8706  
         0    2.0000  -55.0236  
         0         0    3.0000
```

The eigenvalues, which in this case are 1, 2, and 3, are on the diagonal. The fact that the off-diagonal elements are so large indicates that this matrix has poorly conditioned eigenvalues; small changes in the matrix elements produce relatively large changes in its eigenvalues.

Algorithm

Input of Type Double

If *A* has type `double`, `schur` uses the LAPACK routines listed in the following table to compute the Schur form of a matrix:

Matrix A	Routine
Real symmetric	DSYTRD, DSTEQR
	DSYTRD, DORGTR, DSTEQR (with output U)
Real nonsymmetric	DGEHRD, DHSEQR
	DGEHRD, DORGHR, DHSEQR (with output U)
Complex Hermitian	ZHETRD, ZSTEQR
	ZHETRD, ZUNGTR, ZSTEQR (with output U)
Non-Hermitian	ZGEHRD, ZHSEQR
	ZGEHRD, ZUNGHR, ZHSEQR (with output U)

Input of Type Single

If *A* has type `single`, `schur` uses the LAPACK routines listed in the following table to compute the Schur form of a matrix:

Matrix A	Routine
Real symmetric	SSYTRD, SSTEQR
	SSYTRD, SORGTR, SSTEQR (with output U)

Matrix A	Routine
Real nonsymmetric	SGEHRD, SHSEQR
	SGEHRD, SORGHR, SHSEQR (with output U)
Complex Hermitian	CHETRD, CSTEQR
	CHETRD, CUNGTR, CSTEQR (with output U)
Non-Hermitian	CGEHRD, CHSEQR
	CGEHRD, CUNGHR, CHSEQR (with output U)

See Also

eig, hess, qz, rsf2csf

References

[1] Anderson, E., Z. Bai, C. Bischof, S. Blackford, J. Demmel, J. Dongarra, J. Du Croz, A. Greenbaum, S. Hammarling, A. McKenney, and D. Sorensen, *LAPACK User's Guide* (http://www.netlib.org/lapack/lug/lapack_lug.html), Third Edition, SIAM, Philadelphia, 1999.

script

Purpose Script M-file description

Description A script file is an external file that contains a sequence of MATLAB statements. By typing the filename, you can obtain subsequent MATLAB input from the file. Script files have a filename extension of `.m` and are often called M-files.

Scripts are the simplest kind of M-file. They are useful for automating blocks of MATLAB commands, such as computations you have to perform repeatedly from the command line. Scripts can operate on existing data in the workspace, or they can create new data on which to operate. Although scripts do not return output arguments, any variables that they create remain in the workspace, so you can use them in further computations. In addition, scripts can produce graphical output using commands like `plot`.

Scripts can contain any series of MATLAB statements. They require no declarations or begin/end delimiters.

Like any M-file, scripts can contain comments. Any text following a percent sign (`%`) on a given line is comment text. Comments can appear on lines by themselves, or you can append them to the end of any executable line.

See Also `echo`, `function`, `type`

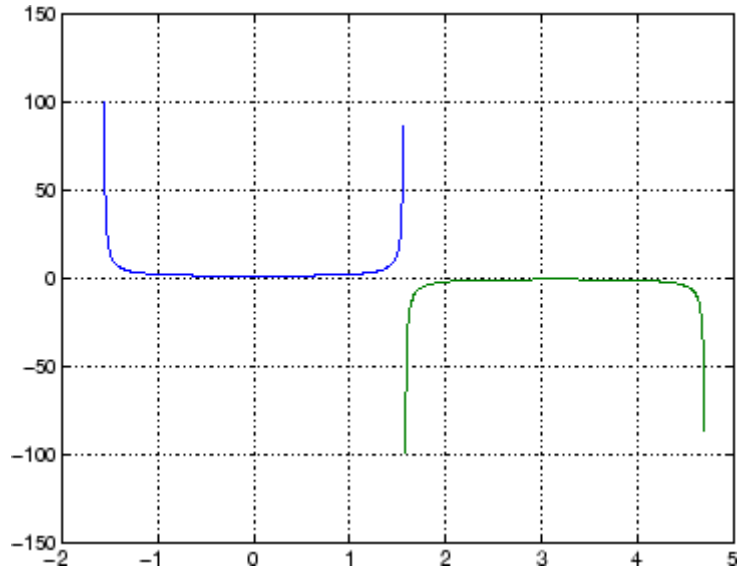
Purpose Secant of argument in radians

Syntax $Y = \sec(X)$

Description The sec function operates element-wise on arrays. The function's domains and ranges include complex values. All angles are in radians. $Y = \sec(X)$ returns an array the same size as X containing the secant of the elements of X .

Examples Graph the secant over the domains $-\pi/2 < x < \pi/2$ and $\pi/2 < x < 3\pi/2$.

```
x1 = -pi/2+0.01:0.01:pi/2-0.01;  
x2 = pi/2+0.01:0.01:(3*pi/2)-0.01;  
plot(x1,sec(x1),x2,sec(x2)), grid on
```



The expression `sec(pi/2)` does not evaluate as infinite but as the reciprocal of the floating-point accuracy `eps`, because `pi` is a floating-point approximation to the exact value of π .

Definition

The secant can be defined as

$$\text{sec}(z) = \frac{1}{\cos(z)}$$

Algorithm

`sec` uses FDLIBM, which was developed at SunSoft, a Sun Microsystems, Inc. business, by Kwok C. Ng, and others. For information about FDLIBM, see <http://www.netlib.org>.

See Also

`secd`, `sech`, `asec`, `asecd`, `asech`

Purpose Secant of argument in degrees

Syntax $Y = \text{secd}(X)$

Description $Y = \text{secd}(X)$ is the secant of the elements of X , expressed in degrees. For odd integers n , $\text{secd}(n*90)$ is infinite, whereas $\text{sec}(n*\pi/2)$ is large but finite, reflecting the accuracy of the floating point value of π .

See Also `sec`, `sech`, `asec`, `asecd`, `asech`

sech

Purpose Hyperbolic secant

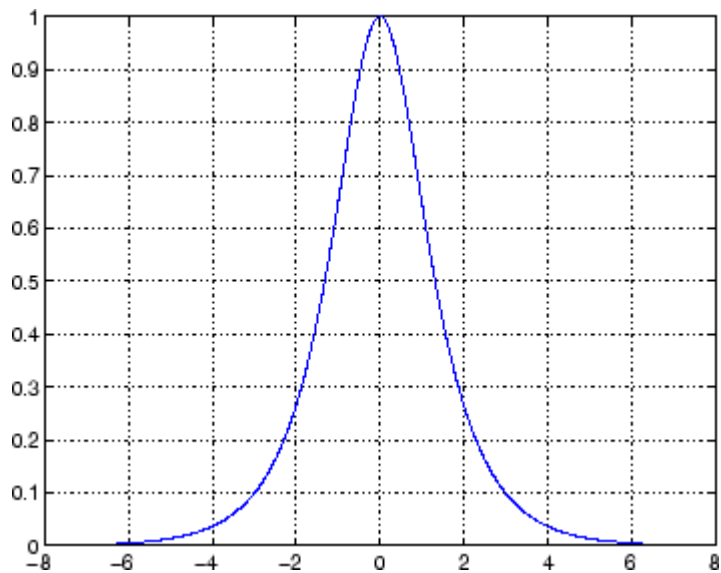
Syntax $Y = \operatorname{sech}(X)$

Description The sech function operates element-wise on arrays. The function's domains and ranges include complex values. All angles are in radians.

$Y = \operatorname{sech}(X)$ returns an array the same size as X containing the hyperbolic secant of the elements of X .

Examples Graph the hyperbolic secant over the domain $-2\pi \leq x \leq 2\pi$.

```
x = -2*pi:0.01:2*pi;  
plot(x,sech(x)), grid on
```



Algorithm sech uses this algorithm.

$$\mathbf{sech}(z) = \frac{1}{\mathbf{cosh}(z)}$$

Definition The secant can be defined as

$$\mathbf{sech}(z) = \frac{1}{\mathbf{cosh}(z)}$$

Algorithm sec uses FDLIBM, which was developed at SunSoft, a Sun Microsystems, Inc. business, by Kwok C. Ng, and others. For information about FDLIBM, see <http://www.netlib.org>.

See Also asec, asech, sec

selectmoveresize

Purpose Select, move, resize, or copy axes and uicontrol graphics objects

Syntax `A = selectmoveresize`
`set(gca, 'ButtonDownFcn', 'selectmoveresize')`

Description `selectmoveresize` is useful as the callback routine for axes and uicontrol button down functions. When executed, it selects the object and allows you to move, resize, and copy it.

`A = selectmoveresize` returns a structure array containing

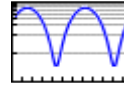
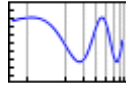
- `A.Type`: a string containing the action type, which can be `Select`, `Move`, `Resize`, or `Copy`
- `A.Handles`: a list of the selected handles, or, for a `Copy`, an m-by-2 matrix containing the original handles in the first column and the new handles in the second column

`set(gca, 'ButtonDownFcn', 'selectmoveresize')` sets the `ButtonDownFcn` property of the current axes to `selectmoveresize`:


See Also The `ButtonDownFcn` property of axes and uicontrol objects
“Object Manipulation” on page 1-107 for related functions

Purpose

Semilogarithmic plots



GUI Alternatives

To graph selected variables, use the Plot Selector  in the Workspace Browser, or use the Figure Palette Plot Catalog. Manipulate graphs in *plot edit* mode with the Property Editor. For details, see Plotting Tools — Interactive Plotting in the MATLAB Graphics documentation and Creating Graphics from the Workspace Browser in the MATLAB Desktop Tools documentation.

Syntax

```
semilogx(Y)
semilogy(...)
semilogx(X1,Y1,...)
semilogx(X1,Y1,LineStyle,...)
semilogx(...,'PropertyName',PropertyValue,...)
h = semilogx(...)
h = semilogy(...)
hlines = semilogx('v6',...)
```

Description

`semilogx` and `semilogy` plot data as logarithmic scales for the x - and y -axis, respectively.

`semilogx(Y)` creates a plot using a base 10 logarithmic scale for the x -axis and a linear scale for the y -axis. It plots the columns of Y versus their index if Y contains real numbers. `semilogx(Y)` is equivalent to `semilogx(real(Y), imag(Y))` if Y contains complex numbers. `semilogx` ignores the imaginary component in all other uses of this function.

`semilogy(...)` creates a plot using a base 10 logarithmic scale for the y -axis and a linear scale for the x -axis.

`semilogx(X1,Y1,...)` plots all X_n versus Y_n pairs. If only X_n or Y_n is a matrix, `semilogx` plots the vector argument versus the rows or

semilogx, semilogy

columns of the matrix, depending on whether the vector's row or column dimension matches the matrix.

`semilogx(X1,Y1,LineStyle,...)` plots all lines defined by the `Xn,Yn,LineStyle` triples. `LineStyle` determines line style, marker symbol, and color of the plotted lines.

`semilogx(...,'PropertyName',PropertyValue,...)` sets property values for all lineseries graphics objects created by `semilogx`.

`h = semilogx(...)` and `h = semilogy(...)` return a vector of handles to lineseries graphics objects, one handle per line.

Backward-Compatible Version

`hlines = semilogx('v6',...)` and `hlines = semilogy('v6',...)` return the handles to line objects instead of lineseries objects.

Note The `v6` option enables users of Version 7.x of MATLAB to create FIG-files that previous versions can open. It is obsolete and will be removed in a future version of MATLAB.

See Plot Objects and Backward Compatibility for more information.

Remarks

If you do not specify a color when plotting more than one line, `semilogx` and `semilogy` automatically cycle through the colors and line styles in the order specified by the current axes `ColorOrder` and `LineStyleOrder` properties.

You can mix `Xn,Yn` pairs with `Xn,Yn,LineStyle` triples; for example,

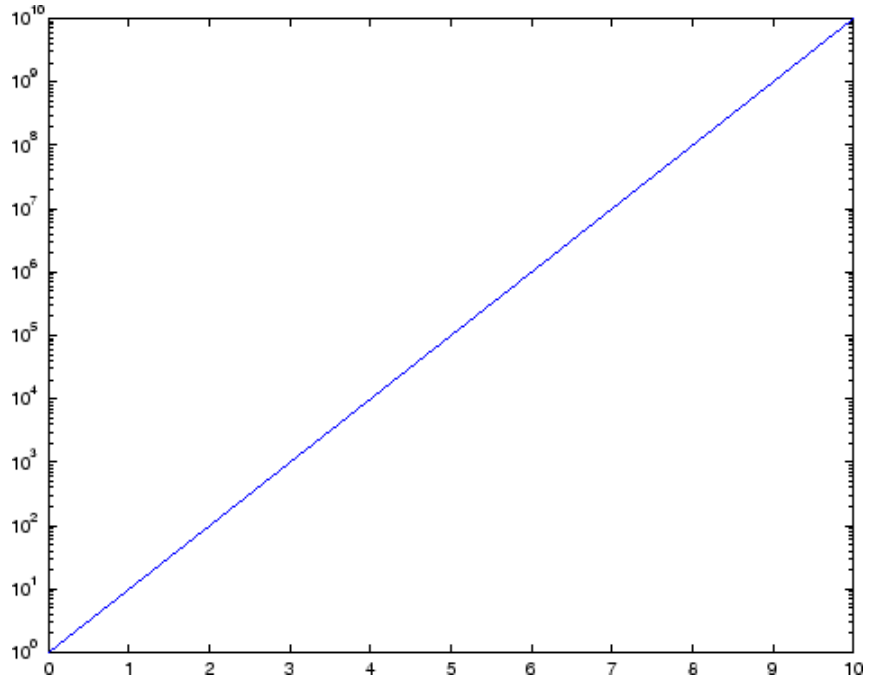
```
semilogx(X1,Y1,X2,Y2,LineStyle,X3,Y3)
```

If you attempt to add a `loglog`, `semilogx`, or `semilogy` plot to a linear axis mode graph with `hold` on, the axis mode will remain as it is and the new data will plot as linear.

Examples

Create a simple semilogy plot.

```
x = 0:.1:10;  
semilogy(x, 10.^x)
```



See Also

line, LineSpec, loglog, plot

“Basic Plots and Graphs” on page 1-93 for related functions

sendmail

Purpose Send e-mail message to address list

Syntax
`sendmail('recipients','subject')`
`sendmail('recipients','subject','message','attachments')`

Description `sendmail('recipients','subject')` sends e-mail to recipients with the specified subject. For recipients, use a string for a single address, or a cell array of strings for multiple addresses.

`sendmail('recipients','subject','message','attachments')` sends message to recipients with the specified subject. For recipients, use a string for a single address, or a cell array of strings for multiple addresses. For message, use a string or cell array. When message is a string, the text automatically wraps at 75 characters. When message is a cell array, it does not wrap but rather each cell is a new line. To force text to start on a new line in strings or cells, use 10, as shown in the “Example of sendmail with New Lines Specified” on page 2-3233. Specify attachments as a cell array of files to send along with message.

To use `sendmail`, you must set the preferences for your e-mail server (Internet SMTP server) and your e-mail address must be set. The MATLAB software tries to read the SMTP mail server from your system registry, but if it cannot, it results in an error. In this event, identify the outgoing mail server for your electronic mail application, which is usually listed in the application’s preferences, or, consult your e-mail system administrator. Then provide the information to MATLAB using:

```
setpref('Internet','SMTP_Server','myserver.myhost.com');
```

If you cannot easily determine your e-mail server, try using `mail`, as in:

```
setpref('Internet','SMTP_Server','mail');
```

which might work because `mail` is often a default for mail systems.

Similarly, if MATLAB cannot determine your e-mail address and produces an error, specify your e-mail address using:

```
setpref('Internet','E_mail','myaddress@example.com');
```

Note The sendmail function does not support e-mail servers that require authentication.

Examples

Example of sendmail with Two Attachments

```
sendmail('user@otherdomain.com',...  
        'Test subject','Test message',...  
        {'directory/attach1.html','attach2.doc'});
```

Example of sendmail with New Lines Specified

This mail message forces the message to start new lines after each 10.

```
sendmail('user@otherdomain.com','New subject', ...  
        ['Line1 of message' 10 'Line2 of message' 10 ...  
        'Line3 of message' 10 'Line4 of message']);
```

The resulting message is:

```
Line1 of message  
Line2 of message  
Line3 of message  
Line4 of message
```

See Also

getpref, setpref

serial

Purpose Create serial port object

Syntax
`obj = serial('port')`
`obj = serial('port', 'PropertyName', PropertyValue, ...)`

Description `obj = serial('port')` creates a serial port object associated with the serial port specified by *port*. If *port* does not exist, or if it is in use, you will not be able to connect the serial port object to the device.

Port object name will depend upon the platform that the serial port is on. `insthwinfo('serial')` provides a list of available serial ports. This list is an example of serial constructors on different platforms:

Platform	Serial Port Constructor
Linux and Linux 64	<code>serial('/dev/ttyS0');</code>
Mac OS X and Mac OS X 64	<code>serial('/dev/tty.KeySerial1');</code>
Solaris 64	<code>serial('/dev/term/a');</code>
Windows 32 and Windows 64	<code>serial('com1');</code>

`obj = serial('port', 'PropertyName', PropertyValue, ...)` creates a serial port object with the specified property names and property values. If an invalid property name or property value is specified, an error is returned and the serial port object is not created.

Remarks When you create a serial port object, these property values are automatically configured:

- The Type property is given by `serial`.
- The Name property is given by concatenating `Serial` with the port specified in the `serial` function.
- The Port property is given by the port specified in the `serial` function.

You can specify the property names and property values using any format supported by the `set` function. For example, you can use property name/property value cell array pairs. Additionally, you can specify property names without regard to case, and you can make use of property name completion. For example, the following commands are all valid on a Windows platform.

```
s = serial('COM1','BaudRate',4800);
s = serial('COM1','baudrate',4800);
s = serial('COM1','BAUD',4800);
```

Refer to [Configuring Property Values](#) for a list of serial port object properties that you can use with `serial`.

Before you can communicate with the device, it must be connected to `obj` with the `fopen` function. A connected serial port object has a `Status` property value of `open`. An error is returned if you attempt a read or write operation while the object is not connected to the device. You can connect only one serial port object to a given serial port.

Example

This example creates the serial port object `s1` associated with the serial port COM1 on a Windows platform.

```
s1 = serial('COM1');
```

The `Type`, `Name`, and `Port` properties are automatically configured.

```
get(s1,{'Type','Name','Port'})
ans =
    'serial'    'Serial-COM1'    'COM1'
```

To specify properties during object creation

```
s2 = serial('COM2','BaudRate',1200,'DataBits',7);
```

See Also

Functions

`fclose`, `fopen`

serial

Properties

Name, Port, Status, Type

Purpose	Send break to device connected to serial port
Syntax	<code>serialbreak(obj)</code> <code>serialbreak(obj,time)</code>
Description	<p><code>serialbreak(obj)</code> sends a break of 10 milliseconds to the device connected to the serial port object, <code>obj</code>.</p> <p><code>serialbreak(obj,time)</code> sends a break to the device with a duration, in milliseconds, specified by <code>time</code>. Note that the duration of the break might be inaccurate under some operating systems.</p>
Remarks	<p>For some devices, the break signal provides a way to clear the hardware buffer.</p> <p>Before you can send a break to the device, it must be connected to <code>obj</code> with the <code>fopen</code> function. A connected serial port object has a <code>Status</code> property value of <code>open</code>. An error is returned if you attempt to send a break while <code>obj</code> is not connected to the device.</p> <p><code>serialbreak</code> is a synchronous function, and blocks the command line until execution is complete.</p> <p>If you issue <code>serialbreak</code> while data is being asynchronously written, an error is returned. In this case, you must call the <code>stopasync</code> function or wait for the write operation to complete.</p>
See Also	Functions <code>fopen</code> , <code>stopasync</code> Properties <code>Status</code>

set

Purpose Set Handle Graphics object properties

Syntax

```
set(H, 'PropertyName', PropertyValue, ...)  
set(H, a)  
set(H, pn, pv, ...)  
set(H, pn, MxN_pv)  
a = set(h)  
pv = set(h, 'PropertyName')
```

Description

Note Do not use the `set` function on Java objects as it will cause a memory leak. For more information, see “Accessing Private and Public Data”

`set(H, 'PropertyName', PropertyValue, ...)` sets the named properties to the specified values on the object(s) identified by H. H can be a vector of handles, in which case `set` sets the properties' values for all the objects.

`set(H, a)` sets the named properties to the specified values on the object(s) identified by H. `a` is a structure array whose field names are the object property names and whose field values are the values of the corresponding properties.

`set(H, pn, pv, ...)` sets the named properties specified in the cell array `pn` to the corresponding value in the cell array `pv` for all objects identified in H.

`set(H, pn, MxN_pv)` sets `n` property values on each of `m` graphics objects, where `m = length(H)` and `n` is equal to the number of property names contained in the cell array `pn`. This allows you to set a given group of properties to different values on each object.

`a = set(h)` returns the user-settable properties and possible values for the object identified by `h`. `a` is a structure array whose field names are the object's property names and whose field values are the possible values of the corresponding properties. If you do not specify an output

argument, the MATLAB software displays the information on the screen. `h` must be scalar.

`pv = set(h, 'PropertyName')` returns the possible values for the named property. If the possible values are strings, `set` returns each in a cell of the cell array `pv`. For other properties, `set` returns a statement indicating that `PropertyName` does not have a fixed set of property values. If you do not specify an output argument, MATLAB displays the information on the screen. `h` must be scalar.

Remarks

You can use any combination of property name/property value pairs, structure arrays, and cell arrays in one call to `set`.

Setting Property Units

Note that if you are setting both the `FontSize` and the `FontUnits` properties in one function call, you must set the `FontUnits` property first so that the MATLAB software can correctly interpret the specified `FontSize`. The same applies to figure and axes units — always set the `Units` property before setting properties whose values you want to be interpreted in those units. For example,

```
f = figure('Units','characters',...
          'Position',[30 30 120 35]);
```

Examples

Set the `Color` property of the current axes to blue.

```
axes;
set(gca, 'Color', 'b')
```

Change all the lines in a plot to black.

```
plot(peaks)
set(findobj('Type','line'),'Color','k')
```

You can define a group of properties in a structure to better organize your code. For example, these statements define a structure called `active`, which contains a set of property definitions used for the

uicontrol objects in a particular figure. When this figure becomes the current figure, MATLAB changes the colors and enables the controls.

```
active.BackgroundColor = [.7 .7 .7];
active.Enable = 'on';
active.ForegroundColor = [0 0 0];

if(gcf == control_fig_handle
    set(findobj(control_fig_handle,'Type','uicontrol'),active)
end
```

You can use cell arrays to set properties to different values on each object. For example, these statements define a cell array to set three properties,

```
PropName(1) = {'BackgroundColor'};
PropName(2) = {'Enable'};
PropName(3) = {'ForegroundColor'};
```

These statements define a cell array containing three values for each of three objects (i.e., a 3-by-3 cell array).

```
PropVal(1,1) = {[.5 .5 .5]};
PropVal(1,2) = {'off'};
PropVal(1,3) = {[.9 .9 .9]};
PropVal(2,1) = {[1 0 0]};
PropVal(2,2) = {'on'};
PropVal(2,3) = {[1 1 1]};
PropVal(3,1) = {[.7 .7 .7]};
PropVal(3,2) = {'on'};
PropVal(3,3) = {[0 0 0]};
```

Now pass the arguments to set,

```
set(H,PropName,PropVal)
```

where `length(H) = 3` and each element is the handle to a uicontrol.

Setting Different Values for the Same Property on Multiple Objects

Suppose you want to set the value of the `Tag` property on five line objects, each to a different value. Note how the value cell array needs to be transposed to have the proper shape.

```
h = plot(rand(5));  
set(h,{'Tag'},{'line1','line2','line3','line4','line5'})
```

See Also

`findobj`, `gca`, `gcf`, `gco`, `gcbo`, `get`

“Graphics Object Identification” on page 1-100 for related functions

set (COM)

Purpose	Set object or interface property to specified value
Syntax	<pre>h.set('pname', value) h.set('pname1', value1, 'pname2', value2, ...) set(h, ...)</pre>
Description	<p><code>h.set('pname', value)</code> sets the property specified in the string <code>pname</code> to the given value.</p> <p><code>h.set('pname1', value1, 'pname2', value2, ...)</code> sets each property specified in the <code>pname</code> strings to the given value.</p> <p><code>set(h, ...)</code> is an alternate syntax for the same operation.</p> <p>See “Handling COM Data in MATLAB Software” in the External Interfaces documentation for information on how MATLAB converts workspace matrices to COM data types.</p>
Remarks	COM functions are available on Microsoft Windows systems only.
Examples	<p>Create an <code>mwsamp</code> control and use <code>set</code> to change the <code>Label</code> and <code>Radius</code> properties:</p> <pre>f = figure ('position', [100 200 200 200]); h = actxcontrol ('mwsamp.mwsampctrl.1', [0 0 200 200], f); h.set('Label', 'Click to fire event', 'Radius', 40); h.invoke('Redraw');</pre> <p>Here is another way to do the same thing, only without <code>set</code> and <code>invoke</code>:</p> <pre>h.Label = 'Click to fire event'; h.Radius = 40; h.Redraw;</pre>
See Also	<code>get (COM)</code> , <code>inspect</code> , <code>isprop</code> , <code>addproperty</code> , <code>deleteproperty</code>

- Purpose** Assign property values to handle objects derived from hgsetget class
- Syntax**
- ```
set(H, 'PropertyName', value, ...)
pv = set(h, 'PropertyName')
S = set(h)
```
- Description**
- set(H, 'PropertyName', value, ...) sets the named property to the specified value for the objects in the handle array H.
- pv = set(h, 'PropertyName') returns the possible values for the named property.
- S = set(h) returns the user-settable properties and possible values for the handle object h. S is a struct whose field names are the object's property names and whose field values are cell arrays containing the possible values of the corresponding properties having finite possible values.
- See Also** See "Implementing a Set/Get Interface for Properties"  
handle, hgsetget, set, get (hgsetget)

# set (RandStream)

---

**Purpose** Set random stream property

**Class** @RandStream

**Syntax**

```
set(S, 'PropertyName', Value)
set(S, 'Property1', Value1, 'Property2', Value2, ...)
set(S, A)
A=set(S, 'Property')
set(S, 'Property')
A=set(S)
set(S)
```

**Description**

`set(S, 'PropertyName', Value)` sets the property 'PropertyName' of the random stream S to the value Value.

`set(S, 'Property1', Value1, 'Property2', Value2, ...)` sets multiple random stream property values with a single statement.

`set(S, A)` where A is a structure whose field names are property names of the random stream S sets the properties of S named by each field with the values contained in those fields.

`A=set(S, 'Property')` or `set(S, 'Property')` displays possible values for the specified property of S.

`A=set(S)` or `set(S)` displays or returns all properties of S and their possible values.

**See Also** @RandStream, get (RandStream), rand, randn, randi



**Purpose** Configure or display serial port object properties

**Syntax**

```
set(obj)
props = set(obj)
set(obj, 'PropertyName')
props = set(obj, 'PropertyName')
set(obj, 'PropertyName', PropertyValue, ...)
set(obj, PN, PV)
set(obj, S)
```

**Description** `set(obj)` displays all configurable properties values for the serial port object, `obj`. If a property has a finite list of possible string values, then these values are also displayed.

`props = set(obj)` returns all configurable properties and their possible values for `obj` to `props`. `props` is a structure whose field names are the property names of `obj`, and whose values are cell arrays of possible property values. If the property does not have a finite set of possible values, then the cell array is empty.

`set(obj, 'PropertyName')` displays the valid values for *PropertyName* if it possesses a finite list of string values.

`props = set(obj, 'PropertyName')` returns the valid values for *PropertyName* to `props`. `props` is a cell array of possible string values or an empty cell array if *PropertyName* does not have a finite list of possible values.

`set(obj, 'PropertyName', PropertyValue, ...)` configures multiple property values with a single command.

`set(obj, PN, PV)` configures the properties specified in the cell array of strings `PN` to the corresponding values in the cell array `PV`. `PN` must be a vector. `PV` can be `m-by-n` where `m` is equal to the number of serial port objects in `obj` and `n` is equal to the length of `PN`.

`set(obj, S)` configures the named properties to the specified values for `obj`. `S` is a structure whose field names are serial port object properties, and whose field values are the values of the corresponding properties.

# serial.set

---

## Remarks

Refer to [Configuring Property Values](#) for a list of serial port object properties that you can configure with `set`.

You can use any combination of property name/property value pairs, structures, and cell arrays in one call to `set`. Additionally, you can specify a property name without regard to case, and you can make use of property name completion. For example, if `s` is a serial port object, then the following commands are all valid.

```
set(s, 'BaudRate')
set(s, 'baudrate')
set(s, 'BAUD')
```

If you use the `help` command to display help for `set`, then you need to supply the pathname shown below.

```
help serial/set
```

## Examples

This example illustrates some of the ways you can use `set` to configure or return property values for the serial port object `s`, on a Windows platform.

```
s = serial('COM1');
set(s, 'BaudRate', 9600, 'Parity', 'even')
set(s, {'StopBits', 'RecordName'}, {2, 'sydney.txt'})
set(s, 'Parity')
[{none} | odd | even | mark | space]
```

## See Also

### Functions

`get`

**Purpose** Configure or display timer object properties

**Syntax**

```
set(obj)
prop_struct = set(obj)
set(obj, 'PropertyName')
prop_cell=set(obj, 'PropertyName')
set(obj, 'PropertyName',PropertyValue,...)
set(obj,S)
set(obj,PN,PV)
```

**Description** `set(obj)` displays property names and their possible values for all configurable properties of timer object `obj`. `obj` must be a single timer object.

`prop_struct = set(obj)` returns the property names and their possible values for all configurable properties of timer object `obj`. `obj` must be a single timer object. The return value, `prop_struct`, is a structure whose field names are the property names of `obj`, and whose values are cell arrays of possible property values or empty cell arrays if the property does not have a finite set of possible string values.

`set(obj, 'PropertyName')` displays the possible values for the specified property, *PropertyName*, of timer object `obj`. `obj` must be a single timer object.

`prop_cell=set(obj, 'PropertyName')` returns the possible values for the specified property, *PropertyName*, of timer object `obj`. `obj` must be a single timer object. The returned array, `prop_cell`, is a cell array of possible value strings or an empty cell array if the property does not have a finite set of possible string values.

`set(obj, 'PropertyName',PropertyValue,...)` configures the property, *PropertyName*, to the specified value, *PropertyValue*, for timer object `obj`. You can specify multiple property name/property value pairs in a single statement. `obj` can be a single timer object or a vector of timer objects, in which case `set` configures the property values for all the timer objects specified.

## set (timer)

---

`set(obj,S)` configures the properties of `obj`, with the values specified in `S`, where `S` is a structure whose field names are object property names.

`set(obj,PN,PV)` configures the properties specified in the cell array of strings, `PN`, to the corresponding values in the cell array `PV`, for the timer object `obj`. `PN` must be a vector. If `obj` is an array of timer objects, `PV` can be an `M`-by-`N` cell array, where `M` is equal to the length of timer object array and `N` is equal to the length of `PN`. In this case, each timer object is updated with a different set of values for the list of property names contained in `PN`.

---

**Note** When specifying parameter/value pairs, you can use any mixture of strings, structures, and cell arrays in the same call to `set`.

---

### Examples

Create a timer object.

```
t = timer;
```

Display all configurable properties and their possible values.

```
set(t)
 BusyMode: [{drop} | queue | error]
 ErrorFcn: string -or- function handle -or- cell array
 ExecutionMode: [{singleShot} | fixedSpacing | fixedDelay | fixedRate]
 Name
 ObjectVisibility: [{on} | off]
 Period
 StartDelay
 StartFcn: string -or- function handle -or- cell array
 StopFcn: string -or- function handle -or- cell array
 Tag
 TasksToExecute
 TimerFcn: string -or- function handle -or- cell array
 UserData
```

View the possible values of the `ExecutionMode` property.

```
set(t, 'ExecutionMode')
[{singleShot} | fixedSpacing | fixedDelay | fixedRate]
```

Set the value of a specific timer object property.

```
set(t, 'ExecutionMode', 'FixedRate')
```

Set the values of several properties of the timer object.

```
set(t, 'TimerFcn', 'callbk', 'Period', 10)
```

Use a cell array to specify the names of the properties you want to set and another cell array to specify the values of these properties.

```
set(t, {'StartDelay', 'Period'}, {30, 30})
```

### See Also

timer, get(timer)

# set (timeseries)

---

**Purpose** Set properties of `timeseries` object

**Syntax**

```
set(ts, 'Property', Value)
set(ts, 'Property1', Value1, 'Property2', Value2, ...)
set(ts, 'Property')
set(ts)
```

**Description** `set(ts, 'Property', Value)` sets the property 'Property' of the `timeseries` object `ts` to the value `Value`. The following syntax is equivalent:

```
ts.Property = Value
```

`set(ts, 'Property1', Value1, 'Property2', Value2, ...)` sets multiple property values for `ts` with a single statement.

`set(ts, 'Property')` displays values for the specified property of the `timeseries` object `ts`.

`set(ts)` displays all properties and values of the `timeseries` object `ts`.

**See Also** `get (timeseries)`

**Purpose**

Set properties of tscollection object

**Syntax**

```
set(tsc, 'Property', Value)
set(tsc, 'Property1', Value1, 'Property2', Value2, ...)
set(tsc, 'Property')
```

**Description**

set(tsc, 'Property', Value) sets the property 'Property' of the tscollection tsc to the value Value. The following syntax is equivalent:

```
tsc.Property = Value
```

set(tsc, 'Property1', Value1, 'Property2', Value2, ...) sets multiple property values for tsc with a single statement.

set(tsc, 'Property') displays values for the specified property in the time-series collection tsc.

set(tsc) displays all properties and values of the tscollection object tsc.

**See Also**

get (tscollection)

# setabstime (timeseries)

---

**Purpose** Set times of timeseries object as date strings

**Syntax**  
`ts = setabstime(ts,Times)`  
`ts = setabstime(ts,Times,Format)`

**Description** `ts = setabstime(ts,Times)` sets the times in `ts` to the date strings specified in `Times`. `Times` must either be a cell array of strings, or a char array containing valid date or time values in the same date format.  
`ts = setabstime(ts,Times,Format)` explicitly specifies the date-string format used in `Times`.

**Examples** **1** Create a time-series object.

```
ts = timeseries(rand(3,1))
```

**2** Set the absolute time vector.

```
ts = setabstime(ts,{'12-DEC-2005 12:34:56',...
 '12-DEC-2005 13:34:56','12-DEC-2005 14:34:56'})
```

**See Also** `datestr`, `getabstime (timeseries)`, `timeseries`



**Purpose** Set times of tscollection object as date strings

**Syntax**

```
tsc = setabstime(tsc,Times)
tsc = setabstime(tsc,Times,format)
```

**Description**

`tsc = setabstime(tsc,Times)` sets the times in `tsc` using the date strings `Times`. `Times` must be either a cell array of strings, or a char array containing valid date or time values in the same date format.

`tsc = setabstime(tsc,Times,format)` specifies the date-string format used in `Times` explicitly.

**Examples**

- 1 Create a tscollection object.

```
tsc = tscollection(timeseries(rand(3,1)))
```

- 2 Set the absolute time vector.

```
tsc = setabstime(tsc,{'12-DEC-2005 12:34:56',...
'12-DEC-2005 13:34:56','12-DEC-2005 14:34:56'})
```

**See Also** `datestr`, `getabstime (tscollection)`, `tscollection`

# setappdata

---

**Purpose** Specify application-defined data

**Syntax** `setappdata(h, 'name', value)`

**Description** `setappdata(h, 'name', value)` sets application-defined data for the object with handle `h`. The application-defined data, which is created if it does not already exist, is assigned the specified name and value. The value can be any type of data.

**Remarks** Application data is data that is meaningful to or defined by your application which you attach to a figure or any GUI component (other than ActiveX controls) through its `AppData` property. Only Handle Graphics MATLAB objects use this property.

**See Also** `getappdata`, `isappdata`, `rmappdata`

## setDefaultStream (RandStream)

---

### Purpose

Set default random number stream

### Syntax

```
prevstream = RandStream.setDefaultStream(stream)
```

### Description

`prevstream = RandStream.setDefaultStream(stream)` returns the current default random number stream, and designates the random number stream `stream` as the new default to be used by the `rand`, `randi`, and `randn` functions.

`rand`, `randi`, and `randn` all rely on the same stream of uniform pseudorandom numbers, known as the default stream. `randi` uses one uniform value from the default stream to generate each integer value. `randn` uses one or more uniform values from the default stream to generate each normal value. Note that there are also `rand`, `randi`, and `randn` methods for which you specify a specific random stream from which to draw values.

### See Also

`getDefaultStream (RandStream)`, `@RandStream`, `rand (RandStream)`, `randn (RandStream)`, `randperm (RandStream)`

# setdiff

---

**Purpose** Find set difference of two vectors

**Syntax**

```
c = setdiff(A, B)
c = setdiff(A, B, 'rows')
[c,i] = setdiff(...)
```

**Description** `c = setdiff(A, B)` returns the values in `A` that are not in `B`. In set theory terms,  $c = A - B$ . Inputs `A` and `B` can be numeric or character vectors or cell arrays of strings. The resulting vector is sorted in ascending order.

`c = setdiff(A, B, 'rows')`, when `A` and `B` are matrices with the same number of columns, returns the rows from `A` that are not in `B`.

`[c,i] = setdiff(...)` also returns an index vector `index` such that `c = a(i)` or `c = a(i,:)`.

**Remarks** Because NaN is considered to be not equal to itself, it is always in the result `c` if it is in `A`.

**Examples**

```
A = magic(5);
B = magic(4);
[c, i] = setdiff(A(:), B(:));
c' = 17 18 19 20 21 22 23 24 25
i' = 1 10 14 18 19 23 2 6 15
```

**See Also** `intersect`, `ismember`, `issorted`, `setxor`, `union`, `unique`

|                    |                                                                                                                                                                                                                                                                                          |
|--------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Purpose</b>     | Override to change command window display                                                                                                                                                                                                                                                |
| <b>Syntax</b>      | setdisp(H)                                                                                                                                                                                                                                                                               |
| <b>Description</b> | setdisp(H) called by <code>set</code> when <code>set</code> is called with no output arguments and a single input argument that is a handle array. Override this <code>hgsetget</code> class method in a subclass to change how property information is displayed in the command window. |
| <b>See Also</b>    | See “Implementing a Set/Get Interface for Properties”<br><code>hgsetget</code> , <code>set (hgsetget)</code>                                                                                                                                                                             |

# setenv

---

**Purpose** Set environment variable

**Syntax** `setenv(name, value)`  
`setenv(name)`

**Description** `setenv(name, value)` sets the value of an environment variable belonging to the underlying operating system. Inputs `name` and `value` are both strings. If `name` already exists as an environment variable, then `setenv` replaces its current value with the string given in `value`. If `name` does not exist, `setenv` creates a new environment variable called `name` and assigns `value` to it.

`setenv(name)` is equivalent to `setenv(name, '')` and assigns a null value to the variable `name`. On the Microsoft Windows platform, this is equivalent to undefining the variable. On most UNIX<sup>25</sup> platforms, it is possible to have an environment variable defined as empty.

The maximum number of characters in `name` is  $2^{15} - 2$  (or 32766). If `name` contains the character `=`, `setenv` throws an error. The behavior of environment variables with `=` in the name is not well-defined.

On all platforms, `setenv` passes the `name` and `value` strings to the operating system unchanged. Special characters such as `;`, `/`, `:`, `$`, `%`, etc. are left unexpanded and intact in the variable value.

Values assigned to variables using `setenv` are picked up by any process that is spawned using the MATLAB system, `unix`, `dos` or `!` functions. You can retrieve any value set with `setenv` by using `getenv(name)`.

## Examples

```
% Set and retrieve a new value for the environment variable TEMP:
```

```
setenv('TEMP', 'C:\TEMP');
getenv('TEMP')
```

```
% Append the Perl\bin directory to your system PATH variable:
```

25. UNIX is a registered trademark of The Open Group in the United States and other countries.

```
setenv('PATH', [getenv('PATH') 'D:\Perl\bin']);
```

**See Also**

getenv, system, unix, dos, !

# setfield

---

**Purpose** Set value of structure array field

**Syntax**  
`s = setfield(s, 'field', v)`  
`s = setfield(s, {i,j}, 'field', {k}, v)`

**Description** `s = setfield(s, 'field', v)`, where `s` is a 1-by-1 structure, sets the contents of the specified field to the value `v`. If `field` is not an existing field in structure `s`, the MATLAB software creates that field and assigns the value `v` to it. This is equivalent to the syntax `s.field = v`.

`s = setfield(s, {i,j}, 'field', {k}, v)` sets the contents of the specified field to the value `v`. If `field` is not an existing field in structure `s`, MATLAB creates that field and assigns the value `v` to it. This is equivalent to the syntax `s(i,j).field(k) = v`. All subscripts must be passed as cell arrays — that is, they must be enclosed in curly braces (similar to `{i,j}` and `{k}` above). Pass field references as strings.

See “Guidelines for Naming Structure Fields” for help on creating valid field names.

**Remarks** In many cases, you can use dynamic field names in place of the `getfield` and `setfield` functions. Dynamic field names express structure fields as variable expressions that MATLAB evaluates at run-time. See Solution 1-19QWG for information about using dynamic field names versus the `getfield` and `setfield` functions.

**Examples** Given the structure

```
mystr(1,1).name = 'alice';
mystr(1,1).ID = 0;
mystr(2,1).name = 'gertrude';
mystr(2,1).ID = 1;
```

You can change the name field of `mystr(2,1)` using

```
mystr = setfield(mystr, {2,1}, 'name', 'ted');
mystr(2,1).name
```



```
ans =
```

```
ted
```

The following example sets fields of a structure using `setfield` with variable and quoted field names and additional subscripting arguments.

```
class = 5; student = 'John_Doe';
grades_Doe = [85, 89, 76, 93, 85, 91, 68, 84, 95, 73];
grades = [];

grades = setfield(grades, {class}, student, 'Math', ...
 {10, 21:30}, grades_Doe);
```

You can check the outcome using the standard structure syntax.

```
grades(class).John_Doe.Math(10, 21:30)
```

```
ans =
```

```
85 89 76 93 85 91 68 84 95 73
```

## See Also

`getfield`, `fieldnames`, `isfield`, `orderfields`, `rmfield`, `dynamic field names`

# setinterpmethod

---

**Purpose** Set default interpolation method for timeseries object

**Syntax**

```
ts = setinterpmethod(ts,Method)
ts = setinterpmethod(ts,FHandle)
ts = setinterpmethod(ts,InterpObj),
```

**Description** `ts = setinterpmethod(ts,Method)` sets the default interpolation method for timeseries object `ts`, where `Method` is a string. `Method` in `ts`. `Method` is either 'linear' or 'zoh' (zero-order hold). For example:

```
ts = timeseries(rand(100,1),1:100);
ts = setinterpmethod(ts,'zoh');
```

`ts = setinterpmethod(ts,FHandle)` sets the default interpolation method for timeseries object `ts`, where `FHandle` is a function handle to the interpolation method defined by the function handle `FHandle`. For example:

```
ts = timeseries(rand(100,1),1:100);
myFuncHandle = @(new_Time,Time,Data)...
 interp1(Time,Data,new_Time,...
 'linear','extrap');
ts = setinterpmethod(ts,myFuncHandle);
ts = resample(ts,[-5:0.1:10]);
plot(ts);
```

---

**Note** For `FHandle`, you must use three input arguments. The order of input arguments must be `new_Time`, `Time`, and `Data`. The single output argument must be the interpolated data only.

---

`ts = setinterpmethod(ts,InterpObj)`, where `InterpObj` is a `tsdata.interpolation` object that directly replaces the interpolation object stored in `ts`. For example:

```
ts = timeseries(rand(100,1),1:100);
```

```
myFuncHandle = @(new_Time,Time,Data)...
 interp1(Time,Data,new_Time,...
 'linear','extrap');
myInterpObj = tsdata.interpolation(myFuncHandle);
ts = setinterpmethod(ts,myInterpObj);
```

This method is case sensitive.

### See Also

getinterpmethod, timeseries, tsprops

# setpixelposition

---

## Purpose

Set component position in pixels

## Syntax

```
setpixelposition(handle,position)
setpixelposition(handle,position,recursive)
```

## Description

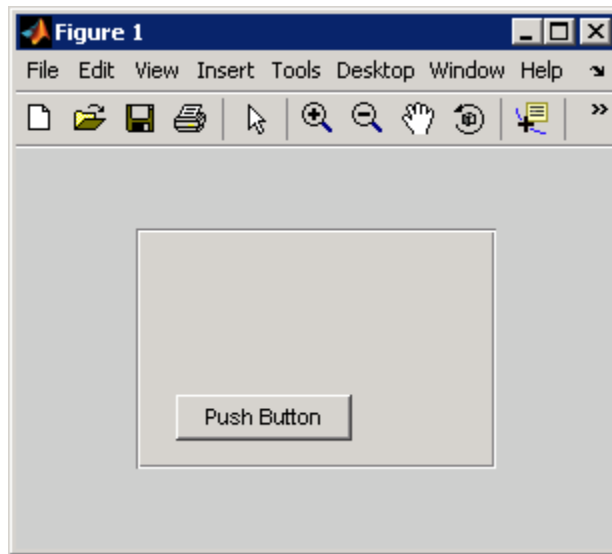
`setpixelposition(handle,position)` sets the position of the component specified by `handle`, to the specified pixel position relative to its parent. `position` is a four-element vector that specifies the location and size of the component: [distance from left, distance from bottom, width, height].

`setpixelposition(handle,position,recursive)` sets the position as above. If `recursive` is true, the position is set relative to the parent figure of `handle`.

## Example

This example first creates a push button within a panel.

```
f = figure('Position',[300 300 300 200]);
p = uipanel('Position',[.2 .2 .6 .6]);
h1 = uicontrol(p,'Style','PushButton','Units','Nomalized',...
 'String','Push Button','Position',[.1 .1 .5 .2]);
```

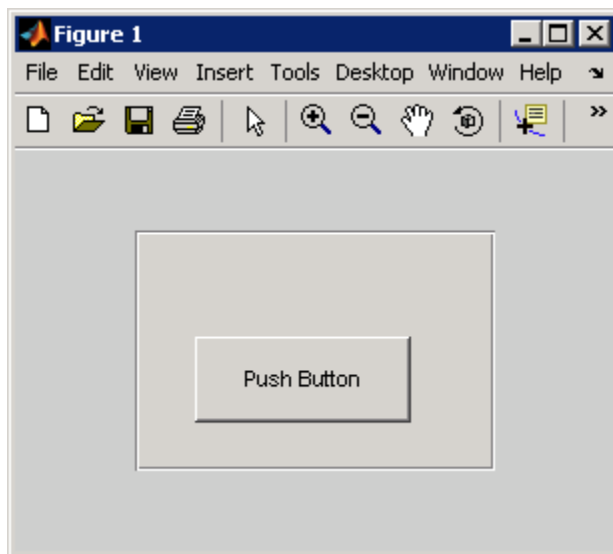


The example then retrieves the position of the push button and changes its position with respect to the panel.

```
pos1 = getpixelposition(h1);
setpixelposition(h1,pos1 + [10 10 25 25]);
```

# setpixelposition

---



**See Also** [getpixelposition](#), [uicontrol](#), [uipanel](#)

**Purpose**

Set preference

**Syntax**

```
setpref('group','pref',val)
setpref('group',{'pref1','pref2',...,'prefn'},{val1,val2,...,
 valn})
```

**Description**

`setpref('group','pref',val)` sets the preference specified by `group` and `pref` to the value `val`. Setting a preference that does not yet exist causes it to be created.

`group` labels a related collection of preferences. You can choose any name that is a legal variable name, and is descriptive enough to be unique, e.g., `'MathWorks_GUIDE_ApplicationPrefs'`. The input argument `pref` identifies an individual preference in that group, and must be a legal variable name.

`setpref('group',{'pref1','pref2',...,'prefn'},{val1,val2,...,valn})` sets each preference specified in the cell array of names to the corresponding value.

---

**Note** Preference values are persistent and maintain their values between MATLAB sessions. Where they are stored is system dependent.

---

**Examples**

```
addpref('mytoolbox','version','0.0')
setpref('mytoolbox','version','1.0')
getpref('mytoolbox','version')
```

```
ans =
 1.0
```

**See Also**

`addpref`, `getpref`, `ispref`, `rmpref`, `uigetpref`, `uisetpref`

# setstr

---

**Purpose** Set string flag

**Description** This MATLAB 4 function has been renamed char in MATLAB 5.



**Purpose** Change name of timeseries object in tscollection

**Syntax** `tsc = settimeseriesnames(tsc,old,new)`

**Description** `tsc = settimeseriesnames(tsc,old,new)` replaces the old name of timeseries object with the new name in tsc.

**See Also** `tscollection`

# setxor

---

**Purpose** Find set exclusive OR of two vectors

**Syntax**

```
c = setxor(A, B)
c = setxor(A, B, 'rows')
[c, ia, ib] = setxor(...)
```

**Description** `c = setxor(A, B)` returns the values that are not in the intersection of A and B. Inputs A and B can be numeric or character vectors or cell arrays of strings. The resulting vector is sorted.

`c = setxor(A, B, 'rows')`, when A and B are matrices with the same number of columns, returns the rows that are not in the intersection of A and B.

`[c, ia, ib] = setxor(...)` also returns index vectors `ia` and `ib` such that `c` is a sorted combination of the elements `c = a(ia)` and `c = b(ib)` or, for row combinations, `c = a(ia,:)` and `c = b(ib,:)`.

**Examples**

```
a = [-1 0 1 Inf -Inf NaN];
b = [-2 pi 0 Inf];
c = setxor(a, b)
```

```
c =
 -Inf -2.0000 -1.0000 1.0000 3.1416 NaN
```

**See Also** `intersect`, `ismember`, `issorted`, `setdiff`, `union`, `unique`

**Purpose** Set color shading properties

**Syntax** shading flat  
shading faceted  
shading interp  
shading(axes\_handle,...)

**Description** The shading function controls the color shading of surface and patch graphics objects.

`shading flat` each mesh line segment and face has a constant color determined by the color value at the endpoint of the segment or the corner of the face that has the smallest index or indices.

`shading faceted` flat shading with superimposed black mesh lines. This is the default shading mode.

`shading interp` varies the color in each line segment and face by interpolating the colormap index or true color value across the line or face.

`shading(axes_handle,...)` applies the shading type to the objects in the axes specified by `axes_handle`, instead of the current axes.

**Examples** Compare a flat, faceted, and interpolated-shaded sphere.

```
subplot(3,1,1)
sphere(16)
axis square
shading flat
title('Flat Shading')
```

```
subplot(3,1,2)
sphere(16)
axis square
shading faceted
title('Faceted Shading')
```

```
subplot(3,1,3)
```

# shading

---

```
sphere(16)
axis square
shading interp
title('Interpolated Shading')
```

## Algorithm

`shading` sets the `EdgeColor` and `FaceColor` properties of all surface and patch graphics objects in the current axes. `shading` sets the appropriate values, depending on whether the surface or patch objects represent meshes or solid surfaces.

## See Also

`fill`, `fill3`, `hidden`, `light`, `lighting`, `mesh`, `patch`, `pcolor`, `surf`

The `EdgeColor` and `FaceColor` properties for patch and surface graphics objects.

“Color Operations” on page 1-105 for related functions

**Purpose** Show most recent graph window

**Syntax** shg

**Description** shg makes the current figure visible and raises it above all other figures on the screen. This is identical to using the command `figure(gca)`.

**See Also** figure, gca, gcf

# shiftdim

---

**Purpose** Shift dimensions

**Syntax** `B = shiftdim(X,n)`  
`[B,nshifts] = shiftdim(X)`

**Description** `B = shiftdim(X,n)` shifts the dimensions of `X` by `n`. When `n` is positive, `shiftdim` shifts the dimensions to the left and wraps the `n` leading dimensions to the end. When `n` is negative, `shiftdim` shifts the dimensions to the right and pads with singletons.

`[B,nshifts] = shiftdim(X)` returns the array `B` with the same number of elements as `X` but with any leading singleton dimensions removed. A singleton dimension is any dimension for which `size(A,dim) = 1`. `nshifts` is the number of dimensions that are removed.

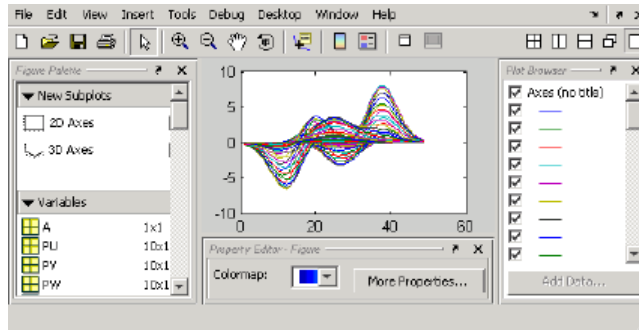
If `X` is a scalar, `shiftdim` has no effect.

**Examples** The `shiftdim` command is handy for creating functions that, like `sum` or `diff`, work along the first nonsingleton dimension.



```
a = rand(1,1,3,1,2);
[b,n] = shiftdim(a); % b is 3-by-1-by-2 and n is 2.
c = shiftdim(b,-n); % c == a.
d = shiftdim(a,3); % d is 1-by-2-by-1-by-1-by-3.
```

**See Also** `circshift`, `reshape`, `squeeze`, `permute`, `ipermute`

**Purpose** Show or hide figure plot tool



## GUI Alternatives

Click the larger Plotting Tools icon  on the figure toolbar to collectively enable plotting tools, and the smaller icon  to collectively disable them. Individually select the **Figure Palette**, **Plot Browser**, and **Property Editor** tools from the figure's **View** menu. For details, see “Plotting Tools — Interactive Plotting” in the MATLAB Graphics documentation.

## Syntax

```
showplottool('tool')
showplottool('on','tool')
showplottool('off','tool')
showplottool('toggle','tool')
showplottool(figure_handle,...)
```

## Description

`showplottool('tool')` shows the specified plot tool on the current figure. `tool` can be one of the following strings:

- `figurepalette`
- `plotbrowser`
- `propertyeditor`

# showplottool

---

`showplottool('on', 'tool')` shows the specified plot tool on the current figure.

`showplottool('off', 'tool')` hides the specified plot tool on the current figure.

`showplottool('toggle', 'tool')` toggles the visibility of the specified plot tool on the current figure.

`showplottool(figure_handle, ...)` operates on the specified figure instead of the current figure.

---

**Note** When you dock, undock, resize, or reposition a plotting tool and then close it, it will still be configured as you left it the next time you open it. There is no command to reset plotting tools to their original, default locations.

---

## See Also

`figurepalette`, `plotbrowser`, `plottools`, `propertyeditor`



## Purpose

Reduce size of patch faces

## Syntax

```
shrinkfaces(p,sf)
nfv = shrinkfaces(p,sf)
nfv = shrinkfaces(fv,sf)
shrinkfaces(p)
nfv = shrinkfaces(f,v,sf)
[nf,nv] = shrinkfaces(...)
```

## Description

`shrinkfaces(p,sf)` shrinks the area of the faces in patch `p` to shrink factor `sf`. A shrink factor of 0.6 shrinks each face to 60% of its original area. If the patch contains shared vertices, the MATLAB software creates nonshared vertices before performing the face-area reduction.

`nfv = shrinkfaces(p,sf)` returns the face and vertex data in the struct `nfv`, but does not set the `Faces` and `Vertices` properties of patch `p`.

`nfv = shrinkfaces(fv,sf)` uses the face and vertex data from the struct `fv`.

`shrinkfaces(p)` and `shrinkfaces(fv)` (without specifying a shrink factor) assume a shrink factor of 0.3.

`nfv = shrinkfaces(f,v,sf)` uses the face and vertex data from the arrays `f` and `v`.

`[nf,nv] = shrinkfaces(...)` returns the face and vertex data in two separate arrays instead of a struct.

## Examples

This example uses the flow data set, which represents the speed profile of a submerged jet within an infinite tank (type `help flow` for more information). Two isosurfaces provide a before and after view of the effects of shrinking the face size.

- First `reducevolume` samples the flow data at every other point and then `isosurface` generates the faces and vertices data.

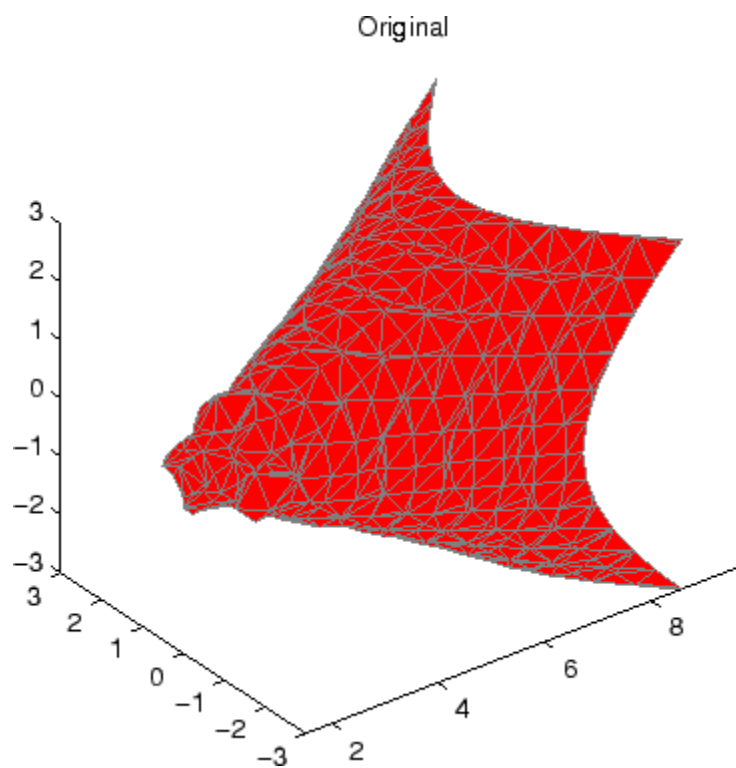
# shrinkfaces

---

- The `patch` command accepts the face/vertex struct and draws the first (p1) isosurface.
- Use the `daspect`, `view`, and `axis` commands to set up the view and then add a title.
- The `shrinkfaces` command modifies the face/vertex data and passes it directly to `patch`.

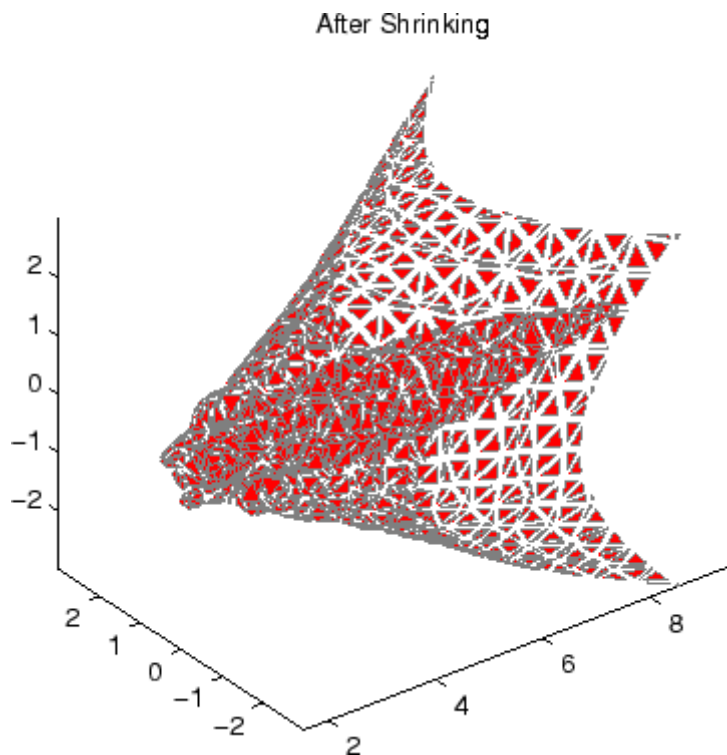
```
[x,y,z,v] = flow;
[x,y,z,v] = reducevolume(x,y,z,v,2);
fv = isosurface(x,y,z,v,-3);
p1 = patch(fv);
set(p1,'FaceColor','red','EdgeColor',[.5,.5,.5]);
daspect([1 1 1]); view(3); axis tight
title('Original')
```

```
figure
p2 = patch(shrinkfaces(fv,.3));
set(p2,'FaceColor','red','EdgeColor',[.5,.5,.5]);
daspect([1 1 1]); view(3); axis tight
title('After Shrinking')
```



# shrinkfaces

---



## See Also

`isosurface`, `patch`, `reducevolume`, `daspect`, `view`, `axis`  
“Volume Visualization” on page 1-108 for related functions

**Purpose** Signum function

**Syntax**  $Y = \text{sign}(X)$

**Description**  $Y = \text{sign}(X)$  returns an array  $Y$  the same size as  $X$ , where each element of  $Y$  is:

- 1 if the corresponding element of  $X$  is greater than zero
- 0 if the corresponding element of  $X$  equals zero
- -1 if the corresponding element of  $X$  is less than zero

For nonzero complex  $X$ ,  $\text{sign}(X) = X ./ \text{abs}(X)$ .

**See Also** `abs`, `conj`, `imag`, `real`

# sin

---

**Purpose** Sine of argument in radians

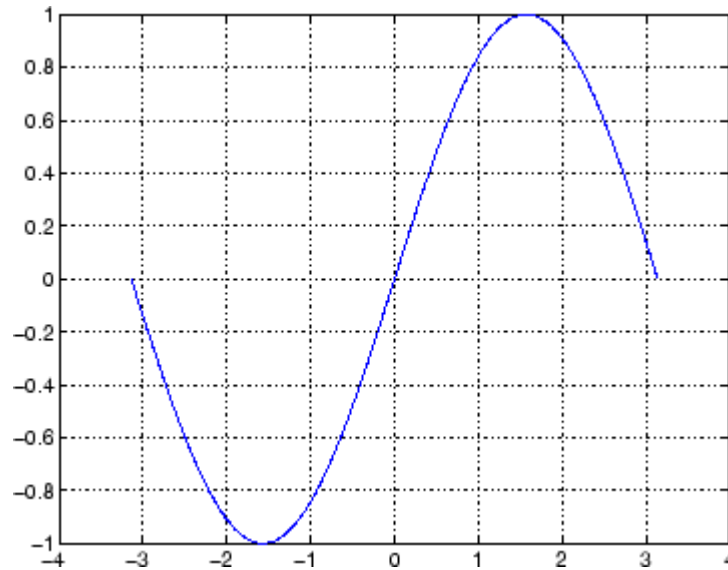
**Syntax**  $Y = \sin(X)$

**Description** The `sin` function operates element-wise on arrays. The function's domains and ranges include complex values. All angles are in radians.

$Y = \sin(X)$  returns the circular sine of the elements of  $X$ .

**Examples** Graph the sine function over the domain  $-\pi \leq x \leq \pi$ .

```
x = -pi:0.01:pi;
plot(x,sin(x)), grid on
```



The expression `sin(pi)` is not exactly zero, but rather a value the size of the floating-point accuracy `eps`, because `pi` is only a floating-point approximation to the exact value of  $\pi$ .

**Definition**

The sine can be defined as

$$\sin(x + iy) = \sin(x)\cosh(y) + i\cos(x)\sinh(y)$$

$$\sin(z) = \frac{e^{iz} - e^{-iz}}{2i}$$

**Algorithm**

sin uses FDLIBM, which was developed at SunSoft, a Sun Microsystems, Inc. business, by Kwok C. Ng, and others. For information about FDLIBM, see <http://www.netlib.org>.

**See Also**

sind, sinh, asin, asind, asinh

# sind

---

**Purpose** Sine of argument in degrees

**Syntax**  $Y = \text{sind}(X)$

**Description**  $Y = \text{sind}(X)$  is the sine of the elements of  $X$ , expressed in degrees. For integers  $n$ ,  $\text{sind}(n \cdot 180)$  is exactly zero, whereas  $\sin(n \cdot \pi)$  reflects the accuracy of the floating point value of  $\pi$ .

**See Also** `sin`, `sinh`, `asin`, `asind`, `asinh`



**Purpose** Convert to single precision

**Syntax** `B = single(A)`

**Description** `B = single(A)` converts the matrix `A` to single precision, returning that value in `B`. `A` can be any numeric object (such as a `double`). If `A` is already single precision, `single` has no effect. Single-precision quantities require less storage than double-precision quantities, but have less precision and a smaller range.

The `single` class is primarily meant to be used to store single-precision values. Hence most operations that manipulate arrays without changing their elements are defined. Examples are `reshape`, `size`, the relational operators, subscripted assignment, and subscripted reference.

You can define your own methods for the `single` class by placing the appropriately named method in an `@single` directory within a directory on your path.

## Examples

```
a = magic(4);
b = single(a);
```

```
whos
```

| Name | Size | Bytes | Class        |
|------|------|-------|--------------|
| a    | 4x4  | 128   | double array |
| b    | 4x4  | 64    | single array |

**See Also** `double`

# sinh

---

**Purpose** Hyperbolic sine of argument in radians

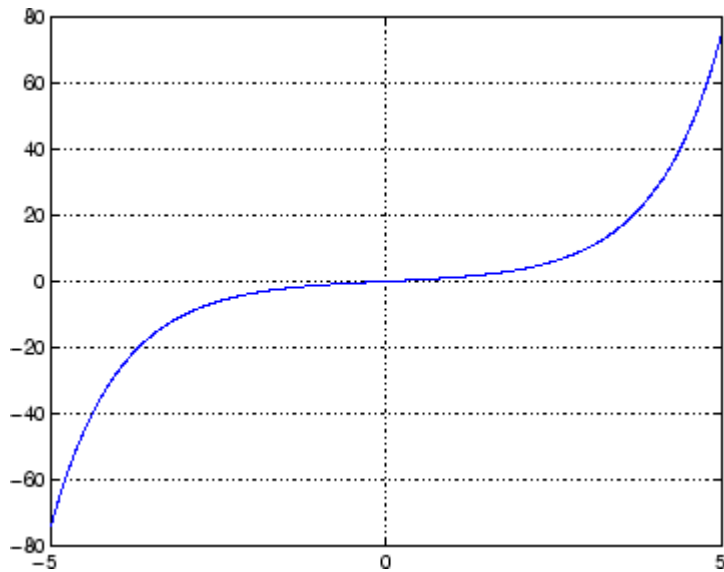
**Syntax**  $Y = \sinh(X)$

**Description** The  $\sinh$  function operates element-wise on arrays. The function's domains and ranges include complex values. All angles are in radians.

$Y = \sinh(X)$  returns the hyperbolic sine of the elements of  $X$ .

**Examples** Graph the hyperbolic sine function over the domain  $-5 \leq x \leq 5$ .

```
x = -5:0.01:5;
plot(x, sinh(x)), grid on
```



**Definition** The hyperbolic sine can be defined as

$$\sinh(z) = \frac{e^z - e^{-z}}{2}$$

**Algorithm**

`sinh` uses FDLIBM, which was developed at SunSoft, a Sun Microsystems, Inc. business, by Kwok C. Ng, and others. For information about FDLIBM, see <http://www.netlib.org>.

**See Also**

`sin`, `sind`, `asin`, `asinh`, `asind`

# size

---

**Purpose** Array dimensions

**Syntax**

```
d = size(X)
[m,n] = size(X)
m = size(X,dim)
[d1,d2,d3,...,dn] = size(X),
```

**Description** `d = size(X)` returns the sizes of each dimension of array `X` in a vector `d` with `ndims(X)` elements. If `X` is a scalar, which MATLAB software regards as a 1-by-1 array, `size(X)` returns the vector `[1 1]`.

`[m,n] = size(X)` returns the size of matrix `X` in separate variables `m` and `n`.

`m = size(X,dim)` returns the size of the dimension of `X` specified by scalar `dim`.

`[d1,d2,d3,...,dn] = size(X)`, for  $n > 1$ , returns the sizes of the dimensions of the array `X` in the variables `d1,d2,d3,...,dn`, provided the number of output arguments `n` equals `ndims(X)`. If `n` does not equal `ndims(X)`, the following exceptions hold:

`n < ndims(X)` `di` equals the size of the  $i$ th dimension of `X` for  $1 \leq i < n$ , but `dn` equals the product of the sizes of the remaining dimensions of `X`, that is, dimensions  $n$  through `ndims(X)`.

`n > ndims(X)` `size` returns ones in the “extra” variables, that is, those corresponding to `ndims(X)+1` through `n`.

---

**Note** For a Java array, `size` returns the length of the Java array as the number of rows. The number of columns is always 1. For a Java array of arrays, the result describes only the top level array.

---

## Examples

### Example 1

The size of the second dimension of `rand(2,3,4)` is 3.

```
m = size(rand(2,3,4),2)
```

```
m =
 3
```

Here the size is output as a single vector.

```
d = size(rand(2,3,4))
```

```
d =
 2 3 4
```

Here the size of each dimension is assigned to a separate variable.

```
[m,n,p] = size(rand(2,3,4))
```

```
m =
 2
```

```
n =
 3
```

```
p =
 4
```

## Example 2

If  $X = \text{ones}(3,4,5)$ , then

```
[d1,d2,d3] = size(X)
```

```
d1 = d2 = d3 =
 3 4 5
```

But when the number of output variables is less than `ndims(X)`:

```
[d1,d2] = size(X)
```

```
d1 = d2 =
 3 20
```

# size

---

The “extra” dimensions are collapsed into a single product.

If  $n > \text{ndims}(X)$ , the “extra” variables all represent singleton dimensions:

```
[d1,d2,d3,d4,d5,d6] = size(X)
```

```
d1 = d2 = d3 =
 3 4 5
```

```
d4 = d5 = d6 =
 1 1 1
```

## See Also

`exist`, `length`, `numel`, `whos`

**Purpose** size of containers.Map object

**Syntax**

```
d = size(M)
d = size(M, dim)
[d1, d2, ..., dn] = size(M)
```

**Description** `d = size(M)` returns the number of key-value pairs in dimensions 1 and 2 of map `M`. Output `d` is a two-element row vector `[n, 1]`, where `n` is the number of key-value pairs.

`d = size(M, dim)` returns the number of key-value pairs if `dim` is 1, and otherwise returns 1.

`[d1, d2, ..., dn] = size(M)` returns `[n, 1, ..., 1]` where `n` is the number of key-value pairs in map `M`.

Read more about Map Containers in the MATLAB Programming Fundamentals documentation.

## Examples

Create a Map object containing the names of several US states and the capital city of each:

```
US_Capitals = containers.Map(...
 {'Arizona', 'Nebraska', 'Nevada', 'New York', ...
 'Georgia', 'Alaska', 'Vermont', 'Oregon'}, ...
 {'Phoenix', 'Lincoln', 'Carson City', 'Albany', ...
 'Atlanta', 'Juneau', 'Montpelier', 'Salem'})
```

Get the dimensions of the Map object array:

```
size(US_Capitals)
ans =
 8 1
```

Use the map to find the capital of one of these states:

```
state = 'Georgia';
sprintf(' The capital of %s is %s', ...
 state, US_Capitals(state))
```

## size (Map)

---

```
ans =
 The capital of Georgia is Atlanta
```

### **See Also**

containers.Map, keys(Map), values(Map), length(Map), isKey(Map),  
remove(Map), handle



**Purpose** Size of serial port object array

**Syntax**

```
d = size(obj)
[m,n] = size(obj)
[m1,m2,m3,...,mn] = size(obj)
m = size(obj,dim)
```

**Description**

`d = size(obj)` returns the two-element row vector `d` containing the number of rows and columns in the serial port object, `obj`.

`[m,n] = size(obj)` returns the number of rows, `m` and columns, `n` in separate output variables.

`[m1,m2,m3,...,mn] = size(obj)` returns the length of the first `n` dimensions of `obj`.

`m = size(obj,dim)` returns the length of the dimension specified by the scalar `dim`. For example, `size(obj,1)` returns the number of rows.

**See Also** **Functions**

`length`

## size (timeseries)

---

|                    |                                                                                                                                                                                                                   |
|--------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Purpose</b>     | Size of timeseries object                                                                                                                                                                                         |
| <b>Syntax</b>      | <code>size(ts)</code>                                                                                                                                                                                             |
| <b>Description</b> | <code>size(ts)</code> returns <code>[n 1]</code> , where <code>n</code> is the length of the time vector for timeseries object <code>ts</code> .                                                                  |
| <b>Remarks</b>     | <p>If you want the size of the whole data set, use the following syntax:</p> <pre>size(ts.data)</pre> <p>If you want the size of each data sample, use the following syntax:</p> <pre>getdatasamplesize(ts)</pre> |
| <b>See Also</b>    | <code>getdatasamplesize</code> , <code>isempty (timeseries)</code> , <code>length (timeseries)</code>                                                                                                             |

**Purpose** Size of triangulation matrix

**Syntax** `size(TR)`

**Description** `size(TR)` provides size information for a triangulation matrix. The matrix is of size `mtri-by-nv`, where `mtri` is the number of simplices and `nv` is the number of vertices per simplex (triangle/tetrahedron, etc).

**Inputs** `TR` Triangulation matrix

**Definitions** A simplex is a triangle/tetrahedron or higher-dimensional equivalent.

**See Also** `size`  
“Triangulation Representations”—How to query triangulation data.

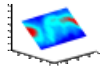
## size (tscollection)


---

|                    |                                                                                                                                                                     |
|--------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Purpose</b>     | Size of tscollection object                                                                                                                                         |
| <b>Syntax</b>      | <code>size(tsc)</code>                                                                                                                                              |
| <b>Description</b> | <code>size(tsc)</code> returns <code>[n m]</code> , where <code>n</code> is the length of the time vector and <code>m</code> is the number of tscollection members. |
| <b>See Also</b>    | <code>length (tscollection)</code> , <code>isempty (tscollection)</code> , <code>tscollection</code>                                                                |

**Purpose**

Volumetric slice plot

**GUI Alternatives**

To graph selected variables, use the Plot Selector  in the Workspace Browser, or use the Figure Palette Plot Catalog. Manipulate graphs in *plot edit* mode with the Property Editor. For details, see Plotting Tools — Interactive Plotting in the MATLAB Graphics documentation and Creating Graphics from the Workspace Browser in the MATLAB Desktop Tools documentation.

**Syntax**

```
slice(V, sx, sy, sz)
slice(X, Y, Z, V, sx, sy, sz)
slice(V, XI, YI, ZI)
slice(X, Y, Z, V, XI, YI, ZI)
slice(..., 'method')
slice(axes_handle, ...)
h = slice(...)
```

**Description**

`slice` displays orthogonal slice planes through volumetric data.

`slice(V, sx, sy, sz)` draws slices along the  $x$ ,  $y$ ,  $z$  directions in the volume  $V$  at the points in the vectors  $sx$ ,  $sy$ , and  $sz$ .  $V$  is an  $m$ -by- $n$ -by- $p$  volume array containing data values at the default location  $X = 1:n$ ,  $Y = 1:m$ ,  $Z = 1:p$ . Each element in the vectors  $sx$ ,  $sy$ , and  $sz$  defines a slice plane in the  $x$ -,  $y$ -, or  $z$ -axis direction.

`slice(X, Y, Z, V, sx, sy, sz)` draws slices of the volume  $V$ .  $X$ ,  $Y$ , and  $Z$  are three-dimensional arrays specifying the coordinates for  $V$ .  $X$ ,  $Y$ , and  $Z$  must be monotonic and orthogonally spaced (as if produced by the function `meshgrid`). The color at each point is determined by 3-D interpolation into the volume  $V$ .

`slice(V, XI, YI, ZI)` draws data in the volume  $V$  for the slices defined by  $XI$ ,  $YI$ , and  $ZI$ .  $XI$ ,  $YI$ , and  $ZI$  are matrices that define a surface, and the volume is evaluated at the surface points.  $XI$ ,  $YI$ , and  $ZI$  must all be the same size.

# slice

---

`slice(X,Y,Z,V,XI,YI,ZI)` draws slices through the volume  $V$  along the surface defined by the arrays  $XI$ ,  $YI$ ,  $ZI$ .

`slice(..., 'method')` specifies the interpolation method. *'method'* is *'linear'*, *'cubic'*, or *'nearest'*.

- `linear` specifies trilinear interpolation (the default).
- `cubic` specifies tricubic interpolation.
- `nearest` specifies nearest-neighbor interpolation.

`slice(axes_handle,...)` plots into the axes with the handle `axes_handle` instead of into the current axes object (`gca`). The `axes clim` property is set to span the finite values of  $V$ .

`h = slice(...)` returns a vector of handles to surface graphics objects.

## Remarks

The color drawn at each point is determined by interpolation into the volume  $V$ .

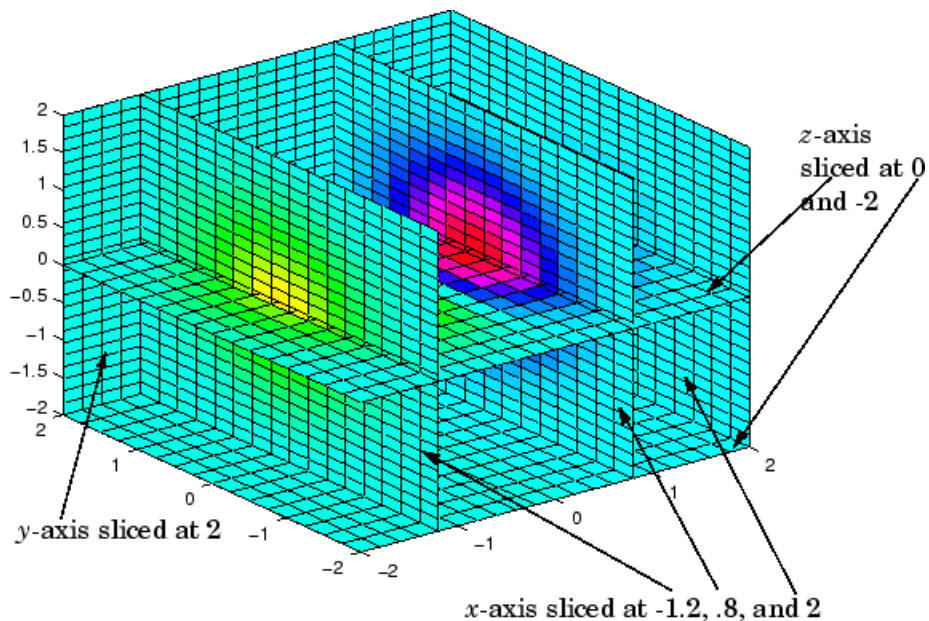
## Examples

Visualize the function

$$v = xe^{(-x^2 - y^2 - z^2)}$$

over the range  $-2 \leq x \leq 2$ ,  $-2 \leq y \leq 2$ ,  $-2 \leq z \leq 2$ :

```
[x,y,z] = meshgrid(-2:.2:2, -2:.25:2, -2:.16:2);
v = x.*exp(-x.^2-y.^2-z.^2);
xslice = [-1.2, .8, 2]; yslice = 2; zslice = [-2, 0];
slice(x,y,z,v,xslice,yslice,zslice)
colormap hsv
```



### Slicing At Arbitrary Angles

You can also create slices that are oriented in arbitrary planes. To do this,

- Create a slice surface in the domain of the volume (`surf`, `linspace`).
- Orient this surface with respect to the axes (`rotate`).
- Get the XData, YData, and ZData of the surface (`get`).
- Use this data to draw the slice plane within the volume.

For example, these statements slice the volume in the first example with a rotated plane. Placing these commands within a for loop “passes” the plane through the volume along the *z*-axis.

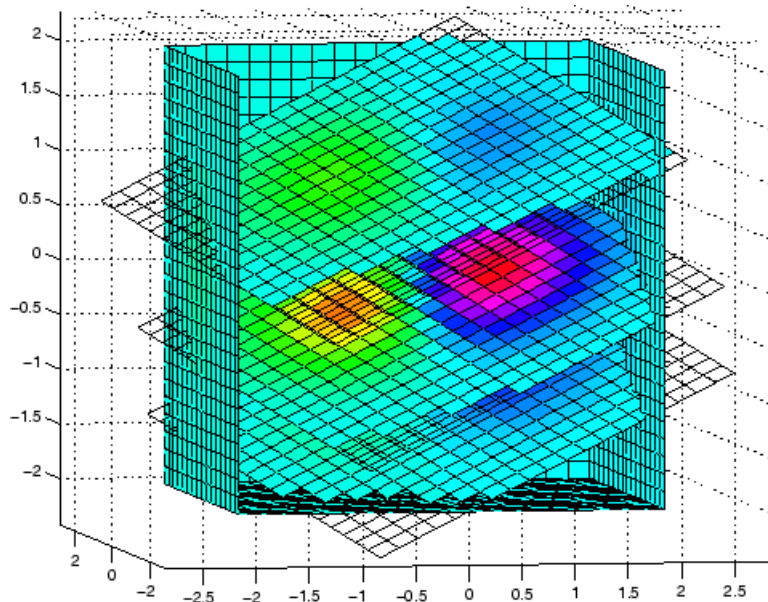
```
for i = -2:.5:2
 hsp = surf(linspace(-2,2,20),linspace(-2,2,20),zeros(20)+i);
```

# slice

---

```
rotate(hsp,[1,-1,1],30)
xd = get(hsp,'XData');
yd = get(hsp,'YData');
zd = get(hsp,'ZData');
delete(hsp)
slice(x,y,z,v,[-2,2],2,-2) % Draw some volume boundaries
hold on
slice(x,y,z,v,xd,yd,zd)
hold off
axis tight
view(-5,10)
drawnow
end
```

The following picture illustrates three positions of the same slice surface as it passes through the volume.





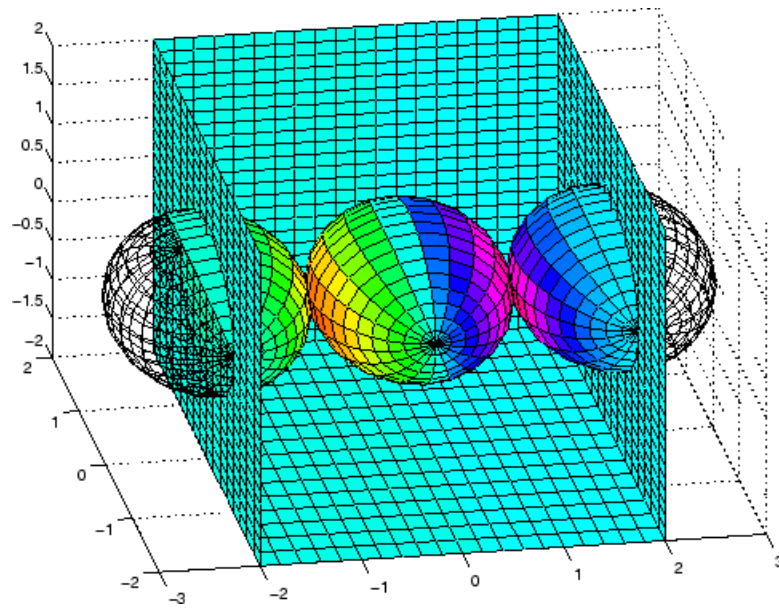
## Slicing with a Nonplanar Surface

You can slice the volume with any surface. This example probes the volume created in the previous example by passing a spherical slice surface through the volume.

```
[xsp,ysp,zsp] = sphere;
slice(x,y,z,v,[-2,2],2,-2) % Draw some volume boundaries

for i = -3:.2:3
 hsp = surface(xsp+i,ysp,zsp);
 rotate(hsp,[1 0 0],90)
 xd = get(hsp,'XData');
 yd = get(hsp,'YData');
 zd = get(hsp,'ZData');
 delete(hsp)
 hold on
 hslicer = slice(x,y,z,v,xd,yd,zd);
 axis tight
 xlim([-3,3])
 view(-10,35)
 drawnow
 delete(hslicer)
 hold off
end
```

The following picture illustrates three positions of the spherical slice surface as it passes through the volume.



## See Also

`interp3`, `meshgrid`

“Volume Visualization” on page 1-108 for related functions

Exploring Volumes with Slice Planes for more examples

**Purpose** Smooth 3-D data

## Syntax

## Description

`W = smooth3(V)` smooths the input data `V` and returns the smoothed data in `W`.

`W = smooth3(V, 'filter')` *filter* determines the convolution kernel and can be the strings

- 'gaussian'
- 'box' (default)

`W = smooth3(V, 'filter', size)` sets the size of the convolution kernel (default is [3 3 3]). If `size` is scalar, then `size` is interpreted as [size, size, size].

`W = smooth3(V, 'filter', size, sd)` sets an attribute of the convolution kernel. When *filter* is gaussian, `sd` is the standard deviation (default is .65).

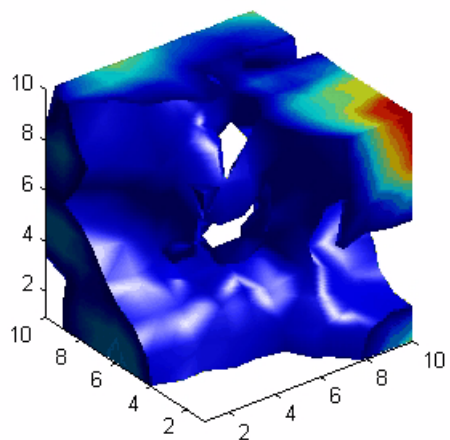
## Examples

This example smooths some random 3-D data and then creates an isosurface with end caps.

```
rand('seed',0)
data = rand(10,10,10);
data = smooth3(data,'box',5);
p1 = patch(isosurface(data,.5), ...
 'FaceColor','blue','EdgeColor','none');
p2 = patch(isocaps(data,.5), ...
 'FaceColor','interp','EdgeColor','none');
isonormals(data,p1)
view(3); axis vis3d tight
camlight; lighting phong
```

## smooth3

---



### See Also

`isocaps`, `isonormals`, `isosurface`, `patch`

“Volume Visualization” on page 1-108 for related functions

See [Displaying an Isosurface](#) for another example.

|                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
|------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Purpose</b>         | Force snapshot of image for inclusion in published document                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| <b>GUI Alternative</b> | As an alternative to <code>snapnow</code> , open an M-File and select <b>Cell &gt; Insert Text Markup &gt; Force Snapshot</b> to insert the <code>snapnow</code> command into the M-File.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| <b>Syntax</b>          | <code>snapnow</code>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| <b>Description</b>     | The <code>snapnow</code> command forces a snapshot of the image or plot that the code has most recently generated for presentation in a published document. The output appears in the published document at the end of the cell that contains the <code>snapnow</code> command. When used outside the context of publishing an M-File, <code>snapnow</code> has the same behavior as <code>drawnow</code> . That is, if you run a file that contains the <code>snapnow</code> command, the MATLAB software interprets it as though it were a <code>drawnow</code> command.                                                                                                                        |
| <b>Example</b>         | <p>This example demonstrates the difference between publishing code that contains the <code>snapnow</code> command and running that code. The first image shows the results of publishing the code and the second image shows the results of running the code.</p> <p>Suppose you have an M-file that contains the following code:</p> <pre>%% Scale magic Data and %% Display as Image:  for i=1:3     i     imagesc(magic(i))     snapnow end</pre> <p>When you publish the code to HTML, the published document contains a title, a table of contents, the commented text, the code, and each of the three images produced by the <code>for</code> loop, along with a display of the value</p> |

of  $i$  corresponding to each image. (In the published document shown, the size of the images have been reduced.)

Web Browser - Scale magic Data and

File Edit View Go Debug

## Scale magic Data and


Contents

- [Display as Image:](#)


Display as Image:

```
for i=1:3
 i
 imagesc(magic(i))
 snapnow
end
```


i =  
1



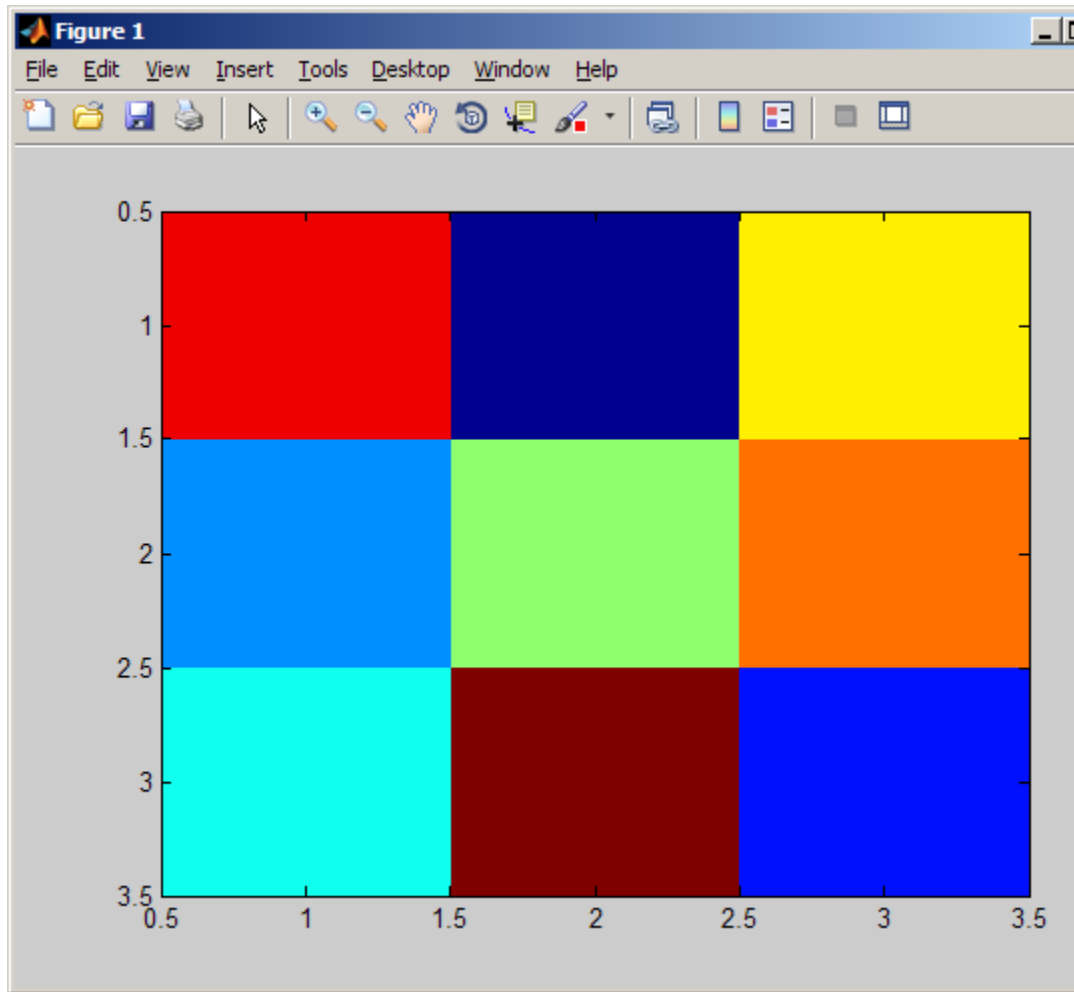
i =  
2



i =  
3



When you run the code, a single Figure window opens and MATLAB updates the image within this window as it evaluates each iteration of the for loop. (Concurrently, the Command Window displays the value of  $i$ .) Each successive image replaces the one that preceded it, so that the Figure window appears as follows when the code evaluation completes.





**See Also**

drawnow

“Forcing a Snapshot of Output in M-Files for Publishing”

# sort

---

**Purpose** Sort array elements in ascending or descending order

**Syntax**

```
B = sort(A)
B = sort(A,dim)
B = sort(...,mode)
[B,IX] = sort(A,...)
```

**Description** B = sort(A) sorts the elements along different dimensions of an array, and arranges those elements in ascending order.

| If A is a ...          | sort(A) ...                                                                              |
|------------------------|------------------------------------------------------------------------------------------|
| Vector                 | Sorts the elements of A.                                                                 |
| Matrix                 | Sorts each column of A.                                                                  |
| Multidimensional array | Sorts A along the first non-singleton dimension, and returns an array of sorted vectors. |
| Cell array of strings  | Sorts the strings in ASCII dictionary order.                                             |

Integer, floating-point, logical, and character arrays are permitted. Floating-point arrays can be complex. For elements of A with identical values, the order of these elements is preserved in the sorted list. When A is complex, the elements are sorted by magnitude, i.e., `abs(A)`, and where magnitudes are equal, further sorted by phase angle, i.e., `angle(A)`, on the interval  $[-\pi, \pi]$ . If A includes any NaN elements, `sort` places these at the high end.

B = `sort(A,dim)` sorts the elements along the dimension of A specified by a scalar `dim`.

B = `sort(...,mode)` sorts the elements in the specified direction, depending on the value of `mode`.

'ascend' Ascending order (default)

'descend' Descending order

`[B,IX] = sort(A,...)` also returns an array of indices `IX`, where `size(IX) == size(A)`. If `A` is a vector, `B = A(IX)`. If `A` is an `m`-by-`n` matrix, then each column of `IX` is a permutation vector of the corresponding column of `A`, such that

```
for j = 1:n
 B(:,j) = A(IX(:,j),j);
end
```

If `A` has repeated elements of equal value, the returned indices preserve the original ordering.

### Sorting Complex Entries

If `A` has complex entries `r` and `s`, `sort` orders them according to the following rule: `r` appears before `s` in `sort(A)` if either of the following hold:

- `abs(r) < abs(s)`
- `abs(r) = abs(s)` and `angle(r) < angle(s)`

where  $-\pi < \text{angle}(r) \leq \pi$

For example,

```
v = [1 -1 i -i];
angle(v)

ans =

 0 3.1416 1.5708 -1.5708
sort(v)

ans =

 0 - 1.0000i 1.0000
 0 + 1.0000i -1.0000
```

---

**Note** `sort` uses a different rule for ordering complex numbers than do the relational operators. See the Relational Operators reference page for more information. For more information about how MATLAB software treats complex numbers, see “Numbers” in the *MATLAB Getting Started Guide*.

---

## Examples

### Example 1

This example sorts a matrix `A` in each dimension, and then sorts it a third time, returning an array of indices for the sorted result.

```
A = [3 7 5
 0 4 2];

sort(A,1)

ans =
 0 4 2
 3 7 5

sort(A,2)

ans =
 3 5 7
 0 2 4

[B,IX] = sort(A,2)

B =
 3 5 7
 0 2 4

IX =
 1 3 2
 1 3 2
```

**Example 2**

This example sorts each column of a matrix in descending order.

```
A = [3 7 5
 6 8 3
 0 4 2];

sort(A,1,'descend')
```

```
ans =
 6 8 5
 3 7 3
 0 4 2
```

This is equivalent to

```
sort(A,'descend')

ans =
 6 8 5
 3 7 3
 0 4 2
```

**See Also**

issorted, max, mean, median, min, sortrows, unique

# sortrows

---

**Purpose** Sort rows in ascending order

**Syntax**  
B = sortrows(A)  
B = sortrows(A,column)  
[B,index] = sortrows(A,...)

**Description** B = sortrows(A) sorts the rows of A in ascending order. Argument A must be either a matrix or a column vector.

For strings, this is the familiar dictionary sort. When A is complex, the elements are sorted by magnitude, and, where magnitudes are equal, further sorted by phase angle on the interval  $[-\pi, \pi]$ .

B = sortrows(A,column) sorts the matrix based on the columns specified in the vector column. If an element of column is positive, the MATLAB software sorts the corresponding column of matrix A in ascending order; if an element of column is negative, MATLAB sorts the corresponding column in descending order. For example, sortrows(A,[2 -3]) sorts the rows of A first in ascending order for the second column, and then by descending order for the third column.

[B,index] = sortrows(A,...) also returns an index vector index.

If A is a column vector, then B = A(index). If A is an m-by-n matrix, then B = A(index,:).

## Examples

Start with a mostly random matrix, A:

```
rand('state',0)
A = floor(rand(6,7) * 100);
A(1:4,1)=95; A(5:6,1)=76; A(2:4,2)=7; A(3,3)=73
A =
 95 45 92 41 13 1 84
 95 7 73 89 20 74 52
 95 7 73 5 19 44 20
 95 7 40 35 60 93 67
 76 61 93 81 27 46 83
 76 79 91 0 19 41 1
```

When called with only a single input argument, `sortrows` bases the sort on the first column of the matrix. For any rows that have equal elements in a particular column, (e.g., `A(1:4,1)` for this matrix), sorting is based on the column immediately to the right, (`A(1:4,2)` in this case):

```
B = sortrows(A)
B =
 76 61 93 81 27 46 83
 76 79 91 0 19 41 1
 95 7 40 35 60 93 67
 95 7 73 5 19 44 20
 95 7 73 89 20 74 52
 95 45 92 41 13 1 84
```

When called with two input arguments, `sortrows` bases the sort entirely on the column specified in the second argument. Rows that have equal elements in the specified column, (e.g., `A(2:4, :)`, if sorting matrix `A` by column 2) remain in their original order:

```
C = sortrows(A,2)
C =
 95 7 73 89 20 74 52
 95 7 73 5 19 44 20
 95 7 40 35 60 93 67
 95 45 92 41 13 1 84
 76 61 93 81 27 46 83
 76 79 91 0 19 41 1
```

This example specifies two columns to sort by: columns 1 and 7. This tells `sortrows` to sort by column 1 first, and then for any rows with equal values in column 1, to sort by column 7:

```
D = sortrows(A,[1 7])
D =
 76 79 91 0 19 41 1
 76 61 93 81 27 46 83
 95 7 73 5 19 44 20
 95 7 73 89 20 74 52
```

## sortrows

---

```
95 7 40 35 60 93 67
95 45 92 41 13 1 84
```

Sort the matrix using the values in column 4 this time and in reverse order:

```
E = sortrows(A, -4)
```

```
E =
```

```
95 7 73 89 20 74 52
76 61 93 81 27 46 83
95 45 92 41 13 1 84
95 7 40 35 60 93 67
95 7 73 5 19 44 20
76 79 91 0 19 41 1
```

### See Also

issorted, sort



---

|                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
|--------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Purpose</b>     | Convert vector into sound                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| <b>Syntax</b>      | <code>sound(y,Fs)</code><br><code>sound(y)</code><br><code>sound(y,Fs,bits)</code>                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| <b>Description</b> | <code>sound(y,Fs)</code> sends the signal in vector <code>y</code> (with sample frequency <code>Fs</code> , in hertz) to the speaker on Microsoft Windows and most UNIX platforms. Values in <code>y</code> are assumed to be in the range $-1.0 \leq y \leq 1.0$ . Values outside that range are clipped. Stereo sound is played on platforms that support it when <code>y</code> is an <code>n</code> -by-2 matrix. The values in column 1 are assigned to the left channel, and those in column 2 to the right. |

---

**Note** The playback duration that results from setting `Fs` depends on the sound card you have installed. Most sound cards support sample frequencies in the range of approximately 5 kHz to 44.1 kHz. Sample frequencies outside this range can produce unexpected results.

---

`sound(y)` plays the sound at the default sample rate or 8192 Hz.

`sound(y,Fs,bits)` plays the sound using `bits` number of bits/sample, if possible. Most platforms support `bits = 8` or `bits = 16`.

|                |                                                                                                                                                                                                                                                                                                                                                                                                       |
|----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Remarks</b> | MATLAB software supports all sound devices compatible with Windows operating systems. Additional sound acquisition and generation capability is available in Data Acquisition Toolbox software. The toolbox functionality includes the ability to buffer the acquisition so that you can analyze the data as it is being acquired. See the examples on MATLAB sound acquisition and sound generation. |
|----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

|                 |                                                                                                                                             |
|-----------------|---------------------------------------------------------------------------------------------------------------------------------------------|
| <b>See Also</b> | <code>auread</code> , <code>auwrite</code> , <code>soundsc</code> , <code>audioplayer</code> , <code>wavread</code> , <code>wavwrite</code> |
|-----------------|---------------------------------------------------------------------------------------------------------------------------------------------|

# soundsc

---

**Purpose** Scale data and play as sound

**Syntax** `soundsc(y,Fs)`  
`soundsc(y)`  
`soundsc(y,Fs,bits)`  
`soundsc(y,...,slim)`

**Description** `soundsc(y,Fs)` sends the signal in vector `y` (with sample frequency `Fs`) to the speaker on PC and most UNIX platforms. The signal `y` is scaled to the range  $-1.0 \leq y \leq 1.0$  before it is played, resulting in a sound that is played as loud as possible without clipping.

---

**Note** The playback duration that results from setting `Fs` depends on the sound card you have installed. Most sound cards support sample frequencies of approximately 5-10 kHz to 44.1 kHz. Sample frequencies outside this range can produce unexpected results.

---

`soundsc(y)` plays the sound at the default sample rate or 8192 Hz.

`soundsc(y,Fs,bits)` plays the sound using `bits` number of bits/sample if possible. Most platforms support `bits = 8` or `bits = 16`.

`soundsc(y,...,slim)`, where `slim = [slow shigh]`, maps the values in `y` between `slow` and `shigh` to the full sound range. The default value is `slim = [min(y) max(y)]`.

**Remarks** MATLAB software supports all Windows-compatible sound devices.

**See Also** `auread`, `auwrite`, `sound`, `wavread`, `wavwrite`

**Purpose** Allocate space for sparse matrix

**Syntax** `S = spalloc(m,n,nzmax)`

**Description** `S = spalloc(m,n,nzmax)` creates an all zero sparse matrix `S` of size `m`-by-`n` with room to hold `nzmax` nonzeros. The matrix can then be generated column by column without requiring repeated storage allocation as the number of nonzeros grows.

`spalloc(m,n,nzmax)` is shorthand for

```
sparse([],[],[],m,n,nzmax)
```

**Examples** To generate efficiently a sparse matrix that has an average of at most three nonzero elements per column

```
S = spalloc(n,n,3*n);
for j = 1:n
 S(:,j) = [zeros(n-3,1)' round(rand(3,1))]' ;end
```

# sparse

---

**Purpose** Create sparse matrix

**Syntax**

```
S = sparse(A)
S = sparse(i, j, s, m, n, nzmax)
S = sparse(i, j, s, m, n)
S = sparse(i, j, s)
S = sparse(m, n)
```

**Description** The sparse function generates matrices in the MATLAB sparse storage organization.

`S = sparse(A)` converts a full matrix to sparse form by squeezing out any zero elements. If `S` is already sparse, `sparse(S)` returns `S`.

`S = sparse(i, j, s, m, n, nzmax)` uses vectors `i`, `j`, and `s` to generate an `m`-by-`n` sparse matrix such that  $S(i(k), j(k)) = s(k)$ , with space allocated for `nzmax` nonzeros. Vectors `i`, `j`, and `s` are all the same length. Any elements of `s` that are zero are ignored, along with the corresponding values of `i` and `j`. Any elements of `s` that have duplicate values of `i` and `j` are added together.

---

**Note** If any value in `i` or `j` is larger than the maximum integer size,  $2^{31}-1$ , then the sparse matrix cannot be constructed.

---

To simplify this six-argument call, you can pass scalars for the argument `s` and one of the arguments `i` or `j`—in which case they are expanded so that `i`, `j`, and `s` all have the same length.

`S = sparse(i, j, s, m, n)` uses `nzmax = length(s)`.

`S = sparse(i, j, s)` uses `m = max(i)` and `n = max(j)`. The maxima are computed before any zeros in `s` are removed, so one of the rows of `[i j s]` might be `[m n 0]`.

`S = sparse(m, n)` abbreviates `sparse([], [], [], m, n, 0)`. This generates the ultimate sparse matrix, an `m`-by-`n` all zero matrix.

## Remarks

All of the MATLAB built-in arithmetic, logical, and indexing operations can be applied to sparse matrices, or to mixtures of sparse and full matrices. Operations on sparse matrices return sparse matrices and operations on full matrices return full matrices.

In most cases, operations on mixtures of sparse and full matrices return full matrices. The exceptions include situations where the result of a mixed operation is structurally sparse, for example,  $A * S$  is at least as sparse as  $S$ .

## Examples

`S = sparse(1:n,1:n,1)` generates a sparse representation of the  $n$ -by- $n$  identity matrix. The same  $S$  results from `S = sparse(eye(n,n))`, but this would also temporarily generate a full  $n$ -by- $n$  matrix with most of its elements equal to zero.

`B = sparse(10000,10000,pi)` is probably not very useful, but is legal and works; it sets up a 10000-by-10000 matrix with only one nonzero element. Don't try `full(B)`; it requires 800 megabytes of storage.

This dissects and then reassembles a sparse matrix:

```
[i,j,s] = find(S);
[m,n] = size(S);
S = sparse(i,j,s,m,n);
```

So does this, if the last row and column have nonzero entries:

```
[i,j,s] = find(S);
S = sparse(i,j,s);
```

## See Also

`diag`, `find`, `full`, `issparse`, `nnz`, `nonzeros`, `nzmax`, `spones`, `sprandn`, `sprandsym`, `spy`

The `sparfun` directory

# spaugment

---

**Purpose** Form least squares augmented system

**Syntax**  
 $S = \text{spaugment}(A, c)$   
 $S = \text{spaugment}(A)$

**Description**  $S = \text{spaugment}(A, c)$  creates the sparse, square, symmetric indefinite matrix  $S = [c \cdot I \ A; \ A' \ 0]$ . The matrix  $S$  is related to the least squares problem

$$\min \text{norm}(b - A \cdot x)$$

by

$$r = b - A \cdot x$$
$$S \cdot [r/c; \ x] = [b; \ 0]$$

The optimum value of the residual scaling factor  $c$ , involves  $\min(\text{svd}(A))$  and  $\text{norm}(r)$ , which are usually too expensive to compute.

$S = \text{spaugment}(A)$  without a specified value of  $c$ , uses  $\max(\max(\text{abs}(A))) / 1000$ .

---

**Note** In previous versions of MATLAB product, the augmented matrix was used by sparse linear equation solvers,  $\backslash$  and  $/$ , for nonsquare problems. Now, MATLAB software performs a least squares solve using the  $qr$  factorization of  $A$  instead.

---

**See Also** `spparms`

**Purpose** Import matrix from sparse matrix external format

**Syntax** `S = spconvert(D)`

**Description** `spconvert` is used to create sparse matrices from a simple sparse format easily produced by non-MATLAB sparse programs. `spconvert` is the second step in the process:

- 1** Load an ASCII data file containing `[i, j, v]` or `[i, j, re, im]` as rows into a MATLAB variable.
- 2** Convert that variable into a MATLAB sparse matrix.

`S = spconvert(D)` converts a matrix `D` with rows containing `[i, j, s]` or `[i, j, r, s]` to the corresponding sparse matrix. `D` must have an `nnz` or `nnz+1` row and three or four columns. Three elements per row generate a real matrix and four elements per row generate a complex matrix. A row of the form `[m n 0]` or `[m n 0 0]` anywhere in `D` can be used to specify `size(S)`. If `D` is already sparse, no conversion is done, so `spconvert` can be used after `D` is loaded from either a MAT-file or an ASCII file.

**Examples** Suppose the ASCII file `uphill.dat` contains

```

1 1 1.0000000000000000
1 2 0.5000000000000000
2 2 0.3333333333333333
1 3 0.3333333333333333
2 3 0.2500000000000000
3 3 0.2000000000000000
1 4 0.2500000000000000
2 4 0.2000000000000000
3 4 0.1666666666666667
4 4 0.142857142857143
4 4 0.0000000000000000
```

Then the statements

## spconvert

---

```
load uphill.dat
H = spconvert(uphill)
```

```
H =
 (1,1) 1.0000
 (1,2) 0.5000
 (2,2) 0.3333
 (1,3) 0.3333
 (2,3) 0.2500
 (3,3) 0.2000
 (1,4) 0.2500
 (2,4) 0.2000
 (3,4) 0.1667
 (4,4) 0.1429
```

recreate `sparse(triu(hilb(4)))`, possibly with roundoff errors. In this case, the last line of the input file is not necessary because the earlier lines already specify that the matrix is at least 4-by-4.



**Purpose**

Extract and create sparse band and diagonal matrices

**Syntax**

```
B = spdiags(A)
[B,d] = spdiags(A)
B = spdiags(A,d)
A = spdiags(B,d,A)
A = spdiags(B,d,m,n)
```

**Description**

The `spdiags` function generalizes the function `diag`. Four different operations, distinguished by the number of input arguments, are possible.

`B = spdiags(A)` extracts all nonzero diagonals from the  $m$ -by- $n$  matrix  $A$ .  $B$  is a  $\min(m,n)$ -by- $p$  matrix whose columns are the  $p$  nonzero diagonals of  $A$ .

`[B,d] = spdiags(A)` returns a vector  $d$  of length  $p$ , whose integer components specify the diagonals in  $A$ .

`B = spdiags(A,d)` extracts the diagonals specified by  $d$ .

`A = spdiags(B,d,A)` replaces the diagonals specified by  $d$  with the columns of  $B$ . The output is sparse.

`A = spdiags(B,d,m,n)` creates an  $m$ -by- $n$  sparse matrix by taking the columns of  $B$  and placing them along the diagonals specified by  $d$ .

---

**Note** In this syntax, if a column of  $B$  is longer than the diagonal it is replacing, and  $m \geq n$ , `spdiags` takes elements of super-diagonals from the lower part of the column of  $B$ , and elements of sub-diagonals from the upper part of the column of  $B$ . However, if  $m < n$ , then super-diagonals are from the upper part of the column of  $B$ , and sub-diagonals from the lower part. (See “Example 5A” on page 2-3331 and “Example 5B” on page 2-3333, below).

---

**Arguments**

The `spdiags` function deals with three matrices, in various combinations, as both input and output.

- A An  $m$ -by- $n$  matrix, usually (but not necessarily) sparse, with its nonzero or specified elements located on  $p$  diagonals.
- B A  $\min(m, n)$ -by- $p$  matrix, usually (but not necessarily) full, whose columns are the diagonals of A.
- d A vector of length  $p$  whose integer components specify the diagonals in A.

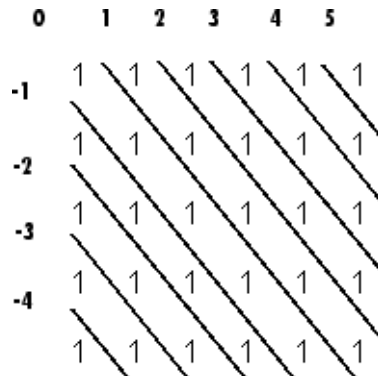
Roughly, A, B, and d are related by

```
for k = 1:p
 B(:,k) = diag(A,d(k))
end
```

Some elements of B, corresponding to positions outside of A, are not defined by these loops. They are not referenced when B is input and are set to zero when B is output.

## How the Diagonals of A are Listed in the Vector d

An  $m$ -by- $n$  matrix A has  $m+n-1$  diagonals. These are specified in the vector d using indices from  $-m+1$  to  $n-1$ . For example, if A is 5-by-6, it has 10 diagonals, which are specified in the vector d using the indices -4, -3, ..., 4, 5. The following diagram illustrates this for a vector of all ones.



**Examples****Example 1**

For the following matrix,

```
A=[0 5 0 10 0 0;...
0 0 6 0 11 0;...
3 0 0 7 0 12;...
1 4 0 0 8 0;...
0 2 5 0 0 9]
```

A =

```
0 5 0 10 0 0
0 0 6 0 11 0
3 0 0 7 0 12
1 4 0 0 8 0
0 2 5 0 0 9
```

the command

```
[B, d] =spdiags(A)
```

returns

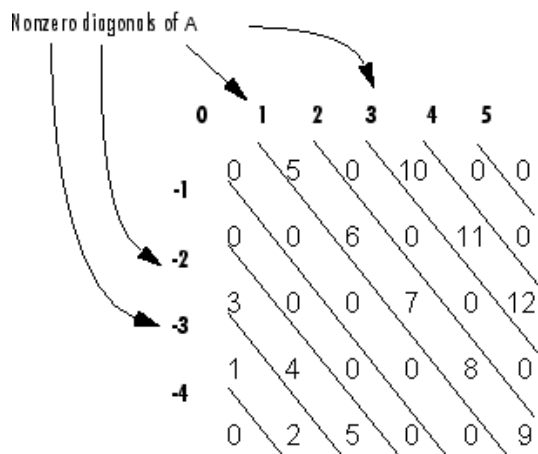
B =

```
0 0 5 10
0 0 6 11
0 3 7 12
1 4 8 0
2 5 9 0
```

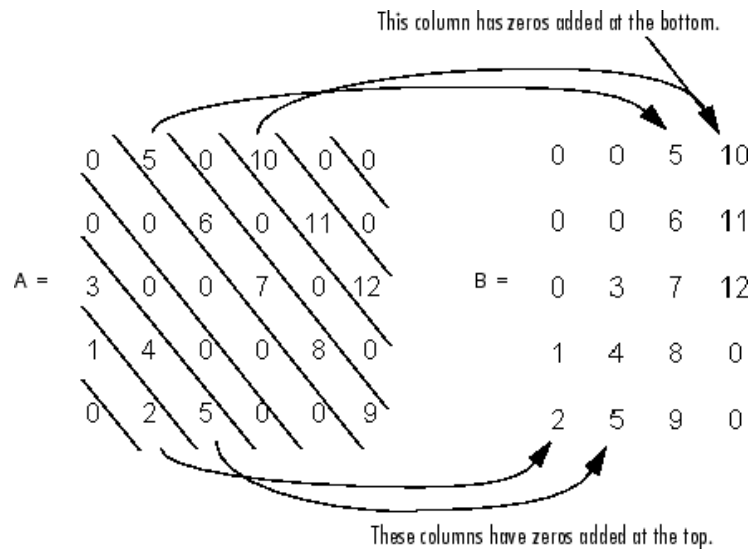
d =

```
-3
-2
 1
```

The columns of the first output **B** contain the nonzero diagonals of **A**. The second output **d** lists the indices of the nonzero diagonals of **A**, as shown in the following diagram. See “How the Diagonals of **A** are Listed in the Vector **d**” on page 2-3326.



Note that the longest nonzero diagonal in **A** is contained in column 3 of **B**. The other nonzero diagonals of **A** have extra zeros added to their corresponding columns in **B**, to give all columns of **B** the same length. For the nonzero diagonals below the main diagonal of **A**, extra zeros are added at the tops of columns. For the nonzero diagonals above the main diagonal of **A**, extra zeros are added at the bottoms of columns. This is illustrated by the following diagram.



### Example 2

This example generates a sparse tridiagonal representation of the classic second difference operator on  $n$  points.

```
e = ones(n,1);
A = spdiags([e -2*e e], -1:1, n, n)
```

Turn it into Wilkinson's test matrix (see gallery):

```
A = spdiags(abs(-(n-1)/2:(n-1)/2)', 0, A)
```

Finally, recover the three diagonals:

```
B = spdiags(A)
```

### Example 3

The second example is not square.

```
A = [11 0 13 0
 0 22 0 24]
```

# spdiags

---

```
 0 0 33 0
 41 0 0 44
 0 52 0 0
 0 0 63 0
 0 0 0 74]
```

Here  $m = 7$ ,  $n = 4$ , and  $p = 3$ .

The statement `[B,d] = spdiags(A)` produces `d = [-3 0 2]'` and

```
B = [41 11 0
 52 22 0
 63 33 13
 74 44 24]
```

Conversely, with the above `B` and `d`, the expression `spdiags(B,d,7,4)` reproduces the original `A`.

## Example 4

This example shows how `spdiags` creates the diagonals when the columns of `B` are longer than the diagonals they are replacing.

```
B = repmat((1:6)', [1 7])
```

```
B =
```

```
 1 1 1 1 1 1 1
 2 2 2 2 2 2 2
 3 3 3 3 3 3 3
 4 4 4 4 4 4 4
 5 5 5 5 5 5 5
 6 6 6 6 6 6 6
```

```
d = [-4 -2 -1 0 3 4 5];
```

```
A = spdiags(B,d,6,6);
```

```
full(A)
```

```
ans =
```

```
1 0 0 4 5 6
1 2 0 0 5 6
1 2 3 0 0 6
0 2 3 4 0 0
1 0 3 4 5 0
0 2 0 4 5 6
```

### Example 5A

This example illustrates the use of the syntax `A = spdiags(B,d,m,n)`, under three conditions:

- `m` is equal to `n`
- `m` is greater than `n`
- `m` is less than `n`

The command used in this example is

```
A = full(spdiags(B, [-2 0 2], m, n))
```

where `B` is the 5-by-3 matrix shown below. The resulting matrix `A` has dimensions `m`-by-`n`, and has nonzero diagonals at `[-2 0 2]` (a sub-diagonal at `-2`, the main diagonal, and a super-diagonal at `2`).

```
B =
 1 6 11
 2 7 12
 3 8 13
 4 9 14
 5 10 15
```

The first and third columns of matrix `B` are used to create the sub- and super-diagonals of `A` respectively. In all three cases though, these two outer columns of `B` are longer than the resulting diagonals of `A`. Because of this, only a part of the columns is used in `A`.

When  $m == n$  or  $m > n$ , `spdiags` takes elements of the super-diagonal in A from the lower part of the corresponding column of B, and elements of the sub-diagonal in A from the upper part of the corresponding column of B.

When  $m < n$ , `spdiags` does the opposite, taking elements of the super-diagonal in A from the upper part of the corresponding column of B, and elements of the sub-diagonal in A from the lower part of the corresponding column of B.

## Part 1 – m is equal to n.

```
A = full(spdiags(B, [-2 0 2], 5, 5))
```

| Matrix B |    |    |               | Matrix A |   |    |    |    |
|----------|----|----|---------------|----------|---|----|----|----|
| 1        | 6  | 11 |               | 6        | 0 | 13 | 0  | 0  |
| 2        | 7  | 12 |               | 0        | 7 | 0  | 14 | 0  |
| 3        | 8  | 13 | == spdiags => | 1        | 0 | 8  | 0  | 15 |
| 4        | 9  | 14 |               | 0        | 2 | 0  | 9  | 0  |
| 5        | 10 | 15 |               | 0        | 0 | 3  | 0  | 10 |

A(3,1), A(4,2), and A(5,3) are taken from the upper part of B(:,1).

A(1,3), A(2,4), and A(3,5) are taken from the lower part of B(:,3).

## Part 2 – m is greater than n.

```
A = full(spdiags(B, [-2 0 2], 5, 4))
```

| Matrix B |    |    |               | Matrix A |   |    |    |
|----------|----|----|---------------|----------|---|----|----|
| 1        | 6  | 11 |               | 6        | 0 | 13 | 0  |
| 2        | 7  | 12 |               | 0        | 7 | 0  | 14 |
| 3        | 8  | 13 | == spdiags => | 1        | 0 | 8  | 0  |
| 4        | 9  | 14 |               | 0        | 2 | 0  | 9  |
| 5        | 10 | 15 |               | 0        | 0 | 3  | 0  |

Same as in Part A.



**Part 3 – m is less than n.**

```
A = full(spdiags(B, [-2 0 2], 4, 5))
Matrix B Matrix A

 1 6 11 6 0 11 0 0
 2 7 12 0 7 0 12 0
 3 8 13 == spdiags => 3 0 8 0 13
 4 9 14 0 4 0 9 0
 5 10 15
```

A(3,1) and A(4,2) are taken from the lower part of B(:,1).

A(1,3), A(2,4), and A(3,5) are taken from the upper part of B(:,3).

**Example 5B**

Extract the diagonals from the first part of this example back into a column format using the command

```
B = spdiags(A)
```

You can see that in each case the original columns are restored (minus those elements that had overflowed the super- and sub-diagonals of matrix A).

**Part 1.**

```
Matrix A Matrix B

 6 0 13 0 0 1 6 0
 0 7 0 14 0 2 7 0
 1 0 8 0 15 == spdiags => 3 8 13
 0 2 0 9 0 0 9 14
 0 0 3 0 10 0 10 15
```

**Part 2.**

```
Matrix A Matrix B
```

# spdiags

---

```
6 0 13 0 1 6 0
0 7 0 14 2 7 0
1 0 8 0 == spdiags => 3 8 13
0 2 0 9 0 9 14
0 0 3 0
```

## Part 3.

```
Matrix A Matrix B
6 0 11 0 0 0 6 11
0 7 0 12 0 0 7 12
3 0 8 0 13 == spdiags => 3 8 13
0 4 0 9 0 4 9 0
```

## See Also

diag, speye

**Purpose** Calculate specular reflectance

**Syntax** `R = specular(Nx,Ny,Nz,S,V)`

**Description** `R = specular(Nx,Ny,Nz,S,V)` returns the reflectance of a surface with normal vector components `[Nx,Ny,Nz]`. `S` and `V` specify the direction to the light source and to the viewer, respectively. You can specify these directions as three vectors `[x,y,z]` or two vectors `[Theta Phi]` (in spherical coordinates).

The specular highlight is strongest when the normal vector is in the direction of  $(S+V)/2$  where `S` is the source direction, and `V` is the view direction.

The surface spread exponent can be specified by including a sixth argument as in `specular(Nx,Ny,Nz,S,V,spread)`.

# speye

---

|                    |                                                                                                                                                                                                                                                                                                                            |
|--------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Purpose</b>     | Sparse identity matrix                                                                                                                                                                                                                                                                                                     |
| <b>Syntax</b>      | <code>S = speye(m,n)</code><br><code>S = speye(n)</code>                                                                                                                                                                                                                                                                   |
| <b>Description</b> | <code>S = speye(m,n)</code> forms an m-by-n sparse matrix with 1s on the main diagonal.<br><code>S = speye(n)</code> abbreviates <code>speye(n,n)</code> .                                                                                                                                                                 |
| <b>Examples</b>    | <code>I = speye(1000)</code> forms the sparse representation of the 1000-by-1000 identity matrix, which requires only about 16 kilobytes of storage. This is the same final result as <code>I = sparse(eye(1000,1000))</code> , but the latter requires eight megabytes for temporary storage for the full representation. |
| <b>See Also</b>    | <code>spalloc</code> , <code>spones</code> , <code>spdiags</code> , <code>sprand</code> , <code>sprandn</code>                                                                                                                                                                                                             |

**Purpose** Apply function to nonzero sparse matrix elements

**Syntax** `f = spfun(fun,S)`

**Description** The `spfun` function selectively applies a function to only the *nonzero* elements of a sparse matrix `S`, preserving the sparsity pattern of the original matrix (except for underflow or if `fun` returns zero for some nonzero elements of `S`).

`f = spfun(fun,S)` evaluates `fun(S)` on the nonzero elements of `S`. `fun` is a function handle. See “Function Handles” in the MATLAB Programming documentation for more information.

“Parametrizing Functions” in the MATLAB Mathematics documentation, explains how to provide additional parameters to the function `fun`, if necessary.

**Remarks** Functions that operate element-by-element, like those in the `elfun` directory, are the most appropriate functions to use with `spfun`.

**Examples** Given the 4-by-4 sparse diagonal matrix

```
S = spdiags([1:4] ',0,4,4)
```

```
S =
(1,1) 1
(2,2) 2
(3,3) 3
(4,4) 4
```

Because `fun` returns nonzero values for all nonzero element of `S`, `f = spfun(@exp,S)` has the same sparsity pattern as `S`.

```
f =
(1,1) 2.7183
(2,2) 7.3891
(3,3) 20.0855
(4,4) 54.5982
```

whereas `exp(S)` has 1s where `S` has 0s.

```
full(exp(S))
```

```
ans =
```

```
2.7183 1.0000 1.0000 1.0000
1.0000 7.3891 1.0000 1.0000
1.0000 1.0000 20.0855 1.0000
1.0000 1.0000 1.0000 54.5982
```

## See Also

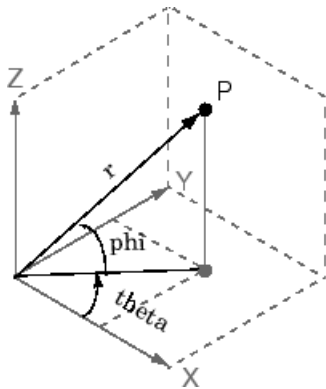
`function_handle` (@)

**Purpose** Transform spherical coordinates to Cartesian

**Syntax** `[x,y,z] = sph2cart(THETA,PHI,R)`

**Description** `[x,y,z] = sph2cart(THETA,PHI,R)` transforms the corresponding elements of spherical coordinate arrays to Cartesian, or  $xyz$ , coordinates. THETA, PHI, and R must all be the same size (or any of them can be scalar). THETA and PHI are angular displacements in radians from the positive  $x$ -axis and from the  $x$ - $y$  plane, respectively.

**Algorithm** The mapping from spherical coordinates to three-dimensional Cartesian coordinates is



$$\begin{aligned}x &= r \cdot \cos(\text{phi}) \cdot \cos(\text{theta}) \\y &= r \cdot \cos(\text{phi}) \cdot \sin(\text{theta}) \\z &= r \cdot \sin(\text{phi})\end{aligned}$$

**See Also** `cart2pol`, `cart2sph`, `pol2cart`

# sphere

---

## Purpose

Generate sphere



## Syntax

```
sphere
sphere(n)
[X,Y,Z] = sphere(n)
```

## Description

The sphere function generates the  $x$ -,  $y$ -, and  $z$ -coordinates of a unit sphere for use with `surf` and `mesh`.

`sphere` generates a sphere consisting of 20-by-20 faces.

`sphere(n)` draws a `surf` plot of an  $n$ -by- $n$  sphere in the current figure.

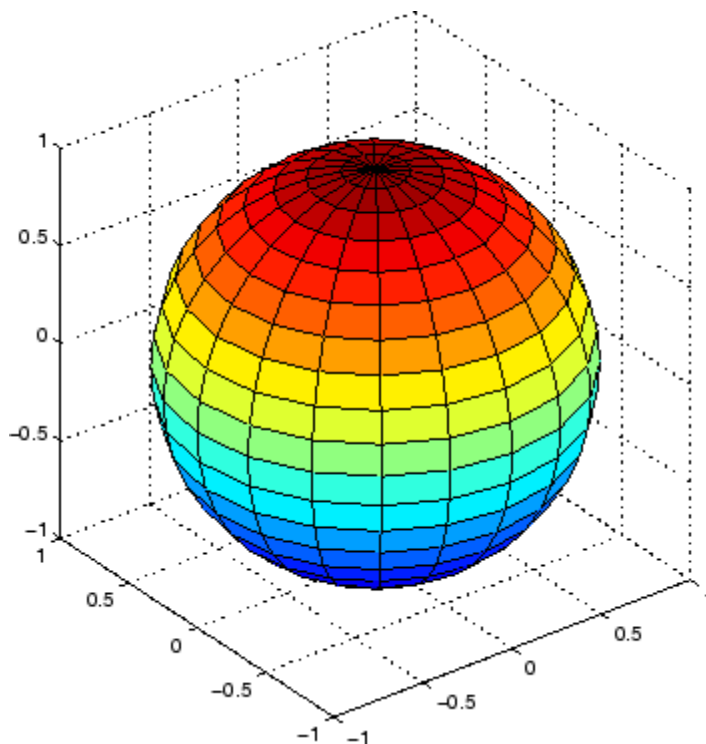
`[X,Y,Z] = sphere(n)` returns the coordinates of a sphere in three matrices that are  $(n+1)$ -by- $(n+1)$  in size. You draw the sphere with `surf(X,Y,Z)` or `mesh(X,Y,Z)`.

## Examples

Generate and plot a sphere.

```
sphere
axis equal
```





**See Also**

cylinder, axis equal

“Polygons and Surfaces” on page 1-97 for related functions

# spinmap

---

**Purpose** Spin colormap

**Syntax** spinmap  
spinmap(t)  
spinmap(t,inc)  
spinmap('inf')

**Description** The spinmap function shifts the colormap RGB values by some incremental value. For example, if the increment equals 1, color 1 becomes color 2, color 2 becomes color 3, etc.

spinmap cyclically rotates the colormap for approximately five seconds using an incremental value of 2.

spinmap(t) rotates the colormap for approximately 10\*t seconds. The amount of time specified by t depends on your hardware configuration (e.g., if you are running MATLAB software over a network).

spinmap(t,inc) rotates the colormap for approximately 10\*t seconds and specifies an increment inc by which the colormap shifts. When inc is 1, the rotation appears smoother than the default (i.e., 2). Increments greater than 2 are less smooth than the default. A negative increment (e.g., -2) rotates the colormap in a negative direction.

spinmap('inf') rotates the colormap for an infinite amount of time. To break the loop, press **Ctrl+C**.

**See Also** colormap, colormapeditor

“Color Operations” on page 1-105 for related functions

**Purpose** Cubic spline data interpolation

**Syntax**  
`yy = spline(x,Y,xx)`  
`pp = spline(x,Y)`

**Description** `yy = spline(x,Y,xx)` uses a cubic spline interpolation to find `yy`, the values of the underlying function `Y` at the values of the interpolant `xx`. For the interpolation, the independent variable is assumed to be the final dimension of `Y` with the breakpoints defined by `x`.

The sizes of `xx` and `yy` are related as follows:

- If `Y` is a scalar or vector, `yy` has the same size as `xx`.
- If `Y` is an array that is not a vector,
  - If `xx` is a scalar or vector, `size(yy)` equals `[d1, d2, ..., dk, length(xx)]`.
  - If `xx` is an array of size `[m1,m2,...,mj]`, `size(yy)` equals `[d1,d2,...,dk,m1,m2,...,mj]`.

`pp = spline(x,Y)` returns the piecewise polynomial form of the cubic spline interpolant for later use with `ppval` and the spline utility `unmkpp`. `x` must be a vector. `Y` can be a scalar, a vector, or an array of any dimension, subject to the following conditions:

- If `Y` is a scalar or vector, it must have the same length as `x`. A scalar value for `x` or `Y` is expanded to have the same length as the other. See Exceptions (1) for an exception to this rule, in which the not-a-knot end conditions are used.
- If `Y` is an array that is not a vector, the size of `Y` must have the form `[d1,d2,...,dk,n]`, where `n` is the length of `x`. The interpolation is performed for each `d1-by-d2-by-...-dk` value in `Y`. See Exceptions (2) for an exception to this rule.

## Exceptions

- 1 If  $Y$  is a vector that contains two more values than  $x$  has entries, the first and last value in  $Y$  are used as the endslopes for the cubic spline. If  $Y$  is a vector, this means
  - $f(x) = Y(2:\text{end}-1)$
  - $df(\min(x)) = Y(1)$
  - $df(\max(x)) = Y(\text{end})$
- 2 If  $Y$  is a matrix or an  $N$ -dimensional array with  $\text{size}(Y,N)$  equal to  $\text{length}(x)+2$ , the following hold:
  - $f(x(j))$  matches the value  $Y(:,\dots,:,j+1)$  for  $j=1:\text{length}(x)$
  - $Df(\min(x))$  matches  $Y(:,\dots,:,1)$
  - $Df(\max(x))$  matches  $Y(:,\dots,:,\text{end})$

---

**Note** You can also perform spline interpolation using the `interp1` function with the command `interp1(x,y,xx,'spline')`. Note that while `spline` performs interpolation on rows of an input matrix, `interp1` performs interpolation on columns of an input matrix.

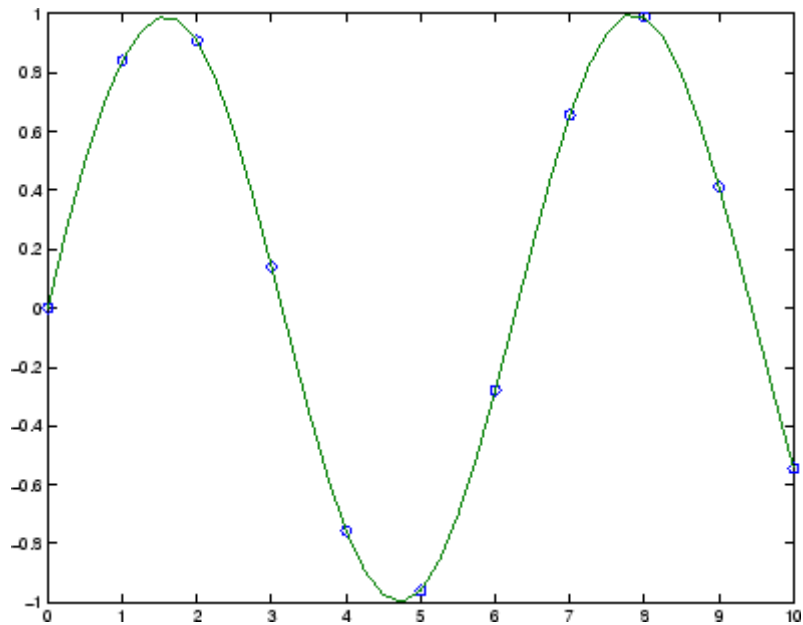
---

## Examples

### Example 1

This generates a sine curve, then samples the spline over a finer mesh.

```
x = 0:10;
y = sin(x);
xx = 0:.25:10;
yy = spline(x,y,xx);
plot(x,y,'o',xx,yy)
```



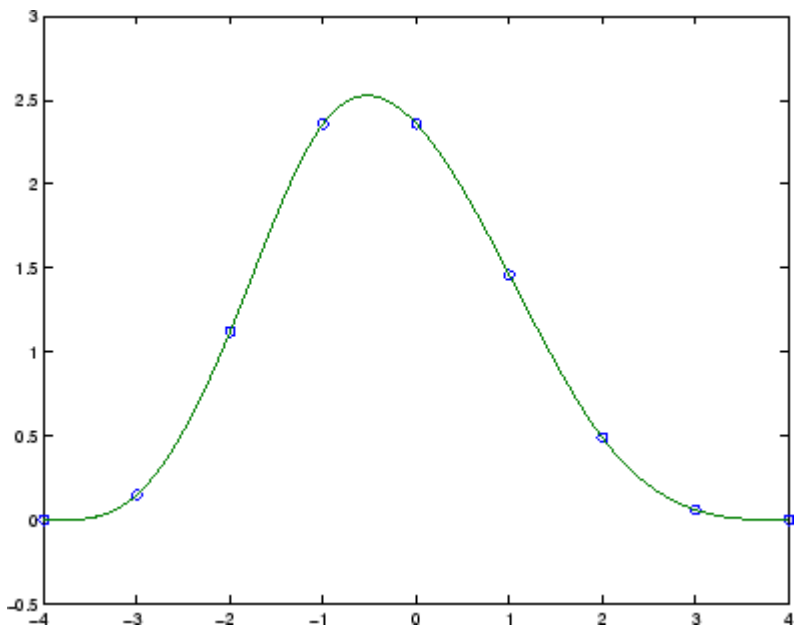
### Example 2

This illustrates the use of clamped or complete spline interpolation where end slopes are prescribed. Zero slopes at the ends of an interpolant to the values of a certain distribution are enforced.

```
x = -4:4;
y = [0 .15 1.12 2.36 2.36 1.46 .49 .06 0];
cs = spline(x,[0 y 0]);
xx = linspace(-4,4,101);
plot(x,y,'o',xx,ppval(cs,xx),'-');
```

# spline

---



## Example 3

The two vectors

```
t = 1900:10:1990;
p = [75.995 91.972 105.711 123.203 131.669 ...
 150.697 179.323 203.212 226.505 249.633];
```

represent the census years from 1900 to 1990 and the corresponding United States population in millions of people. The expression

```
spline(t,p,2000)
```

uses the cubic spline to extrapolate and predict the population in the year 2000. The result is

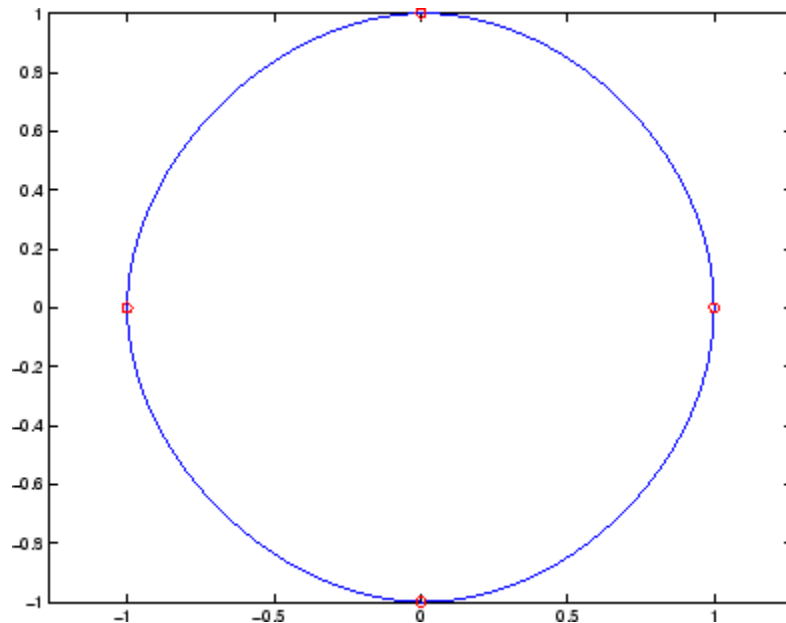
```
ans =
 270.6060
```

### Example 4

The statements

```
x = pi*[0:.5:2];
y = [0 1 0 -1 0 1 0;
 1 0 1 0 -1 0 1];
pp = spline(x,y);
yy = ppval(pp, linspace(0,2*pi,101));
plot(yy(1,:),yy(2:3,:), '-b', yy(1,2:5),yy(2,2:5), 'or'), axis equal
```

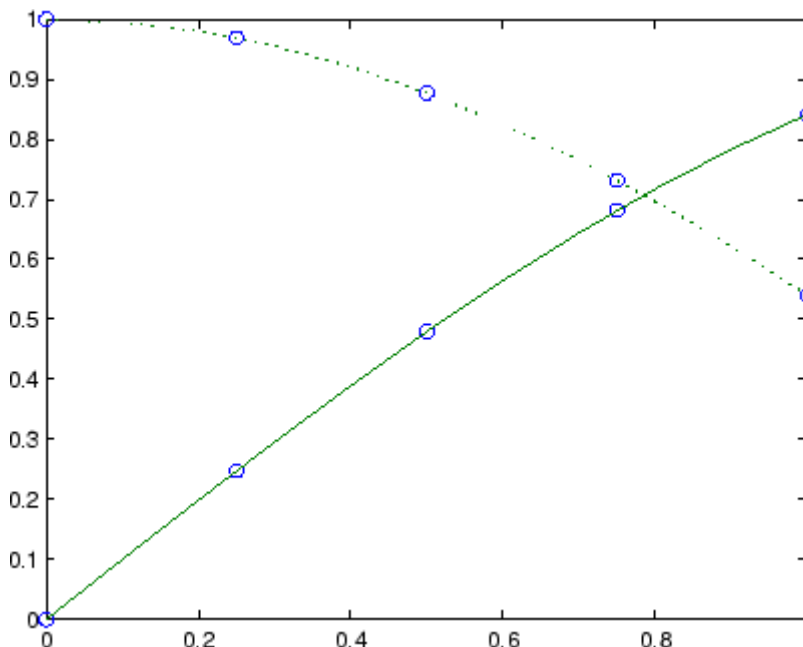
generate the plot of a circle, with the five data points  $y(:,2), \dots, y(:,6)$  marked with o's. Note that this  $y$  contains two more values (i.e., two more columns) than does  $x$ , hence  $y(:,1)$  and  $y(:,end)$  are used as endslopes.



## Example 5

The following code generates sine and cosine curves, then samples the splines over a finer mesh.

```
x = 0:.25:1;
Y = [sin(x); cos(x)];
xx = 0:.1:1;
YY = spline(x,Y,xx);
plot(x,Y(1,:), 'o',xx,YY(1,:), '-'); hold on;
plot(x,Y(2,:), 'o',xx,YY(2,:), ':'); hold off;
```



## Algorithm

A tridiagonal linear system (with, possibly, several right sides) is being solved for the information needed to describe the coefficients of the various cubic polynomials which make up the interpolating spline. spline uses the functions ppval, mkpp, and unmkpp. These routines



form a small suite of functions for working with piecewise polynomials. For access to more advanced features, see the M-file help for these functions and the Spline Toolbox.

**See Also**

`interp1`, `ppval`, `mkpp`, `pchip`, `unmkpp`

**References**

[1] de Boor, C., *A Practical Guide to Splines*, Springer-Verlag, 1978.

# spones

---

**Purpose**

Replace nonzero sparse matrix elements with ones

**Syntax**

`R = spones(S)`

**Description**

`R = spones(S)` generates a matrix `R` with the same sparsity structure as `S`, but with 1's in the nonzero positions.

**Examples**

`c = sum(spones(S))` is the number of nonzeros in each column.

`r = sum(spones(S'))'` is the number of nonzeros in each row.

`sum(c)` and `sum(r)` are equal, and are equal to `nnz(S)`.

**See Also**

`nnz`, `spalloc`, `spfun`

**Purpose** Set parameters for sparse matrix routines

**Syntax**

```
spparms('key',value)
spparms
values = spparms
[keys,values] = spparms
spparms(values)
value = spparms('key')
spparms('default')
spparms('tight')
```

**Description** spparms('key',value) sets one or more of the *tunable* parameters used in the sparse routines, particularly the minimum degree orderings, colmmd and symmmd, and also within sparse backslash. In ordinary use, you should never need to deal with this function.

The meanings of the key parameters are

|                         |                                                                                                        |
|-------------------------|--------------------------------------------------------------------------------------------------------|
| 'spumoni'               | Sparse Monitor flag:                                                                                   |
| 0                       | Produces no diagnostic output, the default                                                             |
| 1                       | Produces information about choice of algorithm based on matrix structure, and about storage allocation |
| 2                       | Also produces very detailed information about the sparse matrix algorithms                             |
| 'thr_rel',<br>'thr_abs' | Minimum degree threshold is thr_rel*mindegree + thr_abs.                                               |
| 'exact_d'               | Nonzero to use exact degrees in minimum degree. Zero to use approximate degrees.                       |
| 'supernd'               | If positive, minimum degree amalgamates the supernodes every supernd stages.                           |

# spparms

---

|           |                                                                                                                                                                                                                                                    |
|-----------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 'rreduce' | If positive, minimum degree does row reduction every rreduce stages.                                                                                                                                                                               |
| 'wh_frac' | Rows with density > wh_frac are ignored in colmmd.                                                                                                                                                                                                 |
| 'autommd' | Nonzero to use minimum degree (MMD) orderings with QR-based \ and /.                                                                                                                                                                               |
| 'autoamd' | Nonzero to use colamd ordering with the UMFPACK LU-based \ and /, and to use amd with CHOLMOD Cholesky-based \ and /.                                                                                                                              |
| 'piv_tol' | Pivot tolerance used by the UMFPACK LU-based \ and /.                                                                                                                                                                                              |
| 'bandden' | Band density used by LAPACK-based \ and / for banded matrices. Band density is defined as (# nonzeros in the band)/(# nonzeros in a full band). If bandden = 1.0, never use band solver. If bandden = 0.0, always use band solver. Default is 0.5. |
| 'umfpack' | Nonzero to use UMFPACK instead of the v4 LU-based solver in \ and /.                                                                                                                                                                               |
| 'sym_tol' | Symmetric pivot tolerance used by UMFPACK. See lu for more information about the role of the symmetric pivot tolerance.                                                                                                                            |

---

**Note** LU-based \ and / (UMFPACK) on square matrices use a modified colamd or amd. Cholesky-based \ and / (CHOLMOD) on symmetric positive definite matrices use amd. QR-based \ and / on rectangular matrices use colmmd.

---

spparms, by itself, prints a description of the current settings.

values = spparms returns a vector whose components give the current settings.

[keys,values] = spparms returns that vector, and also returns a character matrix whose rows are the keywords for the parameters.

spparms(values), with no output argument, sets all the parameters to the values specified by the argument vector.

value = spparms('key') returns the current setting of one parameter.

spparms('default') sets all the parameters to their default settings.

spparms('tight') sets the minimum degree ordering parameters to their *tight* settings, which can lead to orderings with less fill-in, but which make the ordering functions themselves use more execution time.

The key parameters for default and tight settings are

|            | <b>Keyword</b> | <b>Default</b> | <b>Tight</b> |
|------------|----------------|----------------|--------------|
| values(1)  | 'spumoni'      | 0.0            |              |
| values(2)  | 'thr_rel'      | 1.1            | 1.0          |
| values(3)  | 'thr_abs'      | 1.0            | 0.0          |
| values(4)  | 'exact_d'      | 0.0            | 1.0          |
| values(5)  | 'supernd'      | 3.0            | 1.0          |
| values(6)  | 'rreduce'      | 3.0            | 1.0          |
| values(7)  | 'wh_frac'      | 0.5            | 0.5          |
| values(8)  | 'autommd'      | 1.0            |              |
| values(9)  | 'autoamd'      | 1.0            |              |
| values(10) | 'piv_tol'      | 0.1            |              |
| values(11) | 'bandden'      | 0.5            |              |
| values(12) | 'umfpack'      | 1.0            |              |
| values(13) | 'sym_tol'      | 0.001          |              |

## Notes

### **Sparse $A \setminus b$ on Symmetric Positive Definite $A$**

Sparse  $A \setminus b$  on symmetric positive definite  $A$  uses CHOLMOD in conjunction with the amd reordering routine.

The parameter 'autoamd' turns the amd reordering on or off within the solver.

### **Sparse $A \setminus b$ on General Square $A$**

Sparse  $A \setminus b$  on general square  $A$  usually uses UMFPACK in conjunction with amd or a modified colamd reordering routine.

The parameter 'umfpack' turns the use of the UMFPACK software on or off within the solver.

If UMFPACK is used,

- The parameter 'piv\_tol' controls pivoting within the solver.
- The parameter 'autoamd' turns amd and the modified colamd on or off within the solver.

If UMFPACK is not used,

- An LU-based solver is used in conjunction with the colmmd reordering routine.
- If UMFPACK is not used, then the parameter 'autommd' turns the colmmd reordering routine on or off within the solver.
- If UMFPACK is not used and colmmd is used within the solver, then the minimum degree parameters affect the reordering routine within the solver.

### **Sparse $A \setminus b$ on Rectangular $A$**

Sparse  $A \setminus b$  on rectangular  $A$  uses a QR-based solve in conjunction with the colmmd reordering routine.

The parameter 'autommd' turns the colmmd reordering on or off within the solver.

If `colmmd` is used within the solver, then the minimum degree parameters affect the reordering routine within the solver.

**See Also**

`\`, `chol`, `lu`, `qr`, `colamdsymamd`

**References**

[1] Gilbert, John R., Cleve Moler, and Robert Schreiber, "Sparse Matrices in MATLAB: Design and Implementation," *SIAM Journal on Matrix Analysis and Applications*, Vol. 13, 1992, pp. 333-356.

[2] Davis, T. A., *UMFPACK Version 4.6 User Guide* (<http://www.cise.ufl.edu/research/sparse/umfpack/>), Dept. of Computer and Information Science and Engineering, Univ. of Florida, Gainesville, FL, 2002.

[3] Davis, T. A., *CHOLMOD Version 1.0 User Guide* (<http://www.cise.ufl.edu/research/sparse/cholmod>), Dept. of Computer and Information Science and Engineering, Univ. of Florida, Gainesville, FL, 2005.

# sprand

---

**Purpose** Sparse uniformly distributed random matrix

**Syntax**  
R = sprand(S)  
R = sprand(m,n,density)  
R = sprand(m,n,density,rc)

**Description** R = sprand(S) has the same sparsity structure as S, but uniformly distributed random entries.

R = sprand(m,n,density) is a random, m-by-n, sparse matrix with approximately  $\text{density} \cdot m \cdot n$  uniformly distributed nonzero entries ( $0 \leq \text{density} \leq 1$ ).

R = sprand(m,n,density,rc) also has reciprocal condition number approximately equal to rc. R is constructed from a sum of matrices of rank one.

If rc is a vector of length lr, where  $lr \leq \min(m,n)$ , then R has rc as its first lr singular values, all others are zero. In this case, R is generated by random plane rotations applied to a diagonal matrix with the given singular values. It has a great deal of topological and algebraic structure.

sprand uses the internal state information set with the rand function.

**See Also** sprandn, sprandsym



---

|                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|--------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Purpose</b>     | Sparse normally distributed random matrix                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| <b>Syntax</b>      | <code>R = sprandn(S)</code><br><code>R = sprandn(m,n,density)</code><br><code>R = sprandn(m,n,density,rc)</code>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| <b>Description</b> | <p><code>R = sprandn(S)</code> has the same sparsity structure as <code>S</code>, but normally distributed random entries with mean 0 and variance 1.</p> <p><code>R = sprandn(m,n,density)</code> is a random, <code>m</code>-by-<code>n</code>, sparse matrix with approximately <code>density*m*n</code> normally distributed nonzero entries (<code>0 &lt;= density &lt;= 1</code>).</p> <p><code>R = sprandn(m,n,density,rc)</code> also has reciprocal condition number approximately equal to <code>rc</code>. <code>R</code> is constructed from a sum of matrices of rank one.</p> <p>If <code>rc</code> is a vector of length <code>lr</code>, where <code>lr &lt;= min(m,n)</code>, then <code>R</code> has <code>rc</code> as its first <code>lr</code> singular values, all others are zero. In this case, <code>R</code> is generated by random plane rotations applied to a diagonal matrix with the given singular values. It has a great deal of topological and algebraic structure.</p> <p><code>sprandn</code> uses the internal state information set with the <code>randn</code> function.</p> |
| <b>See Also</b>    | <code>sprand</code> , <code>sprandsym</code>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |

# sprandsym

---

**Purpose** Sparse symmetric random matrix

**Syntax**

```
R = sprandsym(S)
R = sprandsym(n,density)
R = sprandsym(n,density,rc)
R = sprandsym(n,density,rc,kind)
```

**Description** `R = sprandsym(S)` returns a symmetric random matrix whose lower triangle and diagonal have the same structure as `S`. Its elements are normally distributed, with mean 0 and variance 1.

`R = sprandsym(n,density)` returns a symmetric random, `n`-by-`n`, sparse matrix with approximately `density*n*n` nonzeros; each entry is the sum of one or more normally distributed random samples, and  $(0 \leq \text{density} \leq 1)$ .

`R = sprandsym(n,density,rc)` returns a matrix with a reciprocal condition number equal to `rc`. The distribution of entries is nonuniform; it is roughly symmetric about 0; all are in `[-1, 1]`.

If `rc` is a vector of length `n`, then `R` has eigenvalues `rc`. Thus, if `rc` is a positive (nonnegative) vector then `R` is a positive definite matrix. In either case, `R` is generated by random Jacobi rotations applied to a diagonal matrix with the given eigenvalues or condition number. It has a great deal of topological and algebraic structure.

`R = sprandsym(n,density,rc,kind)` returns a positive definite matrix. Argument `kind` can be:

- 1 to generate `R` by random Jacobi rotation of a positive definite diagonal matrix. `R` has the desired condition number exactly.
- 2 to generate an `R` that is a shifted sum of outer products. `R` has the desired condition number only approximately, but has less structure.
- 3 to generate an `R` that has the same structure as the matrix `S` and approximate condition number `1/rc`. `density` is ignored.

**See Also** sprand, sprandn

**Purpose** Structural rank

**Syntax** `r = sprank(A)`

**Description** `r = sprank(A)` is the structural rank of the sparse matrix `A`. For all values of `A`,

```
sprank(A) >= rank(full(A))
```

In exact arithmetic, `sprank(A) == rank(full(sprandn(A)))` with a probability of one.

### Examples

```
A = [1 0 2 0
 2 0 4 0];
```

```
A = sparse(A);
```

```
sprank(A)
```

```
ans =
 2
```

```
rank(full(A))
```

```
ans =
 1
```

**See Also** `dmperm`

# sprintf

---

**Purpose** Write formatted data to string

**Syntax** `[s, errmsg] = sprintf(format, A, ...)`

**Description** `[s, errmsg] = sprintf(format, A, ...)` formats the data in matrix A (and in any additional matrix arguments) under control of the specified format string and returns it in the MATLAB string variable s. The `sprintf` function returns an error message string `errmsg` if an error occurred. `errmsg` is an empty matrix if no error occurred.

`sprintf` is the same as `fprintf` except that it returns the data in a MATLAB string variable rather than writing it to a file.

See “Formatting Strings” in the MATLAB Programming Fundamentals documentation for more detailed information on using string formatting commands.

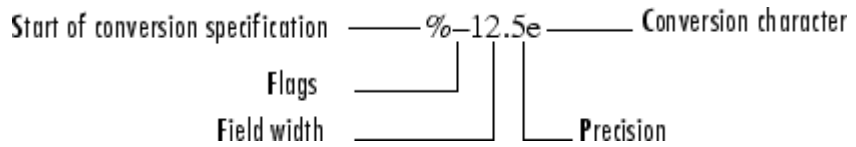
## Format String

The format argument is a string containing ordinary characters and/or C language conversion specifications. A conversion specification controls the notation, alignment, significant digits, field width, and other aspects of output format. The format string can contain escape characters to represent nonprinting characters such as newline characters and tabs.

Conversion specifications begin with the % character and contain these optional and required elements:

- Flags (optional)
- Width and precision fields (optional)
- A subtype specifier (optional)
- Conversion character (required)

You specify these elements in the following order:



### Flags

You can control the alignment of the output using any of these optional flags.

| Character        | Description                                        | Example              |
|------------------|----------------------------------------------------|----------------------|
| A minus sign (-) | Left-justifies the converted argument in its field | <code>% 5.2d</code>  |
| A plus sign (+)  | Always prints a sign character (+ or -)            | <code> %+5.2d</code> |
| Zero (0)         | Pad with zeros rather than spaces.                 | <code>%05.2f</code>  |

### Field Width and Precision Specifications

You can control the width and precision of the output by including these options in the format string.

| Character   | Description                                                                                                                                                   | Example            |
|-------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------|
| Field width | A string specifying the minimum number of characters to be printed. This includes a plus or minus sign, any leading zeros, numeric digits, and decimal point. | <code>%6f</code>   |
| Precision   | A string including a period (.) specifying the number of digits to be printed to the right of the decimal point                                               | <code>%6.2f</code> |

## Conversion Characters

Conversion characters specify the notation of the output.

| Specifier | Description                                                                        |
|-----------|------------------------------------------------------------------------------------|
| %c        | Single character                                                                   |
| %d        | Decimal notation (signed)                                                          |
| %e        | Exponential notation (using a lowercase e as in 3.1415e+00)                        |
| %E        | Exponential notation (using an uppercase E as in 3.1415E+00)                       |
| %f        | Fixed-point notation                                                               |
| %g        | The more compact of %e or %f, as defined in [2]. Insignificant zeros do not print. |
| %G        | Same as %g, but using an uppercase E                                               |
| %o        | Octal notation (unsigned)                                                          |
| %s        | String of characters                                                               |
| %u        | Decimal notation (unsigned)                                                        |
| %x        | Hexadecimal notation (using lowercase letters a–f)                                 |
| %X        | Hexadecimal notation (using uppercase letters A–F)                                 |

The following tables describe the nonalphanumeric characters found in format specification strings.

## Escape Characters

This table lists the escape character sequences you use to specify non-printing characters in a format specification.

| Character | Description |
|-----------|-------------|
| \b        | Backspace   |
| \f        | Form feed   |

| Character              | Description           |
|------------------------|-----------------------|
| \n                     | New line              |
| \r                     | Carriage return       |
| \t                     | Horizontal tab        |
| \\                     | Backslash             |
| \' (two single quotes) | Single quotation mark |
| %%                     | Percent character     |

## Remarks

The `sprintf` function behaves like its ANSI C language namesake with these exceptions and extensions.

- If you use `sprintf` to convert a MATLAB double into an integer, and the double contains a value that cannot be represented as an integer (for example, it contains a fraction), MATLAB ignores the specified conversion and outputs the value in exponential format. To successfully perform this conversion, use the `fix`, `floor`, `ceil`, or `round` functions to change the value in the double into a value that can be represented as an integer before passing it to `sprintf`.
- The following nonstandard subtype specifiers are supported for the conversion characters `%o`, `%u`, `%x`, and `%X`.

|   |                                                                                                                                                                               |
|---|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| b | The underlying C data type is a double rather than an unsigned integer. For example, to print a double-precision value in hexadecimal, use a format like <code>'%bx'</code> . |
| t | The underlying C data type is a float rather than an unsigned integer.                                                                                                        |

For example, to print a double value in hexadecimal use the format `'%bx'`.

- The `sprintf` function is vectorized for nonscalar arguments. The function recycles the format string through the elements of `A`

# sprintf

---

(columnwise) until all the elements are used up. The function then continues in a similar manner through any additional matrix arguments.

- If %s is used to print part of a nonscalar double argument, the following behavior occurs:
  - 1** Successive values are printed as long as they are integers and in the range of a valid character. The first invalid character terminates the printing for this %s specifier and is used for a later specifier. For example, pi terminates the string below and is printed using %f format.

```
Str = [65 66 67 pi];
sprintf('%s %f', Str)
ans =
ABC 3.141593
```

- 2** If the first value to print is not a valid character, then just that value is printed for this %s specifier using an e conversion as a warning to the user. For example, pi is formatted by %s below in exponential notation, and 65, though representing a valid character, is formatted as fixed-point (%f).

```
Str = [pi 65 66 67];
sprintf('%s %f %s', Str)
ans =
3.141593e+000 65.000000 BC
```

- 3** One exception is zero, which is a valid character. If zero is found first, %s prints nothing and the value is skipped. If zero is found after at least one valid character, it terminates the printing for this %s specifier and is used for a later specifier.
- sprintf prints exponents differently on some platforms, as shown in the following table:



### Exponents Printed with %e, %E, %g, or %G

| Platform | Minimum Digits in Exponent | Example   |
|----------|----------------------------|-----------|
| PC       | 3                          | 1.23e+004 |
| UNIX     | 2                          | 1.23e+04  |

You can resolve this difference in exponents by postprocessing the results of `sprintf`. For example, to make the PC output look like that of UNIX, use

```
a = sprintf('%e', 12345.678);
if ispc, a = strrep(a, 'e+0', 'e+'); end
```

### Examples

| Command                                           | Result                                      |
|---------------------------------------------------|---------------------------------------------|
| <code>sprintf('%0.5g', (1+sqrt(5))/2)</code>      | 1.618                                       |
| <code>sprintf('%0.5g', 1/eps)</code>              | 4.5036e+15                                  |
| <code>sprintf('%15.5f', 1/eps)</code>             | 4503599627370496.00000                      |
| <code>sprintf('%d', round(pi))</code>             | 3                                           |
| <code>sprintf('%s', 'hello')</code>               | hello                                       |
| <code>sprintf('The array is %dx%d.', 2, 3)</code> | The array is 2x3                            |
| <code>sprintf('\n')</code>                        | Line termination character on all platforms |

### See Also

`int2str`, `num2str`, `sscanf`

### References

[1] Kernighan, B.W., and D.M. Ritchie, *The C Programming Language, Second Edition*, Prentice-Hall, Inc., 1988.

# **sprintf**

---

[2] ANSI specification X3.159-1989: “Programming Language C,” ANSI, 1430 Broadway, New York, NY 10018.

---

|                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
|--------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Purpose</b>     | Visualize sparsity pattern                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| <b>Syntax</b>      | <pre>spy(S) spy(S,markersize) spy(S,'LineStyle') spy(S,'LineStyle',markersize)</pre>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| <b>Description</b> | <p>plots the</p> <p><code>spy(S)</code> sparsity pattern of any matrix <code>S</code>.</p> <p><code>spy(S,markersize)</code>, where <code>markersize</code> is an integer, plots the sparsity pattern using markers of the specified point size.</p> <p><code>spy(S,'LineStyle')</code>, where <code>LineStyle</code> is a string, uses the specified plot marker type and color.</p> <p><code>spy(S,'LineStyle',markersize)</code> uses the specified type, color, and size for the plot markers.</p> <p><code>S</code> is usually a sparse matrix, but full matrices are acceptable, in which case the locations of the nonzero elements are plotted.</p> |

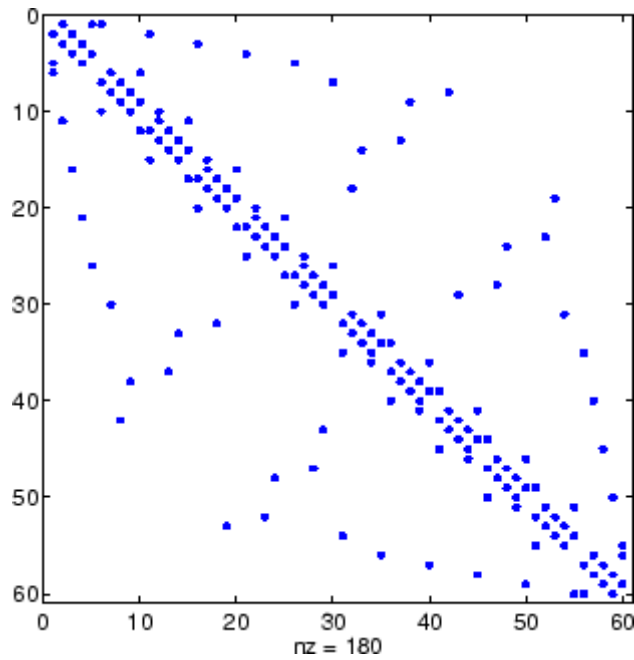
---

**Note** `spy` replaces `format +`, which takes much more space to display essentially the same information.

---

**Examples** This example plots the 60-by-60 sparse adjacency matrix of the connectivity graph of the Buckminster Fuller geodesic dome. This matrix also represents the soccer ball and the carbon-60 molecule.

```
B = bucky;
spy(B)
```



**See Also**

find, gplot, LineSpec, symamd, symrcm

**Purpose** Square root

**Syntax** `B = sqrt(X)`

**Description** `B = sqrt(X)` returns the square root of each element of the array `X`. For the elements of `X` that are negative or complex, `sqrt(X)` produces complex results.

**Remarks** See `sqrtm` for the matrix square root.

**Examples**

```
sqrt((-2:2)')
ans =
 0 + 1.4142i
 0 + 1.0000i
 0
 1.0000
 1.4142
```

**See Also** `sqrtm`, `realsqrt`

# sqrtm

---

**Purpose** Matrix square root

**Syntax**  
 $X = \text{sqrtm}(A)$   
 $[X, \text{resnorm}] = \text{sqrtm}(A)$   
 $[X, \alpha, \text{condest}] = \text{sqrtm}(A)$

**Description**  $X = \text{sqrtm}(A)$  is the principal square root of the matrix  $A$ , i.e.  $X^*X = A$ .

$X$  is the unique square root for which every eigenvalue has nonnegative real part. If  $A$  has any eigenvalues with negative real parts then a complex result is produced. If  $A$  is singular then  $A$  may not have a square root. A warning is printed if exact singularity is detected.

$[X, \text{resnorm}] = \text{sqrtm}(A)$  does not print any warning, and returns the residual,  $\text{norm}(A - X^2, 'fro') / \text{norm}(A, 'fro')$ .

$[X, \alpha, \text{condest}] = \text{sqrtm}(A)$  returns a stability factor  $\alpha$  and an estimate  $\text{condest}$  of the matrix square root condition number of  $X$ . The residual  $\text{norm}(A - X^2, 'fro') / \text{norm}(A, 'fro')$  is bounded approximately by  $n * \alpha * \text{eps}$  and the Frobenius norm relative error in  $X$  is bounded approximately by  $n * \alpha * \text{condest} * \text{eps}$ , where  $n = \max(\text{size}(A))$ .

**Remarks** If  $X$  is real, symmetric and positive definite, or complex, Hermitian and positive definite, then so is the computed matrix square root.

Some matrices, like  $X = \begin{bmatrix} 0 & 1 \\ 0 & 0 \end{bmatrix}$ , do not have any square roots, real or complex, and `sqrtm` cannot be expected to produce one.

**Examples** **Example 1**

A matrix representation of the fourth difference operator is

$$X = \begin{bmatrix} 5 & -4 & 1 & 0 & 0 \\ -4 & 6 & -4 & 1 & 0 \\ 1 & -4 & 6 & -4 & 1 \\ 0 & 1 & -4 & 6 & -4 \\ 0 & 0 & 1 & -4 & 5 \end{bmatrix}$$

This matrix is symmetric and positive definite. Its unique positive definite square root,  $Y = \text{sqrtm}(X)$ , is a representation of the second difference operator.

$$Y = \begin{bmatrix} 2 & -1 & -0 & -0 & -0 \\ -1 & 2 & -1 & 0 & -0 \\ 0 & -1 & 2 & -1 & 0 \\ -0 & 0 & -1 & 2 & -1 \\ -0 & -0 & -0 & -1 & 2 \end{bmatrix}$$

### Example 2

The matrix

$$X = \begin{bmatrix} 7 & 10 \\ 15 & 22 \end{bmatrix}$$

has four square roots. Two of them are

$$Y1 = \begin{bmatrix} 1.5667 & 1.7408 \\ 2.6112 & 4.1779 \end{bmatrix}$$

and

$$Y2 = \begin{bmatrix} 1 & 2 \\ 3 & 4 \end{bmatrix}$$

The other two are  $-Y1$  and  $-Y2$ . All four can be obtained from the eigenvalues and vectors of  $X$ .

$$[V,D] = \text{eig}(X);$$

$$D = \begin{bmatrix} 0.1386 & 0 \\ 0 & 28.8614 \end{bmatrix}$$

## sqrtm

---

The four square roots of the diagonal matrix D result from the four choices of sign in

$$S = \begin{pmatrix} -0.3723 & 0 \\ 0 & -5.3723 \end{pmatrix}$$

All four Ys are of the form

$$Y = V*S/V$$

The sqrtm function chooses the two plus signs and produces Y1, even though Y2 is more natural because its entries are integers.

### See Also

expm, funm, logm



**Purpose** Remove singleton dimensions

**Syntax** `B = squeeze(A)`

**Description** `B = squeeze(A)` returns an array `B` with the same elements as `A`, but with all singleton dimensions removed. A singleton dimension is any dimension for which `size(A,dim) = 1`. Two-dimensional arrays are unaffected by `squeeze`; if `A` is a row or column vector or a scalar (1-by-1) value, then `B = A`.

**Examples** Consider the 2-by-1-by-3 array `Y = rand(2,1,3)`. This array has a singleton column dimension — that is, there's only one column per page.

`Y =`

```
Y(:,:,1) = Y(:,:,2) =
 0.5194 0.0346
 0.8310 0.0535
```

```
Y(:,:,3) =
 0.5297
 0.6711
```

The command `Z = squeeze(Y)` yields a 2-by-3 matrix:

```
Z =
 0.5194 0.0346 0.5297
 0.8310 0.0535 0.6711
```

Consider the 1-by-1-by-5 array `mat= repmat(1,[1,1,5])`. This array has only one scalar value per page.

`mat =`

```
mat(:,:,1) = mat(:,:,2) =
 1 1
```

# squeeze

---

```
mat(:,:,3) = mat(:,:,4) =
```

```
 1 1
```

```
mat(:,:,5) =
```

```
 1
```

The command `squeeze(mat)` yields a 5-by-1 matrix:

```
squeeze(mat)
```

```
ans =
```

```
 1
 1
 1
 1
 1
```

```
size(squeeze(mat))
```

```
ans =
```

```
 5 1
```

## See Also

`reshape`, `shiftdim`

**Purpose** Convert state-space filter parameters to transfer function form

**Syntax** `[b,a] = ss2tf(A,B,C,D,iu)`

**Description** `ss2tf` converts a state-space representation of a given system to an equivalent transfer function representation.

`[b,a] = ss2tf(A,B,C,D,iu)` returns the transfer function

$$H(s) = \frac{B(s)}{A(s)} = C(sI - A)^{-1}B + D$$

of the system

$$\dot{x} = Ax + Bu$$

$$y = Cx + Du$$

from the `iu`-th input. Vector `a` contains the coefficients of the denominator in descending powers of  $s$ . The numerator coefficients are returned in array `b` with as many rows as there are outputs  $y$ . `ss2tf` also works with systems in discrete time, in which case it returns the  $z$ -transform representation.

The `ss2tf` function is part of the standard MATLAB language.

**Algorithm** The `ss2tf` function uses `poly` to find the characteristic polynomial  $\det(sI - A)$  and the equality:

$$H(s) = C(sI - A)^{-1}B = \frac{\det(sI - A + BC) - \det(sI - A)}{\det(sI - A)}$$

# sscanf

---

**Purpose** Read formatted data from string

**Syntax**  
`A = sscanf(s, format)`  
`A = sscanf(s, format, size)`  
`[A, count, errmsg, nextindex] = sscanf(...)`

**Description** `A = sscanf(s, format)` reads data from the MATLAB string `s`, converts it according to the specified format string, and returns it in matrix `A`. `format` is a string specifying the format of the data to be read. See "Remarks" for details. `sscanf` is the same as `fscanf` except that it reads the data from a MATLAB string rather than reading it from a file. If `s` is a character array with more than one row, `sscanf` reads the characters in column order.

`A = sscanf(s, format, size)` reads the amount of data specified by `size` and converts it according to the specified format string. `size` is an argument that determines how much data is read. Valid options are

|                    |                                                                                                                                                                                         |
|--------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <code>n</code>     | Read at most <code>n</code> numbers, characters, or strings.                                                                                                                            |
| <code>inf</code>   | Read to the end of the input string.                                                                                                                                                    |
| <code>[m,n]</code> | Read at most $(m*n)$ numbers, characters, or strings. Fill a matrix of at most <code>m</code> rows in column order. <code>n</code> can be <code>inf</code> , but <code>m</code> cannot. |

Characteristics of the output matrix `A` depend on the values read from the input string and on the `size` argument. If `sscanf` reads only numbers, and if `size` is not of the form `[m,n]`, matrix `A` is a column vector of numbers. If `sscanf` reads only characters or strings, and if `size` is not of the form `[m,n]`, matrix `A` is a row vector of characters. See the Remarks section for more information.

`sscanf` differs from its C language namesake `scanf()` in an important respect — it is *vectorized* to return a matrix argument. The format string is cycled through the input string until the first of these conditions occurs:

- The format string fails to match the data in the input string

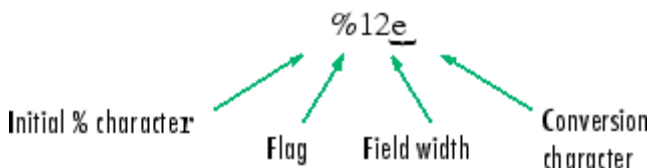
- The amount of data specified by `size` is read
- The end of the string is reached

`[A, count, errmsg, nextindex] = sscanf(...)` reads data from the MATLAB string (character array) `s`, converts it according to the specified format string, and returns it in matrix `A`. `count` is an optional output argument that returns the number of values successfully read. `errmsg` is an optional output argument that returns an error message string if an error occurred or an empty string if an error did not occur. `nextindex` is an optional output argument specifying one more than the number of characters scanned in `s`.

## Remarks

When MATLAB reads a specified string, it attempts to match the data in the input string to the format string. If a match occurs, the data is written into the output matrix. If a partial match occurs, only the matching data is written to the matrix, and the read operation stops.

The format string consists of ordinary characters and/or conversion specifications. Conversion specifications indicate the type of data to be matched and involve the character `%`, optional width fields, and conversion characters, organized as shown below:



Add one or more of these characters between the `%` and the conversion character.

|                 |                                                                                                                                                                                  |
|-----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| An asterisk (*) | Skip over the matched value and do not store it in the output matrix                                                                                                             |
| A digit string  | Maximum field width                                                                                                                                                              |
| A letter        | The size of the receiving object; for example, h for short, as in %hd for a short integer, or l for long, as in %ld for a long integer or %lg for a double floating-point number |

Valid conversion characters are as shown.

|            |                                                                                                                              |
|------------|------------------------------------------------------------------------------------------------------------------------------|
| %c         | Sequence of characters; number specified by field width                                                                      |
| %d         | Base 10 integers                                                                                                             |
| %e, %f, %g | Floating-point numbers                                                                                                       |
| %i         | Defaults to signed base 10 integers. Data starting with 0 is read as base 8. Data starting with 0x or 0X is read as base 16. |
| %o         | Signed octal integer returned as unsigned                                                                                    |
| %s         | A series of non-white-space characters                                                                                       |
| %u         | Unsigned decimal                                                                                                             |
| %x         | Signed hexadecimal integer returned as unsigned                                                                              |
| [...]      | Sequence of characters (scanlist)                                                                                            |

Format specifiers %e, %f, and %g accept the text 'inf', '-inf', 'nan', and '-nan'. This text is not case sensitive. The sscanf function converts these to the numeric representation of Inf, -Inf, NaN, and -NaN.

Use %c to read space characters, or %s to skip all white space.

For more information about format strings, refer to the scanf() and fscanf() routines in a C language reference manual.

### Output Characteristics: Only Numeric Values Read

Format characters that cause `sscanf` to read numbers from the input string are `%d`, `%e`, `%f`, `%g`, `%i`, `%o`, `%u`, and `%x`. When `sscanf` reads only numbers from the input string, the elements of the output matrix `A` are numbers.

When there is no `size` argument or the `size` argument is `inf`, `sscanf` reads to the end of the input string. The output matrix is a column vector with one element for each number read from the input.

When the `size` argument is a scalar `n`, `sscanf` reads at most `n` numbers from the input string. The output matrix is a column vector with one element for each number read from the input.

When the `size` argument is a matrix `[m,n]`, `sscanf` reads at most  $(m*n)$  numbers from the input string. The output matrix contains at most `m` rows and `n` columns. `sscanf` fills the output matrix in column order, using as many columns as it needs to contain all the numbers read from the input. Any unfilled elements in the final column contain zeros.

### Output Characteristics: Only Character Values Read

The format characters that cause `sscanf` to read characters and strings from the input string are `%c` and `%s`. When `sscanf` reads only characters and strings from the input string, the elements of the output matrix `A` are characters. When `sscanf` reads a string from the input, the output matrix includes one element for each character in the string.

When there is no `size` argument or the `size` argument is `inf`, `sscanf` reads to the end of the input string. The output matrix is a row vector with one element for each character read from the input.

When the `size` argument is a scalar `n`, `sscanf` reads at most `n` character or string values from the input string. The output matrix is a row vector with one element for each character read from the input. When string values are read from the input, the output matrix can contain more than `n` columns.

When the `size` argument is a matrix `[m,n]`, `sscanf` reads at most  $(m*n)$  character or string values from the input string. The output

matrix contains at most  $m$  rows. `sscanf` fills the output matrix in column order, using as many columns as it needs to contain all the characters read from the input. When string values are read from the input, the output matrix can contain more than  $n$  columns. Any unfilled elements in the final column contain `char(0)`.

## **Output Characteristics: Both Numeric and Character Values Read**

When `sscanf` reads a combination of numbers and either characters or strings from the input string, the elements of the output matrix  $A$  are numbers. This is true even when a format specifier such as `'%*d %s'` tells MATLAB to ignore numbers in the input string and output only characters or strings. When `sscanf` reads a string from the input, the output matrix includes one element for each character in the string. All characters are converted to their numeric equivalents in the output matrix.

When there is no `size` argument or the `size` argument is `inf`, `sscanf` reads to the end of the input string. The output matrix is a column vector with one element for each character read from the input.

When the `size` argument is a scalar  $n$ , `sscanf` reads at most  $n$  number, character, or string values from the input string. The output matrix contains at most  $n$  rows. `sscanf` fills the output matrix in column order, using as many columns as it needs to represent all the numbers and characters read from the input. When string values are read from the input, the output matrix can contain more than one column. Any unfilled elements in the final column contain zeros.

When the `size` argument is a matrix  $[m,n]$ , `sscanf` reads at most  $(m*n)$  number, character, or string values from the input string. The output matrix contains at most  $m$  rows. `sscanf` fills the output matrix in column order, using as many columns as it needs to represent all the numbers and characters read from the input. When string values are read from the input, the output matrix can contain more than  $n$  columns. Any unfilled elements in the final column contain zeros.



---

**Note** This section applies only when `sscanf` actually reads a combination of numbers and either characters or strings from the input string. Even if the format string has both format characters that would result in numbers (such as `%d`) and format characters that would result in characters or strings (such as `%s`), `sscanf` might actually read only numbers or only characters or strings. If `sscanf` reads only numbers, see “Output Characteristics: Only Numeric Values Read” on page 2-3379. If `sscanf` reads only characters or strings, see “Output Characteristics: Only Character Values Read” on page 2-3379.

---

## Examples

### Example 1

The statements

```
s = '2.7183 3.1416';
A = sscanf(s, '%f')
```

create a two-element vector containing poor approximations to `e` and `pi`.

### Example 2

When using the `%i` conversion specifier, `sscanf` reads data starting with 0 as base 8 and returns the converted value as signed:

```
sscanf('-010', '%i')
ans =
 -8
```

When using `%o`, on the other hand, `sscanf` returns the converted value as unsigned:

```
sscanf('-010', '%o')
ans =
 4.2950e+009
```

### Example 3

Create character array `A` representing both character and numeric data:

# sscanf

---

```
A = ['abc 46 6 ghi'; 'def 7 89 jkl']
A =
 abc 46 6 ghi
 def 7 89 jkl
```

Read A into 2-by-N matrix B, ignoring the character data. As stated in the Description section, `sscanf` reads the characters in A in column order, filling matrix B in column order:

```
B = sscanf(A, '%*s %d %d %*s', [2, inf])
B =
 476
 869
```

If you want `sscanf` to return the numeric data in B in the same order as in A, you can use this technique:

```
for k = 1:2
 C(k,:) = sscanf(A(k, :)', '%*s %d %d %*s', [1, inf]);
end

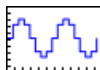
C
C =
 46 6
 7 89
```


## See Also

`eval`, `sprintf`, `textread`

**Purpose**

Stairstep graph

**GUI Alternatives**

To graph selected variables, use the Plot Selector  in the Workspace Browser, or use the Figure Palette Plot Catalog. Manipulate graphs in *plot edit* mode with the Property Editor. For details, see Plotting Tools — Interactive Plotting in the MATLAB Graphics documentation and Creating Graphics from the Workspace Browser in the MATLAB Desktop Tools documentation.

**Syntax**

```
stairs(Y)
stairs(X,Y)
stairs(...,LineStyle)
stairs(...,'PropertyName',propertyvalue)
stairs(axes_handle,...)
h = stairs(...)
[xb,yb] = stairs(Y,...)
hlines = stairs('v6',...)
```

**Description**

Stairstep graphs are useful for drawing time-history graphs of digitally sampled data.

`stairs(Y)` draws a stairstep graph of the elements of `Y`, drawing one line per column for matrices. The axes `ColorOrder` property determines the color of the lines.

When `Y` is a vector, the `x`-axis scale ranges from 1 to `length(Y)`. When `Y` is a matrix, the `x`-axis scale ranges from 1 to the number of rows in `Y`.

`stairs(X,Y)` plots the elements in `Y` at the locations specified in `X`.

`X` must be the same size as `Y` or, if `Y` is a matrix, `X` can be a row or a column vector such that

```
length(X) = size(Y,1)
```

# stairs

---

`stairs(...,LineStyle)` specifies a line style, marker symbol, and color for the graph. (See `LineStyle` for more information.)

`stairs(..., 'PropertyName', propertyvalue)` creates the stairstep graph, applying the specified property settings. See `Stairseries` properties for a description of properties.

`stairs(axes_handle,...)` plots into the axes with the handle `axes_handle` instead of into the current axes object (`gca`).

`h = stairs(...)` returns the handles of the stairseries objects created (one per matrix column).

`[xb,yb] = stairs(Y,...)` does not draw graphs, but returns vectors `xb` and `yb` such that `plot(xb,yb)` plots the stairstep graph.

## Backward-Compatible Version

`hlines = stairs('v6',...)` returns the handles of line objects instead of stairseries objects for compatibility with MATLAB 6.5 and earlier.

---

**Note** The `v6` option enables users of Version 7.x of MATLAB to create FIG-files that previous versions can open. It is obsolete and will be removed in a future version of MATLAB.

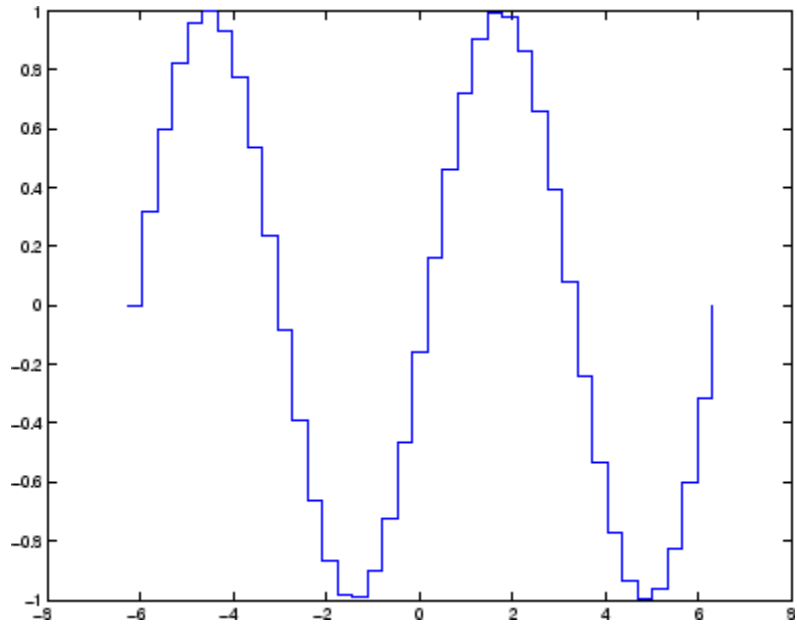
---

See [Plot Objects and Backward Compatibility](#) for more information.

## Examples

Create a stairstep plot of a sine wave.

```
x = linspace(-2*pi,2*pi,40);
stairs(x,sin(x))
```



**See Also**

bar, hist, stem

“Discrete Data Plots” on page 1-96 for related functions

Stairseries Properties for property descriptions

# Stairseries Properties

---

**Purpose** Define stairseries properties

**Modifying Properties** You can set and query graphics object properties using the set and get commands or the Property Editor (propertyeditor).

Note that you cannot define default property values for stairseries objects.

See Plot Objects for information on stairseries objects.

**Stairseries Property Descriptions** This section provides a description of properties. Curly braces { } enclose default values.

Annotation  
hg.Annotation object Read Only

*Control the display of stairseries objects in legends.* The Annotation property enables you to specify whether this stairseries object is represented in a figure legend.

Querying the Annotation property returns the handle of an hg.Annotation object. The hg.Annotation object has a property called LegendInformation, which contains an hg.LegendEntry object.

Once you have obtained the hg.LegendEntry object, you can set its IconDisplayStyle property to control whether the stairseries object is displayed in a figure legend:

| IconDisplayStyle Value | Purpose                                                                               |
|------------------------|---------------------------------------------------------------------------------------|
| on                     | Include the stairseries object in a legend as one entry, but not its children objects |

| IconDisplayStyle Value | Purpose                                                                        |
|------------------------|--------------------------------------------------------------------------------|
| off                    | Do not include the stairseries or its children in a legend (default)           |
| children               | Include only the children of the stairseries as separate entries in the legend |

## Setting the IconDisplayStyle Property

These commands set the `IconDisplayStyle` of a graphics object with handle `hobj` to `children`, which causes each child object to have an entry in the legend:

```
hAnnotation = get(hobj, 'Annotation');
hLegendEntry = get(hAnnotation, 'LegendInformation');
set(hLegendEntry, 'IconDisplayStyle', 'children')
```

## Using the IconDisplayStyle Property

See “Controlling Legends” for more information and examples.

### BeingDeleted

on | {off} Read Only

*This object is being deleted.* The `BeingDeleted` property provides a mechanism that you can use to determine if objects are in the process of being deleted. MATLAB sets the `BeingDeleted` property to `on` when the object’s delete function callback is called (see the `DeleteFcn` property). It remains set to `on` while the delete function executes, after which the object no longer exists.

For example, an object’s delete function might call other functions that act on a number of different objects. These functions might not need to perform actions on objects if the objects are going to be deleted, and therefore, can check the object’s `BeingDeleted` property before acting.

# Stairseries Properties

---

## BusyAction

cancel | {queue}

*Callback routine interruption.* The `BusyAction` property enables you to control how MATLAB handles events that potentially interrupt executing callbacks. If there is a callback function executing, callbacks invoked subsequently always attempt to interrupt it.

If the `Interruptible` property of the object whose callback is executing is set to `on` (the default), then interruption occurs at the next point where the event queue is processed. If the `Interruptible` property is `off`, the `BusyAction` property (of the object owning the executing callback) determines how MATLAB handles the event. The choices are

- `cancel` — Discard the event that attempted to execute a second callback routine.
- `queue` — Queue the event that attempted to execute a second callback routine until the current callback finishes.

## ButtonDownFcn

string or function handle

*Button press callback function.* A callback that executes whenever you press a mouse button while the pointer is over this object, but not over another graphics object. See the `HitTestArea` property for information about selecting objects of this type.

See the figure's `SelectionType` property to determine if modifier keys were also pressed.

This property can be

- A string that is a valid MATLAB expression
- The name of an M-file



- A function handle

Set this property to a function handle that references the callback. The expressions execute in the MATLAB workspace.

See “Function Handle Callbacks” for information on how to use function handles to define the callbacks.

The expression executes in the MATLAB workspace.

See Function Handle Callbacks for information on how to use function handles to define the callbacks.

## Children

array of graphics object handles

*Children of this object.* The handle of a patch object that is the child of this object (whether visible or not).

Note that if a child object’s `HandleVisibility` property is set to `callback` or `off`, its handle does not show up in this object’s `Children` property unless you set the root `ShowHiddenHandles` property to `on`:

```
set(0, 'ShowHiddenHandles', 'on')
```

## Clipping

{on} | off

*Clipping mode.* MATLAB clips graphs to the axes plot box by default. If you set `Clipping` to `off`, portions of graphs can be displayed outside the axes plot box. This can occur if you create a plot object, set `hold` to `on`, freeze axis scaling (`axis manual`), and then create a larger plot object.

## Color

ColorSpec

# Stairseries Properties

---

*Color of the object.* A three-element RGB vector or one of the MATLAB predefined names, specifying the object's color.

See the `ColorSpec` reference page for more information on specifying color.

## `CreateFcn`

string or function handle

*Callback routine executed during object creation.* This property defines a callback that executes when MATLAB creates an object. You must specify the callback during the creation of the object. For example,

```
area(y, 'CreateFcn', @CallbackFcn)
```

where `@CallbackFcn` is a function handle that references the callback function.

MATLAB executes this routine after setting all other object properties. Setting this property on an existing object has no effect.

The handle of the object whose `CreateFcn` is being executed is accessible only through the root `CallbackObject` property, which you can query using `gcbo`.

See “Function Handle Callbacks” for information on how to use function handles to define the callback function.

## `DeleteFcn`

string or function handle

*Callback executed during object deletion.* A callback that executes when this object is deleted (e.g., this might happen when you issue a `delete` command on the object, its parent axes, or the figure containing it). MATLAB executes the callback before destroying

the object's properties so the callback routine can query these values.

The handle of the object whose `DeleteFcn` is being executed is accessible only through the root `CallbackObject` property, which can be queried using `gcbo`.

See “Function Handle Callbacks” for information on how to use function handles to define the callback function.

See the `BeingDeleted` property for related information.

### `DisplayName`

string (default is empty string)

*String used by legend for this stairseries object.* The legend function uses the string defined by the `DisplayName` property to label this stairseries object in the legend.

- If you specify string arguments with the `legend` function, `DisplayName` is set to this stairseries object's corresponding string and that string is used for the legend.
- If `DisplayName` is empty, legend creates a string of the form, `['data' n]`, where *n* is the number assigned to the object based on its location in the list of legend entries. However, legend does not set `DisplayName` to this string.
- If you edit the string directly in an existing legend, `DisplayName` is set to the edited string.
- If you specify a string for the `DisplayName` property and create the legend using the figure toolbar, then MATLAB uses the string defined by `DisplayName`.
- To add programmatically a legend that uses the `DisplayName` string, call `legend` with the `toggle` or `show` option.

See “Controlling Legends” for more examples.

# Stairseries Properties

---

EraseMode

{normal} | none | xor | background

*Erase mode.* This property controls the technique MATLAB uses to draw and erase objects and their children. Alternative erase modes are useful for creating animated sequences, where control of the way individual objects are redrawn is necessary to improve performance and obtain the desired effect.

- **normal** — Redraw the affected region of the display, performing the three-dimensional analysis necessary to ensure that all objects are rendered correctly. This mode produces the most accurate picture, but is the slowest. The other modes are faster, but do not perform a complete redraw and are therefore less accurate.
- **none** — Do not erase objects when they are moved or destroyed. While the objects are still visible on the screen after erasing with EraseMode none, you cannot print these objects because MATLAB stores no information about their former locations.
- **xor** — Draw and erase the object by performing an exclusive OR (XOR) with each pixel index of the screen behind it. Erasing the object does not damage the color of the objects behind it. However, the color of the erased object depends on the color of the screen behind it and it is correctly colored only when it is over the axes background color (or the figure background color if the axes Color property is set to none). That is, it isn't erased correctly if there are objects behind it.
- **background** — Erase the graphics objects by redrawing them in the axes background color, (or the figure background color if the axes Color property is set to none). This damages other graphics objects that are behind the erased object, but the erased object is always properly colored.

## Printing with Nonnormal Erase Modes

MATLAB always prints figures as if the `EraseMode` of all objects is `normal`. This means graphics objects created with `EraseMode` set to `none`, `xor`, or `background` can look different on screen than on paper. On screen, MATLAB can mathematically combine layers of colors (e.g., performing an XOR on a pixel color with that of the pixel behind it) and ignore three-dimensional sorting to obtain greater rendering speed. However, these techniques are not applied to the printed output.

Set the axes background color with the axes `Color` property. Set the figure background color with the figure `Color` property.

You can use the MATLAB `getframe` command or other screen capture applications to create an image of a figure containing nonnormal mode objects.

## `HandleVisibility`

`{on} | callback | off`

*Control access to object's handle by command-line users and GUIs.* This property determines when an object's handle is visible in its parent's list of children. `HandleVisibility` is useful for preventing command-line users from accidentally accessing objects that you need to protect for some reason.

- `on` — Handles are always visible when `HandleVisibility` is `on`.
- `callback` — Setting `HandleVisibility` to `callback` causes handles to be visible from within callback routines or functions invoked by callback routines, but not from within functions invoked from the command line. This provides a means to protect GUIs from command-line users, while allowing callback routines to have access to object handles.
- `off` — Setting `HandleVisibility` to `off` makes handles invisible at all times. This might be necessary when a callback invokes a function that might potentially damage the GUI (such as evaluating a user-typed string) and so temporarily hides its own handles during the execution of that function.

# Stairseries Properties

---

## Functions Affected by Handle Visibility

When a handle is not visible in its parent's list of children, it cannot be returned by functions that obtain handles by searching the object hierarchy or querying handle properties. This includes `get`, `findobj`, `gca`, `gcf`, `gco`, `newplot`, `cla`, `clf`, and `close`.

## Properties Affected by Handle Visibility

When a handle's visibility is restricted using `callback` or `off`, the object's handle does not appear in its parent's `Children` property, figures do not appear in the root's `CurrentFigure` property, objects do not appear in the root's `CallbackObject` property or in the figure's `CurrentObject` property, and axes do not appear in their parent's `CurrentAxes` property.

## Overriding Handle Visibility

You can set the root `ShowHiddenHandles` property to `on` to make all handles visible regardless of their `HandleVisibility` settings (this does not affect the values of the `HandleVisibility` properties). See also `findall`.

## Handle Validity

Handles that are hidden are still valid. If you know an object's handle, you can `set` and `get` its properties and pass it to any function that operates on handles.

---

**Note** If you change one data source property to a variable that contains data of a different dimension, you might cause the function to generate a warning and not render the graph until you have changed all data source properties to appropriate values.

---

## HitTest

{on} | off

*Selectable by mouse click.* HitTest determines whether this object can become the current object (as returned by the `gco` command and the figure `CurrentObject` property) as a result of a mouse click on the objects that compose the area graph. If HitTest is off, clicking this object selects the object below it (which is usually the axes containing it).

## HitTestArea

on | {off}

*Select the object by clicking lines or area of extent.* This property enables you to select plot objects in two ways:

- Select by clicking lines or markers (default).
- Select by clicking anywhere in the extent of the plot.

When HitTestArea is off, you must click the object's lines or markers (excluding the baseline, if any) to select the object. When HitTestArea is on, you can select this object by clicking anywhere within the extent of the plot (i.e., anywhere within a rectangle that encloses it).

## Interruptible

{on} | off

*Callback routine interruption mode.* The Interruptible property controls whether an object's callback can be interrupted by callbacks invoked subsequently.

Only callbacks defined for the `ButtonDownFcn` property are affected by the Interruptible property. MATLAB checks for events that can interrupt a callback only when it encounters a `drawnow`, `figure`, `getframe`, or `pause` command in the routine. See the `BusyAction` property for related information.

# Stairseries Properties

---

Setting `Interruptible` to on allows any graphics object's callback to interrupt callback routines originating from a bar property. Note that MATLAB does not save the state of variables or the display (e.g., the handle returned by the `gca` or `gcf` command) when an interruption occurs.

## LineStyle

{-} | - | : | -. | none

*Line style.* This property specifies the line style of the object. Available line styles are shown in the following table.

| Specifier String | Line Style           |
|------------------|----------------------|
| -                | Solid line (default) |
| --               | Dashed line          |
| :                | Dotted line          |
| -.               | Dash-dot line        |
| none             | No line              |

You can use `LineStyle none` when you want to place a marker at each point but do not want the points connected with a line (see the `Marker` property).

## LineWidth

scalar

*The width of linear objects and edges of filled areas.* Specify this value in points (1 point =  $\frac{1}{72}$  inch). The default `LineWidth` is 0.5 points.

## Marker

character (see table)

*Marker symbol.* The `Marker` property specifies the type of markers that are displayed at plot vertices. You can set values for the



Marker property independently from the `LineStyle` property. Supported markers include those shown in the following table.

| Marker Specifier | Description                   |
|------------------|-------------------------------|
| +                | Plus sign                     |
| o                | Circle                        |
| *                | Asterisk                      |
| .                | Point                         |
| x                | Cross                         |
| s                | Square                        |
| d                | Diamond                       |
| ^                | Upward-pointing triangle      |
| v                | Downward-pointing triangle    |
| >                | Right-pointing triangle       |
| <                | Left-pointing triangle        |
| p                | Five-pointed star (pentagram) |
| h                | Six-pointed star (hexagram)   |
| none             | No marker (default)           |

#### MarkerEdgeColor

`ColorSpec` | none | {auto}

*Marker edge color.* The color of the marker or the edge color for filled markers (circle, square, diamond, pentagram, hexagram, and the four triangles). `ColorSpec` defines the color to use. `none` specifies no color, which makes nonfilled markers invisible. `auto` sets `MarkerEdgeColor` to the same color as the `Color` property.

#### MarkerFaceColor

`ColorSpec` | {none} | auto

# Stairseries Properties

---

*Marker face color.* The fill color for markers that are closed shapes (circle, square, diamond, pentagram, hexagram, and the four triangles). `ColorSpec` defines the color to use. `none` makes the interior of the marker transparent, allowing the background to show through. `auto` sets the fill color to the axes color, or to the figure color if the axes `Color` property is set to `none` (which is the factory default for axes objects).

`MarkerSize`  
size in points

*Marker size.* A scalar specifying the size of the marker in points. The default value for `MarkerSize` is 6 points (1 point = 1/72 inch). Note that MATLAB draws the point marker (specified by the `'.'` symbol) at one-third the specified size.

`Parent`  
handle of parent axes, `hggroup`, or `hgtransform`

*Parent of this object.* This property contains the handle of the object's parent. The parent is normally the axes, `hggroup`, or `hgtransform` object that contains the object.

See “Objects That Can Contain Other Objects” for more information on parenting graphics objects.

`Selected`  
on | {off}

*Is object selected?* When you set this property to `on`, MATLAB displays selection "handles" at the corners and midpoints if the `SelectionHighlight` property is also `on` (the default). You can, for example, define the `ButtonDownFcn` callback to set this property to `on`, thereby indicating that this particular object is selected. This property is also set to `on` when an object is manually selected in plot edit mode.

`SelectionHighlight`  
{on} | off

*Objects are highlighted when selected.* When the Selected property is on, MATLAB indicates the selected state by drawing four edge handles and four corner handles. When SelectionHighlight is off, MATLAB does not draw the handles except when in plot edit mode and objects are selected manually.

Tag

string

*User-specified object label.* The Tag property provides a means to identify graphics objects with a user-specified label. This is particularly useful when you are constructing interactive graphics programs that would otherwise need to define object handles as global variables or pass them as arguments between callbacks. You can define Tag as any string.

For example, you might create an areaseries object and set the Tag property.

```
t = area(Y, 'Tag', 'area1')
```

When you want to access objects of a given type, you can use findobj to find the object's handle. The following statement changes the FaceColor property of the object whose Tag is area1.

```
set(findobj('Tag', 'area1'), 'FaceColor', 'red')
```

Type

string (read only)

*Type of graphics object.* This property contains a string that identifies the class of the graphics object. For stairseries objects, Type is 'hggroup'. The following statement finds all the hggroup objects in the current axes object.

```
t = findobj(gca, 'Type', 'hggroup');
```

# Stairseries Properties

---

## UIContextMenu

handle of a uicontextmenu object

*Associate a context menu with this object.* Assign this property the handle of a uicontextmenu object created in the object's parent figure. Use the uicontextmenu function to create the context menu. MATLAB displays the context menu whenever you right-click over the object.

## UserData

array

*User-specified data.* This property can be any data you want to associate with this object (including cell arrays and structures). The object does not set values for this property, but you can access it using the set and get functions.

## Visible

{on} | off

*Visibility of this object and its children.* By default, a new object's visibility is on. This means all children of the object are visible unless the child object's Visible property is set to off. Setting an object's Visible property to off prevents the object from being displayed. However, the object still exists and you can set and query its properties.

## XData

array

*X-axis location of stairs.* The stairs function uses XData to label the  $x$ -axis. XData can be either a matrix equal in size to YData or a vector equal in length to the number of rows in YData. That is,  $\text{length}(\text{XData}) == \text{size}(\text{YData}, 1)$ .

If you do not specify XData (i.e., the input argument  $x$ ), the stairs function uses the indices of YData to create the stairstep graph. See the XDataMode property for related information.

## XDataMode

{auto} | manual

*Use automatic or user-specified x-axis values.* If you specify XData (by setting the XData property or specifying the x input argument), MATLAB sets this property to manual and uses the specified values to label the x-axis.

If you set XDataMode to auto after having specified XData, MATLAB resets the x-axis ticks to 1:size(YData,1) or to the column indices of the ZData, overwriting any previous values for XData.

## XDataSource

string (MATLAB variable)

*Link XData to MATLAB variable.* Set this property to a MATLAB variable that is evaluated in the base workspace to generate the XData.

MATLAB reevaluates this property only when you set it. Therefore, a change to workspace variables appearing in an expression does not change XData.

You can use the refreshdata function to force an update of the object's data. refreshdata also enables you to specify that the data source variable be evaluated in the workspace of a function from which you call refreshdata.

See the refreshdata reference page for more information.

---

**Note** If you change one data source property to a variable that contains data of a different dimension, you might cause the function to generate a warning and not render the graph until you have changed all data source properties to appropriate values.

---

# Stairseries Properties

---

## YData

scalar, vector, or matrix

*Stairs plot data.* YData contains the data plotted in the staircase graph. Each value in YData is represented by a marker in the staircase graph. If YData is a matrix, the `stairs` function creates a line for each column in the matrix.

The input argument `y` in the `stairs` function calling syntax assigns values to YData.

## YDataSource

string (MATLAB variable)

*Link YData to MATLAB variable.* Set this property to a MATLAB variable that is evaluated in the base workspace to generate the YData.

MATLAB reevaluates this property only when you set it. Therefore, a change to workspace variables appearing in an expression does not change YData.

You can use the `refreshdata` function to force an update of the object's data. `refreshdata` also enables you to specify that the data source variable be evaluated in the workspace of a function from which you call `refreshdata`.

See the `refreshdata` reference page for more information.

---

**Note** If you change one data source property to a variable that contains data of a different dimension, you might cause the function to generate a warning and not render the graph until you have changed all data source properties to appropriate values.

---

**Purpose**

Start timer(s) running

**Syntax**

`start(obj)`

**Description**

`start(obj)` starts the timer running, represented by the timer object, `obj`. If `obj` is an array of timer objects, `start` starts all the timers. Use the `timer` function to create a timer object.

`start` sets the `Running` property of the timer object, `obj`, to `'on'`, initiates `TimerFcn` callbacks, and executes the `StartFcn` callback.

The timer stops running if one of the following conditions apply:

- The first `TimerFcn` callback completes, if `ExecutionMode` is `'singleShot'`.
- The number of `TimerFcn` callbacks specified in `TasksToExecute` have been executed.
- The `stop(obj)` command is issued.
- An error occurred while executing a `TimerFcn` callback.

**See Also**

`timer`, `stop`

# startat

---

**Purpose** Start timer(s) running at specified time

**Syntax**

```
startat(obj,time)
startat(obj,S)
startat(obj,S,pivotyear)
startat(obj,Y,M,D)
startat(obj,[Y,M,D])
startat(obj,Y,M,D,H,MI,S)
startat(obj,[Y,M,D,H,MI,S])
```

**Description** `startat(obj,time)` starts the timer running, represented by the timer object `obj`, at the time specified by the serial date number `time`. If `obj` is an array of timer objects, `startat` starts all the timers running at the specified time. Use the `timer` function to create the timer object.

`startat` sets the `Running` property of the timer object, `obj`, to 'on', initiates `TimerFcn` callbacks, and executes the `StartFcn` callback.

The serial date number, `time`, indicates the number of days that have elapsed since 1-Jan-0000 (starting at 1). See `datenum` for additional information about serial date numbers.

`startat(obj,S)` starts the timer running at the time specified by the date string `S`. The date string must use date format 0, 1, 2, 6, 13, 14, 15, 16, or 23, as defined by the `datestr` function. Date strings with two-character years are interpreted to be within the 100 years centered on the current year.

`startat(obj,S,pivotyear)` uses the specified pivot year as the starting year of the 100-year range in which a two-character year resides. The default pivot year is the current year minus 50 years.

`startat(obj,Y,M,D)` `startat(obj,[Y,M,D])` start the timer at the year (`Y`), month (`M`), and day (`D`) specified. `Y`, `M`, and `D` must be arrays of the same size (or they can be a scalar).

`startat(obj,Y,M,D,H,MI,S)` `startat(obj,[Y,M,D,H,MI,S])` start the timer at the year (`Y`), month (`M`), day (`D`), hour (`H`), minute (`MI`), and second (`S`) specified. `Y`, `M`, `D`, `H`, `MI`, and `S` must be arrays of the same size (or they can be a scalar). Values outside the normal range of each array



are automatically carried to the next unit (for example, month values greater than 12 are carried to years). Month values less than 1 are set to be 1; all other units can wrap and have valid negative values.

The timer stops running if one of the following conditions apply:

- The number of `TimerFcn` callbacks specified in `TasksToExecute` have been executed.
- The `stop(obj)` command is issued.
- An error occurred while executing a `TimerFcn` callback.

## Examples

This example uses a timer object to execute a function at a specified time.

```
t1=timer('TimerFcn','disp(''it is 10 o''''clock'')');
startat(t1,'10:00:00');
```

This example uses a timer to display a message when an hour has elapsed.

```
t2=timer('TimerFcn','disp(''It has been an hour now.'')');
startat(t2,now+1/24);
```

## See Also

`datenum`, `datestr`, `now`, `timer`, `start`, `stop`

# startup

---

**Purpose** Startup M-file for user-defined options

**Syntax** startup

**Description** startup automatically executes the master M-file matlabrc.m and, if it exists, startup.m, when the MATLAB program starts. On multiuser or networked systems, matlabrc.m is reserved for use by the system manager. The file matlabrc.m invokes the file startup.m if it exists on the search path MATLAB uses. You can create a startup.m file in your own startup directory for MATLAB. The file can include physical constants, defaults for Handle Graphics properties, engineering conversion factors, or anything else you want predefined in your workspace.

**Algorithm** At startup, MATLAB only runs matlabrc.m. However, matlabrc.m contains the statements

```
if exist('startup')==2
 startup
end
```

that run startup.m. You can extend this process to create additional startup M-files, if needed.

**See Also** finish, matlabrc, matlabroot, path, quit, userpath

See “Specifying Startup Options Using the Startup File for the MATLAB Program, startup.m” and Preferences in the MATLAB Desktop Tools and Development Environment documentation.

**Purpose** Standard deviation

**Syntax**  
`s = std(X)`  
`s = std(X,flag)`  
`s = std(X,flag,dim)`

**Definition** There are two common textbook definitions for the standard deviation  $s$  of a data vector  $X$ .

$$(1) \quad s = \left( \frac{1}{n-1} \sum_{i=1}^n (x_i - \bar{x})^2 \right)^{\frac{1}{2}}$$

$$(2) \quad s = \left( \frac{1}{n} \sum_{i=1}^n (x_i - \bar{x})^2 \right)^{\frac{1}{2}}$$

where

$$\bar{x} = \frac{1}{n} \sum_{i=1}^n x_i$$

and  $n$  is the number of elements in the sample. The two forms of the equation differ only in  $n - 1$  versus  $n$  in the divisor.

## Description

`s = std(X)`, where  $X$  is a vector, returns the standard deviation using (1) above. The result  $s$  is the square root of an unbiased estimator of the variance of the population from which  $X$  is drawn, as long as  $X$  consists of independent, identically distributed samples.

If  $X$  is a matrix, `std(X)` returns a row vector containing the standard deviation of the elements of each column of  $X$ . If  $X$  is a multidimensional array, `std(X)` is the standard deviation of the elements along the first nonsingleton dimension of  $X$ .

# std

---

`s = std(X,flag)` for `flag = 0`, is the same as `std(X)`. For `flag = 1`, `std(X,1)` returns the standard deviation using (2) above, producing the second moment of the set of values about their mean.

`s = std(X,flag,dim)` computes the standard deviations along the dimension of `X` specified by scalar `dim`. Set `flag` to 0 to normalize `Y` by  $n-1$ ; set `flag` to 1 to normalize by  $n$ .

## Examples

For matrix `X`

```
X =
 1 5 9
 7 15 22
s = std(X,0,1)
s =
 4.2426 7.0711 9.1924
s = std(X,0,2)
s =
 4.000
 7.5056
```

## See Also

`corrcoef`, `cov`, `mean`, `median`, `var`

**Purpose** Standard deviation of timeseries data

**Syntax**

```
ts_std = std(ts)
ts_std = std(ts, 'PropertyName1', PropertyValue1, ...)
```

**Description** `ts_std = std(ts)` returns the standard deviation of the time-series data. When `ts.Data` is a vector, `ts_std` is the standard deviation of `ts.Data` values. When `ts.Data` is a matrix, `ts_std` is the standard deviation of each column of `ts.Data` (when `IsTimeFirst` is true and the first dimension of `ts` is aligned with time). For the N-dimensional `ts.Data` array, `std` always operates along the first nonsingleton dimension of `ts.Data`.

```
ts_std = std(ts, 'PropertyName1', PropertyValue1, ...)
```

specifies the following optional input arguments:

- 'MissingData' property has two possible values, 'remove' (default) or 'interpolate', indicating how to treat missing data during the calculation.
- 'Quality' values are specified by a vector of integers, indicating which quality codes represent missing samples (for vector data) or missing observations (for data arrays with two or more dimensions).
- 'Weighting' property has two possible values, 'none' (default) or 'time'.  
When you specify 'time', larger time values correspond to larger weights.

**Examples** 1 Load a 24-by-3 data array.

```
load count.dat
```

2 Create a timeseries object with 24 time values.

```
count_ts = timeseries(count,1:24,'Name','CountPerSecond')
```

## std (timeseries)

---

- 3** Calculate the standard deviation of each data column for this `timeseries` object.

```
std(count_ts)

ans =

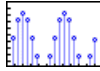
 25.3703 41.4057 68.0281
```

The standard deviation is calculated independently for each data column in the `timeseries` object.


### See Also

```
iqr (timeseries), mean (timeseries), median (timeseries), var
(timeseries), timeseries
```

**Purpose** Plot discrete sequence data



## GUI Alternatives

To graph selected variables, use the Plot Selector  in the Workspace Browser, or use the Figure Palette Plot Catalog. Manipulate graphs in *plot edit* mode with the Property Editor. For details, see Plotting Tools — Interactive Plotting in the MATLAB Graphics documentation and Creating Graphics from the Workspace Browser in the MATLAB Desktop Tools documentation.

## Syntax

```
stem(Y)
stem(X,Y)
stem(...,'fill')
stem(...,LineStyle)
stem(axes_handle,...)
h = stem(...)
hlines = stem('v6',...)
```

## Description

A two-dimensional stem plot displays data as lines extending from a baseline along the  $x$ -axis. A circle (the default) or other marker whose  $y$ -position represents the data value terminates each stem.

`stem(Y)` plots the data sequence  $Y$  as stems that extend from equally spaced and automatically generated values along the  $x$ -axis. When  $Y$  is a matrix, `stem` plots all elements in a row against the same  $x$  value.

`stem(X,Y)` plots  $X$  versus the columns of  $Y$ .  $X$  and  $Y$  must be vectors or matrices of the same size. Additionally,  $X$  can be a row or a column vector and  $Y$  a matrix with `length(X)` rows.

`stem(...,'fill')` specifies whether to color the circle at the end of the stem.

`stem(...,LineStyle)` specifies the line style, marker symbol, and color for the stem and top marker (the baseline is not affected). See `LineStyle` for more information.

`stem(axes_handle,...)` plots into the axes object with the handle `axes_handle` instead of into the current axes object (`gca`).

`h = stem(...)` returns a vector of stemseries object handles in `h`, one handle per column of data in `Y`.

## Backward-Compatible Version

`hlines = stem('v6',...)` returns the handles of line objects instead of stemseries objects for compatibility with MATLAB 6.5 and earlier.

`hlines` contains the handles to three line graphics objects:

- `hlines(1)` — The marker symbol at the top of each stem
- `hlines(2)` — The stem line
- `hlines(3)` — The baseline handle

---

**Note** The `v6` option enables users of Version 7.x of MATLAB to create FIG-files that previous versions can open. It is obsolete and will be removed in a future version of MATLAB.

---

See Plot Objects and Backward Compatibility for more information.

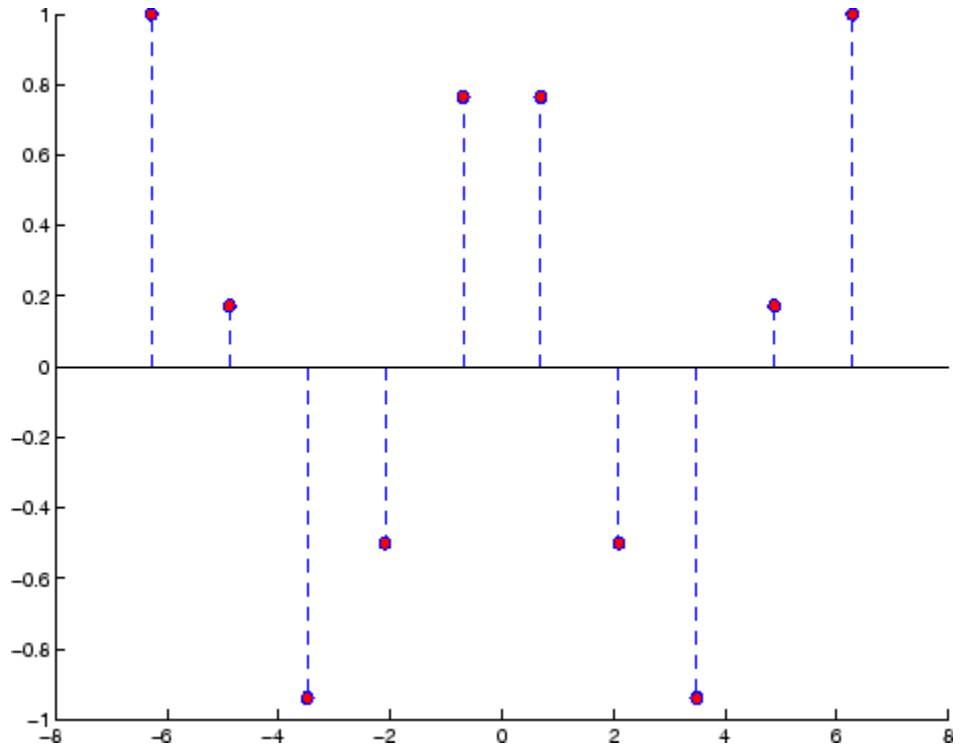
## Examples

### Single Series of Data

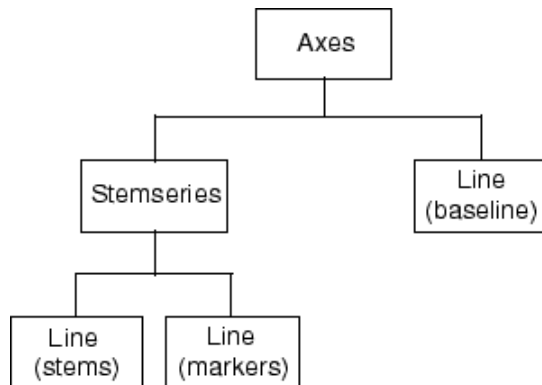
This example creates a stem plot representing the cosine of 10 values linearly spaced between 0 and  $2\pi$ . Note that the line style of the baseline is set by first getting its handle from the stemseries object's `BaseLine` property.

```
t = linspace(-2*pi,2*pi,10);
h = stem(t,cos(t),'fill','--');
set(get(h,'BaseLine'),'LineStyle',':')
set(h,'MarkerFaceColor','red')
```





The following diagram illustrates the parent-child relationship in the previous stem plot. Note that the stemsseries object contains two line objects used to draw the stem lines and the end markers. The baseline is a separate line object.



If you do not want the baseline to show, you can remove it with the following command:

```
delete(get(stem_handle, 'Baseline'))
```

where `stem_handle` is the handle for the stemsseries object. You can use similar code to change the color or style of the baseline, specifying any line property and value, for example,

```
set(get(stem_handle, 'Baseline'), 'LineWidth', 3)
```

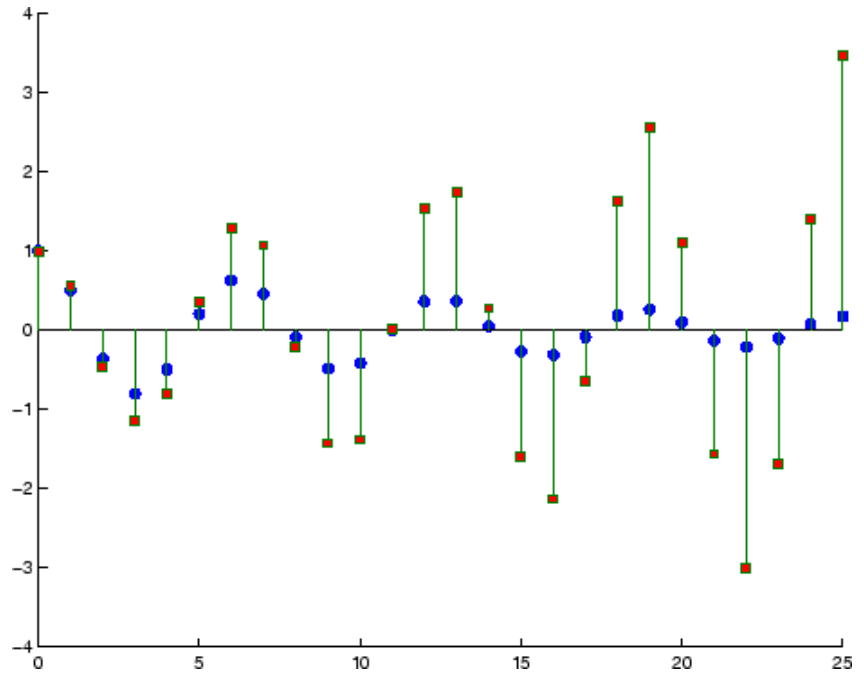
## Two Series of Data on One Graph

The following example creates a stem plot from a two-column matrix. In this case, the `stem` function creates two stemsseries objects, one of each column of data. Both objects' handles are returned in the output argument `h`.

- `h(1)` is the handle to the stemsseries object plotting the expression `exp(-.07*x).*cos(x)`.
- `h(2)` is the handle to the stemsseries object plotting the expression `exp(.05*x).*cos(x)`.

```
x = 0:25;
y = [exp(-.07*x).*cos(x);exp(.05*x).*cos(x)]';
h = stem(x,y);
```

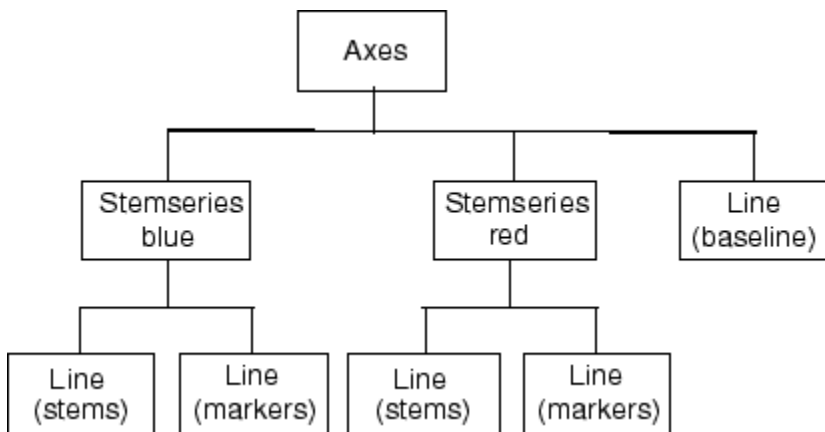
```
set(h(1), 'MarkerFaceColor', 'blue')
set(h(2), 'MarkerFaceColor', 'red', 'Marker', 'square')
```



The following diagram illustrates the parent-child relationship in the previous stem plot. Note that each column in the input matrix  $y$  results in the creation of a stemseries object, which contains two line objects (one for the stems and one for the markers). The baseline is shared by both stemseries objects.

# stem

---



## See Also


bar, plot, stairs

Stemseries properties for property descriptions

**Purpose** Plot 3-D discrete sequence data



## GUI Alternatives

To graph selected variables, use the Plot Selector  in the Workspace Browser, or use the Figure Palette Plot Catalog. Manipulate graphs in *plot edit* mode with the Property Editor. For details, see Plotting Tools — Interactive Plotting in the MATLAB Graphics documentation and Creating Graphics from the Workspace Browser in the MATLAB Desktop Tools documentation.

## Syntax

```
stem3(Z)
stem3(X,Y,Z)
stem3(...,'fill')
stem3(...,LineStyle)
h = stem3(...)
hlines = stem3('v6',...)
```

## Description

Three-dimensional stem plots display lines extending from the  $x$ - $y$  plane. A circle (the default) or other marker symbol whose  $z$ -position represents the data value terminates each stem.

`stem3(Z)` plots the data sequence  $Z$  as stems that extend from the  $x$ - $y$  plane.  $x$  and  $y$  are generated automatically. When  $Z$  is a row vector, `stem3` plots all elements at equally spaced  $x$  values against the same  $y$  value. When  $Z$  is a column vector, `stem3` plots all elements at equally spaced  $y$  values against the same  $x$  value.

`stem3(X,Y,Z)` plots the data sequence  $Z$  at values specified by  $X$  and  $Y$ .  $X$ ,  $Y$ , and  $Z$  must all be vectors or matrices of the same size.

`stem3(...,'fill')` specifies whether to color the interior of the circle at the end of the stem.

`stem3(...,LineStyle)` specifies the line style, marker symbol, and color for the stems. See `LineStyle` for more information.

`h = stem3(...)` returns handles to stemseries graphics objects.

## stem3

---

### Backward-Compatible Version

`hlines = stem3('v6',...)` returns the handles of line objects instead of stemseries objects for compatibility with MATLAB 6.5 and earlier.

---

**Note** The `v6` option enables users of Version 7.x of MATLAB to create FIG-files that previous versions can open. It is obsolete and will be removed in a future version of MATLAB.

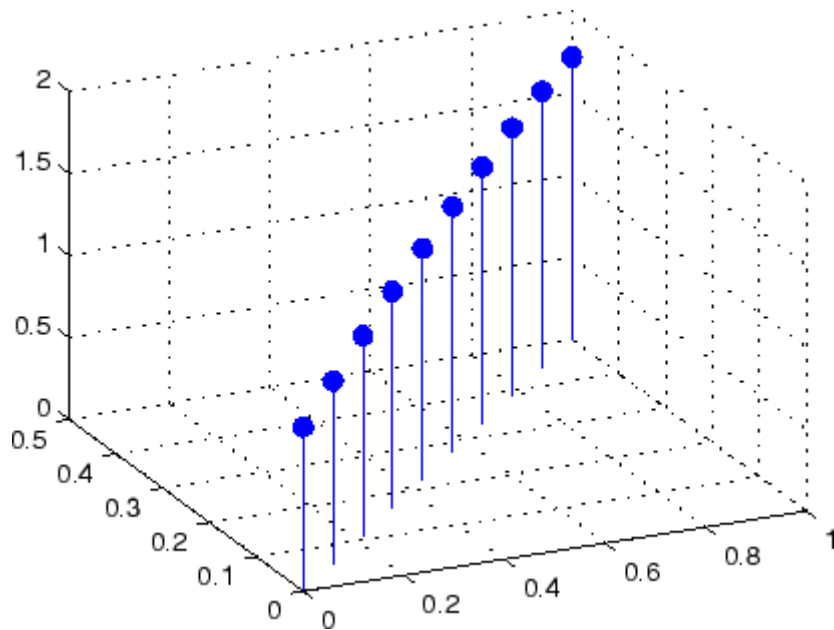
---

See Plot Objects and Backward Compatibility for more information.

### Examples

Create a three-dimensional stem plot to visualize a function of two variables.

```
X = linspace(0,1,10);
Y = X./2;
Z = sin(X) + cos(Y);
stem3(X,Y,Z,'fill')
view(-25,30)
```

**See Also**

`bar`, `plot`, `stairs`, `stem`

“Discrete Data Plots” on page 1-96 for related functions

`StemSeries` `Properties` for descriptions of properties

Three-Dimensional Stem Plots for more examples

# Stemseries Properties

---

**Purpose** Define stemseries properties

**Modifying Properties** You can set and query graphics object properties using the `set` and `get` commands or with the property editor (`propertyeditor`).

Note that you cannot define default properties for stemseries objects.

See Plot Objects for information on stemseries objects.

**Stemseries Property Descriptions** This section provides a description of properties. Curly braces { } enclose default values.

Annotation  
hg.Annotation object Read Only

*Control the display of stemseries objects in legends.* The Annotation property enables you to specify whether this stemseries object is represented in a figure legend.

Querying the Annotation property returns the handle of an hg.Annotation object. The hg.Annotation object has a property called LegendInformation, which contains an hg.LegendEntry object.

Once you have obtained the hg.LegendEntry object, you can set its IconDisplayStyle property to control whether the stemseries object is displayed in a figure legend:

| IconDisplayStyle Value | Purpose                                                                              |
|------------------------|--------------------------------------------------------------------------------------|
| on                     | Include the stemseries object in a legend as one entry, but not its children objects |
| off                    | Do not include the stemseries or its children in a legend (default)                  |
| children               | Include only the children of the stemseries as separate entries in the legend        |



## Setting the IconDisplayStyle Property

These commands set the `IconDisplayStyle` of a graphics object with handle `hobj` to `children`, which causes each child object to have an entry in the legend:

```
hAnnotation = get(hobj, 'Annotation');
hLegendEntry = get(hAnnotation, 'LegendInformation');
set(hLegendEntry, 'IconDisplayStyle', 'children')
```

## Using the IconDisplayStyle Property

See “Controlling Legends” for more information and examples.

### BaseLine

handle of baseline

*Handle of the baseline object.* This property contains the handle of the line object used as the baseline. You can set the properties of this line using its handle. For example, the following statements create a stem plot, obtain the handle of the baseline from the `stemseries` object, and then set line properties that make the baseline a dashed, red line.

```
stem_handle = stem(randn(10,1));
baseline_handle = get(stem_handle, 'BaseLine');
set(baseline_handle, 'LineStyle', '--', 'Color', 'red')
```

### BaseValue

*y*-axis value

*Y-axis value where baseline is drawn.* You can specify the value along the *y*-axis at which the MATLAB software draws the baseline.

### BeingDeleted

on | {off} Read Only

# Stemseries Properties

---

*This object is being deleted.* The `BeingDeleted` property provides a mechanism that you can use to determine if objects are in the process of being deleted. MATLAB sets the `BeingDeleted` property to `on` when the object's delete function callback is called (see the `DeleteFcn` property). It remains set to `on` while the delete function executes, after which the object no longer exists.

For example, an object's delete function might call other functions that act on a number of different objects. These functions might not need to perform actions on objects if the objects are going to be deleted, and therefore, can check the object's `BeingDeleted` property before acting.

`BusyAction`  
cancel | {queue}

*Callback routine interruption.* The `BusyAction` property enables you to control how MATLAB handles events that potentially interrupt executing callbacks. If there is a callback function executing, callbacks invoked subsequently always attempt to interrupt it.

If the `Interruptible` property of the object whose callback is executing is set to `on` (the default), then interruption occurs at the next point where the event queue is processed. If the `Interruptible` property is `off`, the `BusyAction` property (of the object owning the executing callback) determines how MATLAB handles the event. The choices are

- `cancel` — Discard the event that attempted to execute a second callback routine.
- `queue` — Queue the event that attempted to execute a second callback routine until the current callback finishes.

`ButtonDownFcn`  
string or function handle

*Button press callback function.* A callback that executes whenever you press a mouse button while the pointer is over this object, but not over another graphics object. See the `HitTestArea` property for information about selecting objects of this type.

See the figure's `SelectionType` property to determine if modifier keys were also pressed.

This property can be

- A string that is a valid MATLAB expression
- The name of an M-file
- A function handle

Set this property to a function handle that references the callback. The expressions execute in the MATLAB workspace.

See “Function Handle Callbacks” for information on how to use function handles to define the callbacks.

## Children

array of graphics object handles

*Children of this object.* The handle of a patch object that is the child of this object (whether visible or not).

Note that if a child object's `HandleVisibility` property is set to `callback` or `off`, its handle does not show up in this object's `Children` property unless you set the root `ShowHiddenHandles` property to `on`:

```
set(0, 'ShowHiddenHandles', 'on')
```

## Clipping

{on} | off

# Stemseries Properties

---

*Clipping mode.* MATLAB clips graphs to the axes plot box by default. If you set `Clipping` to `off`, portions of graphs can be displayed outside the axes plot box. This can occur if you create a plot object, set `hold` to `on`, freeze axis scaling (`axis manual`), and then create a larger plot object.

## Color

ColorSpec

*Color of stem lines.* A three-element RGB vector or one of the MATLAB predefined names, specifying the line color. See the `ColorSpec` reference page for more information on specifying color.

For example, the following statement would produce a stem plot with red lines.

```
h = stem(randn(10,1), 'Color', 'r');
```

## CreateFcn

string or function handle

*Callback routine executed during object creation.* This property defines a callback that executes when MATLAB creates an object. You must specify the callback during the creation of the object. For example,

```
area(y, 'CreateFcn', @CallbackFcn)
```

where `@CallbackFcn` is a function handle that references the callback function.

MATLAB executes this routine after setting all other object properties. Setting this property on an existing object has no effect.

The handle of the object whose `CreateFcn` is being executed is accessible only through the root `CallbackObject` property, which you can query using `gcbo`.

See “Function Handle Callbacks” for information on how to use function handles to define the callback function.

## `DeleteFcn`

string or function handle

*Callback executed during object deletion.* A callback that executes when this object is deleted (e.g., this might happen when you issue a `delete` command on the object, its parent axes, or the figure containing it). MATLAB executes the callback before destroying the object’s properties so the callback routine can query these values.

The handle of the object whose `DeleteFcn` is being executed is accessible only through the root `CallbackObject` property, which can be queried using `gcbo`.

See “Function Handle Callbacks” for information on how to use function handles to define the callback function.

See the `BeingDeleted` property for related information.

## `DisplayName`

string (default is empty string)

*String used by legend for this stemseries object.* The `legend` function uses the string defined by the `DisplayName` property to label this stemseries object in the legend.

- If you specify string arguments with the `legend` function, `DisplayName` is set to this stemseries object’s corresponding string and that string is used for the legend.
- If `DisplayName` is empty, legend creates a string of the form, `['data' n]`, where `n` is the number assigned to the object

# Stemseries Properties

---

based on its location in the list of legend entries. However, legend does not set `DisplayName` to this string.

- If you edit the string directly in an existing legend, `DisplayName` is set to the edited string.
- If you specify a string for the `DisplayName` property and create the legend using the figure toolbar, then MATLAB uses the string defined by `DisplayName`.
- To add programmatically a legend that uses the `DisplayName` string, call `legend` with the `toggle` or `show` option.

See “Controlling Legends” for more examples.

## EraseMode

{normal} | none | xor | background

*Erase mode.* This property controls the technique MATLAB uses to draw and erase objects and their children. Alternative erase modes are useful for creating animated sequences, where control of the way individual objects are redrawn is necessary to improve performance and obtain the desired effect.

- `normal` — Redraw the affected region of the display, performing the three-dimensional analysis necessary to ensure that all objects are rendered correctly. This mode produces the most accurate picture, but is the slowest. The other modes are faster, but do not perform a complete redraw and are therefore less accurate.
- `none` — Do not erase objects when they are moved or destroyed. While the objects are still visible on the screen after erasing with `EraseMode none`, you cannot print these objects because MATLAB stores no information about their former locations.
- `xor` — Draw and erase the object by performing an exclusive OR (XOR) with each pixel index of the screen behind it. Erasing the object does not damage the color of the objects behind it. However, the color of the erased object depends on the color of

the screen behind it and it is correctly colored only when it is over the axes background color (or the figure background color if the axes `Color` property is set to none). That is, it isn't erased correctly if there are objects behind it.

- `background` — Erase the graphics objects by redrawing them in the axes background color, (or the figure background color if the axes `Color` property is set to none). This damages other graphics objects that are behind the erased object, but the erased object is always properly colored.

## Printing with Nonnormal Erase Modes

MATLAB always prints figures as if the `EraseMode` of all objects is `normal`. This means graphics objects created with `EraseMode` set to `none`, `xor`, or `background` can look different on screen than on paper. On screen, MATLAB can mathematically combine layers of colors (e.g., performing an XOR on a pixel color with that of the pixel behind it) and ignore three-dimensional sorting to obtain greater rendering speed. However, these techniques are not applied to the printed output.

Set the axes background color with the axes `Color` property. Set the figure background color with the figure `Color` property.

You can use the MATLAB `getframe` command or other screen capture applications to create an image of a figure containing nonnormal mode objects.

`HandleVisibility`  
{on} | callback | off

*Control access to object's handle by command-line users and GUIs.* This property determines when an object's handle is visible in its parent's list of children. `HandleVisibility` is useful for preventing command-line users from accidentally accessing objects that you need to protect for some reason.

# Stemseries Properties

---

- `on` — Handles are always visible when `HandleVisibility` is `on`.
- `callback` — Setting `HandleVisibility` to `callback` causes handles to be visible from within callback routines or functions invoked by callback routines, but not from within functions invoked from the command line. This provides a means to protect GUIs from command-line users, while allowing callback routines to have access to object handles.
- `off` — Setting `HandleVisibility` to `off` makes handles invisible at all times. This might be necessary when a callback invokes a function that might potentially damage the GUI (such as evaluating a user-typed string) and so temporarily hides its own handles during the execution of that function.

## Functions Affected by Handle Visibility

When a handle is not visible in its parent's list of children, it cannot be returned by functions that obtain handles by searching the object hierarchy or querying handle properties. This includes `get`, `findobj`, `gca`, `gcf`, `gco`, `newplot`, `cla`, `clf`, and `close`.

## Properties Affected by Handle Visibility

When a handle's visibility is restricted using `callback` or `off`, the object's handle does not appear in its parent's `Children` property, figures do not appear in the root's `CurrentFigure` property, objects do not appear in the root's `CallbackObject` property or in the figure's `CurrentObject` property, and axes do not appear in their parent's `CurrentAxes` property.

## Overriding Handle Visibility

You can set the root `ShowHiddenHandles` property to `on` to make all handles visible regardless of their `HandleVisibility` settings (this does not affect the values of the `HandleVisibility` properties). See also `findall`.



## Handle Validity

Handles that are hidden are still valid. If you know an object's handle, you can `set` and `get` its properties and pass it to any function that operates on handles.

---

**Note** If you change one data source property to a variable that contains data of a different dimension, you might cause the function to generate a warning and not render the graph until you have changed all data source properties to appropriate values.

---

## HitTest

{on} | off

*Selectable by mouse click.* HitTest determines whether this object can become the current object (as returned by the `gco` command and the figure `CurrentObject` property) as a result of a mouse click on the objects that compose the area graph. If HitTest is off, clicking this object selects the object below it (which is usually the axes containing it).

## HitTestArea

on | {off}

*Select the object by clicking lines or area of extent.* This property enables you to select plot objects in two ways:

- Select by clicking lines or markers (default).
- Select by clicking anywhere in the extent of the plot.

When HitTestArea is off, you must click the object's lines or markers (excluding the baseline, if any) to select the object. When HitTestArea is on, you can select this object by clicking anywhere within the extent of the plot (i.e., anywhere within a rectangle that encloses it).

# Stemseries Properties

---

**Interruptible**  
{on} | off

*Callback routine interruption mode.* The **Interruptible** property controls whether an object's callback can be interrupted by callbacks invoked subsequently.

Only callbacks defined for the **ButtonDownFcn** property are affected by the **Interruptible** property. MATLAB checks for events that can interrupt a callback only when it encounters a `drawnow`, `figure`, `getframe`, or `pause` command in the routine. See the **BusyAction** property for related information.

Setting **Interruptible** to `on` allows any graphics object's callback to interrupt callback routines originating from a `bar` property. Note that MATLAB does not save the state of variables or the display (e.g., the handle returned by the `gca` or `gcf` command) when an interruption occurs.

**LineStyle**  
{-} | - | : | -. | none

*Line style.* This property specifies the line style of the object. Available line styles are shown in the following table.

| <b>Specifier String</b> | <b>Line Style</b>    |
|-------------------------|----------------------|
| -                       | Solid line (default) |
| --                      | Dashed line          |
| :                       | Dotted line          |
| -.                      | Dash-dot line        |
| none                    | No line              |

You can use `LineStyle` `none` when you want to place a marker at each point but do not want the points connected with a line (see the `Marker` property).

`LineWidth`  
scalar

*The width of linear objects and edges of filled areas.* Specify this value in points (1 point =  $1/72$  inch). The default `LineWidth` is 0.5 points.

`Marker`  
character (see table)

*Marker symbol.* The `Marker` property specifies the type of markers that are displayed at plot vertices. You can set values for the `Marker` property independently from the `LineStyle` property. Supported markers include those shown in the following table.

| Marker Specifier | Description                   |
|------------------|-------------------------------|
| +                | Plus sign                     |
| o                | Circle                        |
| *                | Asterisk                      |
| .                | Point                         |
| x                | Cross                         |
| s                | Square                        |
| d                | Diamond                       |
| ^                | Upward-pointing triangle      |
| v                | Downward-pointing triangle    |
| >                | Right-pointing triangle       |
| <                | Left-pointing triangle        |
| p                | Five-pointed star (pentagram) |

# Stemseries Properties

---

| Marker Specifier | Description                 |
|------------------|-----------------------------|
| h                | Six-pointed star (hexagram) |
| none             | No marker (default)         |

## MarkerEdgeColor

ColorSpec | none | {auto}

*Marker edge color.* The color of the marker or the edge color for filled markers (circle, square, diamond, pentagram, hexagram, and the four triangles). ColorSpec defines the color to use. none specifies no color, which makes nonfilled markers invisible. auto sets MarkerEdgeColor to the same color as the Color property.

## MarkerFaceColor

ColorSpec | {none} | auto

*Marker face color.* The fill color for markers that are closed shapes (circle, square, diamond, pentagram, hexagram, and the four triangles). ColorSpec defines the color to use. none makes the interior of the marker transparent, allowing the background to show through. auto sets the fill color to the axes color, or to the figure color if the axes Color property is set to none (which is the factory default for axes objects).

## MarkerSize

size in points

*Marker size.* A scalar specifying the size of the marker in points. The default value for MarkerSize is 6 points (1 point = 1/72 inch). Note that MATLAB draws the point marker (specified by the '.' symbol) at one-third the specified size.

## Parent

handle of parent axes, hggroup, or hgtransform

*Parent of this object.* This property contains the handle of the object's parent. The parent is normally the axes, hgggroup, or hgtransform object that contains the object.

See “Objects That Can Contain Other Objects” for more information on parenting graphics objects.

**Selected**  
on | {off}

*Is object selected?* When you set this property to on, MATLAB displays selection "handles" at the corners and midpoints if the SelectionHighlight property is also on (the default). You can, for example, define the ButtonDownFcn callback to set this property to on, thereby indicating that this particular object is selected. This property is also set to on when an object is manually selected in plot edit mode.

**SelectionHighlight**  
{on} | off

*Objects are highlighted when selected.* When the Selected property is on, MATLAB indicates the selected state by drawing four edge handles and four corner handles. When SelectionHighlight is off, MATLAB does not draw the handles except when in plot edit mode and objects are selected manually.

**Tag**  
string

*User-specified object label.* The Tag property provides a means to identify graphics objects with a user-specified label. This is particularly useful when you are constructing interactive graphics programs that would otherwise need to define object handles as global variables or pass them as arguments between callbacks.

For example, you might create a stemseries object and set the Tag property:

# Stemseries Properties

---

```
t = stem(Y, 'Tag', 'stem1')
```

When you want to access the stemseries object, you can use `findobj` to find the stemseries object's handle. The following statement changes the `MarkerFaceColor` property of the object whose `Tag` is `stem1`.

```
set(findobj('Tag', 'stem1'), 'MarkerFaceColor', 'red')
```

## Type

string (read only)

*Type of graphics object.* This property contains a string that identifies the class of the graphics object. For stemseries objects, `Type` is `'hgroup'`. The following statement finds all the `hgroup` objects in the current axes object.

```
t = findobj(gca, 'Type', 'hgroup');
```

## UIContextMenu

handle of a `uicontextmenu` object

*Associate a context menu with this object.* Assign this property the handle of a `uicontextmenu` object created in the object's parent figure. Use the `uicontextmenu` function to create the context menu. MATLAB displays the context menu whenever you right-click over the object.

## UserData

array

*User-specified data.* This property can be any data you want to associate with this object (including cell arrays and structures). The object does not set values for this property, but you can access it using the `set` and `get` functions.

## Visible

{on} | off

*Visibility of this object and its children.* By default, a new object's visibility is on. This means all children of the object are visible unless the child object's `Visible` property is set to `off`. Setting an object's `Visible` property to `off` prevents the object from being displayed. However, the object still exists and you can set and query its properties.

## `XData`

array

*X-axis location of stems.* The stem function draws an individual stem at each *x*-axis location in the `XData` array. `XData` can be either a matrix equal in size to `YData` or a vector equal in length to the number of rows in `YData`. That is, `length(XData) == size(YData,1)`. `XData` does not need to be monotonically increasing.

If you do not specify `XData` (i.e., the input argument `x`), the stem function uses the indices of `YData` to create the stem plot. See the `XDataMode` property for related information.

## `XDataMode`

{auto} | manual

*Use automatic or user-specified x-axis values.* If you specify `XData` (by setting the `XData` property or specifying the `x` input argument), MATLAB sets this property to `manual` and uses the specified values to label the *x*-axis.

If you set `XDataMode` to `auto` after having specified `XData`, MATLAB resets the *x*-axis ticks to `1:size(YData,1)` or to the column indices of the `ZData`, overwriting any previous values for `XData`.

## `XDataSource`

string (MATLAB variable)

# Stemseries Properties

---

*Link XData to MATLAB variable.* Set this property to a MATLAB variable that is evaluated in the base workspace to generate the XData.

MATLAB reevaluates this property only when you set it. Therefore, a change to workspace variables appearing in an expression does not change XData.

You can use the `refreshdata` function to force an update of the object's data. `refreshdata` also enables you to specify that the data source variable be evaluated in the workspace of a function from which you call `refreshdata`.

See the `refreshdata` reference page for more information.

---

**Note** If you change one data source property to a variable that contains data of a different dimension, you might cause the function to generate a warning and not render the graph until you have changed all data source properties to appropriate values.

---

## YData

scalar, vector, or matrix

*Stem plot data.* YData contains the data plotted as stems. Each value in YData is represented by a marker in the stem plot. If YData is a matrix, MATLAB creates a series of stems for each column in the matrix.

The input argument `y` in the `stem` function calling syntax assigns values to YData.

## YDataSource

string (MATLAB variable)



*Link YData to MATLAB variable.* Set this property to a MATLAB variable that is evaluated in the base workspace to generate the YData.

MATLAB reevaluates this property only when you set it. Therefore, a change to workspace variables appearing in an expression does not change YData.

You can use the `refreshdata` function to force an update of the object's data. `refreshdata` also enables you to specify that the data source variable be evaluated in the workspace of a function from which you call `refreshdata`.

See the `refreshdata` reference page for more information.

---

**Note** If you change one data source property to a variable that contains data of a different dimension, you might cause the function to generate a warning and not render the graph until you have changed all data source properties to appropriate values.

---

## ZData

vector of coordinates

*Z-coordinates.* A data defining the stems for 3-D stem graphs. XData and YData (if specified) must be the same size.

## ZDataSource

string (MATLAB variable)

*Link ZData to MATLAB variable.* Set this property to a MATLAB variable that is evaluated in the base workspace to generate the ZData.

## Stemseries Properties

---

MATLAB reevaluates this property only when you set it. Therefore, a change to workspace variables appearing in an expression does not change ZData.

You can use the `refreshdata` function to force an update of the object's data. `refreshdata` also enables you to specify that the data source variable be evaluated in the workspace of a function from which you call `refreshdata`.

See the `refreshdata` reference page for more information.

---

**Note** If you change one data source property to a variable that contains data of a different dimension, you might cause the function to generate a warning and not render the graph until you have changed all data source properties to appropriate values.

---

**Purpose** Stop timer(s)

**Syntax** stop(obj)

**Description** stop(obj) stops the timer, represented by the timer object, obj. If obj is an array of timer objects, the stop function stops them all. Use the timer function to create a timer object.

The stop function sets the Running property of the timer object, obj, to 'off', halts further TimerFcn callbacks, and executes the StopFcn callback.

**See Also** timer, start

# stopasync

---

|                    |                                                                                                                                               |
|--------------------|-----------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Purpose</b>     | Stop asynchronous read and write operations                                                                                                   |
| <b>Syntax</b>      | <code>stopasync(obj)</code>                                                                                                                   |
| <b>Description</b> | <code>stopasync(obj)</code> stops any asynchronous read or write operation that is in progress for the serial port object, <code>obj</code> . |

**Remarks** You can write data asynchronously using the `fprintf` or `fwrite` function. You can read data asynchronously using the `readasync` function, or by configuring the `ReadAsyncMode` property to `continuous`. In-progress asynchronous operations are indicated by the `TransferStatus` property.

If `obj` is an array of serial port objects and one of the objects cannot be stopped, the remaining objects in the array are stopped and a warning is returned. After an object stops:

- Its `TransferStatus` property is configured to `idle`.
- Its `ReadAsyncMode` property is configured to `manual`.
- The data in its output buffer is flushed.

Data in the input buffer is not flushed. You can return this data to the MATLAB workspace using any of the synchronous read functions. If you execute the `readasync` function, or configure the `ReadAsyncMode` property to `continuous`, then the new data is appended to the existing data in the input buffer.

**See Also** **Functions**  
`fprintf`, `fwrite`, `readasync`

**Properties**  
`ReadAsyncMode`, `TransferStatus`

**Purpose** Convert string to double-precision value

**Syntax**

```
X = str2double('str')
X = str2double(C)
```

**Description** `X = str2double('str')` converts the string `str`, which should be an ASCII character representation of a real or complex scalar value, to the MATLAB double-precision representation. The string can contain digits, a comma (thousands separator), a decimal point, a leading + or - sign, an `e` preceding a power of 10 scale factor, and an `i` for a complex unit.

If `str` does not represent a valid scalar value, `str2double` returns NaN.

`X = str2double(C)` converts the strings in the cell array of strings `C` to double precision. The matrix `X` returned will be the same size as `C`.

**Examples** Here are some valid `str2double` conversions.

```
str2double('123.45e7')
str2double('123 + 45i')
str2double('3.14159')
str2double('2.7i - 3.14')
str2double({'2.71' '3.1415'})
str2double('1,200.34')
```

**See Also** `char`, `hex2num`, `num2str`, `str2num`

# str2func

---

**Purpose** Construct function handle from function name string

**Syntax** `str2func('str')`

**Description** `str2func('str')` constructs a function handle `fhandle` for the function named in the string `'str'`. The contents of `str` can be the name of a function M-file, or the name of an anonymous function.

You can create a function handle `fh` using any of the following four methods:

- Create a handle to a named function:

```
fh = @functionName;
fh = str2func(functionName);
```

- Create a handle to an anonymous function:

```
fh = @(x)functionDef(x);
fh = str2func('@(x)functionDef(x)');
```

You can create an array of function handles from strings by creating the handles individually with `str2func`, and then storing these handles in a cell array.

**Remarks** Nested functions are not accessible to `str2func`. To construct a function handle for a nested function, you must use the function handle constructor, `@`.

**Examples** **Example 1**

To convert the string, `'sin'`, into a handle for that function, type

```
fh = str2func('sin')
fh =
 @sin
```

## Example 2

If you pass a function name string in a variable, the function that receives the variable can convert the function name to a function handle using `str2func`. The example below passes the variable, `funcname`, to function `makeHandle`, which then creates a function handle. Here is the function M-file:

```
function fh = makeHandle(funcname)
 fh = str2func(funcname);
```

This is the code that calls `makeHandle` to construct the function handle:

```
makeHandle('sin')
ans =
 @sin
```

## Example 3

To call `str2func` on a cell array of strings, use the `cellfun` function. This returns a cell array of function handles:

```
fh_array = cellfun(@str2func, {'sin' 'cos' 'tan'}, ...
 'UniformOutput', false);

fh_array{2}(5)
ans =
 0.2837
```

## Example 4

In the following example, the `myminbnd` function expects to receive either a function handle or string in the first argument. If you pass a string, `myminbnd` constructs a function handle from it using `str2func`, and then uses that handle in a call to `fminbnd`:

```
function myminbnd(fhandle, lower, upper)
 if ischar(fhandle)
 disp 'converting function string to function handle ...'
 fhandle = str2func(fhandle);
 end
```

```
fminbnd(fhandle, lower, upper)
```

Whether you call `myminbnd` with a function handle or function name string, the function can handle the argument appropriately:

```
myminbnd('humps', 0.3, 1)
converting function string to function handle ...
ans =
 0.6370
```

### Example 5

The `dirByType` function shown here creates an anonymous function called `dirCheck`. What the anonymous function does depends upon the value of the `dirType` argument passed in to the primary function. The example demonstrates one possible use of `str2func` with anonymous functions:

```
function dirByType(dirType)
switch(dirType)
 case 'class', leadchar = '@';
 case 'package', leadchar = '+';
 otherwise disp('ERROR: Unrecognized type'), return;
end

dirfile = @(fs)isdir(fs.name);
dirCheckStr = ['@(fs)strcmp(fs.name(1,1),'', leadchar, '')'];
dirCheckFun = str2func(dirCheckStr);
s = dir; filecount = length(s);

for k=1:filecount
 fstruct = s(k);
 if dirfile(fstruct) && dirCheckFun(fstruct)
 fprintf('%s directory: %s\n', dirType, fstruct.name)
 end
end
```

Generate a list of class and package directories:



```
dirByType('class')
class directory: @Point
class directory: @asset
class directory: @bond
```

```
dirByType('package')
package directory: +containers
package directory: +event
package directory: +mypkg
```

**See Also**

`function_handle`, `func2str`, `functions`

# str2mat

---

**Purpose** Form blank-padded character matrix from strings

**Syntax** `S = str2mat(T1, T2, T3, ...)`

**Description** `S = str2mat(T1, T2, T3, ...)` forms the matrix `S` containing the text strings `T1`, `T2`, `T3`, ... as rows. The function automatically pads each string with blanks in order to form a valid matrix. Each text parameter, `Ti`, can itself be a string matrix. This allows the creation of arbitrarily large string matrices. Empty strings are significant.

---

**Note** This routine will become obsolete in a future version. Use `char` instead.

---

**Remarks** `str2mat` differs from `strvcat` in that empty strings produce blank rows in the output. In `strvcat`, empty strings are ignored.

**Examples** `x = str2mat('36842', '39751', '38453', '90307');`

```
whos x
 Name Size Bytes Class
 x 4x5 40 char array
```

```
x(2,3)
```

```
ans =
```

```
7
```

**See Also** `char`, `strvcat`

**Purpose** Convert string to number

**Syntax**

```
x = str2num('str')
[x, status] = str2num('str')
```

## Description

---

**Note** str2num uses the eval function to convert the input argument. Side effects can occur if the string contains calls to functions. Using str2double can avoid some of these side effects.

---

`x = str2num('str')` converts the string `str`, which is an ASCII character representation of a numeric value, to numeric representation. `str2num` also converts string matrices to numeric matrices. If the input string does not represent a valid number or matrix, `str2num(str)` returns the empty matrix in `x`.

The input string can contain one or more numbers separated by spaces, commas, or semicolons, such as '5', '10,11,12', or '5,10;15,20'. In addition to numerical values and delimiters, the input string can also include a decimal point, leading + or - signs, the letter e or d preceding a power of 10 scale factor, or the letter i or j indicating a complex or imaginary number.

The following table shows several examples of valid inputs to `str2num`:

| String Input             | Numeric Output                              | Output Class                   |
|--------------------------|---------------------------------------------|--------------------------------|
| '500'                    | 500                                         | 1-by-1 scalar double           |
| '500 250 125 67'         | 500, 250, 125,<br>67                        | 1-by-4 row vector of double    |
| '500; 250; 125;<br>62.5' | 500.0000<br>250.0000<br>125.0000<br>62.5000 | 4-by-1 column vector of double |

# str2num

| String Input       | Numeric Output           | Output Class            |
|--------------------|--------------------------|-------------------------|
| '1 23 6 21; 53:56' | 1 23 6 21<br>53 54 55 56 | 2-by-5 matrix of double |
| '12e-3 5.9e-3'     | 0.0120 0.0059            | vector of double        |
| 'uint16(500)'      | 500                      | 16-bit unsigned integer |

If the input string does not represent a valid number or matrix, `str2num(str)` returns the empty matrix in `x`.

`[x, status] = str2num('str')` returns the status of the conversion in logical `status`, where `status` equals logical 1 (true) if the conversion succeeds, and logical 0 (false) otherwise.

Space characters can be significant. For instance, `str2num('1+2i')` and `str2num('1 + 2i')` produce `x = 1+2i`, while `str2num('1 +2i')` produces `x = [1 2i]`. You can avoid these problems by using the `str2double` function.

## Examples

Input a character string that contains a single number. The output is a scalar double:

```
A = str2num('500')
A =
 500

class(A)
ans =
 double
```

Repeat this operation, but this time using an unsigned 16-bit integer:

```
A = str2num('uint16(500)')
A =
 500

class(A)
```

```
ans =
 uint16
```

Try three different ways of specifying a row vector. Each returns the same answer:

```
str2num('2 4 6 8') % Separate with spaces.
ans =
 2 4 6 8

str2num('2,4,6,8') % Separate with commas.
ans =
 2 4 6 8

str2num('[2 4 6 8]') % Enclose in brackets.
ans =
 2 4 6 8
```

Note that the first two of these commands do not need the MATLAB square bracket operator to create a matrix. The `str2num` function inserts the brackets for you if they are needed.

Use a column vector this time:

```
str2num('2; 4; 6; 8')
ans =
 2
 4
 6
 8
```

And now a 2-by-2 matrix:

```
str2num('2 4; 6 8')
ans =
 2 4
 6 8
```

# str2num

---

## See Also

num2str, str2double, hex2num, sscanf, sparse, char, special characters

**Purpose** Concatenate strings horizontally

**Syntax** `t = strcat(s1, s2, s3, ...)`

**Description** `t = strcat(s1, s2, s3, ...)` horizontally concatenates corresponding rows of the character arrays `s1`, `s2`, `s3`, etc. All input arrays must have the same number of rows (or any can be a single string). When the inputs are all character arrays, the output is also a character array.

When any of the inputs is a cell array of strings, `strcat` returns a cell array of strings formed by concatenating corresponding elements of `s1`, `s2`, etc. The inputs must all have the same size (or any can be a scalar). Any of the inputs can also be character arrays.

`strcat` ignores trailing ASCII white space characters and omits all such characters from the output. White space characters in ASCII are space, newline, carriage return, tab, vertical tab, or form-feed characters, all of which return a `true` response from the MATLAB `isspace` function. Use the concatenation syntax `[s1 s2 s3 ...]` to preserve trailing spaces. `strcat` does not ignore inputs that are cell arrays of strings.

**Remarks** `strcat` and matrix operation are different for strings that contain trailing spaces:

```
a = 'hello '
b = 'goodbye'
strcat(a, b)
ans =
hellogoodbye
[a b]
ans =
hello goodbye
```

**Examples** Given two 1-by-2 cell arrays `a` and `b`,

```
a = b =
'abcde' 'fghi' 'jkl' 'mn'
```

## strcat

---

the command `t = strcat(a,b)` yields

```
t =
 'abcdeijkl' 'fghimn'
```

Given the 1-by-1 cell array `c = {'Q'}`, the command `t = strcat(a,b,c)` yields

```
t =
 'abcdeijklQ' 'fghimnQ'
```

### See Also

`strvcat`, `cat`, `vertcat`, `horzcat`, `cellstr`, `special character []`



**Purpose** Compare strings

**Syntax**

```
TF = strcmp('str1', 'str2')
TF = strcmp('str', C)
TF = strcmp(C1, C2)
```

Each of these syntaxes applies to both `strcmp` and `strcmpi`. The `strcmp` function is case sensitive in matching strings, while `strcmpi` is not.

**Description** Although the following descriptions show only `strcmp`, they apply to `strcmpi` as well. The two functions are the same except that `strcmpi` compares strings without sensitivity to letter case:

`TF = strcmp('str1', 'str2')` compares the strings `str1` and `str2` and returns logical 1 (`true`) if they are identical, and returns logical 0 (`false`) otherwise. `str1` and `str2` can be character arrays of any dimension, but `strcmp` does not return `true` unless the sizes of both arrays are equal, and the contents of the two arrays are the same.

`TF = strcmp('str', C)` compares string `str` to the each element of cell array `C`, where `str` is a character vector (or a 1-by-1 cell array) and `C` is a cell array of strings. The function returns `TF`, a logical array that is the same size as `C` and contains logical 1 (`true`) for those elements of `C` that are a match, and logical 0 (`false`) for those elements that are not. The order of the first two input arguments is not important.

`TF = strcmp(C1, C2)` compares each element of `C1` to the same element in `C2`, where `C1` and `C2` are equal-size cell arrays of strings. Input `C1` or `C2` can also be a character array with the right number of rows. The function returns `TF`, a logical array that is the same size as `C1` and `C2`, and contains logical 1 (`true`) for those elements of `C1` and `C2` that are a match, and logical 0 (`false`) for those elements that are not.

**Remarks** These functions are intended for comparison of character data. When used to compare numeric data, they return logical 0.

Any leading and trailing blanks in either of the strings are explicitly included in the comparison.

# strcmp, strcmpi

---

The value returned by `strcmp` and `strcmpi` is not the same as the C language convention.

`strcmp` and `strcmpi` support international character sets.

## Examples

### Example 1

Perform a simple comparison of two strings:

```
strcmp('Yes', 'No')
ans =
 0
strcmp('Yes', 'Yes')
ans =
 1
```

### Example 2

Create 3 cell arrays of strings:

```
A = {'MATLAB', 'SIMULINK'; ...
 'Toolboxes', 'The MathWorks'};

B = {'Handle Graphics', 'Real Time Workshop'; ...
 'Toolboxes', 'The MathWorks'};

C = {'handle graphics', 'Signal Processing'; ...
 ' Toolboxes', 'The MATHWORKS'};
```

Compare cell arrays A and B with sensitivity to case:

```
strcmp(A, B)
ans =
 0 0
 1 1
```

Compare cell arrays B and C without sensitivity to case. Note that 'Toolboxes' doesn't match because of the leading space characters in C{2,1} that do not appear in B{2,1}:

```
strcmpi(B, C)
ans =
 1 0
 0 1
```

### Example 3

Compare a string vector to a cell array of strings, a string vector to a string array, and a string array to a cell array of strings. Start by creating a cell array of strings (`cellArr`), a string array containing the same strings plus space characters for padding `s(strArr)`, and a string vector containing one of the strings plus padding (`strVec`):

```
cellArr = { ...
 'There are 10 kinds of people in the world,'; ...
 'those who understand binary math,'; ...
 'and those who don't.'};

strArr = char(cellArr);
strVec = strArr(2,:);
strVec =
 those who understand binary math,
```

Remove the space padding from the string vector and compare it to the cell array. The MATLAB software compares the string with each row of the cell array, finding a match on the second row:

```
strcmp(deblank(strVec), cellArr)
ans =
 0
 1
 0
```

Compare the string vector with the string array. Unlike the case above, MATLAB does not compare the string vector with each row of the string array. It compares the entire contents of one against the entire contents of the other:

```
strcmp(strVec, strArr)
```

## strcmp, strcmpi

---

```
ans =
 0
```

Lastly, compare each row of the three-row string array against the same rows of the cell array. MATLAB finds them all to be equivalent. Note that in this case you do not have to remove the space padding from the string array:

```
strcmp(strArr, cellArr)
ans =
 1
 1
 1
```

### See Also

strncmp, strncmpi, strmatch, strfind, findstr, regexp, regexpi, regexprep, regexptranslate

|                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|--------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Purpose</b>     | Compute 2-D streamline data                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| <b>Syntax</b>      | <pre>XY = stream2(x,y,u,v,startx,starty) XY = stream2(u,v,startx,starty) XY = stream2(...,options)</pre>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| <b>Description</b> | <p><code>XY = stream2(x,y,u,v,startx,starty)</code> computes streamlines from vector data <code>u</code> and <code>v</code>. The arrays <code>x</code> and <code>y</code> define the coordinates for <code>u</code> and <code>v</code> and must be monotonic and 2-D plaid (such as the data produced by <code>meshgrid</code>). <code>startx</code> and <code>starty</code> define the starting positions of the streamlines. The section "Specifying Starting Points for Stream Plots" provides more information on defining starting points.</p> <p>The returned value <code>XY</code> contains a cell array of vertex arrays.</p> <p><code>XY = stream2(u,v,startx,starty)</code> assumes the arrays <code>x</code> and <code>y</code> are defined as <code>[x,y] = meshgrid(1:n,1:m)</code> where <code>[m,n] = size(u)</code>.</p> <p><code>XY = stream2(...,options)</code> specifies the options used when creating the streamlines. Define <code>options</code> as a one- or two-element vector containing the step size or the step size and the maximum number of vertices in a streamline:</p> <pre>[stepsize]</pre> <p>or</p> <pre>[stepsize, max_number_vertices]</pre> <p>If you do not specify a value, MATLAB software uses the default:</p> <ul style="list-style-type: none"><li>• Step size = 0.1 (one tenth of a cell)</li><li>• Maximum number of vertices = 10000</li></ul> <p>Use the <code>streamline</code> command to plot the data returned by <code>stream2</code>.</p> |
| <b>Examples</b>    | <p>This example draws 2-D streamlines from data representing air currents over regions of North America.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |

## stream2

---

```
load wind
[sx,sy] = meshgrid(80,20:10:50);
streamline(stream2(x(:, :, 5),y(:, :, 5),u(:, :, 5),v(:, :, 5),sx,sy));
```

### See Also

coneplot, stream3, streamline

“Volume Visualization” on page 1-108 for related functions

Specifying Starting Points for Stream Plots for related information

**Purpose**

Compute 3-D streamline data

**Syntax**

```
XYZ = stream3(X,Y,Z,U,V,W,startx,starty,startz)
XYZ = stream3(U,V,W,startx,starty,startz)
XYZ = stream3(...,options)
```

**Description**

`XYZ = stream3(X,Y,Z,U,V,W,startx,starty,startz)` computes streamlines from vector data `U, V, W`. The arrays `X, Y, Z` define the coordinates for `U, V, W` and must be monotonic and 3-D plaid (such as the data produced by `meshgrid`). `startx, starty, and startz` define the starting positions of the streamlines. The section "Specifying Starting Points for Stream Plots" provides more information on defining starting points.

The returned value `XYZ` contains a cell array of vertex arrays.

`XYZ = stream3(U,V,W,startx,starty,startz)` assumes the arrays `X, Y, and Z` are defined as `[X,Y,Z] = meshgrid(1:N,1:M,1:P)` where `[M,N,P] = size(U)`.

`XYZ = stream3(...,options)` specifies the options used when creating the streamlines. Define `options` as a one- or two-element vector containing the step size or the step size and the maximum number of vertices in a streamline:

```
[stepsize]
```

or

```
[stepsize, max_number_vertices]
```

If you do not specify values, MATLAB software uses the default:

- Step size = 0.1 (one tenth of a cell)
- Maximum number of vertices = 10000

Use the `streamline` command to plot the data returned by `stream3`.

# stream3

---

## Examples

This example draws 3-D streamlines from data representing air currents over regions of North America.

```
load wind
[sx sy sz] = meshgrid(80,20:10:50,0:5:15);
streamline(stream3(x,y,z,u,v,w,sx,sy,sz))
view(3)
```

## See Also

coneplot, stream2, streamline

“Volume Visualization” on page 1-108 for related functions


Specifying Starting Points for Stream Plots for related information



**Purpose** Plot streamlines from 2-D or 3-D vector data



## GUI Alternatives

To graph selected variables, use the Plot Selector  in the Workspace Browser, or use the Figure Palette Plot Catalog. Manipulate graphs in *plot edit* mode with the Property Editor. For details, see Plotting Tools — Interactive Plotting in the MATLAB Graphics documentation and Creating Graphics from the Workspace Browser in the MATLAB Desktop Tools documentation.

## Syntax

```
streamline(X,Y,Z,U,V,W,startx,starty,startz)
streamline(U,V,W,startx,starty,startz)
streamline(XYZ)
streamline(X,Y,U,V,startx,starty)
streamline(U,V,startx,starty)
streamline(XY)
streamline(...,options)
streamline(axes_handle,...)
h = streamline(...)
```

## Description

`streamline(X,Y,Z,U,V,W,startx,starty,startz)` draws streamlines from 3-D vector data `U, V, W`. The arrays `X, Y, Z` define the coordinates for `U, V, W` and must be monotonic and 3-D plaid (such as the data produced by `meshgrid`). `startx, starty, startz` define the starting positions of the streamlines. The section [Specifying Starting Points for Stream Plots](#) provides more information on defining starting points.

`streamline(U,V,W,startx,starty,startz)` assumes the arrays `X, Y, and Z` are defined as `[X,Y,Z] = meshgrid(1:N,1:M,1:P)`, where `[M,N,P] = size(U)`.

`streamline(XYZ)` assumes `XYZ` is a precomputed cell array of vertex arrays (as produced by `stream3`).

`streamline(X,Y,U,V,startx,starty)` draws streamlines from 2-D vector data `U, V`. The arrays `X, Y` define the coordinates for `U, V` and must

# streamline

---

be monotonic and 2-D plaid (such as the data produced by `meshgrid`). `startx` and `starty` define the starting positions of the streamlines. The output argument `h` contains a vector of line handles, one handle for each streamline.

`streamline(U,V,startx,starty)` assumes the arrays `X` and `Y` are defined as `[X,Y] = meshgrid(1:N,1:M)`, where `[M,N] = size(U)`.

`streamline(XY)` assumes `XY` is a precomputed cell array of vertex arrays (as produced by `stream2`).

`streamline(...,options)` specifies the options used when creating the streamlines. Define `options` as a one- or two-element vector containing the step size or the step size and the maximum number of vertices in a streamline:

`[stepsize]`

or

`[stepsize, max_number_vertices]`

If you do not specify values, MATLAB uses the default:

- Step size = 0.1 (one tenth of a cell)
- Maximum number of vertices = 1000

`streamline(axes_handle,...)` plots into the axes object with the handle `axes_handle` instead of the into current axes object (`gca`).

`h = streamline(...)` returns a vector of line handles, one handle for each streamline.

## Examples

This example draws streamlines from data representing air currents over a region of North America. Loading the wind data set creates the variables `x`, `y`, `z`, `u`, `v`, and `w` in the MATLAB workspace.

The plane of streamlines indicates the flow of air from the west to the east (the `x`-direction) beginning at `x = 80` (which is close to

the minimum value of the x coordinates). The y- and z-coordinate starting points are multivalued and approximately span the range of these coordinates. `meshgrid` generates the starting positions of the streamlines.

```
load wind
[sx,sy,sz] = meshgrid(80,20:10:50,0:5:15);
h = streamline(x,y,z,u,v,w,sx,sy,sz);
set(h,'Color','red')
view(3)
```

## See Also

`coneplot`, `stream2`, `stream3`, `streamparticles`

“Volume Visualization” on page 1-108 for related functions


Specifying Starting Points for Stream Plots for related information

Stream Line Plots of Vector Data for another example

# streamparticles

---

**Purpose** Plot stream particles

**GUI Alternatives** To graph selected variables, use the Plot Selector  in the Workspace Browser, or use the Figure Palette Plot Catalog. Manipulate graphs in *plot edit* mode with the Property Editor. For details, see Plotting Tools — Interactive Plotting in the MATLAB Graphics documentation and Creating Graphics from the Workspace Browser in the MATLAB Desktop Tools documentation.

**Syntax**

```
streamparticles(vertices)
streamparticles(vertices,n)
streamparticles(...,'PropertyName',PropertyValue,...)
streamparticles(line_handle,...)
h = streamparticles(...)
```

**Description** `streamparticles(vertices)` draws stream particles of a vector field. Stream particles are usually represented by markers and can show the position and velocity of a streamline. `vertices` is a cell array of 2-D or 3-D vertices (as if produced by `stream2` or `stream3`).

`streamparticles(vertices,n)` uses `n` to determine how many stream particles to draw. The `ParticleAlignment` property controls how `n` is interpreted.

- If `ParticleAlignment` is set to `off` (the default) and `n` is greater than 1, approximately `n` particles are drawn evenly spaced over the streamline vertices.

If `n` is less than or equal to 1, `n` is interpreted as a fraction of the original stream vertices; for example, if `n` is 0.2, approximately 20% of the vertices are used.

`n` determines the upper bound for the number of particles drawn. The actual number of particles can deviate from `n` by as much as a factor of 2.

- If `ParticleAlignment` is on, `n` determines the number of particles on the streamline having the most vertices and sets the spacing on the other streamlines to this value. The default value is `n = 1`.

`streamparticles(..., 'PropertyName', PropertyValue, ...)`  
controls the stream particles using named properties and specified values. Any unspecified properties have default values. MATLAB ignores the case of property names.

## Stream Particle Properties

`Animate` — Stream particle motion [nonnegative integer]

The number of times to animate the stream particles. The default is 0, which does not animate. `Inf` animates until you enter **Ctrl+C**.

`FrameRate` — Animation frames per second [nonnegative integer]

This property specifies the number of frames per second for the animation. `Inf`, the default, draws the animation as fast as possible. Note that the speed of the animation might be limited by the speed of the computer. In such cases, the value of `FrameRate` cannot necessarily be achieved.

`ParticleAlignment` — Align particles with streamlines [ on | {off} ]

Set this property to `on` to draw particles at the beginning of each streamline. This property controls how `streamparticles` interprets the argument `n` (number of stream particles).

Stream particles are line objects. In addition to stream particle properties, you can specify any line object property, such as `Marker` and `EraseMode`. `streamparticles` sets the following line properties when called.

| Line Property          | Value Set by <code>streamparticles</code> |
|------------------------|-------------------------------------------|
| <code>EraseMode</code> | <code>xor</code>                          |
| <code>LineStyle</code> | <code>none</code>                         |
| <code>Marker</code>    | <code>0</code>                            |

# streamparticles

---

| Line Property   | Value Set by streamparticles |
|-----------------|------------------------------|
| MarkerEdgeColor | none                         |
| MarkerFaceColor | red                          |

You can override any of these properties by specifying a property name and value as arguments to `streamparticles`. For example, this statement uses RGB values to set the `MarkerFaceColor` to medium gray:

```
streamparticles(vertices,'MarkerFaceColor',[.5 .5 .5])
```

`streamparticles(line_handle,...)` uses the line object identified by `line_handle` to draw the stream particles.

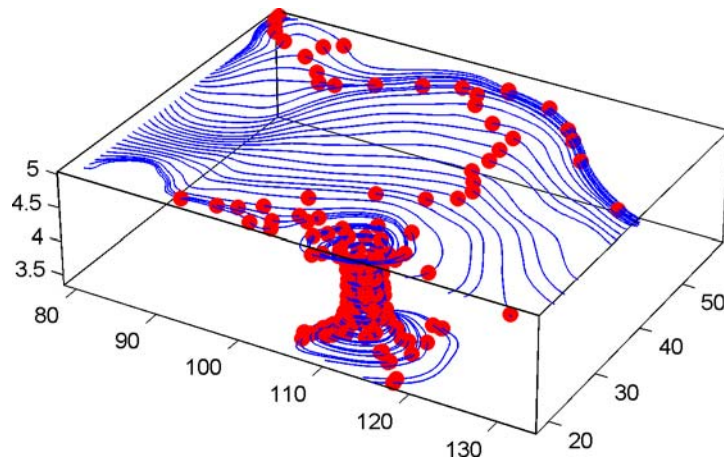
`h = streamparticles(...)` returns a vector of handles to the line objects it creates.

## Examples

This example combines streamlines with stream particle animation. The `interpstreamspeed` function determines the vertices along the streamlines where stream particles will be drawn during the animation, thereby controlling the speed of the animation. Setting the axes `DrawMode` property to `fast` provides faster rendering.

```
load wind
[sx sy sz] = meshgrid(80,20:1:55,5);
verts = stream3(x,y,z,u,v,w,sx,sy,sz);
sl = streamline(verts);
iverts = interpstreamspeed(x,y,z,u,v,w,verts,.025);
axis tight; view(30,30); daspect([1 1 .125])
camproj perspective; camva(8)
set(gca,'DrawMode','fast')
box on
streamparticles(iverts,35,'animate',10,'ParticleAlignment','on')
```

The following picture is a static view of the animation.



This example uses the streamlines in the  $z = 5$  plane to animate the flow along these lines with `streamparticles`.

```
load wind
daspect([1 1 1]); view(2)
[verts averts] = streamslice(x,y,z,u,v,w,[],[],[5]);
sl = streamline([verts averts]);
axis tight off;
set(sl,'Visible','off')
iverts = interpstreamspeed(x,y,z,u,v,w,verts,.05);
set(gca,'DrawMode','fast','Position',[0 0 1 1],'ZLim',[4.9 5.1])
set(gcf,'Color','black')
streamparticles(iverts, 200, ...
 'Animate',100,'FrameRate',40, ...
 'MarkerSize',10,'MarkerFaceColor','yellow')
```

## See Also

`interpstreamspeed`, `stream3`, `streamline`

“Volume Visualization” on page 1-108 for related functions

Creating Stream Particle Animations for more details

Specifying Starting Points for Stream Plots for related information


# streamribbon

---

**Purpose** 3-D stream ribbon plot from vector volume data



## GUI Alternatives

To graph selected variables, use the Plot Selector  in the Workspace Browser, or use the Figure Palette Plot Catalog. Manipulate graphs in *plot edit* mode with the Property Editor. For details, see [Plotting Tools — Interactive Plotting in the MATLAB Graphics documentation](#) and [Creating Graphics from the Workspace Browser in the MATLAB Desktop Tools documentation](#).

## Syntax

```
streamribbon(X,Y,Z,U,V,W,startx,starty,startz)
streamribbon(U,V,W,startx,starty,startz)
streamribbon(vertices,X,Y,Z,cav,speed)
streamribbon(vertices,cav,speed)
streamribbon(vertices,twistangle)
streamribbon(...,width)
streamribbon(axes_handle,...)
h = streamribbon(...)
```

## Description

`streamribbon(X,Y,Z,U,V,W,startx,starty,startz)` draws stream ribbons from vector volume data `U, V, W`. The arrays `X, Y, Z` define the coordinates for `U, V, W` and must be monotonic and 3-D plaid (as if produced by `meshgrid`). `startx, starty, and startz` define the starting positions of the stream ribbons at the center of the ribbons. The section [Specifying Starting Points for Stream Plots](#) provides more information on defining starting points.

The twist of the ribbons is proportional to the curl of the vector field. The width of the ribbons is calculated automatically.

Generally, you should set the `DataAspectRatio (daspect)` before calling `streamribbon`.

`streamribbon(U,V,W,startx,starty,startz)` assumes `X, Y, and Z` are determined by the expression



```
[X,Y,Z] = meshgrid(1:n,1:m,1:p)
```

where `[m,n,p] = size(U)`.

`streamribbon(vertices,X,Y,Z,cav,speed)` assumes precomputed streamline vertices, curl angular velocity, and flow speed. `vertices` is a cell array of streamline vertices (as produced by `stream3`). `X`, `Y`, `Z`, `cav`, and `speed` are 3-D arrays.

`streamribbon(vertices,cav,speed)` assumes `X`, `Y`, and `Z` are determined by the expression

```
[X,Y,Z] = meshgrid(1:n,1:m,1:p)
```

where `[m,n,p] = size(cav)`.

`streamribbon(vertices,twistangle)` uses the cell array of vectors `twistangle` for the twist of the ribbons (in radians). The size of each corresponding element of `vertices` and `twistangle` must be equal.

`streamribbon(...,width)` sets the width of the ribbons to `width`.

`streamribbon(axes_handle,...)` plots into the axes object with the handle `axes_handle` instead of into the current axes object (`gca`).

`h = streamribbon(...)` returns a vector of handles (one per start point) to surface objects.

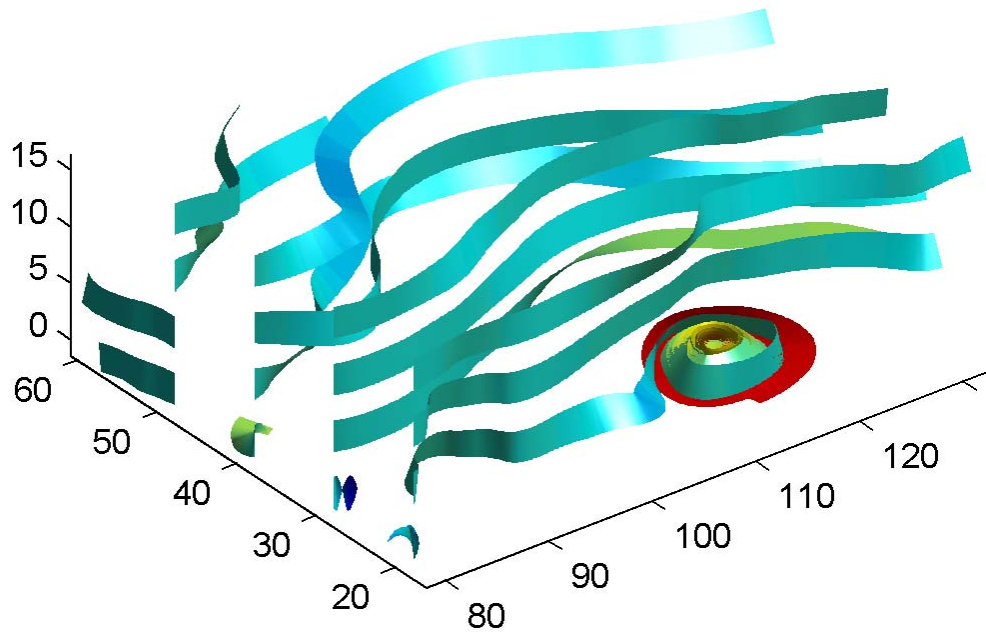
## Examples

This example uses stream ribbons to indicate the flow in the wind data set. Inputs include the coordinates, vector field components, and starting location for the stream ribbons.

```
load wind
[sx sy sz] = meshgrid(80,20:10:50,0:5:15);
daspect([1 1 1])
streamribbon(x,y,z,u,v,w,sx,sy,sz);
%-----Define viewing and lighting
axis tight
shading interp;
view(3);
```

# streamribbon

```
camlight; lighting gouraud
```

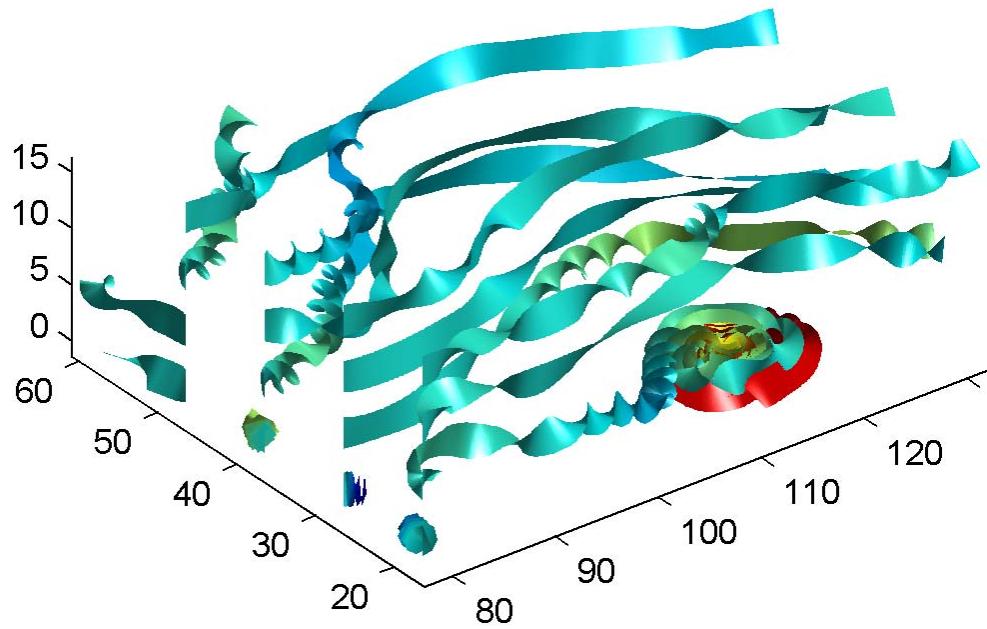


This example uses precalculated vertex data (`stream3`), curl average velocity (`curl1`), and speed  $\sqrt{u^2 + v^2 + w^2}$ . Using precalculated data enables you to use values other than those calculated from the single data source. In this case, the speed is reduced by a factor of 10 compared to the previous example.

```
load wind
[sx sy sz] = meshgrid(80,20:10:50,0:5:15);
daspect([1 1 1])
verts = stream3(x,y,z,u,v,w,sx,sy,sz);
cav = curl(x,y,z,u,v,w);
spd = sqrt(u.^2 + v.^2 + w.^2).*0.1;
streamribbon(verts,x,y,z,cav,spd);
%-----Define viewing and lighting
axis tight
shading interp
view(3)
camlight; lighting gouraud
```

# streamribbon

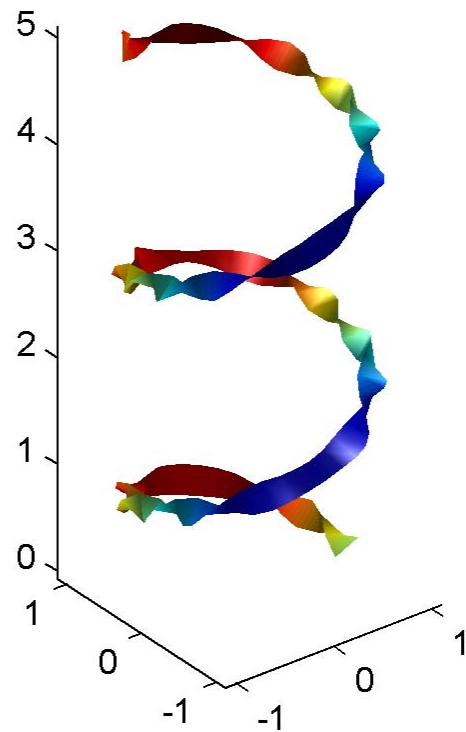
---



This example specifies a twist angle for the stream ribbon.

```
t = 0:.15:15;
verts = {[cos(t)' sin(t)' (t/3)']};
twistangle = {cos(t)'};
daspect([1 1 1])
streamribbon(verts,twistangle);
%-----Define viewing and lighting
```

```
axis tight
shading interp;
view(3);
camlight; lighting gouraud
```

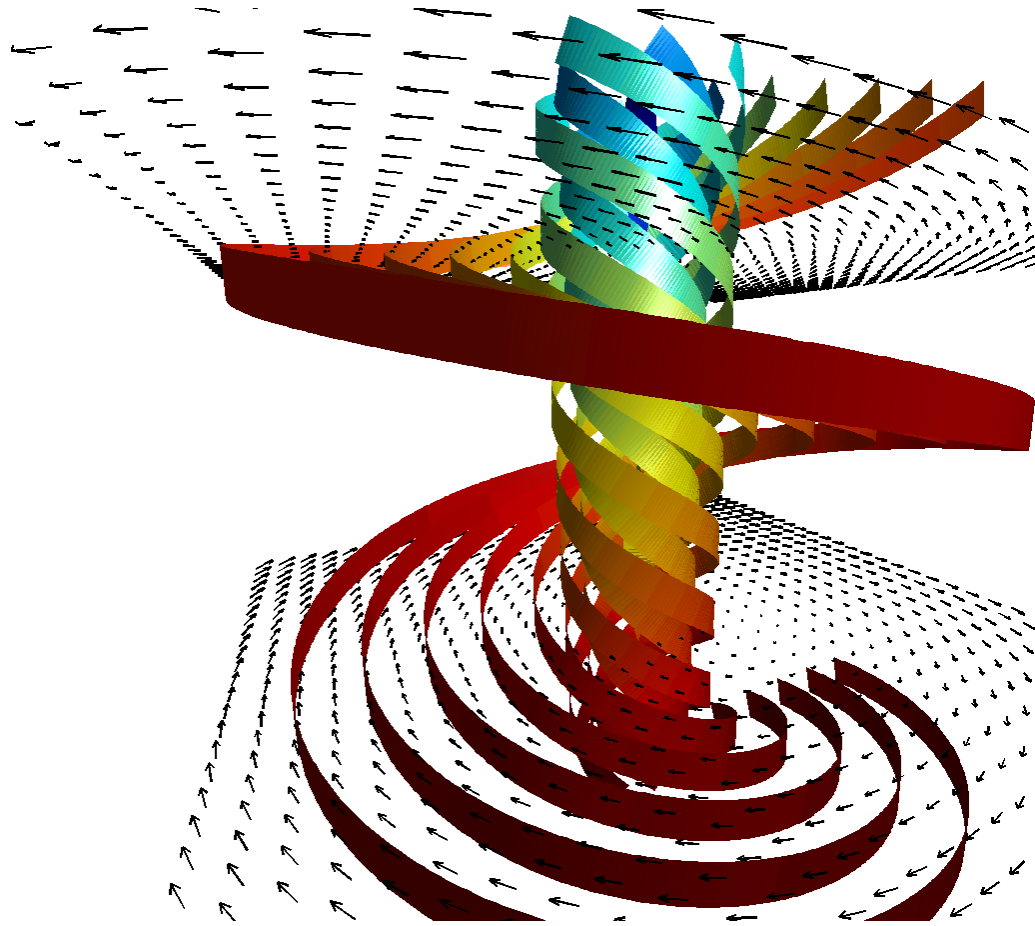


This example combines cone plots (coneplot) and stream ribbon plots in one graph.

# streamribbon

---

```
%-----Define 3-D arrays x, y, z, u, v, w
xmin = -7; xmax = 7;
ymin = -7; ymax = 7;
zmin = -7; zmax = 7;
x = linspace(xmin,xmax,30);
y = linspace(ymin,ymax,20);
z = linspace(zmin,zmax,20);
[x y z] = meshgrid(x,y,z);
u = y; v = -x; w = 0*x+1;
daspect([1 1 1]);
[cx cy cz] = meshgrid(linspace(xmin,xmax,30),...
 linspace(ymin,ymax,30),[-3 4]);
h = coneplot(x,y,z,u,v,w,cx,cy,cz,'quiver');
set(h,'color','k');
%-----Plot two sets of streamribbons
[sx sy sz] = meshgrid([-1 0 1],[-1 0 1],-6);
streamribbon(x,y,z,u,v,w,sx,sy,sz);
[sx sy sz] = meshgrid([1:6],[0],-6);
streamribbon(x,y,z,u,v,w,sx,sy,sz);
%-----Define viewing and lighting
shading interp
view(-30,10) ; axis off tight
camproj perspective; camva(66); camlookat;
camdolly(0,0,.5,'fixtarget')
camlight
```



**See Also**

`curl`, `streamtube`, `streamline`, `stream3`

“Volume Visualization” on page 1-108 for related functions

Displaying Curl with Stream Ribbons for another example

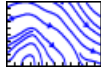
Specifying Starting Points for Stream Plots for related information

# streamslice


---

## Purpose

Plot streamlines in slice planes



## GUI Alternatives

To graph selected variables, use the Plot Selector  in the Workspace Browser, or use the Figure Palette Plot Catalog. Manipulate graphs in *plot edit* mode with the Property Editor. For details, see Plotting Tools — Interactive Plotting in the MATLAB Graphics documentation and Creating Graphics from the Workspace Browser in the MATLAB Desktop Tools documentation.

## Syntax

```
streamslice(X,Y,Z,U,V,W,startx,starty,startz)
streamslice(U,V,W,startx,starty,startz)
streamslice(X,Y,U,V)
streamslice(U,V)
streamslice(...,density)
streamslice(...,'arrowmode')
streamslice(...,'method')
streamslice(axes_handle,...)
h = streamslice(...)
[vertices arrowvertices] = streamslice(...)
```

## Description

`streamslice(X,Y,Z,U,V,W,startx,starty,startz)` draws well-spaced streamlines (with direction arrows) from vector data `U`, `V`, `W` in axis aligned  $x$ -,  $y$ -,  $z$ -planes starting at the points in the vectors `startx`, `starty`, `startz`. (The section Specifying Starting Points for Stream Plots provides more information on defining starting points.) The arrays `X`, `Y`, `Z` define the coordinates for `U`, `V`, `W` and must be monotonic and 3-D plaid (as if produced by `meshgrid`). `U`, `V`, `W` must be  $m$ -by- $n$ -by- $p$  volume arrays.

Do not assume that the flow is parallel to the slice plane. For example, in a stream slice at a constant  $z$ , the  $z$  component of the vector field `W` is ignored when you are calculating the streamlines for that plane.



Stream slices are useful for determining where to start streamlines, stream tubes, and stream ribbons. It is good practice is to set the axes `DataAspectRatio` to `[1 1 1]` when using `streamslice`.

`streamslice(U,V,W,startx,starty,startz)` assumes `X`, `Y`, and `Z` are determined by the expression

```
[X,Y,Z] = meshgrid(1:n,1:m,1:p)
```

where `[m,n,p] = size(U)`.

`streamslice(X,Y,U,V)` draws well-spaced streamlines (with direction arrows) from vector volume data `U`, `V`. The arrays `X`, `Y` define the coordinates for `U`, `V` and must be monotonic and 2-D plaid (as if produced by `meshgrid`).

`streamslice(U,V)` assumes `X`, `Y`, and `Z` are determined by the expression

```
[X,Y,Z] = meshgrid(1:n,1:m,1:p)
```

where `[m,n,p] = size(U)`.

`streamslice(...,density)` modifies the automatic spacing of the streamlines. `density` must be greater than 0. The default value is 1; higher values produce more streamlines on each plane. For example, 2 produces approximately twice as many streamlines, while 0.5 produces approximately half as many.

`streamslice(...,'arrowmode')` determines if direction arrows are present or not. `arrowmode` can be

- `arrows` — Draw direction arrows on the streamlines (default).
- `noarrows` — Do not draw direction arrows.

`streamslice(...,'method')` specifies the interpolation method to use. `method` can be

- `linear` — Linear interpolation (default)

# streamslice

---

- `cubic` — Cubic interpolation
- `nearest` — Nearest-neighbor interpolation

See `interp3` for more information on interpolation methods.

`streamslice(axes_handle, ...)` plots into the axes object with the handle `axes_handle` instead of into the current axes object (`gca`).

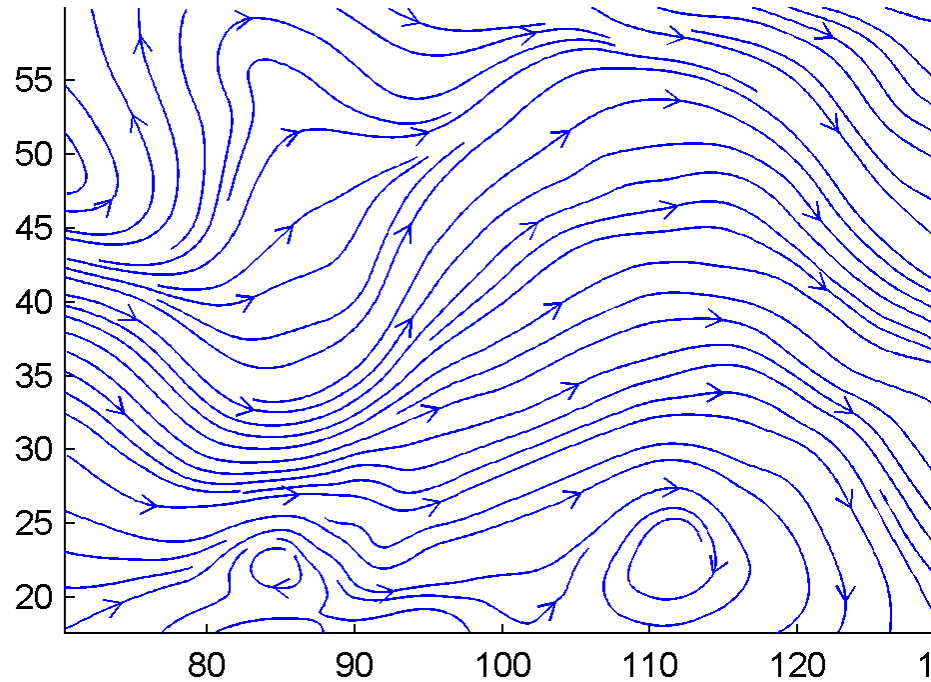
`h = streamslice(...)` returns a vector of handles to the line objects created.

`[vertices arrowvertices] = streamslice(...)` returns two cell arrays of vertices for drawing the streamlines and the arrows. You can pass these values to any of the streamline drawing functions (`streamline`, `streamribbon`, `streamtube`).

## Examples

This example creates a stream slice in the wind data set at `z = 5`.

```
load wind
daspect([1 1 1])
streamslice(x,y,z,u,v,w,[],[],[5])
axis tight
```



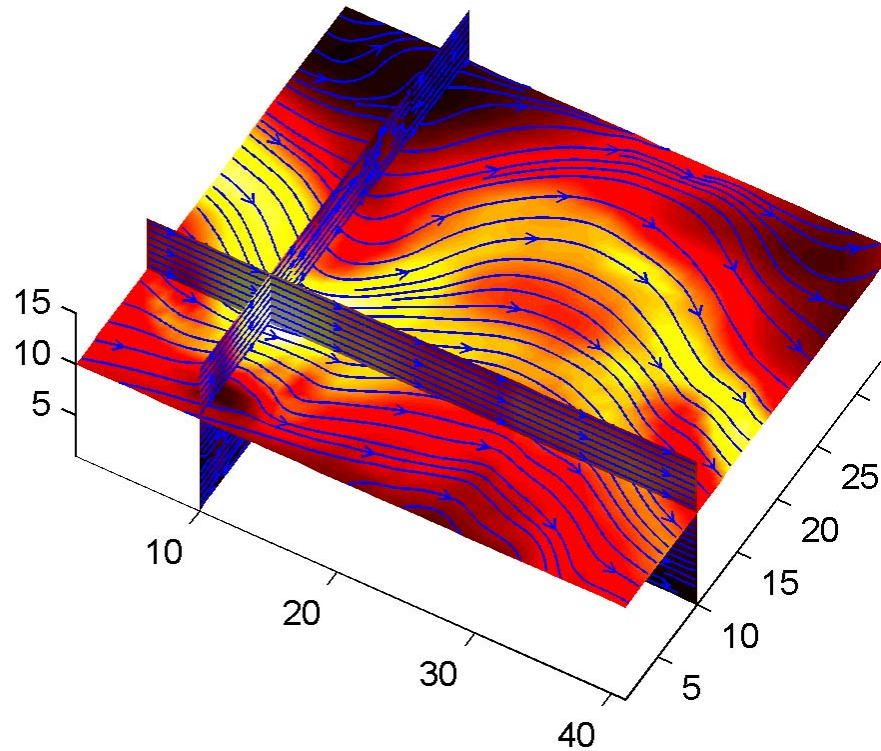
This example uses `streamslic` to calculate vertex data for the streamlines and the direction arrows. This data is then used by `streamline` to plot the lines and arrows. Slice planes illustrating with color the wind speed  $\sqrt{u^2 + v^2 + w^2}$  are drawn by `slice` in the same planes.

load wind

## streamslice

---

```
daspect([1 1 1])
[verts averts] = streamslice(u,v,w,10,10,10);
streamline([verts averts])
spd = sqrt(u.^2 + v.^2 + w.^2);
hold on;
slice(spd,10,10,10);
colormap(hot)
shading interp
view(30,50); axis(volumebounds(spd));
camlight; material([.5 1 0])
```



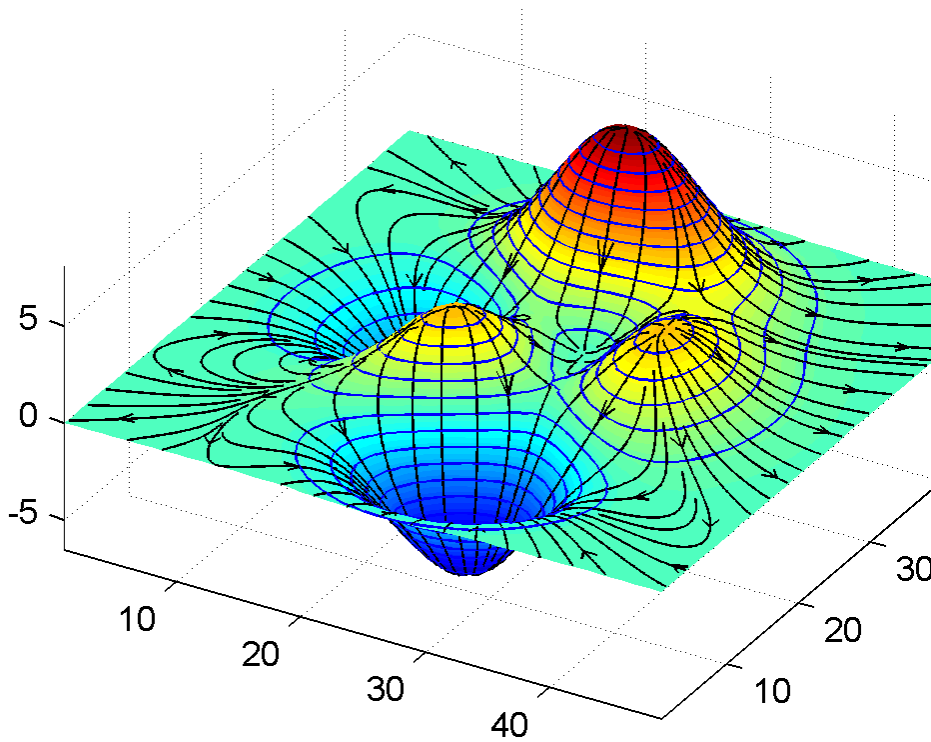
This example superimposes contour lines on a surface and then uses `streamslice` to draw lines that indicate the gradient of the surface. `interp2` is used to find the points for the lines that lie on the surface.

```
z = peaks;
surf(z)
shading interp
hold on
```

## streamslice

---

```
[c ch] = contour3(z,20); set(ch,'edgecolor','b')
[u v] = gradient(z);
h = streamslice(-u,-v);
set(h,'color','k')
for i=1:length(h);
 zi = interp2(z,get(h(i),'xdata'),get(h(i),'ydata'));
 set(h(i),'zdata',zi);
end
view(30,50); axis tight
```

**See Also**

contourslice, slice, streamline, volumebounds

“Volume Visualization” on page 1-108 for related functions

Specifying Starting Points for Stream Plots for related information


# streamtube

---

**Purpose** Create 3-D stream tube plot



## GUI Alternatives

To graph selected variables, use the Plot Selector  in the Workspace Browser, or use the Figure Palette Plot Catalog. Manipulate graphs in *plot edit* mode with the Property Editor. For details, see Plotting Tools — Interactive Plotting in the MATLAB Graphics documentation and Creating Graphics from the Workspace Browser in the MATLAB Desktop Tools documentation.

## Syntax

```
streamtube(X,Y,Z,U,V,W,startx,starty,startz)
streamtube(U,V,W,startx,starty,startz)
streamtube(vertices,X,Y,Z,divergence)
streamtube(vertices,divergence)
streamtube(vertices,width)
streamtube(vertices)
streamtube(...,[scale n])
streamtube(axes_handle,...)
h = streamtube(...z)
```

## Description

`streamtube(X,Y,Z,U,V,W,startx,starty,startz)` draws stream tubes from vector volume data `U`, `V`, `W`. The arrays `X`, `Y`, `Z` define the coordinates for `U`, `V`, `W` and must be monotonic and 3-D plaid (as if produced by `meshgrid`). `startx`, `starty`, and `startz` define the starting positions of the streamlines at the center of the tubes. The section Specifying Starting Points for Stream Plots provides more information on defining starting points.

The width of the tubes is proportional to the normalized divergence of the vector field.

Generally, you should set the `DataAspectRatio` (`daspect`) before calling `streamtube`.

`streamtube(U,V,W,startx,starty,startz)` assumes `X`, `Y`, and `Z` are determined by the expression



```
[X,Y,Z] = meshgrid(1:n,1:m,1:p)
```

where `[m,n,p] = size(U)`.

`streamtube(vertices,X,Y,Z,divergence)` assumes precomputed streamline vertices and divergence. `vertices` is a cell array of streamline vertices (as produced by `stream3`). `X`, `Y`, `Z`, and `divergence` are 3-D arrays.

`streamtube(vertices,divergence)` assumes `X`, `Y`, and `Z` are determined by the expression

```
[X,Y,Z] = meshgrid(1:n,1:m,1:p)
```

where `[m,n,p] = size(divergence)`.

`streamtube(vertices,width)` specifies the width of the tubes in the cell array of vectors, `width`. The size of each corresponding element of `vertices` and `width` must be equal. `width` can also be a scalar, specifying a single value for the width of all stream tubes.

`streamtube(vertices)` selects the width automatically.

`streamtube(...,[scale n])` scales the width of the tubes by `scale`. The default is `scale = 1`. When the stream tubes are created, using start points or divergence, specifying `scale = 0` suppresses automatic scaling. `n` is the number of points along the circumference of the tube. The default is `n = 20`.

`streamtube(axes_handle,...)` plots into the axes object with the handle `axes_handle` instead of into the current axes object (`gca`).

`h = streamtube(...,z)` returns a vector of handles (one per start point) to surface objects used to draw the stream tubes.

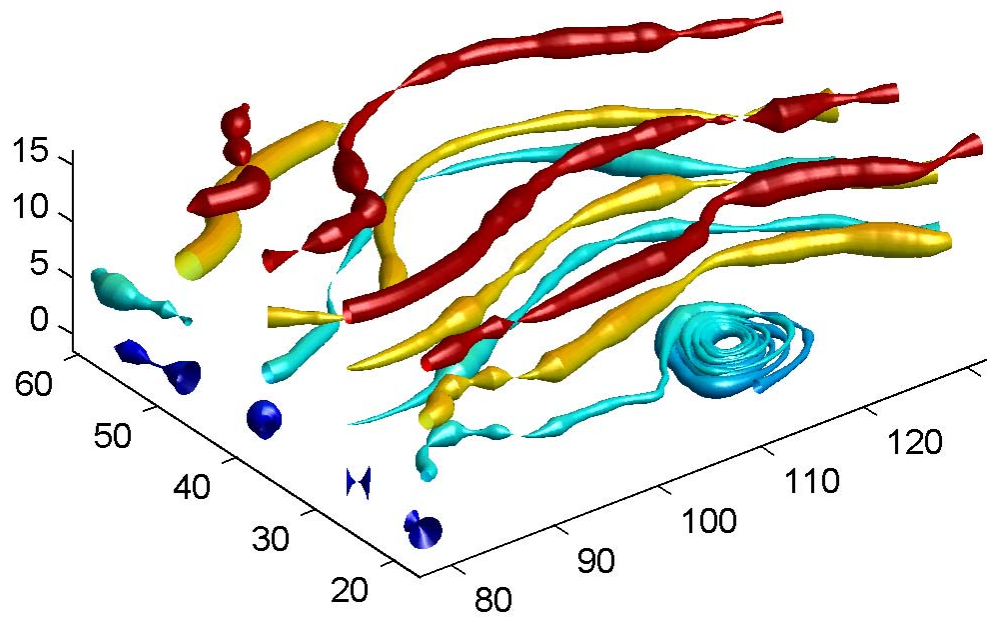
## Examples

This example uses stream tubes to indicate the flow in the wind data set. Inputs include the coordinates, vector field components, and starting location for the stream tubes.

```
load wind
[sx sy sz] = meshgrid(80,20:10:50,0:5:15);
```

# streamtube

```
daspect([1 1 1])
streamtube(x,y,z,u,v,w,sx,sy,sz);
%-----Define viewing and lighting
view(3)
axis tight
shading interp;
camlight; lighting gouraud
```

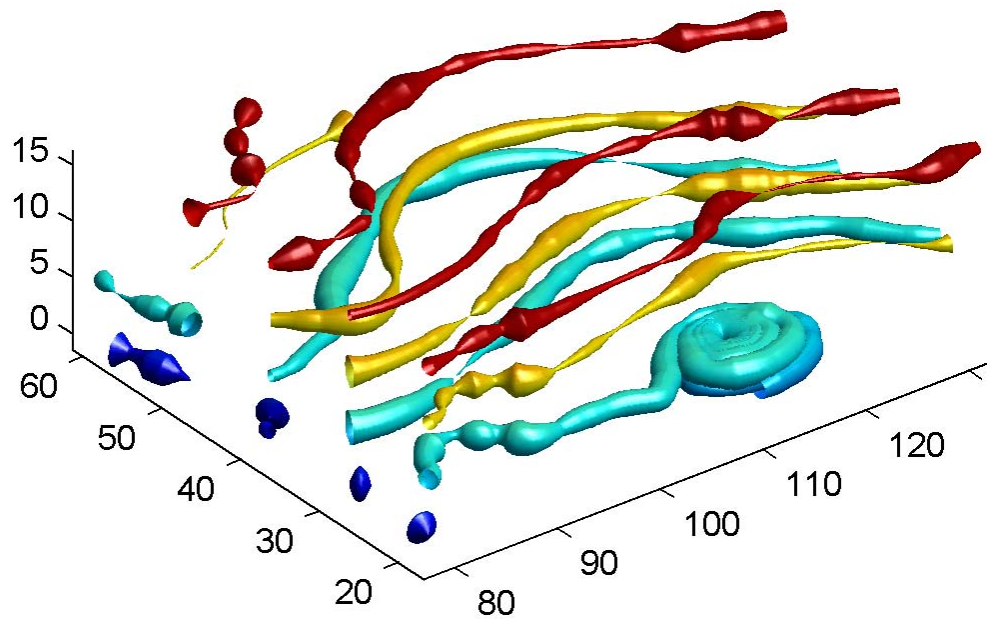


This example uses precalculated vertex data (stream3) and divergence (divergence).

```
load wind
[sx sy sz] = meshgrid(80,20:10:50,0:5:15);
daspect([1 1 1])
verts = stream3(x,y,z,u,v,w,sx,sy,sz);
div = divergence(x,y,z,u,v,w);
streamtube(verts,x,y,z,-div);
%----Define viewing and lighting
view(3)
axis tight
shading interp
camlight; lighting gouraud
```

# streamtube

---



## See Also

`divergence`, `streamribbon`, `streamline`, `stream3`

“Volume Visualization” on page 1-108 for related functions

Displaying Divergence with Stream Tubes for another example

Specifying Starting Points for Stream Plots for related information

**Purpose** Find one string within another

**Syntax** `k = strfind(str, pattern)`  
`k = strfind(cellstr, pattern)`

**Description** `k = strfind(str, pattern)` searches the string `str` for occurrences of a shorter string, `pattern`, and returns the starting index of each such occurrence in the double array `k`. If `pattern` is not found in `str`, or if `pattern` is longer than `str`, then `strfind` returns the empty array `[]`.

`k = strfind(cellstr, pattern)` searches each string in cell array of strings `cellstr` for occurrences of a shorter string, `pattern`, and returns the starting index of each such occurrence in cell array `k`. If `pattern` is not found in a string or if `pattern` is longer than all strings in the cell array, then `strfind` returns the empty array `[]`, for that string in the cell array.

The search performed by `strfind` is case sensitive. Any leading and trailing blanks in `pattern` or in the strings being searched are explicitly included in the comparison.

**Examples** Use `strfind` to find a two-letter pattern in string `S`:

```
S = 'Find the starting indices of the pattern string';
strfind(S, 'in')
ans =
 2 15 19 45

strfind(S, 'In')
ans =
 []

strfind(S, ' ')
ans =
 5 9 18 26 29 33 41
```

Use `strfind` on a cell array of strings:

# strfind

---

```
cstr = {'How much wood would a woodchuck chuck';
 'if a woodchuck could chuck wood?'};

idx = strfind(cstr, 'wood');

idx{:,:}
ans =
 10 23
ans =
 6 28
```

This means that 'wood' occurs at indices 10 and 23 in the first string and at indices 6 and 28 in the second.

## See Also

findstr, strmatch, strtok, strcmp, strncmp, strcmpi, strncmpi, regexp, regexpi, regexprep

**Purpose**

String handling

**Syntax**

```
S = 'Any Characters'
S = [S1 S2 ...]
S = strcat(S1, S2, ...)
```

**Description**

`S = 'Any Characters'` creates a character array, or string. The string is actually a vector whose components are the numeric codes for the characters (the first 127 codes are ASCII). The actual characters displayed depend on the character encoding scheme for a given font. The length of `S` is the number of characters. A quotation within the string is indicated by two quotes.

`S = [S1 S2 ...]` concatenates character arrays `S1`, `S2`, etc. into a new character array, `S`.

`S = strcat(S1, S2, ...)` concatenates `S1`, `S2`, etc., which can be character arrays or “Cell Arrays of Strings”. When the inputs are all character arrays, the output is also a character array. When any of the inputs is a cell array of strings, `strcat` returns a cell array of strings.

Trailing spaces in `strcat` character array inputs are ignored and do not appear in the output. This is not true for `strcat` inputs that are cell arrays of strings. Use the `S = [S1 S2 ...]` concatenation syntax, shown above, to preserve trailing spaces.

`S = char(X)` can be used to convert an array that contains positive integers representing numeric codes into a MATLAB character array.

`X = double(S)` converts the string to its equivalent double-precision numeric codes.

A collection of strings can be created in either of the following two ways:

- As the rows of a character array via `strvcat`
- As a cell array of strings via the curly braces

You can convert between character array and cell array of strings using `char` and `cellstr`. Most string functions support both types.

# strings

---

`ischar(S)` tells if `S` is a string variable. `iscellstr(S)` tells if `S` is a cell array of strings.

## Examples

Create a simple string that includes a single quote.

```
msg = 'You're right!'

msg =
You're right!
```

Create the string name using two methods of concatenation.

```
name = ['Thomas' ' R. ' 'Lee']
name = strcat('Thomas',' R.',' Lee')
```

Create a vertical array of strings.

```
C = strvcat('Hello','Yes','No','Goodbye')

C =
Hello
Yes
No
Goodbye
```

Create a cell array of strings.

```
S = {'Hello' 'Yes' 'No' 'Goodbye'}

S =
'Hello' 'Yes' 'No' 'Goodbye'
```

## See Also

`char`, `isstrprop`, `cellstr`, `ischar`, `isletter`, `isspace`, `iscellstr`, `strvcat`, `sprintf`, `sscanf`, `text`, `input`



**Purpose** Justify character array

**Syntax**  
T = strjust(S)  
T = strjust(S, 'right')  
T = strjust(S, 'left')  
T = strjust(S, 'center')

**Description** T = strjust(S) or T = strjust(S, 'right') returns a right-justified version of the character array S.

T = strjust(S, 'left') returns a left-justified version of S.

T = strjust(S, 'center') returns a center-justified version of S.

**See Also** deblank, strtrim

# strmatch

---

**Purpose** Find possible matches for string

**Syntax**  
`x = strmatch(str, strarray)`  
`x = strmatch(str, strarray, 'exact')`

**Description** `x = strmatch(str, strarray)` looks through the rows of the character array or cell array of strings `strarray` to find strings that begin with the text contained in `str`, and returns the matching row indices. Any trailing space characters in `str` or `strarray` are ignored when matching. `strmatch` is fastest when `strarray` is a character array.

`x = strmatch(str, strarray, 'exact')` compares `str` with each row of `strarray`, looking for an exact match of the entire strings. Any trailing space characters in `str` or `strarray` are ignored when matching.

**Examples** The statement

```
x = strmatch('max', strvcat('max', 'minimax', 'maximum'))
```

returns `x = [1; 3]` since rows 1 and 3 begin with 'max'. The statement

```
x = strmatch('max', strvcat('max', 'minimax', 'maximum'),'exact')
```

returns `x = 1`, since only row 1 matches 'max' exactly.

**See Also** `strcmp`, `strcmpi`, `strncmp`, `strncmpi`, `strfind`, `findstr`, `strvcat`, `regex`, `regexpi`, `regexprep`

## Purpose

Compare first *n* characters of strings

## Syntax

```
TF = strncmp('str1', 'str2', n)
```

```
TF = strncmp('str', C, n)
```

```
TF = strncmp(C1, C2, n)
```

Each of these syntaxes applies to both `strncmp` and `strncmpi`. The `strncmp` function is case sensitive in matching strings, while `strncmpi` is not.

## Description

Although the following descriptions show only `strncmp`, they apply to `strncmpi` as well. The two functions are the same except that `strncmpi` compares strings without sensitivity to letter case:

`TF = strncmp('str1', 'str2', n)` compares the first *n* characters of strings `str1` and `str2` and returns logical 1 (`true`) if they are identical, and returns logical 0 (`false`) otherwise. `str1` and `str2` can be character arrays of any dimension, but `strncmp` does not return `true` unless the sizes of both arrays are equal, and the contents of the two arrays are the same.

`TF = strncmp('str', C, n)` compares the first *n* characters of `str` to the first *n* characters of each element of cell array `C`, where `str` is a character vector (or a 1-by-1 cell array), and `C` is a cell array of strings. The function returns `TF`, a logical array that is the same size as `C` and contains logical 1 (`true`) for those elements of `C` that are a match, and logical 0 (`false`) for those elements that are not. The order of the first two input arguments is not important.

`TF = strncmp(C1, C2, n)` compares each element of `C1` to the same element in `C2`, where `C1` and `C2` are equal-size cell arrays of strings. Input `C1` or `C2` can also be a character array with the right number of rows. The function attempts to match only the first *n* characters of each string. The function returns `TF`, a logical array that is the same size as `C1` and `C2`, and contains logical 1 (`true`) for those elements of `C1` and `C2` that are a match, and logical 0 (`false`) for those elements that are not.

# strcmp, strcmpi

---

## Remarks

These functions are intended for comparison of character data. When used to compare numeric data, they return logical 0.

Any leading and trailing blanks in either of the strings are explicitly included in the comparison.

The value returned by strcmp and strcmpi is not the same as the C language convention.

strcmp and strcmpi support international character sets.

## Examples

### Example 1

From a list of 10 MATLAB functions, find those that apply to using a camera:

```
function_list = {'calendar' 'case' 'camdolly' 'circshift' ...
 'caxis' 'camtarget' 'cast' 'camorbit' ...
 'callib' 'cart2sph'};
```

```
strcmp(function_list, 'cam', 3)
ans =
 0 0 1 0 0 1 0 1 0 0
```

```
function_list(strcmp(function_list, 'cam', 3))
ans =
 camdolly
ans =
 camtarget
ans =
 camorbit
```

### Example 2

Create two 5-by-10 string arrays str1 and str2 that are equal except for the element at row 4, column 3. Using linear indexing, this is element 14:

```
str1 = ['AAAAAAAAA'; 'BBBBBBBBBB'; 'CCCCCCCCC'; ...
 'DDDDDDDDD'; 'EEEEEEEEEE']
```

```
str1 =
 AAAAAAAAAA
 BBBBBBBBBB
 CCCCCCCCCC
 DDDDDDDDDD
 EEEEEEEEEE

str2 = str1;
str2(4,3) = '-'
str2 =
 AAAAAAAAAA
 BBBBBBBBBB
 CCCCCCCCCC
 DD-DDDDDD
 EEEEEEEEEE
```

Because MATLAB compares the arrays in linear order (that is, column by column rather than row by row), `strncmp` finds only the first 13 elements to be the same:

```
str1 A B C D E A B C D E A B C D E
str2 A B C D E A B C D E A B C - E
 |
 element 14
```

```
strncmp(str1, str2, 13)
ans =
 1
```

```
strncmp(str1, str2, 14)
ans =
 0
```

## See Also

`strcmp`, `strcmpi`, `strmatch`, `strfind`, `findstr`, `regexp`, `regexpi`, `regexprep`, `regexpttranslate`

# strread

---

## Purpose

Read formatted data from string

---

**Note** `strread` is not recommended. Use `textscan` to read data from a string.

---

## Syntax

```
A = strread('str')
[A, B, ...] = strread('str')
[A, B, ...] = strread('str', 'format')
[A, B, ...] = strread('str', 'format', N)
[A, B, ...] = strread('str', 'format', N, param, value, ...)
```

## Description

`A = strread('str')` reads numeric data from input string `str` into a 1-by-`N` vector `A`, where `N` equals the number of whitespace-separated numbers in `str`. Use this form only with strings containing numeric data. See “Example 1” on page 2-3502 below.

`[A, B, ...] = strread('str')` reads numeric data from the string input `str` into scalar output variables `A`, `B`, and so on. The number of output variables must equal the number of whitespace-separated numbers in `str`. Use this form only with strings containing numeric data. See “Example 2” on page 2-3502 below.

`[A, B, ...] = strread('str', 'format')` reads data from `str` into variables `A`, `B`, and so on using the specified `format`. The number of output variables `A`, `B`, etc. must be equal to the number of format specifiers (e.g., `%s` or `%d`) in the `format` argument. You can read all of the data in `str` to a single output variable as long as you use only one format specifier in the command. See “Example 4” on page 2-3503 and “Example 5” on page 2-3503 below.

The table [Formats for strread](#) on page 2-3499 lists the valid format specifiers. More information on using formats is available under “[Formats](#)” on page 2-3501 in the Remarks section below.

`[A, B, ...] = strread('str', 'format', N)` reads data from `str` reusing the format string `N` times, where `N` is an integer greater than zero. If `N` is -1, `strread` reads the entire string. When `str` contains

only numeric data, you can set `format` to the empty string (''). See “Example 3” on page 2-3503 below.

`[A, B, ...] = strread('str', 'format', N, param, value, ...)` customizes `strread` using `param/value` pairs, as listed in the table Parameters and Values for `strread` on page 2-3500 below. When `str` contains only numeric data, you can set `format` to the empty string (''). The `N` argument is optional and may be omitted entirely. See “Example 7” on page 2-3504 below.

**Formats for strread**

| <b>Format</b>                     | <b>Action</b>                                                                                                                                                                                    | <b>Output</b>         |
|-----------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|
| Literals<br>(ordinary characters) | Ignore the matching characters. For example, in a string that has Dept followed by a number (for department number), to skip the Dept and read only the number, use 'Dept' in the format string. | None                  |
| %d                                | Read a signed integer value.                                                                                                                                                                     | Double array          |
| %u                                | Read an integer value.                                                                                                                                                                           | Double array          |
| %f                                | Read a floating-point value.                                                                                                                                                                     | Double array          |
| %s                                | Read a white-space separated string.                                                                                                                                                             | Cell array of strings |
| %q                                | Read a double quoted string, ignoring the quotes.                                                                                                                                                | Cell array of strings |
| %c                                | Read characters, including white space.                                                                                                                                                          | Character array       |
| %[...]                            | Read the longest string containing characters specified in the brackets.                                                                                                                         | Cell array of strings |

## Formats for strread (Continued)

| Format    | Action                                                                                                            | Output                |
|-----------|-------------------------------------------------------------------------------------------------------------------|-----------------------|
| %[ ^... ] | Read the longest nonempty string containing characters that are not specified in the brackets.                    | Cell array of strings |
| %*...     | Ignore the characters following *. See “Example 8” on page 2-3504 below.                                          | No output             |
| %w...     | Read field width specified by w. The %f format supports %w.pf, where w is the field width and p is the precision. |                       |

## Parameters and Values for strread

| param      | value                                                                                                                                                          | Action                                                                       |
|------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------|
| whitespace | Any from the list below:<br>\b Backspace<br>\n New line<br>\r Carriage return<br>\t Horizontal tab<br>\ Backslash<br>% Percent sign<br>' Single quotation mark | Treats vector of characters, *, as white space. Default is \b\r\n\t.         |
| delimiter  | Delimiter character                                                                                                                                            | Specifies delimiter character. Default is one or more whitespace characters. |
| expchars   | Exponent characters                                                                                                                                            | Default is eEdD.                                                             |



**Parameters and Values for strread (Continued)**

| <b>param</b> | <b>value</b>     | <b>Action</b>                                                   |
|--------------|------------------|-----------------------------------------------------------------|
| bufsize      | Positive integer | Specifies the maximum string length, in bytes. Default is 4095. |
| commentstyle | matlab           | Ignores characters after %.                                     |
| commentstyle | shell            | Ignores characters after #.                                     |
| commentstyle | c                | Ignores characters between /* and */.                           |
| commentstyle | c++              | Ignores characters after //.                                    |

**Remarks**

**Delimiters**

If your data uses a character other than a space as a delimiter, you must use the `strread` parameter `'delimiter'` to specify the delimiter. For example, if the string `str` used a semicolon as a delimiter, you would use this command:

```
[names, types, x, y, answer] = strread(str, '%s %s %f ...
 %d %s', 'delimiter', ';')
```

**Formats**

The format string determines the number and types of return arguments. The number of return arguments must match the number of conversion specifiers in the format string.

The `strread` function continues reading `str` until the entire string is read. If there are fewer format specifiers than there are entities in `str`, `strread` reapplies the format specifiers, starting over at the beginning. See “Example 5” on page 2-3503 below.

# strread

---

The format string supports a subset of the conversion specifiers and conventions of the C language `fscanf` routine. White-space characters in the format string are ignored.

## Preserving White-Space

If you want to preserve leading and trailing spaces in a string, use the `whitespace` parameter as shown here:

```
str = ' An example of preserving spaces ';

strread(str, '%s', 'whitespace', '')
ans =
 ' An example of preserving spaces '
```

## Examples

### Example 1

Read numeric data into a 1-by-5 vector:

```
a = strread('0.41 8.24 3.57 6.24 9.27')
a =
 0.4100 8.2400 3.5700 6.2400 9.2700
```

### Example 2

Read numeric data into separate scalar variables:

```
[a b c d e] = strread('0.41 8.24 3.57 6.24 9.27')
a =
 0.4100
b =
 8.2400
c =
 3.5700
d =
 6.2400
e =
 9.2700
```

## Example 3

Read the only first three numbers in the string, also formatting as floating point:

```
a = strread('0.41 8.24 3.57 6.24 9.27', '%4.2f', 3)
```

```
a =
 0.4100
 8.2400
 3.5700
```

## Example 4

Truncate the data to one decimal digit by specifying format %3.1f. The second specifier, %\*1d, tells strread not to read in the remaining decimal digit:

```
a = strread('0.41 8.24 3.57 6.24 9.27', '%3.1f %*1d')
```

```
a =
 0.4000
 8.2000
 3.5000
 6.2000
 9.2000
```

## Example 5

Read six numbers into two variables, reusing the format specifiers:

```
[a b] = strread('0.41 8.24 3.57 6.24 9.27 3.29', '%f %f')
```

```
a =
 0.4100
 3.5700
 9.2700
b =
 8.2400
 6.2400
```

3.2900

## Example 6

Read string and numeric data to two output variables. Ignore commas in the input string:

```
str = 'Section 4, Page 7, Line 26';

[name value] = strread(str, '%s %d,')
name =
 'Section'
 'Page'
 'Line'
value =
 4
 7
 26
```

## Example 7

Read the string used in the last example, but this time delimiting with commas instead of spaces:

```
str = 'Section 4, Page 7, Line 26';

[a b c] = strread(str, '%s %s %s', 'delimiter', ',')
a =
 'Section 4'
b =
 'Page 7'
c =
 'Line 26'
```

## Example 8

Read selected portions of the input string:

```
str = '<table border=5 width="100%" cellpadding=0>';

[border width space] = strread(str, ...
```

```

 '%*s%*s %c %*s "%4s" %*s %c', 'delimiter', '= ')
border =
 5
width =
 '100%'
space =
 0

```

### Example 9

Read the string into two vectors, restricting the Answer values to T and F. Also note that two delimiters (comma and space) are used here:

```

str = 'Answer_1: T, Answer_2: F, Answer_3: F';

[a b] = strread(str, '%s %[TF]', 'delimiter', ', ', ')
a =
 'Answer_1:'
 'Answer_2:'
 'Answer_3:'
b =
 'T'
 'F'
 'F'

```

### See Also

textscan, sscanf

# strrep

---

**Purpose** Find and replace substring

**Syntax** `str = strrep(str1, str2, str3)`

**Description** `str = strrep(str1, str2, str3)` replaces all occurrences of the string `str2` within string `str1` with the string `str3`.

`strrep(str1, str2, str3)`, when any of `str1`, `str2`, or `str3` is a cell array of strings, returns a cell array the same size as `str1`, `str2`, and `str3` obtained by performing a `strrep` using corresponding elements of the inputs. The inputs must all be the same size (or any can be a scalar cell). Any one of the strings can also be a character array with the right number of rows.

## Examples

```
s1 = 'This is a good example.';
str = strrep(s1, 'good', 'great')
str =
This is a great example.
A =
 'MATLAB' 'SIMULINK'
 'Toolboxes' 'The MathWorks'
B =
 'Handle Graphics' 'Real Time Workshop'
 'Toolboxes' 'The MathWorks'
C =
 'Signal Processing' 'Image Processing'
 'MATLAB' 'SIMULINK'
strrep(A, B, C)
ans =
 'MATLAB' 'SIMULINK'
 'MATLAB' 'SIMULINK'
```

**See Also** `strfind`

**Purpose**

Selected parts of string

**Syntax**

```
token = strtok('str')
token = strtok('str', delimiter)
[token, remain] = strtok('str', ...)
```

**Description**

`token = strtok('str')` returns in `token` that part of the input string `str` that precedes the first white-space character (the default delimiter). Parsing of the string begins at the first nondelimiting (i.e., nonwhite-space) character and continues to the right until the MATLAB software either locates a delimiter or reaches the end of the string. If no delimiters are found in the body of the input string, then the entire string (excluding any leading delimiting characters) is returned.

White-space characters include space (ASCII 32), tab (ASCII 9), and carriage return (ASCII 13).

If `str` is a cell array of strings, `token` is a cell array of tokens.

`token = strtok('str', delimiter)` is the same as the above syntax except that you can specify one or more nondefault delimiters in the character vector, `delimiter`. Ignoring any leading delimiters, MATLAB returns in `token` that part of the input string that precedes one of the characters from the given `delimiter` vector.

`[token, remain] = strtok('str', ...)` returns in `remain` a substring of the input string that begins immediately after the `token` substring and ends with the last character in `str`. If no delimiters are found in the body of the input string, then the entire string (excluding any leading delimiting characters) is returned in `token`, and `remain` is an empty string ('').

If `str` is a cell array of strings, `token` is a cell array of tokens and `remain` is a character array.

**Examples****Example 1**

This example uses the default white-space delimiter:

```
s = ' This is a simple example.';
```

```
[token, remain] = strtok(s)
token =
 This
remain =
 is a simple example.
```

## Example 2

Take a string of HTML code and break it down into segments delimited by the < and > characters. Write a while loop to parse the string and print each segment:

```
s = sprintf('%s%s%s', ...
'<ul class=continued><li class=continued>', ...
'<pre>token = strtok', ...
(''str'', delimiter)', ...
'token = strtok(''str'')');

remain = s;

while true
 [str, remain] = strtok(remain, '<>');
 if isempty(str), break; end
 disp(sprintf('%s', str))
end
```

Here is the output:

```
ul class=continued
li class=continued
pre
a name="13474"
/a
token = strtok('str', delimiter)
a name="13475"
/a
token = strtok('str')
```



### Example 3

Using `strtok` on a cell array of strings returns a cell array of strings in `token` and a character array in `remain`:

```
s = {'all in good time'; ...
 'my dog has fleas'; ...
 'leave no stone unturned'};

remain = s;

for k = 1:4
 [token, remain] = strtok(remain);
 token
end
```

Here is the output:

```
token =
 'all'
 'my'
 'leave'
token =
 'in'
 'dog'
 'no'
token =
 'good'
 'has'
 'stone'
token =
 'time'
 'fleas'
 'unturned'
```

### See Also

`findstr`, `strmatch`

# strtrim

---

**Purpose** Remove leading and trailing white space from string

**Syntax** S = strtrim(str)  
C = strtrim(cstr)

**Description** S = strtrim(str) returns a copy of string str with all leading and trailing white-space characters removed. A white-space character is one for which the isspace function returns logical 1 (true).

C = strtrim(cstr) returns a copy of the cell array of strings cstr with all leading and trailing white-space characters removed from each string in the cell array.

**Examples** Remove the leading white-space characters (spaces and tabs) from str:

```
str = sprintf(' \t Remove leading white-space')
str =
 Remove leading white-space
```

```
str = strtrim(str)
str =
Remove leading white-space
```

Remove leading and trailing white-space from the cell array of strings:

```
cstr = {' Trim leading white-space';
 'Trim trailing white-space '};

cstr = strtrim(cstr)
cstr =
 'Trim leading white-space'
 'Trim trailing white-space'
```

**See Also** isspace, cellstr, deblank, strjust

**Purpose**

Create structure array

**Syntax**

```
s = struct('field1', values1, 'field2', values2, ...)
s = struct('field1', {}, 'field2', {}, ...)
s = struct
s = struct([])
s = struct(obj)
```

**Description**

`s = struct('field1', values1, 'field2', values2, ...)` creates a structure array with the specified fields and values. Each value input (values1, values2, etc.), can either be a cell array or a scalar value. Those that are cell arrays must all have the same dimensions.

The size of the resulting structure is the same size as the value cell arrays, or 1-by-1 if none of the values is a cell array. Elements of the value array inputs are placed into corresponding structure array elements.

---

**Note** If any of the values fields is an empty cell array {}, the MATLAB software creates an empty structure array in which all fields are also empty.

---

Structure field names must begin with a letter, and are case-sensitive. The rest of the name may contain letters, numerals, and underscore characters. Use the `namelengthmax` function to determine the maximum length of a field name.

`s = struct('field1', {}, 'field2', {}, ...)` creates an empty structure with fields `field1`, `field2`, ...

`s = struct` creates a 1-by-1 structure with no fields.

`s = struct([])` creates an empty structure with no fields.

`s = struct(obj)` creates a structure `s` that is identical to the underlying structure in the input object `obj`. MATLAB does not convert

obj, but rather creates s as a new structure. This structure does not retain the class information in obj.

## Remarks

### Two Ways to Access Fields

The most common way to access the data in a structure is by specifying the name of the field that you want to reference. Another means of accessing structure data is to use dynamic field names. These names express the field as a variable expression that MATLAB evaluates at run-time.

### Fields That Are Cell Arrays

To create fields that contain cell arrays, place the cell arrays within a value cell array. For instance, to create a 1-by-1 structure, type

```
s = struct('strings', {'hello', 'yes'}, 'lengths', [5 3])
s =
 strings: {'hello' 'yes'}
 lengths: [5 3]
```

### Specifying Cell Versus Noncell Values

When using the syntax

```
s = struct('field1', values1, 'field2', values2, ...)
```

the values inputs can be cell arrays or scalar values. For those values that are specified as a cell array, MATLAB assigns each element of values{m,n,...} to the corresponding field in each element of structure s:

```
s(m,n,...).fieldN = valuesN{m,n,...}
```

For those values that are scalar, MATLAB assigns that single value to the corresponding field for all elements of structure s:

```
s(m,n,...).fieldN = valuesN
```

See Example 3, below.

## Examples

### Example 1

The command

```
s = struct('type', {'big','little'}, 'color', {'red'}, ...
 'x', {3 4})
```

produces a structure array s:

```
s =
1x2 struct array with fields:
 type
 color
 x
```

The value arrays have been distributed among the fields of s:

```
s(1)
ans =
 type: 'big'
 color: 'red'
 x: 3

s(2)
ans =
 type: 'little'
 color: 'red'
 x: 4
```

### Example 2

Similarly, the command

```
a.b = struct('z', {});
```

produces an empty structure a.b with field z.

```
a.b
ans =
 0x0 struct array with fields:
 z
```

## Example 3

This example initializes one field `f1` using a cell array, and the other `f2` using a scalar value:

```
s = struct('f1', {1 3; 2 4}, 'f2', 25)
s =
2x2 struct array with fields:
 f1
 f2
```

Field `f1` in each element of `s` is assigned the corresponding value from the cell array `{1 3; 2 4}`:

```
s.f1
ans =
 1
ans =
 2
ans =
 3
ans =
 4
```

Field `f2` for all elements of `s` is assigned one common value because the values input for this field was specified as a scalar:

```
s.f2
ans =
 25
ans =
 25
ans =
 25
ans =
 25
```

**See Also**

isstruct, fieldnames, isfield, orderfields, getfield,  
setfield, rmfield, substruct, deal, cell2struct, struct2cell,  
namelengthmax, dynamic field names

# struct2cell

---

**Purpose** Convert structure to cell array

**Syntax** `c = struct2cell(s)`

**Description** `c = struct2cell(s)` converts the `m`-by-`n` structure `s` (with `p` fields) into a `p`-by-`m`-by-`n` cell array `c`.

If structure `s` is multidimensional, cell array `c` has size `[p size(s)]`.

**Examples** The commands

```
clear s, s.category = 'tree';
s.height = 37.4; s.name = 'birch';
```

create the structure

```
s =
 category: 'tree'
 height: 37.4000
 name: 'birch'
```

Converting the structure to a cell array,

```
c = struct2cell(s)

c =
 'tree'
 [37.4000]
 'birch'
```

**See Also** `cell2struct`, `cell`, `iscell`, `struct`, `isstruct`, `fieldnames`, `dynamic field names`



**Purpose**

Apply function to each field of scalar structure

**Syntax**

```
A = structfun(fun, S)
[A, B, ...] = structfun(fun, S)
[A, ...] = structfun(fun, S, 'param1', value1, ...)
```

**Description**

`A = structfun(fun, S)` applies the function specified by `fun` to each field of scalar structure `S`, and returns the results in array `A`. `fun` is a function handle to a function that takes one input argument and returns a scalar value. Return value `A` is a column vector that has one element for each field in input structure `S`. The `N`th element of `A` is the result of applying `fun` to the `N`th field of `S`, and the order of the fields is the same as that returned by a call to `fieldnames`. (`A` is returned as one or more scalar structures when the `UniformOutput` option is set to `false`. See the table below.))

`fun` must return values of the same class each time it is called. If `fun` is a handle to an overloaded function, then `structfun` follows MATLAB dispatching rules in calling the function.

`[A, B, ...] = structfun(fun, S)` returns arrays `A, B, ...`, each array corresponding to one of the output arguments of `fun`. `structfun` calls `fun` each time with as many outputs as there are in the call to `structfun`. `fun` can return output arguments having different classes, but the class of each output must be the same each time `fun` is called.

`[A, ...] = structfun(fun, S, 'param1', value1, ...)` enables you to specify optional parameter name/parameter value pairs. Parameters are

# structfun

| Parameter       | Value                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
|-----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 'UniformOutput' | <p>Logical value indicating whether or not the outputs of fun can be returned without encapsulation in a structure. The default value is true.</p> <p>If equal to logical 1 (true), fun must return scalar values that can be concatenated into an array. The outputs can be any of the following types: numeric, logical, char, struct, or cell.</p> <p>If equal to logical 0 (false), structfun returns a scalar structure or multiple scalar structures having fields that are the same as the fields of the input structure S. The values in the output structure fields are the results of calling fun on the corresponding values in the input structure B. In this case, the outputs can be of any data type.</p>                                                                                                                                                                                                                                                                                                |
| 'ErrorHandler'  | <p>Function handle specifying the function MATLAB is to call if the call to fun fails. MATLAB calls the error handling function with the following input arguments:</p> <ul style="list-style-type: none"><li>• A structure, with the fields 'identifier', 'message', and 'index', respectively containing the identifier of the error that occurred, the text of the error message, and the number of the field (in the same order as returned by field names) at which the error occurred.</li><li>• The input argument at which the call to the function failed.</li></ul> <p>The error handling function should either rethrow an error or return the same number of outputs as fun. These outputs are then returned as the outputs of structfun. If 'UniformOutput' is true, the outputs of the error handler must also be scalars of the same type as the outputs of fun.</p> <p>For example,</p> <pre>function [A, B] = errorFunc(S, ...     varargin) warning(S.identifier, S.message); A = NaN; B = NaN;</pre> |

**Examples**

To create shortened weekday names from the full names, for example:  
Create a structure with strings in several fields:

```
s.f1 = 'Sunday';
s.f2 = 'Monday';
s.f3 = 'Tuesday';
s.f4 = 'Wednesday';
s.f5 = 'Thursday';
s.f6 = 'Friday';
s.f7 = 'Saturday';

shortNames = structfun(@(x) (x(1:3)), s, ...
 'UniformOutput', false);
```

**See Also**

[cellfun](#), [arrayfun](#), [function\\_handle](#), [cell2mat](#), [spfun](#)

# strvcat

---

**Purpose** Concatenate strings vertically

**Syntax** `S = strvcat(t1, t2, t3, ...)`  
`S = strvcat(c)`

**Description** `S = strvcat(t1, t2, t3, ...)` forms the character array `S` containing the text strings (or string matrices) `t1, t2, t3, ...` as rows. Spaces are appended to each string as necessary to form a valid matrix. Empty arguments are ignored.

`S = strvcat(c)` when `c` is a cell array of strings, passes each element of `c` as an input to `strvcat`. Empty strings in the input are ignored.

**Remarks** If each text parameter, `ti`, is itself a character array, `strvcat` appends them vertically to create arbitrarily large string matrices.

**Examples** The command `strvcat('Hello', 'Yes')` is the same as `['Hello'; 'Yes']`, except that `strvcat` performs the padding automatically.

```
t1 = 'first'; t2 = 'string'; t3 = 'matrix'; t4 = 'second';
```

```
S1 = strvcat(t1, t2, t3) S2 = strvcat(t4, t2, t3)
```

```
S1 = S2 =
```

```
first second
string string
matrix matrix
```

```
S3 = strvcat(S1, S2)
```

```
S3 =
first
string
matrix
second
string
```

matrix

## See Also

strcat, cat, vertcat, horzcat, int2str, mat2str, num2str, strings,  
special character []

# sub2ind

---

**Purpose** Single index from subscripts

**Syntax**  
`IND = sub2ind(siz,I,J)`  
`IND = sub2ind(siz,I1,I2,...,In)`

**Description** The `sub2ind` command determines the equivalent single index corresponding to a set of subscript values.

`IND = sub2ind(siz,I,J)` returns the linear index equivalent to the row and column subscripts `I` and `J` for a matrix of size `siz`. `siz` is a vector with `ndim(A)` elements (in this case, 2), where `siz(1)` is the number of rows and `siz(2)` is the number of columns.

`IND = sub2ind(siz,I1,I2,...,In)` returns the linear index equivalent to the `n` subscripts `I1,I2,...,In` for an array of size `siz`. `siz` is an `n`-element vector that specifies the size of each array dimension.

**Examples** Create a 3-by-4-by-2 array, `A`.

```
A = [17 24 1 8; 2 22 7 14; 4 6 13 20];
A(:,:,2) = A - 10
```

```
A(:,:,1) =

 17 24 1 8
 2 22 7 14
 4 6 13 20
```

```
A(:,:,2) =

 7 14 -9 -2
 -8 12 -3 4
 -6 -4 3 10
```

The value at row 2, column 1, page 2 of the array is -8.

```
A(2,1,2)
```

```
ans =
```

```
-8
```

To convert `A(2,1,2)` into its equivalent single subscript, use `sub2ind`.

```
sub2ind(size(A),2,1,2)
```

```
ans =
```

```
14
```

You can now access the same location in `A` using the single subscripting method.

```
A(14)
```

```
ans =
```

```
-8
```

**See Also**

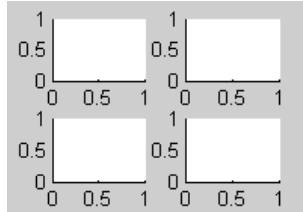
`ind2sub`, `find`, `size`

# subplot

---

## Purpose

Create axes in tiled positions



## GUI Alternatives

To add subplots to a figure, click one of the *New Subplot* icons in the Figure Palette, and slide right to select an arrangement of subplots. For details, see [Plotting Tools — Interactive Plotting in the MATLAB Graphics documentation](#).

## Syntax

```
h = subplot(m,n,p) or subplot(mnp)
subplot(m,n,p,'replace')
subplot(m,n,P)
subplot(h)
subplot('Position',[left bottom width height])
subplot(..., prop1, value1, prop2, value2, ...)
h = subplot(...)
subplot(m,n,p,'v6')
```

## Description

`subplot` divides the current figure into rectangular panes that are numbered rowwise. Each pane contains an axes object. Subsequent plots are output to the current pane.

`h = subplot(m,n,p)` or `subplot(mnp)` breaks the figure window into an  $m$ -by- $n$  matrix of small axes, selects the  $p$ th axes object for the current plot, and returns the axes handle. The axes are counted along the top row of the figure window, then the second row, etc. For example,

```
subplot(2,1,1), plot(income)
subplot(2,1,2), plot(outgo)
```



plots income on the top half of the window and outgo on the bottom half. If the `CurrentAxes` is nested in a `uipanel`, the panel is used as the parent for the subplot instead of the current figure. The new axes object becomes the current axes.

`subplot(m,n,p, 'replace')` If the specified axes object already exists, delete it and create a new axes.

`subplot(m,n,P)`, where `P` is a vector, specifies an axes position that covers all the subplot positions listed in `P`, including those spanned by `P`. For example, `subplot(2,3,[2 5])` creates one axes spanning positions 2 and 5 only (because there are no intervening locations in the grid), while `subplot(2,3,[2 6])` creates one axes spanning positions 2, 3, 5, and 6.

`subplot(h)` makes the axes object with handle `h` current for subsequent plotting commands.

`subplot('Position',[left bottom width height])` creates an axes at the position specified by a four-element vector. `left`, `bottom`, `width`, and `height` are in normalized coordinates in the range from 0.0 to 1.0.

`subplot(..., prop1, value1, prop2, value2, ...)` sets the specified property-value pairs on the subplot axis. To add the subplot to a specific figure pass the figure handle as the value for the `Parent` property. You cannot specify both a `Parent` and a `Position`; that is, `subplot('Position',[left bottom width height], 'Parent',h)` is not a valid syntax.

`h = subplot(...)` returns the handle to the new axes object.

### Backward-Compatible Version

`subplot(m,n,p, 'v6')` places the axes so that the plot boxes are aligned, but does not prevent the labels and ticks from overlapping. Saved subplots created with the `v6` option are compatible with MATLAB 6.5 and earlier versions.

Use the subplot `'v6'` option and save the figure with the `'v6'` option when you want to be able to load a FIG-file containing subplots into MATLAB Version 6.5 or earlier.

# subplot

---

---

**Note** The `v6` option enables users of Version 7.x of MATLAB to create FIG-files that previous versions can open. It is obsolete and will be removed in a future version of MATLAB.

---

See Plot Objects and Backward Compatibility for more information.

## Remarks

If a subplot specification causes a new axis to overlap a existing axis, the existing axis is deleted - unless the position of the new and existing axis are identical. For example, the statement `subplot(1,2,1)` deletes all existing axes overlapping the left side of the figure window and creates a new axis on that side—unless there is an axes there with a position that exactly matches the position of the new axes (and `'replace'` was not specified), in which case all other overlapping axes will be deleted and the matching axes will become the current axes.

You can add subplots to GUIs as well as to figures. For information about creating subplots in a GUIDE-generated GUI, see “Creating Subplots” in the MATLAB Creating Graphical User Interfaces documentation.

If a subplot specification causes a new axes object to overlap any existing axes, `subplot` deletes the existing axes object and `uicontrol` objects. However, if the subplot specification exactly matches the position of an existing axes object, the matching axes object is not deleted and it becomes the current axes.

`subplot(1,1,1)` or `clf` deletes all axes objects and returns to the default `subplot(1,1,1)` configuration.

You can omit the parentheses and specify `subplot` as

```
subplot mnp
```

where `m` refers to the row, `n` refers to the column, and `p` specifies the pane.

Be aware when creating subplots from scripts that the `Position` property of subplots is not finalized until either

- A `drawnow` command is issued.
- MATLAB returns to await a user command.

That is, the value obtained for subplot `i` by the command

```
get(h(i), 'position')
```

will not be correct until the script refreshes the plot or exits.

### Special Case: `subplot(111)`

The command `subplot(111)` is not identical in behavior to `subplot(1,1,1)` and exists only for compatibility with previous releases. This syntax does not immediately create an axes object, but instead sets up the figure so that the next graphics command executes a `clf reset` (deleting all figure children) and creates a new axes object in the default position. This syntax does not return a handle, so it is an error to specify a return argument. (MATLAB implements this behavior by setting the figure's `NextPlot` property to `replace`.)

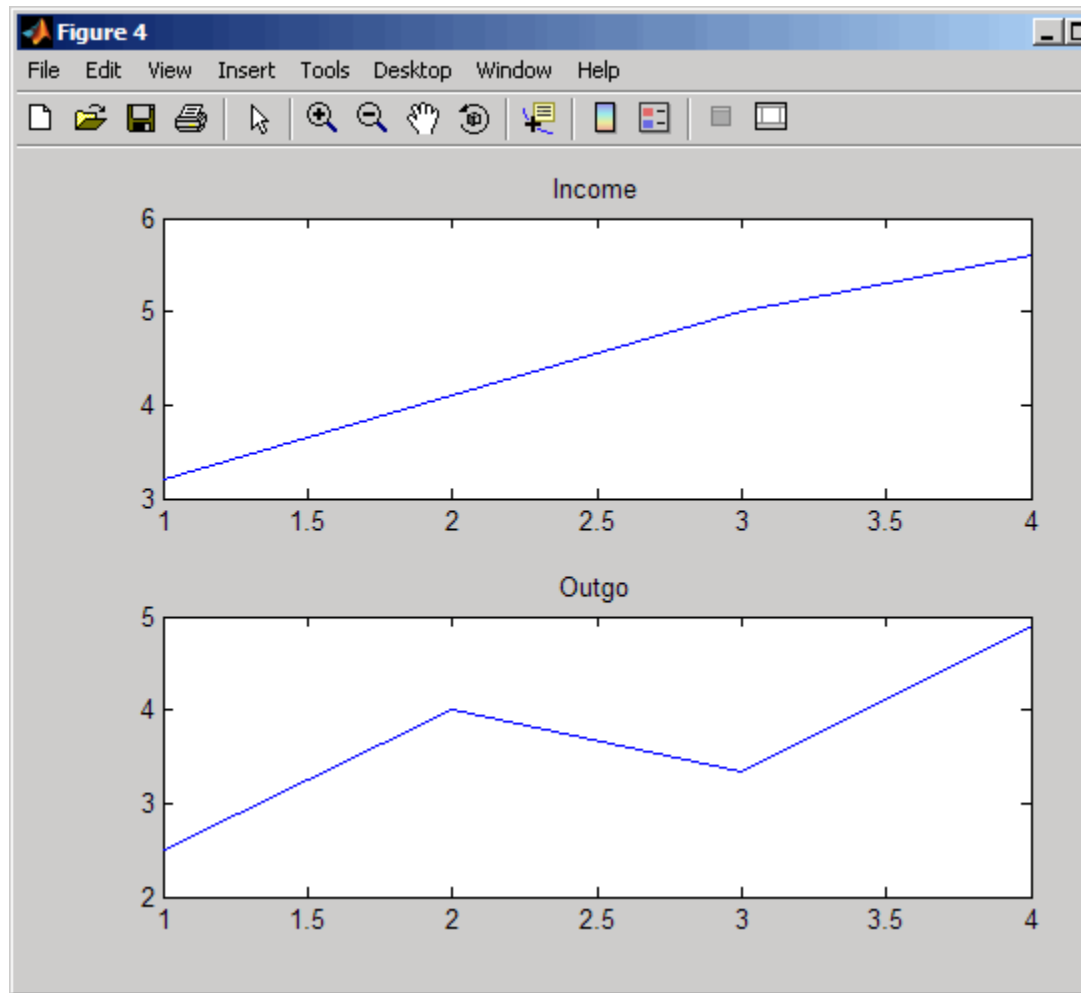
## Examples

### Upper and Lower Subplots with Titles

To plot income in the top half of a figure and outgo in the bottom half,

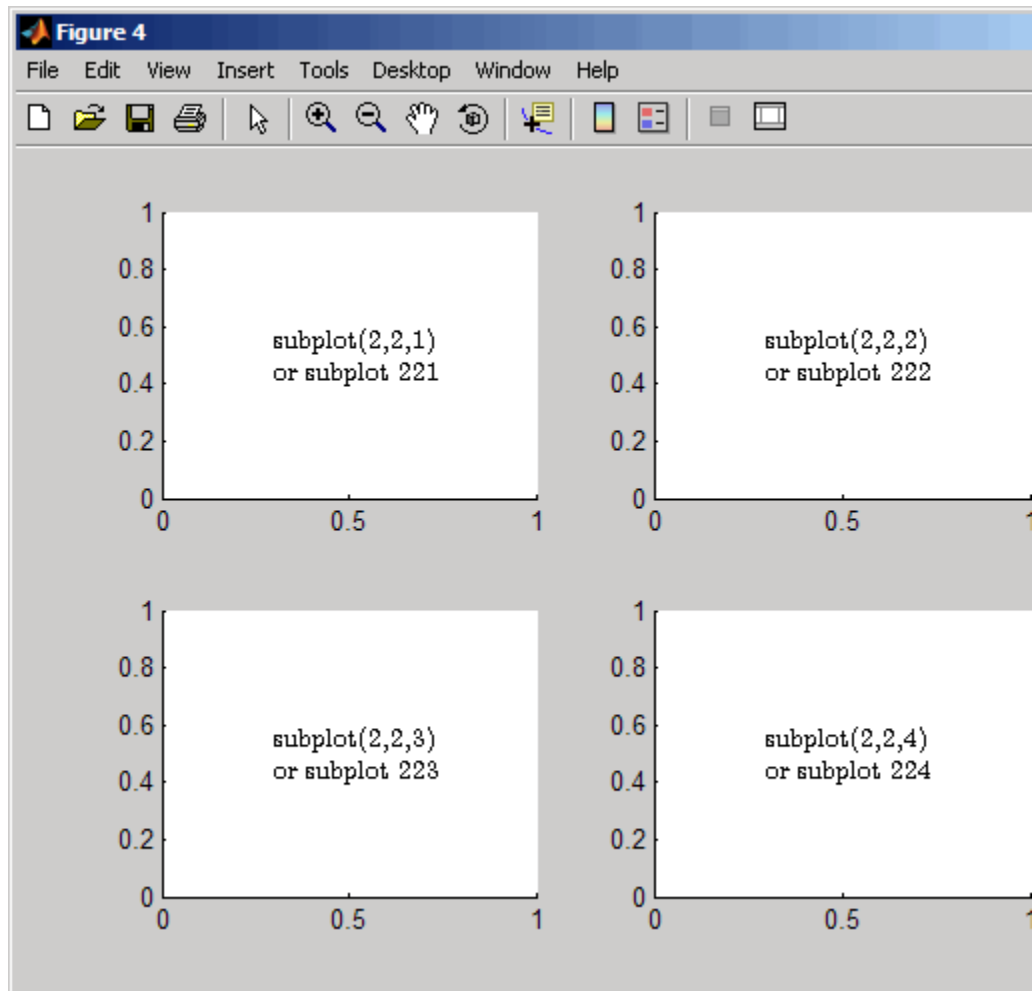
```
income = [3.2 4.1 5.0 5.6];
outgo = [2.5 4.0 3.35 4.9];
subplot(2,1,1); plot(income)
title('Income')
subplot(2,1,2); plot(outgo)
title('Outgo')
```

# subplot



## Subplots in Quadrants

The following illustration shows four subplot regions and indicates the command used to create each.



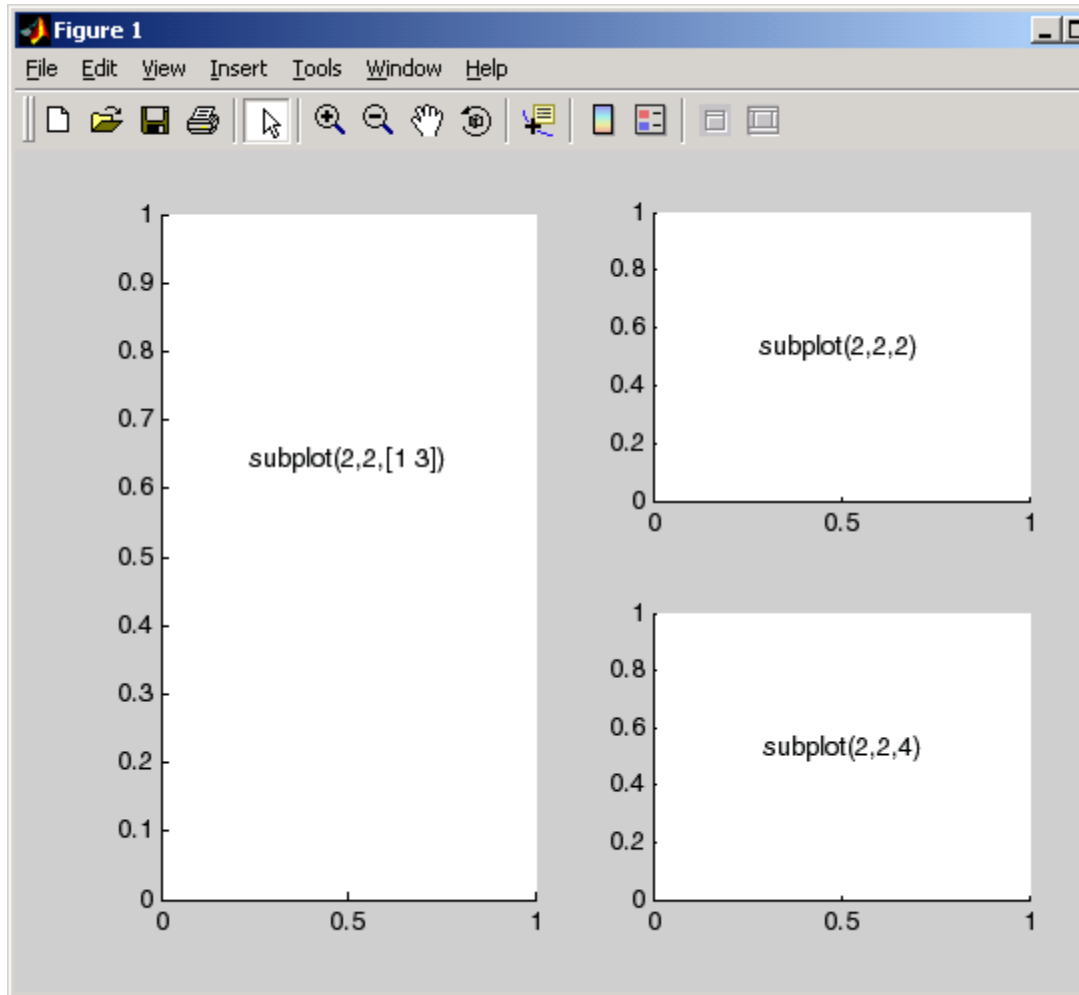
### Assymetrical Subplots

The following combinations produce asymmetrical arrangements of subplots.

```
subplot(2,2,[1 3])
```

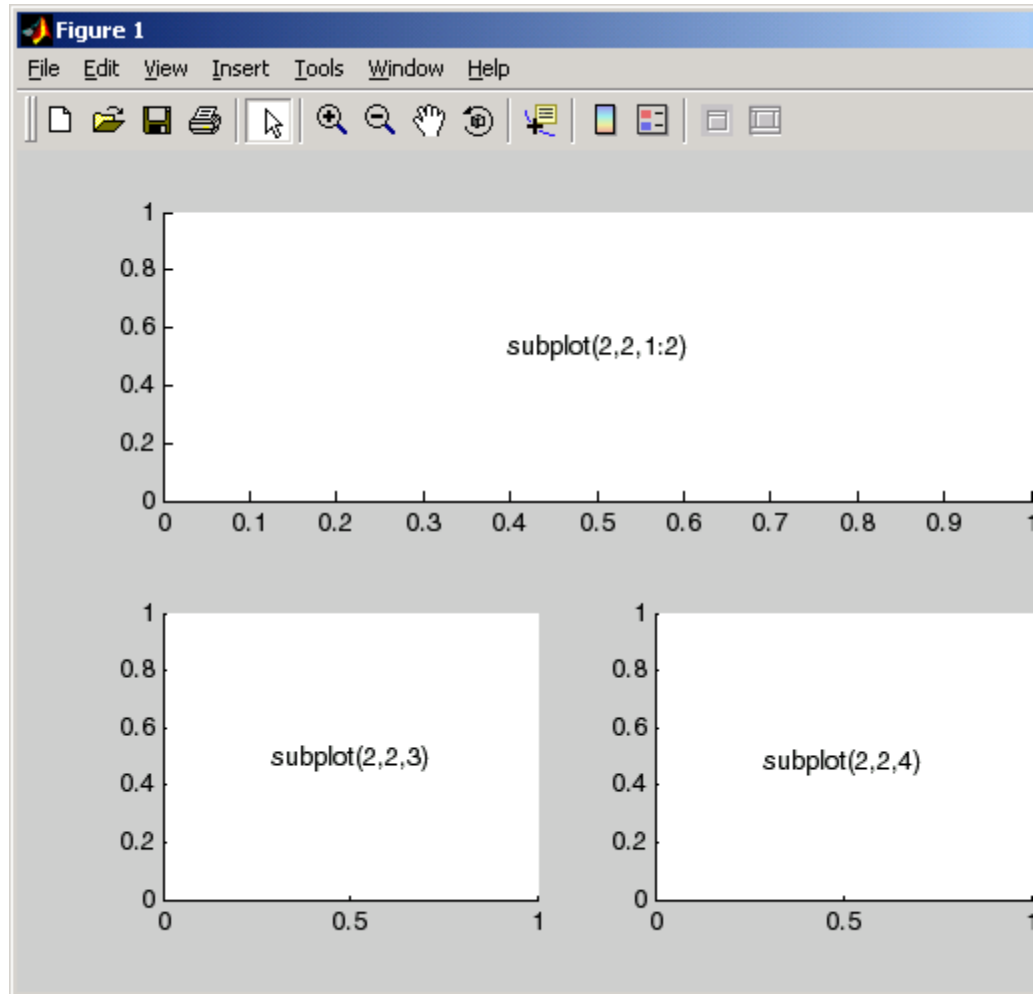
# subplot

```
subplot(2,2,2)
subplot(2,2,4)
```



You can also use the colon operator to specify multiple locations if they are in sequence.

```
subplot(2,2,1:2)
subplot(2,2,3)
subplot(2,2,4)
```

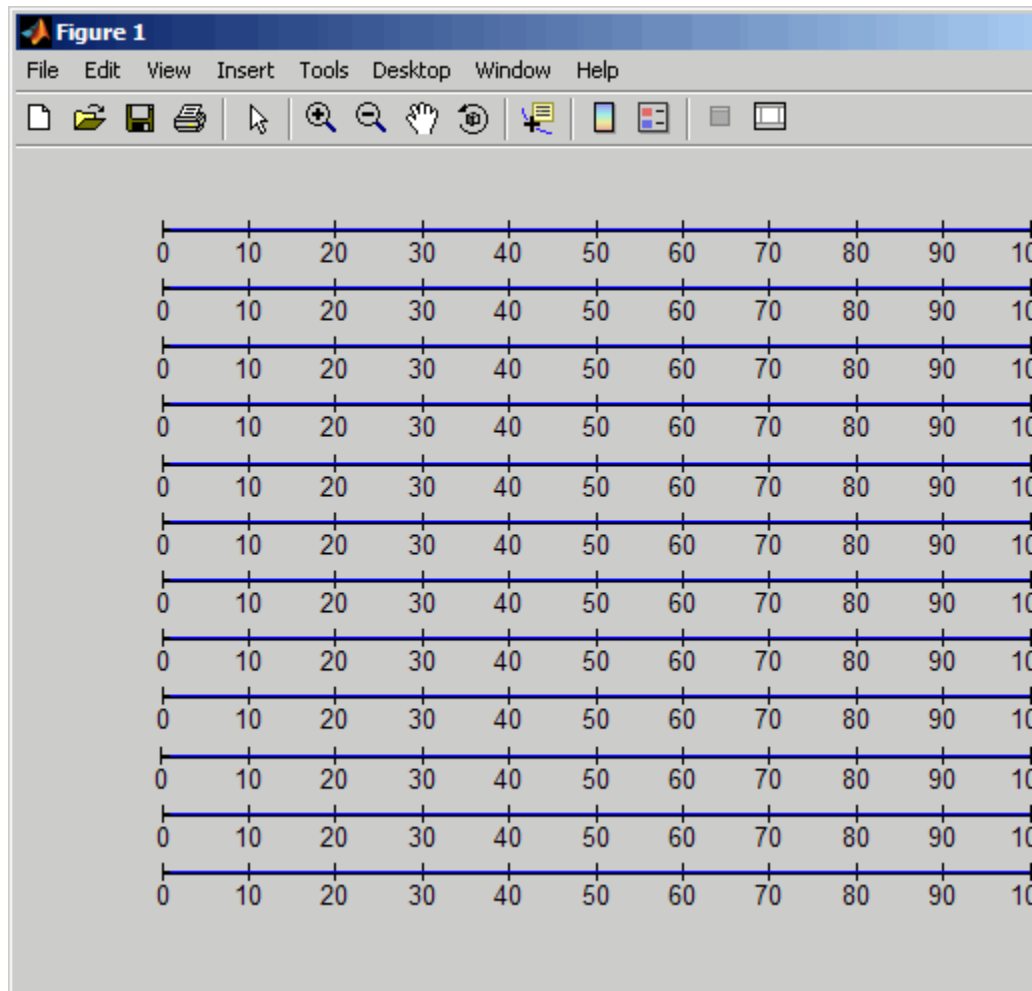


## Suppressing Axis Ticks

When you create many subplots in a figure, the axes tickmarks, which are shown by default, can either be obliterated or can cause axes to collapse, as the following code demonstrates:

```
figure
for i=1:12
 subplot(12,1,i)
 plot (sin(1:100)*10^(i-1))
end
```





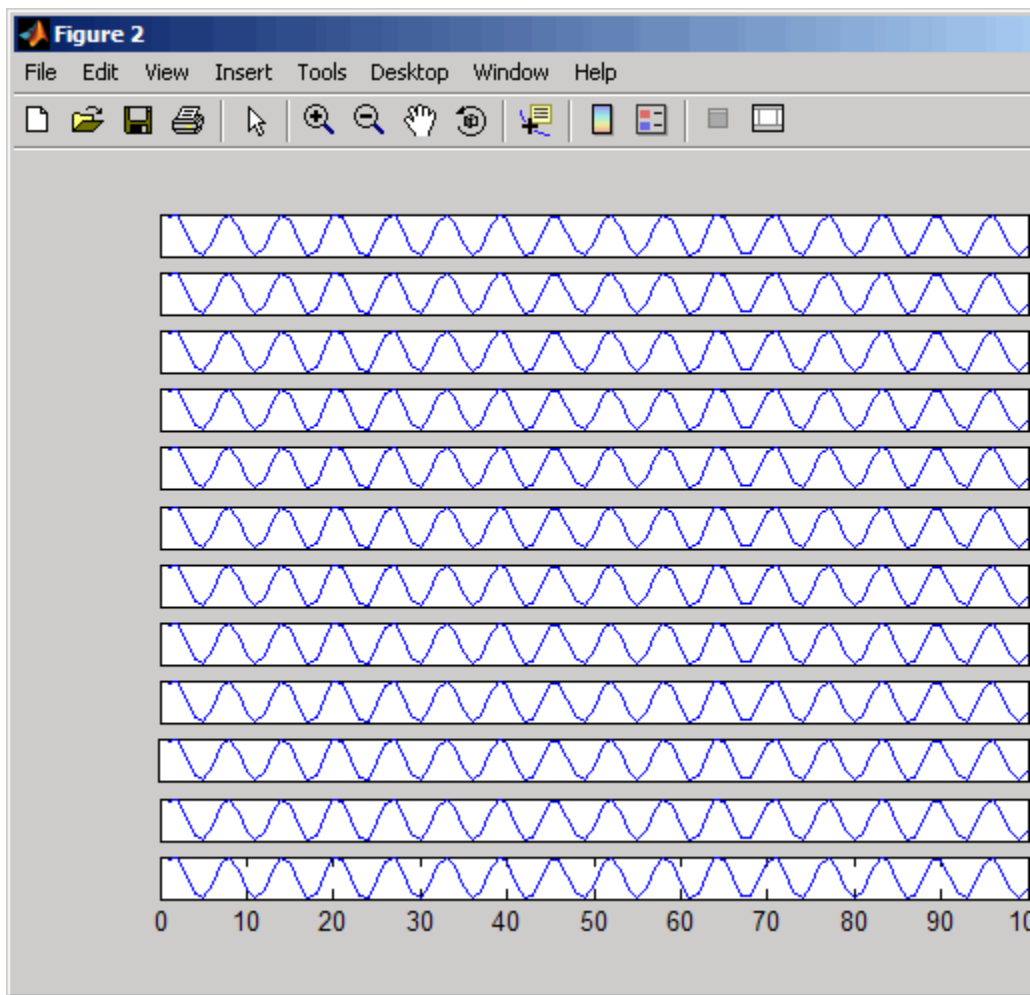
One way to get around this issue is to enlarge the figure to create enough space to properly display the tick labels.

Another approach is to eliminate the clutter by suppressing `xticks` and `yticks` for subplots as data are plotted into them. You can then label a single axes if the subplots are stacked, as follows:

# subplot

---

```
figure
for i=1:12
 subplot(12,1,i)
 plot (sin(1:100)*10^(i-1))
 set(gca,'xtick',[],'ytick',[])
end
% Reset the bottom subplot to have xticks
set(gca,'xtickMode', 'auto')
```

**See Also**

`axes`, `cla`, `clf`, `figure`, `gca`

“Basic Plots and Graphs” on page 1-93 for more information

# subplot

---

“Creating Subplots” in the MATLAB Creating Graphical User Interfaces documentation describes adding subplots to GUIs.

|                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
|--------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Purpose</b>     | Subscripted assignment for objects                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| <b>Syntax</b>      | $A = \text{subsasgn}(A, S, B)$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| <b>Description</b> | <p><math>A = \text{subsasgn}(A, S, B)</math> is called for the syntax <math>A(i)=B</math>, <math>A\{i\}=B</math>, or <math>A.i=B</math> when <math>A</math> is an object. <math>S</math> is a structure array with the fields</p> <ul style="list-style-type: none"><li>• <b>type</b> — A string containing '()', '{}', or '.', where '()' specifies integer subscripts, '{}' specifies cell array subscripts, and '.' specifies subscripted structure fields.</li><li>• <b>subs</b> — A cell array or string containing the actual subscripts.</li></ul> <p>The MATLAB interpreter uses the built-in <code>subsasgn</code> function to interpret indexed assignment statements, such as <math>A(i) = x</math>;</p> <p>You can modify the indexed assignment behavior of classes that you define (using the <code>classdef</code> syntax) by overloading <code>subsasgn</code> in your class. See “Indexed Reference and Assignment” for information on how to use <code>subsasgn</code> in your class definition.</p>                                                    |
| <b>Remarks</b>     | <p>In the assignment <math>A(J,K,\dots) = B(M,N,\dots)</math>, subscripts <math>J, K, M, N</math>, etc. can be scalar, vector, or arrays, provided that all of the following are true:</p> <ul style="list-style-type: none"><li>• The number of subscripts specified for <math>B</math>, excluding trailing subscripts equal to 1, does not exceed the value returned by <code>ndims(B)</code>.</li><li>• The number of nonscalar subscripts specified for <math>A</math> equals the number of nonscalar subscripts specified for <math>B</math>. For example, <math>A(5, 1:4, 1, 2) = B(5:8)</math> is valid because both sides of the equation use one nonscalar subscript.</li><li>• The order and length of all nonscalar subscripts specified for <math>A</math> matches the order and length of nonscalar subscripts specified for <math>B</math>. For example, <math>A(1:4, 3, 3:9) = B(5:8, 1:7)</math> is valid because both sides of the equation (ignoring the one scalar subscript 3) use a 4-element subscript followed by a 7-element subscript.</li></ul> |

See the Remarks section of the `numel` reference page for information concerning the use of `numel` with regards to the overloaded `subsasgn` function.

## Classes Defined Prior to Version 7.6

For MATLAB objects defined prior to Version 7.6, if `A` is an array of one of the “Fundamental MATLAB Classes”, then assigning a value to `A` with indexed assignment calls the built-in MATLAB `subsasgn` method. It does not call any `subsasgn` method that you might have overloaded for that class. For example, if `A` is an array of type `double`, and there is an `@double/subsasgn` method on your MATLAB path, the statement `A(I) = B` does not call this method, but calls the MATLAB built-in `subsasgn` method instead.

## Examples

The syntax `A(1:2,:)=B` calls `A=subsasgn(A,S,B)` where `S` is a 1-by-1 structure with `S.type='()'` and `S.subs = {1:2, ':'}`. A colon used as a subscript is passed as the string `'.'`.

The syntax `A{1:2}=B` calls `A=subsasgn(A,S,B)` where `S.type='{}'`.

The syntax `A.field=B` calls `subsasgn(A,S,B)` where `S.type='.'` and `S.subs='field'`.

These simple calls are combined in a straightforward way for more complicated subscripting expressions. In such cases `length(S)` is the number of subscripting levels. For instance, `A(1,2).name(3:5)=B` calls `A=subsasgn(A,S,B)` where `S` is a 3-by-1 structure array with the following values:

|                              |                               |                              |
|------------------------------|-------------------------------|------------------------------|
| <code>S(1).type='()'</code>  | <code>S(2).type='.'</code>    | <code>S(3).type='()'</code>  |
| <code>S(1).subs={1,2}</code> | <code>S(2).subs='name'</code> | <code>S(3).subs={3:5}</code> |

## See Also

`subsref`, `substruct`

**Purpose** Subscripted indexing using object as index

**Syntax** `ind = subsindex(A)`

**Description** `ind = subsindex(A)` is called for the syntax '`X(A)`' when `A` is an object. `subsindex` must return the value of the object as a zero-based integer index. (`ind` must contain integer values in the range 0 to `prod(size(X))-1`.) `subsindex` is called by the default `subsref` and `subsasgn` functions, and you can call it if you overload these functions. See “Indexing an Object with Another Object” for more information.

**See Also** `subsasgn`, `subsref`

# subspace

---

**Purpose** Angle between two subspaces

**Syntax** `theta = subspace(A,B)`

**Description** `theta = subspace(A,B)` finds the angle between two subspaces specified by the columns of A and B. If A and B are column vectors of unit length, this is the same as `acos(A'*B)`.

**Remarks** If the angle between the two subspaces is small, the two spaces are nearly linearly dependent. In a physical experiment described by some observations A, and a second realization of the experiment described by B, `subspace(A,B)` gives a measure of the amount of new information afforded by the second experiment not associated with statistical errors of fluctuations.

**Examples** Consider two subspaces of a Hadamard matrix, whose columns are orthogonal.

```
H = hadamard(8);
A = H(:,2:4);
B = H(:,5:8);
```

Note that matrices A and B are different sizes — A has three columns and B four. It is not necessary that two subspaces be the same size in order to find the angle between them. Geometrically, this is the angle between two hyperplanes embedded in a higher dimensional space.

```
theta = subspace(A,B)
theta =
 1.5708
```

That A and B are orthogonal is shown by the fact that theta is equal to  $\pi/2$ .

```
theta - pi/2
ans =
 0
```



|                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
|--------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Purpose</b>     | Subscripted reference for objects                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| <b>Syntax</b>      | <code>B = subsref(A, S)</code>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| <b>Description</b> | <p><code>B = subsref(A, S)</code> is called for the syntax <code>A(i)</code>, <code>A{i}</code>, or <code>A.i</code> when <code>A</code> is an object. <code>S</code> is a structure array with the fields</p> <ul style="list-style-type: none"><li>• <code>type</code>: A string containing <code>'()'</code>, <code>'{}'</code>, or <code>'.'</code>, where <code>'()'</code> specifies integer subscripts, <code>'{}'</code> specifies cell array subscripts, and <code>'.'</code> specifies subscripted structure fields.</li><li>• <code>subs</code>: A cell array or string containing the actual subscripts.</li></ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| <b>Remarks</b>     | <p><code>subsref</code> is designed to be used by the MATLAB interpreter to handle indexed references to objects. Calling <code>subsref</code> directly as a function is not recommended. If you do use <code>subsref</code> in this way, it conforms to the formal MATLAB dispatching rules and can yield unexpected results.</p> <p>See the Remarks section of the <code>numel</code> reference page for information concerning the use of <code>numel</code> with regards to the overloaded <code>subsref</code> function.</p> <p>If <code>A</code> is an array of one of the MATLAB built-in classes, then referencing a value of <code>A</code> using an indexed reference calls the built-in MATLAB <code>subsref</code> method. It does not call any <code>subsref</code> method that you may have overloaded for that class. For example, if <code>A</code> is an array of type <code>double</code>, and there is an <code>@double/subsref</code> method on your MATLAB path, the statement <code>B = A(I)</code> does not call this method, but calls the MATLAB built-in <code>subsref</code> method instead.</p> |
| <b>Examples</b>    | <p>The syntax <code>A(1:2,:)</code> calls <code>subsref(A,S)</code> where <code>S</code> is a 1-by-1 structure with <code>S.type='()'</code> and <code>S.subs={1:2, ':'}</code>. A colon used as a subscript is passed as the string <code>':'</code>.</p> <p>The syntax <code>A{1:2}</code> calls <code>subsref(A,S)</code> where <code>S.type='{}'</code> and <code>S.subs={1:2}</code>.</p> <p>The syntax <code>A.field</code> calls <code>subsref(A,S)</code> where <code>S.type='.'</code> and <code>S.subs='field'</code>.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |

## subsref

---

These simple calls are combined in a straightforward way for more complicated subscripting expressions. In such cases `length(S)` is the number of subscripting levels. For instance, `A(1,2).name(3:5)` calls `subsref(A,S)` where `S` is a 3-by-1 structure array with the following values:

```
S(1).type='()' S(2).type='.' S(3).type='()'
S(1).subs={1,2} S(2).subs='name' S(3).subs={3:5}
```

### See Also

`numel`, `subsasgn`, `substruct`

See “Indexed Reference and Assignment” for information on object indexing and `subsref`.

## Purpose

Create structure argument for subsasgn or subsref

## Syntax

```
S = substruct(type1, subs1, type2, subs2, ...)
```

## Description

S = substruct(type1, subs1, type2, subs2, ...) creates a structure with the fields required by an overloaded subsref or subsasgn method. Each type string must be one of '.', '()', or '{}'. The corresponding subs argument must be either a field name (for the '.' type) or a cell array containing the index vectors (for the '()' or '{}' types).

The output S is a structure array containing the fields

- type: one of '.', '()', or '{}'
- subs: subscript values (field name or cell array of index vectors)

## Examples

To call subsref with parameters equivalent to the syntax

```
B = A(3,5).field
```

you can use

```
S = substruct('()', {3,5}, '.', 'field');
B = subsref(A, S);
```

The structure created by substruct in this example contains the following:

```
S(1)

ans =

 type: '()'
 subs: {[3] [5]}

S(2)
```

# substruct

---

```
ans =
 type: '.'
 subs: 'field'
```

## See Also

subsasgn, subsref

**Purpose** Extract subset of volume data set

**Syntax**

```
[Nx,Ny,Nz,Nv] = subvolume(X,Y,Z,V,limits)
[Nx,Ny,Nz,Nv] = subvolume(V,limits)
Nv = subvolume(...)
```

**Description** `[Nx,Ny,Nz,Nv] = subvolume(X,Y,Z,V,limits)` extracts a subset of the volume data set `V` using the specified axis-aligned `limits`. `limits = [xmin,xmax,ymin,ymax,zmin,zmax]` (Any NaNs in the limits indicate that the volume should not be cropped along that axis.)

The arrays `X`, `Y`, and `Z` define the coordinates for the volume `V`. The subvolume is returned in `NV` and the coordinates of the subvolume are given in `NX`, `NY`, and `NZ`.

`[Nx,Ny,Nz,Nv] = subvolume(V,limits)` assumes the arrays `X`, `Y`, and `Z` are defined as

```
[X,Y,Z] = meshgrid(1:N,1:M,1:P)
```

where `[M,N,P] = size(V)`.

`Nv = subvolume(...)` returns only the subvolume.

## Examples

This example uses a data set that is a collection of MRI slices of a human skull. The data is processed in a variety of ways:

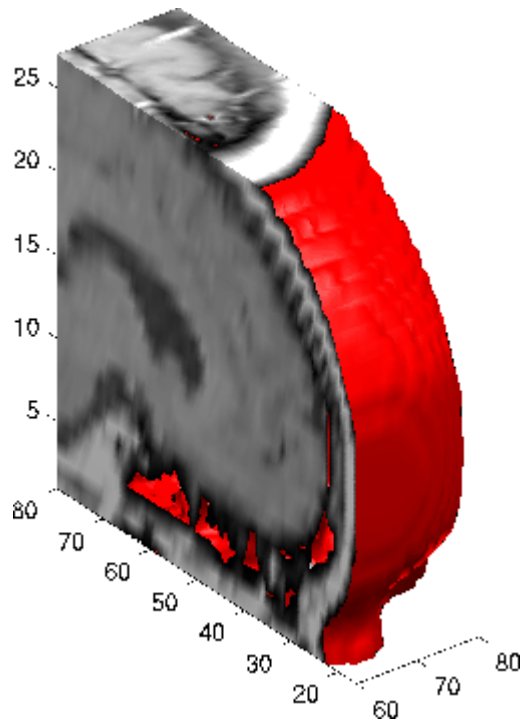
- The 4-D array is squeezed (`squeeze`) into three dimensions and then a subset of the data is extracted (`subvolume`).
- The outline of the skull is an isosurface generated as a patch (`p1`) whose vertex normals are recalculated to improve the appearance when lighting is applied (`patch`, `isosurface`, `isonormals`).
- A second patch (`p2`) with interpolated face color draws the end caps (`FaceColor`, `isocaps`).
- The view of the object is set (`view`, `axis`, `daspect`).

## subvolume

---

- A 100-element grayscale colormap provides coloring for the end caps (colormap).
- Adding lights to the right and left of the camera illuminates the object (camlight, lighting).

```
load mri
D = squeeze(D);
[x,y,z,D] = subvolume(D,[60,80,nan,80,nan,nan]);
p1 = patch(isosurface(x,y,z,D, 5),...
 'FaceColor','red','EdgeColor','none');
isonormals(x,y,z,D,p1);
p2 = patch(isocaps(x,y,z,D, 5),...
 'FaceColor','interp','EdgeColor','none');
view(3); axis tight; daspect([1,1,.4])
colormap(gray(100))
camlight right; camlight left; lighting gouraud
```



**See Also**

isocaps, isonormals, isosurface, reducepatch, reducevolume, smooth3

“Volume Visualization” on page 1-108 for related functions

# sum

---

**Purpose** Sum of array elements

**Syntax**

```
B = sum(A)
B = sum(A,dim)
B = sum(..., 'double')
B = sum(..., dim,'double')
B = sum(..., 'native')
B = sum(..., dim,'native')
```

**Description** `B = sum(A)` returns sums along different dimensions of an array.

If `A` is a vector, `sum(A)` returns the sum of the elements.

If `A` is a matrix, `sum(A)` treats the columns of `A` as vectors, returning a row vector of the sums of each column.

If `A` is a multidimensional array, `sum(A)` treats the values along the first non-singleton dimension as vectors, returning an array of row vectors.

`B = sum(A,dim)` sums along the dimension of `A` specified by scalar `dim`. The `dim` input is an integer value from 1 to `N`, where `N` is the number of dimensions in `A`. Set `dim` to 1 to compute the sum of each column, 2 to sum rows, etc.

`B = sum(..., 'double')` and `B = sum(..., dim,'double')` performs additions in double-precision and return an answer of type `double`, even if `A` has data type `single` or an integer data type. This is the default for integer data types.

`B = sum(..., 'native')` and `B = sum(..., dim,'native')` performs additions in the native data type of `A` and return an answer of the same data type. This is the default for `single` and `double`.

**Remarks** `sum(diag(X))` is the trace of `X`.

**Examples** The magic square of order 3 is

```
M = magic(3)
M =
```



```

8 1 6
3 5 7
4 9 2

```

This is called a magic square because the sums of the elements in each column are the same.

```

sum(M) =
 15 15 15

```

as are the sums of the elements in each row, obtained either by transposing or using the `dim` argument.

- Transposing

```

sum(M') =
 15 15 15

```

- Using the `dim` argument

```

sum(M,1)

ans =

 15 15 15

```

## Nondouble Data Type Support

This section describes the support of `sum` for data types other than `double`.

### Data Type `single`

You can apply `sum` to an array of type `single` and MATLAB software returns an answer of type `single`. For example,

```

sum(single([2 5 8]))

ans =

 15

```

```
class(ans)
```

```
ans =
```

```
single
```

## Integer Data Types

When you apply `sum` to any of the following integer data types, MATLAB software returns an answer of type `double`:

- `int8` and `uint8`
- `int16` and `uint16`
- `int32` and `uint32`

For example,

```
sum(single([2 5 8]));
```

```
class(ans)
```

```
ans =
```

```
single
```

If you want MATLAB to perform additions on an integer data type in the same integer type as the input, use the syntax

```
sum(int8([2 5 8], 'native');
```

```
class(ans)
```

```
ans =
```

```
int8
```

## See Also

`accumarray`, `cumsum`, `diff`, `isfloat`, `prod`

**Purpose** Sum of timeseries data

**Syntax**

```
ts_sm = sum(ts)
ts_sm = sum(ts, 'PropertyName1', PropertyValue1, ...)
```

**Description** `ts_sm = sum(ts)` returns the sum of the time-series data. When `ts.Data` is a vector, `ts_sm` is the sum of `ts.Data` values. When `ts.Data` is a matrix, `ts_sm` is a row vector containing the sum of each column of `ts.Data` (when `IsTimeFirst` is true and the first dimension of `ts` is aligned with time). For the N-dimensional `ts.Data` array, `sum` always operates along the first nonsingleton dimension of `ts.Data`.

`ts_sm = sum(ts, 'PropertyName1', PropertyValue1, ...)` specifies the following optional input arguments:

- 'MissingData' property has two possible values, 'remove' (default) or 'interpolate', indicating how to treat missing data during the calculation.
- 'Quality' values are specified by a vector of integers, indicating which quality codes represent missing samples (for vector data) or missing observations (for data arrays with two or more dimensions).
- 'Weighting' property has two possible values, 'none' (default) or 'time'.  
When you specify 'time', larger time values correspond to larger weights.

**Examples** 1 Load a 24-by-3 data array.

```
load count.dat
```

2 Create a timeseries object with 24 time values.

```
count_ts = timeseries(count, 1:24, 'Name', 'CountPerSecond')
```

3 Calculate the sum of each data column for this timeseries object.

```
sum(count_ts)
```

## sum (timeseries)

---

```
ans =
```

```
 768 1117 1574
```

The sum is calculated independently for each data column in the `timeseries` object.

### See Also

```
iqr (timeseries), mean (timeseries), median (timeseries), std
(timeseries), var (timeseries), timeseries
```

---

|                    |                                                                                                              |
|--------------------|--------------------------------------------------------------------------------------------------------------|
| <b>Purpose</b>     | Establish superior class relationship                                                                        |
| <b>Syntax</b>      | <code>superiorto('class1', 'class2', ...)</code>                                                             |
| <b>Description</b> | The <code>superiorto</code> function establishes a precedence that determines which object method is called. |

---

**Note** You can use this function only from a constructor that calls the `class` function to create an object, which was the only way to create MATLAB classes prior to MATLAB Version 7.6.

---

See *Object-Oriented Programming* for information on the creating MATLAB classes.

`superiorto('class1', 'class2', ...)` invoked within a class constructor method, establishes that class as having precedence over the classes in the function argument list for purposes of function dispatching (i.e., which method or function is called in any given situation).

**Remarks** Suppose `a` is an object of class `'class_a'`, `b` is an object of class `'class_b'` and `c` is an object of class `'class_c'`. Also suppose the constructor method for `class_c.m` contains the statement `superiorto('class_a')`. Then, either of the following two statements:

```
e = fun(a,c);
e = fun(c,a);
```

invokes `class_c/fun`.

If a function is called with two objects having an unspecified relationship, the two objects are considered to have equal precedence, and the left-most object's method is called. So `fun(b,c)` calls `class_b/fun`, while `fun(c,b)` calls `class_c/fun`.

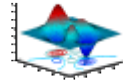
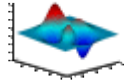
**See Also** `inferiorto`

# support


---

|                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
|--------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Purpose</b>     | Open MathWorks Technical Support Web page                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| <b>Syntax</b>      | support                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| <b>Description</b> | <p>support opens the MathWorks Technical Support Web page, <a href="http://www.mathworks.com/support">http://www.mathworks.com/support</a>, in the MATLAB Web browser.</p> <p>This Web page contains resources including</p> <ul style="list-style-type: none"><li>• A search engine, including an option for solutions to common problems</li><li>• Information about installation and licensing</li><li>• A patch archive for bug fixes you can download</li><li>• Other useful resources</li></ul> |
| <b>See Also</b>    | doc, web                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |

**Purpose** 3-D shaded surface plot



## GUI Alternatives

To graph selected variables, use the Plot Selector  in the Workspace Browser, or use the Figure Palette Plot Catalog. Manipulate graphs in *plot edit* mode with the Property Editor. For details, see Plotting Tools — Interactive Plotting in the MATLAB Graphics documentation and Creating Graphics from the Workspace Browser in the MATLAB Desktop Tools documentation.

## Syntax

```
surf(Z)
surf(Z,C)
surf(X,Y,Z)
surf(X,Y,Z,C)
surf(...,'PropertyName',PropertyValue)
surf(axes_handles,...)
surfc(...)
h = surf(...)
hsurface = surf('v6',...)
hsurface = surfc('v6',...)
```

## Description

Use `surf` and `surfc` to view mathematical functions over a rectangular region. `surf` and `surfc` create colored parametric surfaces specified by `X`, `Y`, and `Z`, with color specified by `Z` or `C`.

`surf(Z)` creates a three-dimensional shaded surface from the  $z$  components in matrix `Z`, using  $x = 1:n$  and  $y = 1:m$ , where  $[m,n] = \text{size}(Z)$ . The height, `Z`, is a single-valued function defined over a geometrically rectangular grid. `Z` specifies the color data as well as surface height, so color is proportional to surface height.

`surf(Z,C)` plots the height of `Z`, a single-valued function defined over a geometrically rectangular grid, and uses matrix `C`, assumed to be the same size as `Z`, to color the surface.

## surf, surfc

---

`surf(X,Y,Z)` creates a shaded surface using `Z` for the color data as well as surface height. `X` and `Y` are vectors or matrices defining the `x` and `y` components of a surface. If `X` and `Y` are vectors, `length(X) = n` and `length(Y) = m`, where `[m,n] = size(Z)`. In this case, the vertices of the surface faces are  $(X(j), Y(i), Z(i,j))$  triples. To create `X` and `Y` matrices for arbitrary domains, use the `meshgrid` function.

`surf(X,Y,Z,C)` creates a shaded surface, with color defined by `C`. MATLAB performs a linear transformation on this data to obtain colors from the current colormap.

`surf(..., 'PropertyName', PropertyValue)` specifies surface properties along with the data.

`surf(axes_handles,...)` and `surfc(axes_handles,...)` plot into the axes with handle `axes_handle` instead of the current axes (`gca`).

`surfc(...)` draws a contour plot beneath the surface.

`h = surf(...)` and `h = surfc(...)` return a handle to a surfaceplot graphics object.

### Backward-Compatible Version

`hsurface = surf('v6',...)` and `hsurface = surfc('v6',...)` return the handles of surface objects instead of surfaceplot objects for compatibility with MATLAB 6.5 and earlier.

---

**Note** The `v6` option enables users of Version 7.x of MATLAB to create FIG-files that previous versions can open. It is obsolete and will be removed in a future version of MATLAB.

---

See Plot Objects and Backward Compatibility for more information.

### Remarks

`surf` and `surfc` do not accept complex inputs.

### Algorithm

Abstractly, a parametric surface is parameterized by two independent variables, `i` and `j`, which vary continuously over a rectangle; for



example,  $1 \leq i \leq m$  and  $1 \leq j \leq n$ . The three functions  $x(i, j)$ ,  $y(i, j)$ , and  $z(i, j)$  specify the surface. When  $i$  and  $j$  are integer values, they define a rectangular grid with integer grid points. The functions  $x(i, j)$ ,  $y(i, j)$ , and  $z(i, j)$  become three  $m$ -by- $n$  matrices,  $X$ ,  $Y$ , and  $Z$ . Surface color is a fourth function,  $c(i, j)$ , denoted by matrix  $C$ .

Each point in the rectangular grid can be thought of as connected to its four nearest neighbors.

$$\begin{array}{c} i-1, j \\ | \\ i, j-1 - i, j - i, j+1 \\ | \\ i+1, j \end{array}$$

This underlying rectangular grid induces four-sided patches on the surface. To express this another way,  $[X(:) Y(:) Z(:)]$  returns a list of triples specifying points in 3-space. Each interior point is connected to the four neighbors inherited from the matrix indexing. Points on the edge of the surface have three neighbors; the four points at the corners of the grid have only two neighbors. This defines a mesh of quadrilaterals or a *quad-mesh*.

Surface color can be specified in two different ways: at the vertices or at the centers of each patch. In this general setting, the surface need not be a single-valued function of  $x$  and  $y$ . Moreover, the four-sided surface patches need not be planar. For example, you can have surfaces defined in polar, cylindrical, and spherical coordinate systems.

The shading function sets the shading. If the shading is `interp`,  $C$  must be the same size as  $X$ ,  $Y$ , and  $Z$ ; it specifies the colors at the vertices. The color within a surface patch is a bilinear function of the local coordinates. If the shading is `faceted` (the default) or `flat`,  $C(i, j)$  specifies the constant color in the surface patch:

$$\begin{array}{c} (i, j) \quad - \quad (i, j+1) \\ | \quad C(i, j) \quad | \\ (i+1, j) \quad - \quad (i+1, j+1) \end{array}$$

## surf, surfc

---

In this case, `C` can be the same size as `X`, `Y`, and `Z` and its last row and column are ignored. Alternatively, its row and column dimensions can be one less than those of `X`, `Y`, and `Z`.

The `surf` and `surfc` functions specify the viewpoint using `view(3)`.

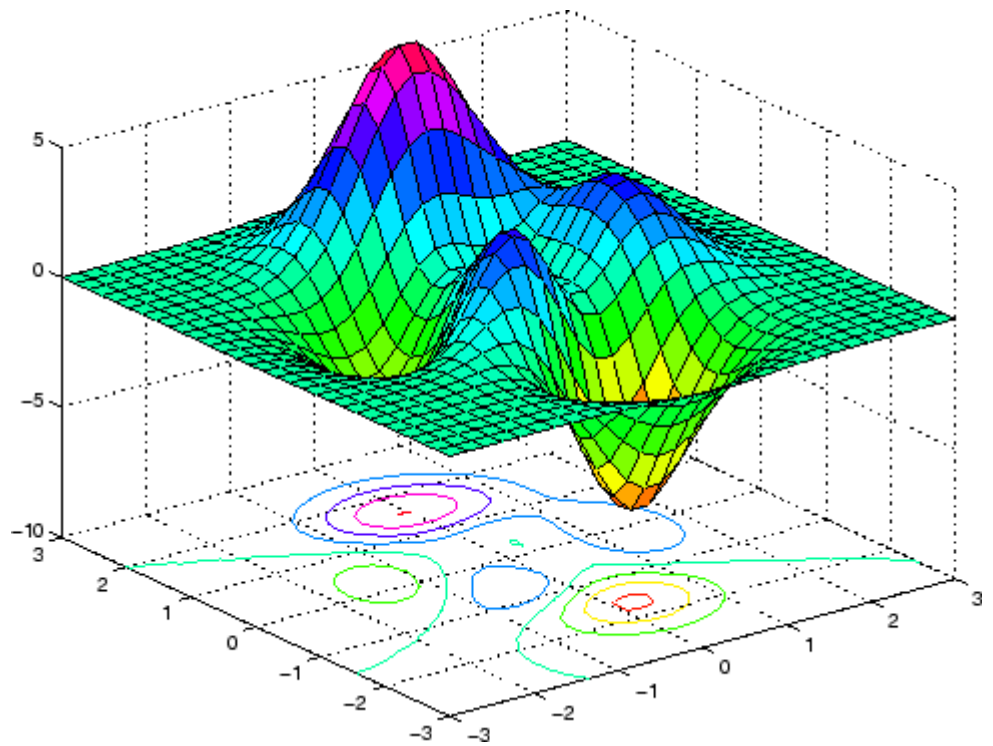
The range of `X`, `Y`, and `Z` or the current setting of the axes `XLimMode`, `YLimMode`, and `ZLimMode` properties (also set by the `axis` function) determines the axis labels.

The range of `C` or the current setting of the axes `CLim` and `CLimMode` properties (also set by the `caxis` function) determines the color scaling. The scaled color values are used as indices into the current colormap.

### Examples

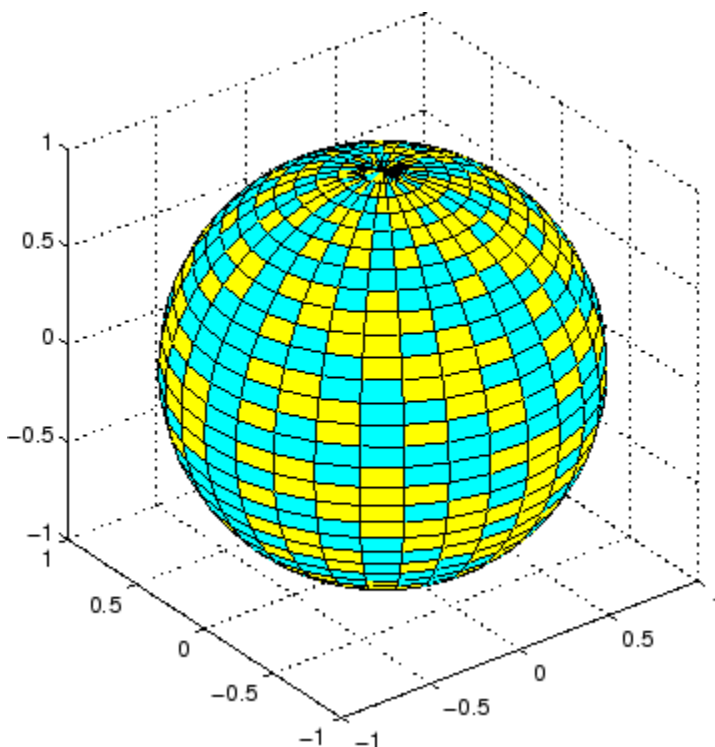
Display a surfaceplot and contour plot of the peaks surface.

```
[X,Y,Z] = peaks(30);
surfc(X,Y,Z)
colormap hsv
axis([-3 3 -3 3 -10 5])
```



Color a sphere with the pattern of +1s and -1s in a Hadamard matrix.

```
k = 5;
n = 2^k-1;
[x,y,z] = sphere(n);
c = hadamard(2^k);
surf(x,y,z,c);
colormap([1 1 0; 0 1 1])
axis equal
```



### See Also

`axis`, `caxis`, `colormap`, `contour`, `delaunay`, `imagesc`, `mesh`, `meshgrid`, `pcolor`, `shading`, `trisurf`, `view`

Properties for surfaceplot graphics objects

“Surface and Mesh Creation” on page 1-104 for related functions

“Creating Mesh and Surface Plots” in the Getting Started with MATLAB documentation for background and examples.

Representing a Matrix as a Surface in the MATLAB 3-D Visualization documentation for further examples

Coloring Mesh and Surface Plots for information about how to control the coloring of surfaces

**Purpose**

Convert surface data to patch data

**Syntax**

```
fvc = surf2patch(Z)
fvc = surf2patch(Z,C)
fvc = surf2patch(X,Y,Z)
fvc = surf2patch(X,Y,Z,C)
fvc = surf2patch(...,'triangles')
[f,v,c] = surf2patch(...)
```

**Description**

```
fvc = surf2patch(h)
```

converts the geometry and color data from the surface object identified by the handle `h` into patch format and returns the face, vertex, and color data in the struct `fvc`. You can pass this struct directly to the `patch` command.

`fvc = surf2patch(Z)` calculates the patch data from the surface's ZData matrix `Z`.

`fvc = surf2patch(Z,C)` calculates the patch data from the surface's ZData and CData matrices `Z` and `C`.

`fvc = surf2patch(X,Y,Z)` calculates the patch data from the surface's XData, YData, and ZData matrices `X`, `Y`, and `Z`.

`fvc = surf2patch(X,Y,Z,C)` calculates the patch data from the surface's XData, YData, ZData, and CData matrices `X`, `Y`, `Z`, and `C`.

`fvc = surf2patch(...,'triangles')` creates triangular faces instead of the quadrilaterals that compose surfaces.

`[f,v,c] = surf2patch(...)` returns the face, vertex, and color data in the three arrays `f`, `v`, and `c` instead of a struct.

**Examples**

The first example uses the `sphere` command to generate the XData, YData, and ZData of a surface, which is then converted to a patch. Note that the ZData (`z`) is passed to `surf2patch` as both the third and fourth arguments — the third argument is the ZData and the fourth argument is taken as the CData. This is because the `patch` command does not

# surf2patch

---

automatically use the  $z$ -coordinate data for the color data, as does the `surface` command.

Also, because `patch` is a low-level command, you must set the `view` to 3-D and `shading` to `faceted` to produce the same results produced by the `surf` command.

```
[x y z] = sphere;
patch(surf2patch(x,y,z,z));
shading faceted; view(3)
```

In the second example `surf2patch` calculates face, vertex, and color data from a surface whose handle has been passed as an argument.

```
s = surf(peaks);
pause
patch(surf2patch(s));
delete(s)
shading faceted; view(3)
```

## See Also

`patch`, `reducepatch`, `shrinkfaces`, `surface`, `surf`

“Volume Visualization” on page 1-108 for related functions

**Purpose**

Create surface object

**Syntax**

```
surface(Z)
surface(Z,C)
surface(X,Y,Z)
surface(X,Y,Z,C)
surface(x,y,Z)
surface(... 'PropertyName',PropertyValue,...)
h = surface(...)
```

**Description**

`surface` is the low-level function for creating surface graphics objects. Surfaces are plots of matrix data created using the row and column indices of each element as the  $x$ - and  $y$ -coordinates and the value of each element as the  $z$ -coordinate.

`surface(Z)` plots the surface specified by the matrix  $Z$ . Here,  $Z$  is a single-valued function, defined over a geometrically rectangular grid.

`surface(Z,C)` plots the surface specified by  $Z$  and colors it according to the data in  $C$  (see "Examples").

`surface(X,Y,Z)` uses  $C = Z$ , so color is proportional to surface height above the  $x$ - $y$  plane.

`surface(X,Y,Z,C)` plots the parametric surface specified by  $X$ ,  $Y$ , and  $Z$ , with color specified by  $C$ .

`surface(x,y,Z)`, `surface(x,y,Z,C)` replaces the first two matrix arguments with vectors and must have `length(x) = n` and `length(y) = m` where `[m,n] = size(Z)`. In this case, the vertices of the surface facets are the triples  $(x(j), y(i), Z(i,j))$ . Note that  $x$  corresponds to the columns of  $Z$  and  $y$  corresponds to the rows of  $Z$ . For a complete discussion of parametric surfaces, see the `surf` function.

`surface(... 'PropertyName',PropertyValue,...)` follows the  $X$ ,  $Y$ ,  $Z$ , and  $C$  arguments with property name/property value pairs to specify additional surface properties.

`h = surface(...)` returns a handle to the created surface object.

## Remarks

`surface` does not respect the settings of the figure and axes `NextPlot` properties. It simply adds the surface object to the current axes.

If you do not specify separate color data (`C`), MATLAB uses the matrix (`Z`) to determine the coloring of the surface. In this case, color is proportional to values of `Z`. You can specify a separate matrix to color the surface independently of the data defining the area of the surface.

You can specify properties as property name/property value pairs, structure arrays, and cell arrays (see `set` and `get` for examples of how to specify these data types).

`surface` provides convenience forms that allow you to omit the property name for the `XData`, `YData`, `ZData`, and `CData` properties. For example,

```
surface('XData',X,'YData',Y,'ZData',Z,'CData',C)
```

is equivalent to

```
surface(X,Y,Z,C)
```

When you specify only a single matrix input argument,

```
surface(Z)
```

MATLAB assigns the data properties as if you specified

```
surface('XData',[1:size(Z,2)],...
 'YData',[1:size(Z,1)],...
 'ZData',Z,...
 'CData',Z)
```

The axis, `caxis`, `colormap`, `hold`, `shading`, and `view` commands set graphics properties that affect surfaces. You can also set and query surface property values after creating them using the `set` and `get` commands.

## Example

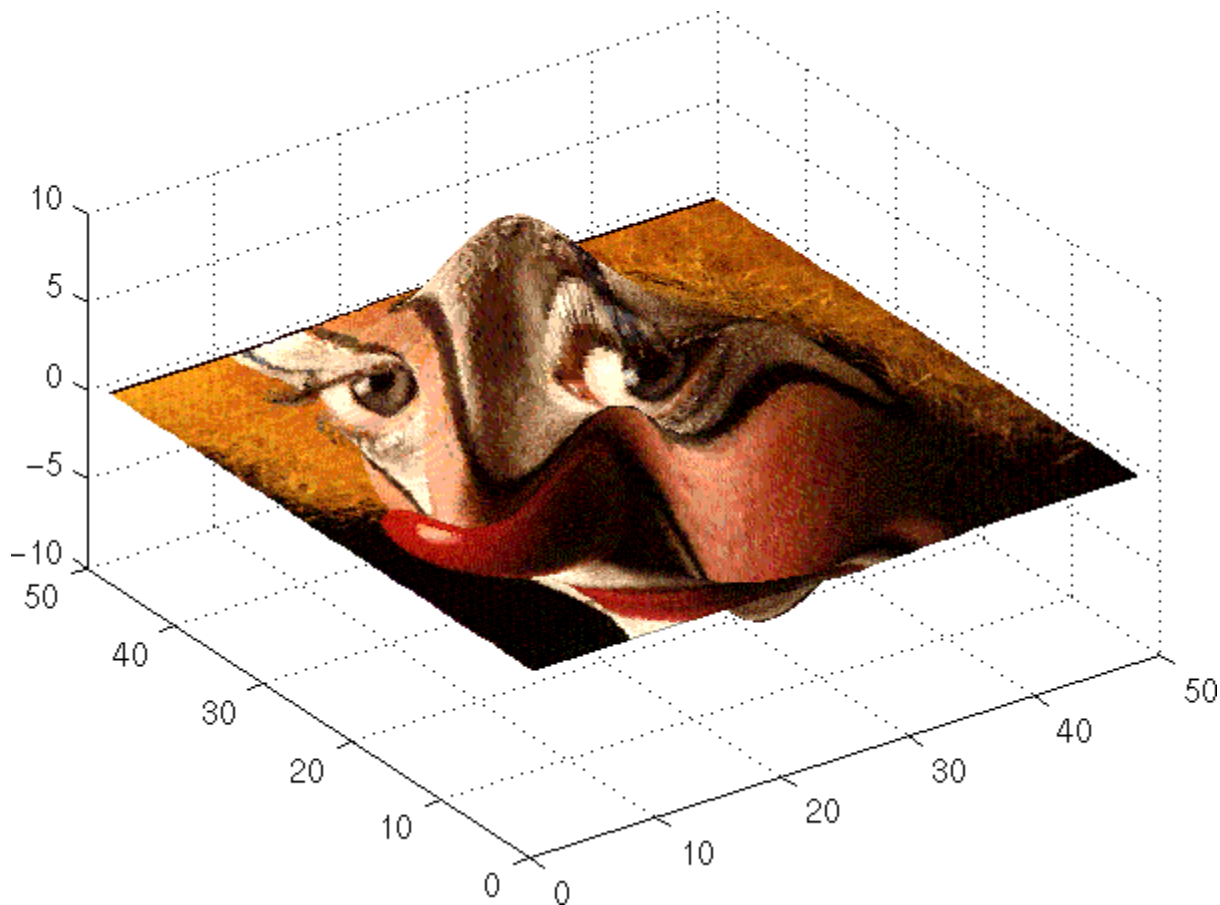
This example creates a surface using the `peaks` M-file to generate the data, and colors it using the `clown` image. The `ZData` is a 49-by-49



element matrix, while the CData is a 200-by-320 matrix. You must set the surface's FaceColor to texturemap to use ZData and CData of different dimensions.

```
load clown
surface(peaks,flipud(X),...
 'FaceColor','texturemap',...
 'EdgeColor','none',...
 'CDataMapping','direct')
colormap(map)
view(-35,45)
```

## surface



Note the use of the `surface(Z,C)` convenience form combined with property name/property value pairs.

Since the clown data (X) is typically viewed with the `image` command, which MATLAB normally displays with 'ij' axis numbering and `direct CDataMapping`, this example reverses the data in the vertical direction using `flipud` and sets the `CDataMapping` property to `direct`.

## Setting Default Properties

You can set default surface properties on the axes, figure, and root object levels:

```
set(0, 'DefaultSurfaceProperty', PropertyValue...)
set(gcf, 'DefaultSurfaceProperty', PropertyValue...)
set(gca, 'DefaultSurfaceProperty', PropertyValue...)
```

where *Property* is the name of the surface property whose default value you want to set and *PropertyValue* is the value you are specifying. Use `set` and `get` to access the surface properties.

## See Also

`ColorSpec`, `patch`, `pcolor`, `surf`

Representing a Matrix as a Surface for examples

“Surface and Mesh Creation” on page 1-104 and “Object Creation” on page 1-101 for related functions

Surface Properties for property descriptions

# Surface Properties

---

## Purpose

Surface properties

## Modifying Properties

You can set and query graphics object properties in two ways:

- The Property Editor is an interactive tool that enables you to see and change object property values.
- The set and get commands enable you to set and query the values of properties.

To change the default values of properties, see [Setting Default Property Values](#).

See “Core Graphics Objects” for general information about this type of object.

## Surface Property Descriptions

This section lists property names along with the types of values each accepts. Curly braces { } enclose default values.

### AlphaData

m-by-n matrix of double or uint8

*The transparency data.* A matrix of non-NaN values specifying the transparency of each face or vertex of the object. The AlphaData can be of class double or uint8.

MATLAB software determines the transparency in one of three ways:

- Using the elements of AlphaData as transparency values (AlphaDataMapping set to none)
- Using the elements of AlphaData as indices into the current alphamap (AlphaDataMapping set to direct)
- Scaling the elements of AlphaData to range between the minimum and maximum values of the axes ALim property (AlphaDataMapping set to scaled, the default)

## AlphaDataMapping

none | direct | {scaled}

*Transparency mapping method.* This property determines how MATLAB interprets indexed alpha data. This property can be any of the following:

- **none** — The transparency values of AlphaData are between 0 and 1 or are clamped to this range (the default).
- **scaled** — Transform the AlphaData to span the portion of the alphamap indicated by the axes ALim property, linearly mapping data values to alpha values.
- **direct** — use the AlphaData as indices directly into the alphamap. When not scaled, the data are usually integer values ranging from 1 to length(alphamap). MATLAB maps values less than 1 to the first alpha value in the alphamap, and values greater than length(alphamap) to the last alpha value in the alphamap. Values with a decimal portion are fixed to the nearest lower integer. If AlphaData is an array of uint8 integers, then the indexing begins at 0 (i.e., MATLAB maps a value of 0 to the first alpha value in the alphamap).

## AmbientStrength

scalar  $\geq 0$  and  $\leq 1$

*Strength of ambient light.* This property sets the strength of the ambient light, which is a nondirectional light source that illuminates the entire scene. You must have at least one visible light object in the axes for the ambient light to be visible. The axes AmbientLightColor property sets the color of the ambient light, which is therefore the same on all objects in the axes.

You can also set the strength of the diffuse and specular contribution of light objects. See the surface DiffuseStrength and SpecularStrength properties.

# Surface Properties

---

## Annotation

hg.Annotation object Read Only

*Control the display of surface objects in legends.* The Annotation property enables you to specify whether this surface object is represented in a figure legend.

Querying the Annotation property returns the handle of an hg.Annotation object. The hg.Annotation object has a property called LegendInformation, which contains an hg.LegendEntry object.

Once you have obtained the hg.LegendEntry object, you can set its IconDisplayStyle property to control whether the surface object is displayed in a figure legend:

| IconDisplayStyle Value | Purpose                                                 |
|------------------------|---------------------------------------------------------|
| on                     | Represent this surface object in a legend (default)     |
| off                    | Do not include this surface object in a legend          |
| children               | Same as on because surface objects do not have children |

## Setting the IconDisplayStyle property

These commands set the IconDisplayStyle of a graphics object with handle hobj to off:

```
hAnnotation = get(hobj, 'Annotation');
hLegendEntry = get(hAnnotation, 'LegendInformation');
set(hLegendEntry, 'IconDisplayStyle', 'off')
```

## Using the IconDisplayStyle property

See “Controlling Legends” for more information and examples.

## BackFaceLighting

unlit | lit | reverselit

*Face lighting control.* This property determines how faces are lit when their vertex normals point away from the camera.

- **unlit** — Face is not lit.
- **lit** — Face is lit in normal way.
- **reverselit** — Face is lit as if the vertex pointed towards the camera.

This property is useful for discriminating between the internal and external surfaces of an object. See “Back Face Lighting” for an example.

## BeingDeleted

on | {off} Read Only

*This object is being deleted.* The `BeingDeleted` property provides a mechanism that you can use to determine if objects are in the process of being deleted. MATLAB sets the `BeingDeleted` property to `on` when the object’s delete function callback is called (see the `DeleteFcn` property). It remains set to `on` while the delete function executes, after which the object no longer exists.

For example, an object’s delete function might call other functions that act on a number of different objects. These functions may not need to perform actions on objects that are going to be deleted, and therefore, can check the object’s `BeingDeleted` property before acting.

## BusyAction

cancel | {queue}

*Callback routine interruption.* The `BusyAction` property enables you to control how MATLAB handles events that potentially

# Surface Properties

---

interrupt executing callback routines. If there is a callback routine executing, callback routines invoked subsequently always attempt to interrupt it. If the `Interruptible` property of the object whose callback is executing is set to on (the default), then interruption occurs at the next point where the event queue is processed. If the `Interruptible` property is off, the `BusyAction` property (of the object owning the executing callback) determines how MATLAB handles the event. The choices are

- `cancel` — Discard the event that attempted to execute a second callback routine.
- `queue` — Queue the event that attempted to execute a second callback routine until the current callback finishes.

## `ButtonDownFcn`

function handle, cell array containing function handle and additional arguments, or string (not recommended)

*Button press callback function.* A callback function that executes whenever you press a mouse button while the pointer is over the surface object.

See the figure's `SelectionType` property to determine if modifier keys were also pressed.

Set this property to a function handle that references the callback. The function must define at least two input arguments (handle of object associated with the button down event and an event structure, which is empty for this property). For example, the following function takes different action depending on what type of selection was made:

```
function button_down(src,evnt)
% src - the object that is the source of the event
% evnt - empty for this property
 sel_typ = get(gcf,'SelectionType')
 switch sel_typ
 case 'normal'
```



```
 disp('User clicked left-mouse button')
 set(src,'Selected','on')
 case 'extend'
 disp('User did a shift-click')
 set(src,'Selected','on')
 case 'alt'
 disp('User did a control-click')
 set(src,'Selected','on')
 set(src,'SelectionHighlight','off')
 end
end
end
```

Suppose `h` is the handle of a surface object and that the `button_down` function is on your MATLAB path. The following statement assigns the function above to the `ButtonDownFcn`:

```
set(h, 'ButtonDownFcn', @button_down)
```

See “Function Handle Callbacks” for information on how to use function handles to define the callback function.

## CData

matrix (of type `double`)

*Vertex colors.* A matrix containing values that specify the color at every point in `ZData`.

### Mapping CData to a Colormap

You can specify color as indexed values or true color. Indexed color data specifies a single value for each vertex. These values are either scaled to map linearly into the current colormap (see `caxis`) or interpreted directly as indices into the colormap, depending on the setting of the `CDataMapping` property.

### CData as True Color

# Surface Properties

---

True color defines an RGB value for each vertex. If the coordinate data (`XData`, for example) are contained in  $m$ -by- $n$  matrices, then `CData` must be an  $m$ -by- $n$ -3 array. The first page contains the red components, the second the green components, and the third the blue components of the colors.

## Texturemapping the Surface `FaceColor`

If you set the `FaceColor` property to `texturemap`, `CData` does not need to be the same size as `ZData`, but must be of type `double` or `uint8`. In this case, MATLAB maps `CData` to conform to the surface defined by `ZData`.

`CDataMapping`  
{scaled} | direct

*Direct or scaled color mapping.* This property determines how MATLAB interprets indexed color data used to color the surface. (If you use true color specification for `CData`, this property has no effect.)

- `scaled` — Transform the color data to span the portion of the colormap indicated by the axes `CLim` property, linearly mapping data values to colors. See the `caxis` reference page for more information on this mapping.
- `direct` — Use the color data as indices directly into the colormap. The color data should then be integer values ranging from 1 to `length(colormap)`. MATLAB maps values less than 1 to the first color in the colormap, and values greater than `length(colormap)` to the last color in the colormap. Values with a decimal portion are fixed to the nearest lower integer.

`Children`  
matrix of handles

Always the empty matrix; surface objects have no children.

## Clipping

{on} | off

*Clipping to axes rectangle.* When Clipping is on, MATLAB does not display any portion of the surface that is outside the axes rectangle.

## CreateFcn

function handle, cell array containing function handle and additional arguments, or string (not recommended)

*Callback function executed during object creation.* This property defines a callback function that executes when MATLAB creates a surface object. You must define this property as a default value for surfaces or set the CreateFcn property during object creation.

For example, the following statement creates a surface (assuming `x`, `y`, `z`, and `c` are defined), and executes the function referenced by the function handle `@myCreateFcn`.

```
surface(x,y,z,c,'CreateFcn',@myCreateFcn)
```

MATLAB executes this routine after setting all surface properties. Setting this property on an existing surface object has no effect.

The handle of the object whose CreateFcn is being executed is passed by MATLAB as the first argument to the callback function and is also accessible through the root `CallbackObject` property, which you can query using `gcbo`.

See “Function Handle Callbacks” for information on how to use function handles to define the callback function.

## DeleteFcn

function handle, cell array containing function handle and additional arguments, or string (not recommended)

# Surface Properties

---

*Delete surface callback function.* A callback function that executes when you delete the surface object (e.g., when you issue a `delete` command or clear the axes `cla` or figure `clf`). For example, the following function displays object property data before the object is deleted.

```
function delete_fcn(src, evnt)
% src - the object that is the source of the event
% evnt - empty for this property
 obj_tp = get(src, 'Type');
 disp([obj_tp, ' object deleted'])
 disp('Its user data is:')
 disp(get(src, 'UserData'))
end
```

MATLAB executes the function before deleting the object's properties so these values are available to the callback function. The function must define at least two input arguments (handle of object being deleted and an event structure, which is empty for this property)

The handle of the object whose `DeleteFcn` is being executed is passed by MATLAB as the first argument to the callback function and is also accessible through the root `CallbackObject` property, which you can query using `gcbo`.

See “Function Handle Callbacks” for information on how to use function handles to define the callback function.

**DiffuseStrength**  
scalar  $\geq 0$  and  $\leq 1$

*Intensity of diffuse light.* This property sets the intensity of the diffuse component of the light falling on the surface. Diffuse light comes from light objects in the axes.

You can also set the intensity of the ambient and specular components of the light on the surface object. See the `AmbientStrength` and `SpecularStrength` properties.

## DisplayName

string (default is empty string)

*String used by legend for this surface object.* The `legend` function uses the string defined by the `DisplayName` property to label this surface object in the legend.

- If you specify string arguments with the `legend` function, `DisplayName` is set to this surface object's corresponding string and that string is used for the legend.
- If `DisplayName` is empty, `legend` creates a string of the form, `['data' n]`, where  $n$  is the number assigned to the object based on its location in the list of legend entries. However, `legend` does not set `DisplayName` to this string.
- If you edit the string directly in an existing legend, `DisplayName` is set to the edited string.
- If you specify a string for the `DisplayName` property and create the legend using the figure toolbar, then MATLAB uses the string defined by `DisplayName`.
- To add programmatically a legend that uses the `DisplayName` string, call `legend` with the `toggle` or `show` option.

See “Controlling Legends” for more examples.

## EdgeAlpha

{scalar = 1} | flat | interp

*Transparency of the surface edges.* This property can be any of the following:

- `scalar` — A single non-Nan scalar value between 0 and 1 that controls the transparency of all the edges of the object.

# Surface Properties

---

1 (the default) means fully opaque and 0 means completely transparent.

- `flat` — The alpha data (`AlphaData`) value for the first vertex of the face determines the transparency of the edges.
- `interp` — Linear interpolation of the alpha data (`AlphaData`) values at each vertex determines the transparency of the edge.

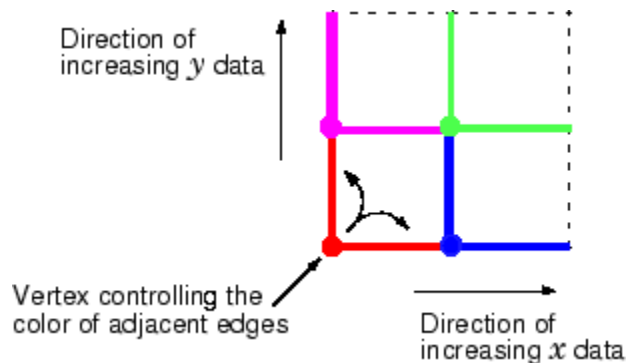
Note that you must specify `AlphaData` as a matrix equal in size to `ZData` to use `flat` or `interp` `EdgeAlpha`.

## EdgeColor

`{ColorSpec} | none | flat | interp`

*Color of the surface edge.* This property determines how MATLAB colors the edges of the individual faces that make up the surface:

- `ColorSpec` — A three-element RGB vector or one of the MATLAB predefined names, specifying a single color for edges. The default `EdgeColor` is black. See `ColorSpec` for more information on specifying color.
- `none` — Edges are not drawn.
- `flat` — The `CData` value of the first vertex for a face determines the color of each edge.



- `interp` — Linear interpolation of the `CData` values at the face vertices determines the edge color.

## EdgeLighting

`{none} | flat | gouraud | phong`

*Algorithm used for lighting calculations.* This property selects the algorithm used to calculate the effect of light objects on surface edges. Choices are

- `none` — Lights do not affect the edges of this object.
- `flat` — The effect of light objects is uniform across each edge of the surface.
- `gouraud` — The effect of light objects is calculated at the vertices and then linearly interpolated across the edge lines.
- `phong` — The effect of light objects is determined by interpolating the vertex normals across each edge line and calculating the reflectance at each pixel. Phong lighting generally produces better results than Gouraud lighting, but takes longer to render.

## EraseMode

`{normal} | none | xor | background`

*Erase mode.* This property controls the technique MATLAB uses to draw and erase surface objects. Alternative erase modes are useful for creating animated sequences, where control of the way individual objects are redrawn is necessary to improve performance and obtain the desired effect.

- `normal` — Redraw the affected region of the display, performing the three-dimensional analysis necessary to ensure that all objects are rendered correctly. This mode produces the most accurate picture, but is the slowest. The other modes are faster, but do not perform a complete redraw and are therefore less accurate.

# Surface Properties

---

- `none` — Do not erase the surface when it is moved or destroyed. While the object is still visible on the screen after erasing with `EraseMode none`, you cannot print it because MATLAB stores no information about its former location.
- `xor` — Draw and erase the surface by performing an exclusive OR (XOR) with each pixel index of the screen behind it. Erasing the surface does not damage the color of the objects behind it. However, surface color depends on the color of the screen behind it and is correctly colored only when over the axes background `Color`, or the figure background `Color` if the axes `Color` is set to `none`.
- `background` — Erase the surface by drawing it in the axes background `Color`, or the figure background `Color` if the axes `Color` is set to `none`. This damages objects that are behind the erased object, but surface objects are always properly colored.

## Printing with Nonnormal Erase Modes

MATLAB always prints figures as if the `EraseMode` of all objects is `normal`. This means graphics objects created with `EraseMode` set to `none`, `xor`, or `background` can look different on screen than on paper. On screen, MATLAB may mathematically combine layers of colors (e.g., performing an XOR of a pixel color with that of the pixel behind it) and ignore three-dimensional sorting to obtain greater rendering speed. However, these techniques are not applied to the printed output.

You can use the MATLAB `getframe` command or other screen capture application to create an image of a figure containing nonnormal mode objects.

## FaceAlpha

`{scalar = 1} | flat | interp | texturemap`

*Transparency of the surface faces.* This property can be any of the following:



- `scalar` — A single non-`NaN` scalar value between 0 and 1 that controls the transparency of all the faces of the object. 1 (the default) means fully opaque and 0 means completely transparent (invisible).
- `flat` — The values of the alpha data (`AlphaData`) determine the transparency for each face. The alpha data at the first vertex determine the transparency of the entire face.
- `interp` — Bilinear interpolation of the alpha data (`AlphaData`) at each vertex determines the transparency of each face.
- `texturemap` — Use transparency for the texture map.

Note that you must specify `AlphaData` as a matrix equal in size to `ZData` to use `flat` or `interp` `FaceAlpha`.

## `FaceColor`

`ColorSpec` | `none` | `{flat}` | `interp` | `texturemap`

*Color of the surface face.* This property can be any of the following:

- `ColorSpec` — A three-element RGB vector or one of the MATLAB predefined names, specifying a single color for faces. See `ColorSpec` for more information on specifying color.
- `none` — Do not draw faces. Note that edges are drawn independently of faces.
- `flat` — The values of `CData` determine the color for each face of the surface. The color data at the first vertex determine the color of the entire face.
- `interp` — Bilinear interpolation of the values at each vertex (the `CData`) determines the coloring of each face.
- `texturemap` — Texture map the `CData` to the surface. MATLAB transforms the color data so that it conforms to the surface. (See the texture mapping example.)

## `FaceLighting`

`{none}` | `flat` | `gouraud` | `phong`

# Surface Properties

---

*Algorithm used for lighting calculations.* This property selects the algorithm used to calculate the effect of light objects on the surface. Choices are

- none — Lights do not affect the faces of this object.
- flat — The effect of light objects is uniform across the faces of the surface. Select this choice to view faceted objects.
- gouraud — The effect of light objects is calculated at the vertices and then linearly interpolated across the faces. Select this choice to view curved surfaces.
- phong — The effect of light objects is determined by interpolating the vertex normals across each face and calculating the reflectance at each pixel. Select this choice to view curved surfaces. Phong lighting generally produces better results than Gouraud lighting, but takes longer to render.

HandleVisibility

{on} | callback | off

*Control access to object's handle by command-line users and GUIs.* This property determines when an object's handle is visible in its parent's list of children. This property is useful for preventing command-line users from accidentally drawing into or deleting a figure that contains only user interface devices (such as a dialog box).

Handles are always visible when HandleVisibility is on.

Setting HandleVisibility to callback causes handles to be visible from within callback routines or functions invoked by callback routines, but not from within functions invoked from the command line. This provides a means to protect GUIs from command-line users, while allowing callback routines to have complete access to object handles.

Setting `HandleVisibility` to `off` makes handles invisible at all times. This might be necessary when a callback routine invokes a function that could potentially damage the GUI (such as evaluating a user-typed string), and so temporarily hides its own handles during the execution of that function.

When a handle is not visible in its parent's list of children, it cannot be returned by functions that obtain handles by searching the object hierarchy or querying handle properties. This includes `get`, `findobj`, `gca`, `gcf`, `gco`, `newplot`, `cla`, `clf`, and `close`.

When a handle's visibility is restricted using `callback` or `off`, the object's handle does not appear in its parent's `Children` property, figures do not appear in the root's `CurrentFigure` property, objects do not appear in the root's `CallbackObject` property or in the figure's `CurrentObject` property, and axes do not appear in their parent's `CurrentAxes` property.

You can set the root `ShowHiddenHandles` property to `on` to make all handles visible, regardless of their `HandleVisibility` settings (this does not affect the values of the `HandleVisibility` properties).

Handles that are hidden are still valid. If you know an object's handle, you can set and get its properties, and pass it to any function that operates on handles.

`HitTest`  
{on} | off

*Selectable by mouse click.* `HitTest` determines if the surface can become the current object (as returned by the `gco` command and the figure `CurrentObject` property) as a result of a mouse click on the surface. If `HitTest` is `off`, clicking on the surface selects the object below it (which may be the axes containing it).

`Interruptible`  
{on} | off

# Surface Properties

---

*Callback routine interruption mode.* The `Interruptible` property controls whether a surface callback routine can be interrupted by subsequently invoked callback routines. Only callback routines defined for the `ButtonDownFcn` are affected by the `Interruptible` property. MATLAB checks for events that can interrupt a callback routine only when it encounters a `drawnow`, `figure`, `getframe`, or `pause` command in the routine. See the `BusyAction` property for related information.

## LineStyle

{-} | -- | : | -. | none

*Edge line type.* This property determines the line style used to draw surface edges. The available line styles are shown in this table.

| Symbol | Line Style           |
|--------|----------------------|
|        | Solid line (default) |
| --     | Dashed line          |
| :      | Dotted line          |
| .-     | Dash-dot line        |
| none   | No line              |

## LineWidth

scalar

*Edge line width.* The width of the lines in points used to draw surface edges. The default width is 0.5 points (1 point = 1/72 inch).

## Marker

marker symbol (see table)

*Marker symbol.* The `Marker` property specifies symbols that are displayed at vertices. You can set values for the `Marker` property independently from the `LineStyle` property.

You can specify these markers.

| Marker Specifier | Description                   |
|------------------|-------------------------------|
| +                | Plus sign                     |
| o                | Circle                        |
| *                | Asterisk                      |
| .                | Point                         |
| x                | Cross                         |
| s                | Square                        |
| d                | Diamond                       |
| ^                | Upward-pointing triangle      |
| v                | Downward-pointing triangle    |
| >                | Right-pointing triangle       |
| <                | Left-pointing triangle        |
| p                | Five-pointed star (pentagram) |
| h                | Six-pointed star (hexagram)   |
| none             | No marker (default)           |

## MarkerEdgeColor

none | {auto} | flat | ColorSpec

*Marker edge color.* The color of the marker or the edge color for filled markers (circle, square, diamond, pentagram, hexagram, and the four triangles).

- none specifies no color, which makes nonfilled markers invisible.
- auto uses the same color as the EdgeColor property.
- flat uses the CData value of the vertex to determine the color of the maker edge.

# Surface Properties

---

- `ColorSpec` defines a single color to use for the edge (see `ColorSpec` for more information).

`MarkerFaceColor`

{none} | auto | flat | `ColorSpec`

*Marker face color.* The fill color for markers that are closed shapes (circle, square, diamond, pentagram, hexagram, and the four triangles).

- `none` makes the interior of the marker transparent, allowing the background to show through.
- `auto` uses the axes `Color` for the marker face color.
- `flat` uses the `CData` value of the vertex to determine the color of the face.
- `ColorSpec` defines a single color to use for all markers on the surface (see `ColorSpec` for more information).

`MarkerSize`

size in points

*Marker size.* A scalar specifying the marker size, in points. The default value for `MarkerSize` is 6 points (1 point = 1/72 inch). Note that MATLAB draws the point marker at 1/3 the specified marker size.

`MeshStyle`

{both} | row | column

*Row and column lines.* This property specifies whether to draw all edge lines or just row or column edge lines.

- `both` draws edges for both rows and columns.
- `row` draws row edges only.
- `column` draws column edges only.

## NormalMode

{auto} | manual

*MATLAB generated or user-specified normal vectors.* When this property is auto, MATLAB calculates vertex normals based on the coordinate data. If you specify your own vertex normals, MATLAB sets this property to manual and does not generate its own data. See also the VertexNormals property.

## Parent

handle of axes, hggroup, or hgtransform

*Parent of surface object.* This property contains the handle of the surface object's parent. The parent of a surface object is the axes, hggroup, or hgtransform object that contains it.

See “Objects That Can Contain Other Objects” for more information on parenting graphics objects.

## Selected

on | {off}

*Is object selected?* When this property is on, MATLAB displays a dashed bounding box around the surface if the SelectionHighlight property is also on. You can, for example, define the ButtonDownFcn to set this property, allowing users to select the object with the mouse.

## SelectionHighlight

{on} | off

*Objects are highlighted when selected.* When the Selected property is on, MATLAB indicates the selected state by drawing a dashed bounding box around the surface. When SelectionHighlight is off, MATLAB does not draw the handles.

## SpecularColorReflectance

scalar in the range 0 to 1

# Surface Properties

---

*Color of specularly reflected light.* When this property is 0, the color of the specularly reflected light depends on both the color of the object from which it reflects and the color of the light source. When set to 1, the color of the specularly reflected light depends only on the color of the light source (i.e., the light object `Color` property). The proportions vary linearly for values in between.

**SpecularExponent**

scalar  $\geq 1$

*Harshness of specular reflection.* This property controls the size of the specular spot. Most materials have exponents in the range of 5 to 20.

**SpecularStrength**

scalar  $\geq 0$  and  $\leq 1$

*Intensity of specular light.* This property sets the intensity of the specular component of the light falling on the surface. Specular light comes from light objects in the axes.

You can also set the intensity of the ambient and diffuse components of the light on the surface object. See the `AmbientStrength` and `DiffuseStrength` properties. Also see the `material` function.

**Tag**

string

*User-specified object label.* The `Tag` property provides a means to identify graphics objects with a user-specified label. This is particularly useful when you are constructing interactive graphics programs that would otherwise need to define object handles as global variables or pass them as arguments between callback routines. You can define `Tag` as any string.

**Type**

string (read only)



*Class of the graphics object.* The class of the graphics object. For surface objects, `Type` is always the string `'surface'`.

## UIContextMenu

handle of a `uicontextmenu` object

*Associate a context menu with the surface.* Assign this property the handle of a `uicontextmenu` object created in the same figure as the surface. Use the `uicontextmenu` function to create the context menu. MATLAB displays the context menu whenever you right-click over the surface.

## UserData

matrix

*User-specified data.* Any matrix you want to associate with the surface object. MATLAB does not use this data, but you can access it using the `set` and `get` commands.

## VertexNormals

vector or matrix

*Surface normal vectors.* This property contains the vertex normals for the surface. MATLAB generates this data to perform lighting calculations. You can supply your own vertex normal data, even if it does not match the coordinate data. This can be useful to produce interesting lighting effects.

## Visible

{on} | off

*Surface object visibility.* By default, all surfaces are visible. When set to `off`, the surface is not visible, but still exists, and you can query and set its properties.

## XData

vector or matrix

# Surface Properties

---

*X-coordinates.* The  $x$ -position of the surface points. If you specify a row vector, `surface` replicates the row internally until it has the same number of columns as `ZData`.

`YData`

vector or matrix

*Y-coordinates.* The  $y$ -position of the surface points. If you specify a row vector, `surface` replicates the row internally until it has the same number of rows as `ZData`.

`ZData`

matrix

*Z-coordinates.* The  $z$ -position of the surfaceplot data points. See the Description section for more information.

## Purpose

Define surfaceplot properties

## Modifying Properties

You can set and query graphics object properties in two ways:

- The Property Editor is an interactive tool that enables you to see and change object property values.
- The `set` and `get` commands enable you to set and query the values of properties.

Note that you cannot define default properties for surfaceplot objects.

See Plot Objects for information on surfaceplot objects.

## Surfaceplot Property Descriptions

This section lists property names along with the types of values each accepts. Curly braces `{ }` enclose default values.

`AlphaData`

m-by-n matrix of `double` or `uint8`

*The transparency data.* A matrix of non-NaN values specifying the transparency of each face or vertex of the object. The `AlphaData` can be of class `double` or `uint8`.

MATLAB software determines the transparency in one of three ways:

- Using the elements of `AlphaData` as transparency values (`AlphaDataMapping` set to `none`)
- Using the elements of `AlphaData` as indices into the current `alphamap` (`AlphaDataMapping` set to `direct`)
- Scaling the elements of `AlphaData` to range between the minimum and maximum values of the axes `ALim` property (`AlphaDataMapping` set to `scaled`, the default)

`AlphaDataMapping`

`{none} | direct | scaled`

# Surfaceplot Properties

---

*Transparency mapping method.* This property determines how MATLAB interprets indexed alpha data. It can be any of the following:

- `none` — The transparency values of `AlphaData` are between 0 and 1 or are clamped to this range (the default).
- `scaled` — Transform the `AlphaData` to span the portion of the `alphamap` indicated by the axes `ALim` property, linearly mapping data values to alpha values.
- `direct` — Use the `AlphaData` as indices directly into the `alphamap`. When not scaled, the data are usually integer values ranging from 1 to `length(alphamap)`. MATLAB maps values less than 1 to the first alpha value in the `alphamap`, and values greater than `length(alphamap)` to the last alpha value in the `alphamap`. Values with a decimal portion are fixed to the nearest, lower integer. If `AlphaData` is an array of `uint8` integers, then the indexing begins at 0 (i.e., MATLAB maps a value of 0 to the first alpha value in the `alphamap`).

`AmbientStrength`

scalar  $\geq 0$  and  $\leq 1$

*Strength of ambient light.* This property sets the strength of the ambient light, which is a nondirectional light source that illuminates the entire scene. You must have at least one visible light object in the axes for the ambient light to be visible. The axes `AmbientLightColor` property sets the color of the ambient light, which is therefore the same on all objects in the axes.

You can also set the strength of the diffuse and specular contribution of light objects. See the `surfaceplot` `DiffuseStrength` and `SpecularStrength` properties.

`Annotation`

`hg.Annotation` object Read Only

*Control the display of surfaceplot objects in legends.* The `Annotation` property enables you to specify whether this surfaceplot object is represented in a figure legend.

Querying the `Annotation` property returns the handle of an `hg.Annotation` object. The `hg.Annotation` object has a property called `LegendInformation`, which contains an `hg.LegendEntry` object.

Once you have obtained the `hg.LegendEntry` object, you can set its `IconDisplayStyle` property to control whether the surfaceplot object is displayed in a figure legend:

| <b>IconDisplayStyle Value</b> | <b>Purpose</b>                                              |
|-------------------------------|-------------------------------------------------------------|
| on                            | Represent this surfaceplot object in a legend (default)     |
| off                           | Do not include this surfaceplot object in a legend          |
| children                      | Same as on because surfaceplot objects do not have children |

## Setting the `IconDisplayStyle` property

These commands set the `IconDisplayStyle` of a graphics object with handle `hobj` to `off`:

```
hAnnotation = get(hobj, 'Annotation');
hLegendEntry = get(hAnnotation, 'LegendInformation');
set(hLegendEntry, 'IconDisplayStyle', 'off')
```

## Using the `IconDisplayStyle` property

See “Controlling Legends” for more information and examples.

# Surfaceplot Properties

---

## BackFaceLighting

unlit | lit | reverselit

*Face lighting control.* This property determines how faces are lit when their vertex normals point away from the camera.

- `unlit` — Face is not lit.
- `lit` — Face is lit in normal way.
- `reverselit` — Face is lit as if the vertex pointed towards the camera.

This property is useful for discriminating between the internal and external surfaces of an object. See Back Face Lighting for an example.

## BeingDeleted

on | {off} Read Only

*This object is being deleted.* The `BeingDeleted` property provides a mechanism that you can use to determine if objects are in the process of being deleted. MATLAB sets the `BeingDeleted` property to `on` when the object's delete function callback is called (see the `DeleteFcn` property). It remains set to `on` while the delete function executes, after which the object no longer exists.

For example, an object's delete function might call other functions that act on a number of different objects. These functions might not need to perform actions on objects if the objects are going to be deleted, and therefore, can check the object's `BeingDeleted` property before acting.

## BusyAction

cancel | {queue}

*Callback routine interruption.* The `BusyAction` property enables you to control how MATLAB handles events that potentially interrupt executing callbacks. If there is a callback function

executing, callbacks invoked subsequently always attempt to interrupt it.

If the `Interruptible` property of the object whose callback is executing is set to `on` (the default), then interruption occurs at the next point where the event queue is processed. If the `Interruptible` property is `off`, the `BusyAction` property (of the object owning the executing callback) determines how MATLAB handles the event. The choices are

- `cancel` — Discard the event that attempted to execute a second callback routine.
- `queue` — Queue the event that attempted to execute a second callback routine until the current callback finishes.

## `ButtonDownFcn`

`cancel` | `{queue}`

*Callback routine interruption.* The `BusyAction` property enables you to control how MATLAB handles events that potentially interrupt executing callbacks. If there is a callback function executing, callbacks invoked subsequently always attempt to interrupt it.

If the `Interruptible` property of the object whose callback is executing is set to `on` (the default), then interruption occurs at the next point where the event queue is processed. If the `Interruptible` property is `off`, the `BusyAction` property (of the object owning the executing callback) determines how MATLAB handles the event. The choices are

- `cancel` — Discard the event that attempted to execute a second callback routine.
- `queue` — Queue the event that attempted to execute a second callback routine until the current callback finishes.

# Surfaceplot Properties

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## CData

matrix

*Vertex colors.* A matrix containing values that specify the color at every point in ZData. If you set the FaceColor property to texturemap, CData does not need to be the same size as ZData. In this case, MATLAB maps CData to conform to the surfaceplot defined by ZData.

You can specify color as indexed values or true color. Indexed color data specifies a single value for each vertex. These values are either scaled to map linearly into the current colormap (see caxis) or interpreted directly as indices into the colormap, depending on the setting of the CDataMapping property. Note that any non-texture data passed as an input argument must be of type double.

True color defines an RGB value for each vertex. If the coordinate data (XData, for example) are contained in  $m$ -by- $n$  matrices, then CData must be an  $m$ -by- $n$ -by-3 array. The first page contains the red components, the second the green components, and the third the blue components of the colors.

## CDataMapping

{scaled} | direct

*Direct or scaled color mapping.* This property determines how MATLAB interprets indexed color data used to color the surfaceplot. (If you use true color specification for CData, this property has no effect.)

- **scaled** — Transform the color data to span the portion of the colormap indicated by the axes CLim property, linearly mapping data values to colors. See the caxis reference page for more information on this mapping.
- **direct** — Use the color data as indices directly into the colormap. The color data should then be integer values ranging



from 1 to `length(colormap)`. MATLAB maps values less than 1 to the first color in the colormap, and values greater than `length(colormap)` to the last color in the colormap. Values with a decimal portion are fixed to the nearest lower integer.

## CDataMode

{auto} | manual

*Use automatic or user-specified color data values.* If you specify CData, MATLAB sets this property to `manual` and uses the CData values to color the surfaceplot.

If you set CDataMode to `auto` after having specified CData, MATLAB resets the color data of the surfaceplot to that defined by ZData, overwriting any previous values for CData.

## CDataSource

string (MATLAB variable)

*Link CData to MATLAB variable.* Set this property to a MATLAB variable that is evaluated in the base workspace to generate the CData.

MATLAB reevaluates this property only when you set it. Therefore, a change to workspace variables appearing in an expression does not change CData.

You can use the `refreshdata` function to force an update of the object's data. `refreshdata` also enables you to specify that the data source variable be evaluated in the workspace of a function from which you call `refreshdata`.

See the `refreshdata` reference page for more information.

# Surfaceplot Properties

---

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**Note** If you change one data source property to return data of a different dimension, you might cause the function to generate a warning and not render the graph until you have changed all data source properties to appropriate values.

---

## Children

matrix of handles

Always the empty matrix; surfaceplot objects have no children.

## Clipping

{on} | off

*Clipping to axes rectangle.* When Clipping is on, MATLAB does not display any portion of the surfaceplot that is outside the axes rectangle.

## CreateFcn

string or function handle

*Callback routine executed during object creation.* This property defines a callback that executes when MATLAB creates an object. You must specify the callback during the creation of the object. For example,

```
area(y, 'CreateFcn', @CallbackFcn)
```

where *@CallbackFcn* is a function handle that references the callback function.

MATLAB executes this routine after setting all other object properties. Setting this property on an existing object has no effect.

The handle of the object whose `CreateFcn` is being executed is accessible only through the root `CallbackObject` property, which you can query using `gcbo`.

See “Function Handle Callbacks” for information on how to use function handles to define the callback function.

## `DeleteFcn`

string or function handle

*Callback executed during object deletion.* A callback that executes when this object is deleted (e.g., this might happen when you issue a `delete` command on the object, its parent axes, or the figure containing it). MATLAB executes the callback before destroying the object’s properties so the callback routine can query these values.

The handle of the object whose `DeleteFcn` is being executed is accessible only through the root `CallbackObject` property, which can be queried using `gcbo`.

See “Function Handle Callbacks” for information on how to use function handles to define the callback function.

See the `BeingDeleted` property for related information.

## `DiffuseStrength`

scalar  $\geq 0$  and  $\leq 1$

*Intensity of diffuse light.* This property sets the intensity of the diffuse component of the light falling on the surface. Diffuse light comes from light objects in the axes.

You can also set the intensity of the ambient and specular components of the light on the object. See the `AmbientStrength` and `SpecularStrength` properties.

# Surfaceplot Properties

---

## DisplayName

string (default is empty string)

*String used by legend for this surfaceplot object. The legend function uses the string defined by the DisplayName property to label this surfaceplot object in the legend.*

- If you specify string arguments with the legend function, DisplayName is set to this surfaceplot object's corresponding string and that string is used for the legend.
- If DisplayName is empty, legend creates a string of the form, [ 'data' *n* ], where *n* is the number assigned to the object based on its location in the list of legend entries. However, legend does not set DisplayName to this string.
- If you edit the string directly in an existing legend, DisplayName is set to the edited string.
- If you specify a string for the DisplayName property and create the legend using the figure toolbar, then MATLAB uses the string defined by DisplayName.
- To add programmatically a legend that uses the DisplayName string, call legend with the toggle or show option.

See “Controlling Legends” for more examples.

## EdgeAlpha

{scalar = 1} | flat | interp

*Transparency of the patch and surface edges. This property can be any of the following:*

- **scalar** — A single non-Nan scalar value between 0 and 1 that controls the transparency of all the edges of the object. 1 (the default) means fully opaque and 0 means completely transparent.
- **flat** — The alpha data (AlphaData) value for the first vertex of the face determines the transparency of the edges.

- `interp` — Linear interpolation of the alpha data (`AlphaData`) values at each vertex determines the transparency of the edge.

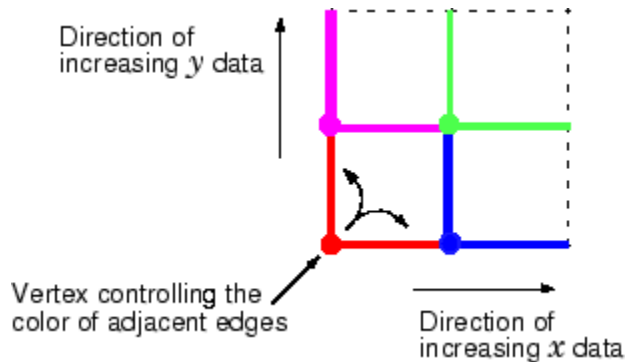
Note that you must specify `AlphaData` as a matrix equal in size to `ZData` to use `flat` or `interp` `EdgeAlpha`.

## EdgeColor

{ColorSpec} | none | flat | interp

*Color of the surfaceplot edge.* This property determines how MATLAB colors the edges of the individual faces that make up the surface:

- `ColorSpec` — A three-element RGB vector or one of the MATLAB predefined names, specifying a single color for edges. The default `EdgeColor` is black. See `ColorSpec` for more information on specifying color.
- `none` — Edges are not drawn.
- `flat` — The `CData` value of the first vertex for a face determines the color of each edge.



- `interp` — Linear interpolation of the `CData` values at the face vertices determines the edge color.

# Surfaceplot Properties

---

## EdgeLighting

{none} | flat | gouraud | phong

*Algorithm used for lighting calculations.* This property selects the algorithm used to calculate the effect of light objects on surfaceplot edges. Choices are

- none — Lights do not affect the edges of this object.
- flat — The effect of light objects is uniform across each edge of the surface.
- gouraud — The effect of light objects is calculated at the vertices and then linearly interpolated across the edge lines.
- phong — The effect of light objects is determined by interpolating the vertex normals across each edge line and calculating the reflectance at each pixel. Phong lighting generally produces better results than Gouraud lighting, but takes longer to render.

## EraseMode

{normal} | none | xor | background

*Erase mode.* This property controls the technique MATLAB uses to draw and erase objects and their children. Alternative erase modes are useful for creating animated sequences, where control of the way individual objects are redrawn is necessary to improve performance and obtain the desired effect.

- normal — Redraw the affected region of the display, performing the three-dimensional analysis necessary to ensure that all objects are rendered correctly. This mode produces the most accurate picture, but is the slowest. The other modes are faster, but do not perform a complete redraw and are therefore less accurate.
- none — Do not erase objects when they are moved or destroyed. While the objects are still visible on the screen after erasing

with `EraseMode` `none`, you cannot print these objects because MATLAB stores no information about their former locations.

- `xor` — Draw and erase the object by performing an exclusive OR (XOR) with each pixel index of the screen behind it. Erasing the object does not damage the color of the objects behind it. However, the color of the erased object depends on the color of the screen behind it and it is correctly colored only when it is over the axes background color (or the figure background color if the axes `Color` property is set to `none`). That is, it isn't erased correctly if there are objects behind it.
- `background` — Erase the graphics objects by redrawing them in the axes background color, (or the figure background color if the axes `Color` property is set to `none`). This damages other graphics objects that are behind the erased object, but the erased object is always properly colored.

## Printing with Nonnormal Erase Modes

MATLAB always prints figures as if the `EraseMode` of all objects is `normal`. This means graphics objects created with `EraseMode` set to `none`, `xor`, or `background` can look different on screen than on paper. On screen, MATLAB can mathematically combine layers of colors (e.g., performing an XOR on a pixel color with that of the pixel behind it) and ignore three-dimensional sorting to obtain greater rendering speed. However, these techniques are not applied to the printed output.

Set the axes background color with the axes `Color` property. Set the figure background color with the figure `Color` property.

You can use the MATLAB `getframe` command or other screen capture applications to create an image of a figure containing nonnormal mode objects.

```
FaceAlpha
{scalar = 1} | flat | interp | texturemap
```

# Surfaceplot Properties

---

*Transparency of the surfaceplot faces.* This property can be any of the following:

- **scalar** — A single non-NaN scalar value between 0 and 1 that controls the transparency of all the faces of the object. 1 (the default) means fully opaque and 0 means completely transparent (invisible).
- **flat** — The values of the alpha data (**AlphaData**) determine the transparency for each face. The alpha data at the first vertex determine the transparency of the entire face.
- **interp** — Bilinear interpolation of the alpha data (**AlphaData**) at each vertex determines the transparency of each face.
- **texturemap** — Use transparency for the texture map.

Note that you must specify **AlphaData** as a matrix equal in size to **ZData** to use **flat** or **interp** **FaceAlpha**.

## FaceColor

**ColorSpec** | none | {flat} | interp

*Color of the surfaceplot face.* This property can be any of the following:

- **ColorSpec** — A three-element RGB vector or one of the MATLAB predefined names, specifying a single color for faces. See **ColorSpec** for more information on specifying color.
- **none** — Do not draw faces. Note that edges are drawn independently of faces.
- **flat** — The values of **CData** determine the color for each face of the surface. The color data at the first vertex determine the color of the entire face.
- **interp** — Bilinear interpolation of the values at each vertex (the **CData**) determines the coloring of each face.



- `texturemap` — Texture map the `Cdata` to the surface. MATLAB transforms the color data so that it conforms to the surface. (See the texture mapping example for `surface`.)

## FaceLighting

`{none} | flat | gouraud | phong`

*Algorithm used for lighting calculations.* This property selects the algorithm used to calculate the effect of light objects on the surface. Choices are

- `none` — Lights do not affect the faces of this object.
- `flat` — The effect of light objects is uniform across the faces of the surface. Select this choice to view faceted objects.
- `gouraud` — The effect of light objects is calculated at the vertices and then linearly interpolated across the faces. Select this choice to view curved surfaces.
- `phong` — The effect of light objects is determined by interpolating the vertex normals across each face and calculating the reflectance at each pixel. Select this choice to view curved surfaces. Phong lighting generally produces better results than Gouraud lighting, but takes longer to render.

## HandleVisibility

`{on} | callback | off`

*Control access to object's handle by command-line users and GUIs.* This property determines when an object's handle is visible in its parent's list of children. `HandleVisibility` is useful for preventing command-line users from accidentally accessing objects that you need to protect for some reason.

- `on` — Handles are always visible when `HandleVisibility` is `on`.
- `callback` — Setting `HandleVisibility` to `callback` causes handles to be visible from within callback routines or functions invoked by callback routines, but not from within functions invoked from the command line. This provides a means to

# Surfaceplot Properties

---

protect GUIs from command-line users, while allowing callback routines to have access to object handles.

- `off` — Setting `HandleVisibility` to `off` makes handles invisible at all times. This might be necessary when a callback invokes a function that might potentially damage the GUI (such as evaluating a user-typed string) and so temporarily hides its own handles during the execution of that function.

## Functions Affected by Handle Visibility

When a handle is not visible in its parent's list of children, it cannot be returned by functions that obtain handles by searching the object hierarchy or querying handle properties. This includes `get`, `findobj`, `gca`, `gcf`, `gco`, `newplot`, `cla`, `clf`, and `close`.

## Properties Affected by Handle Visibility

When a handle's visibility is restricted using `callback` or `off`, the object's handle does not appear in its parent's `Children` property, figures do not appear in the root's `CurrentFigure` property, objects do not appear in the root's `CallbackObject` property or in the figure's `CurrentObject` property, and axes do not appear in their parent's `CurrentAxes` property.

## Overriding Handle Visibility

You can set the root `ShowHiddenHandles` property to `on` to make all handles visible regardless of their `HandleVisibility` settings (this does not affect the values of the `HandleVisibility` properties). See also `findall`.

## Handle Validity

Handles that are hidden are still valid. If you know an object's handle, you can `set` and `get` its properties and pass it to any function that operates on handles.

---

**Note** If you change one data source property to a variable that contains data of a different dimension, you might cause the function to generate a warning and not render the graph until you have changed all data source properties to appropriate values.

---

## HitTest

{on} | off

*Selectable by mouse click.* HitTest determines whether this object can become the current object (as returned by the `gco` command and the figure `CurrentObject` property) as a result of a mouse click on the objects that compose the area graph. If HitTest is off, clicking this object selects the object below it (which is usually the axes containing it).

## Interruptible

{on} | off

*Callback routine interruption mode.* The Interruptible property controls whether an object's callback can be interrupted by callbacks invoked subsequently.

Only callbacks defined for the `ButtonDownFcn` property are affected by the Interruptible property. MATLAB checks for events that can interrupt a callback only when it encounters a `drawnow`, `figure`, `getframe`, or `pause` command in the routine. See the `BusyAction` property for related information.

Setting Interruptible to on allows any graphics object's callback to interrupt callback routines originating from a bar property. Note that MATLAB does not save the state of variables or the display (e.g., the handle returned by the `gca` or `gcf` command) when an interruption occurs.

## LineStyle

{-} | - | : | -. | none

# Surfaceplot Properties

---

*Line style.* This property specifies the line style of the object. Available line styles are shown in the following table.

| Specifier String | Line Style           |
|------------------|----------------------|
| -                | Solid line (default) |
| --               | Dashed line          |
| :                | Dotted line          |
| -.               | Dash-dot line        |
| none             | No line              |

You can use `LineStyle none` when you want to place a marker at each point but do not want the points connected with a line (see the `Marker` property).

`LineWidth`  
scalar

*The width of linear objects and edges of filled areas.* Specify this value in points (1 point =  $1/72$  inch). The default `LineWidth` is 0.5 points.

`Marker`  
character (see table)

*Marker symbol.* The `Marker` property specifies the type of markers that are displayed at plot vertices. You can set values for the `Marker` property independently from the `LineStyle` property. Supported markers include those shown in the following table.

| Marker Specifier | Description |
|------------------|-------------|
| +                | Plus sign   |
| o                | Circle      |

| Marker Specifier | Description                   |
|------------------|-------------------------------|
| *                | Asterisk                      |
| .                | Point                         |
| x                | Cross                         |
| s                | Square                        |
| d                | Diamond                       |
| ^                | Upward-pointing triangle      |
| v                | Downward-pointing triangle    |
| >                | Right-pointing triangle       |
| <                | Left-pointing triangle        |
| p                | Five-pointed star (pentagram) |
| h                | Six-pointed star (hexagram)   |
| none             | No marker (default)           |

## MarkerEdgeColor

none | {auto} | flat | ColorSpec

*Marker edge color.* The color of the marker or the edge color for filled markers (circle, square, diamond, pentagram, hexagram, and the four triangles).

- none specifies no color, which makes nonfilled markers invisible.
- auto uses the same color as the EdgeColor property.
- flat uses the CData value of the vertex to determine the color of the maker edge.
- ColorSpec defines a single color to use for the edge (see ColorSpec for more information).

## MarkerFaceColor

{none} | auto | flat | ColorSpec

# Surfaceplot Properties

---

*Marker face color.* The fill color for markers that are closed shapes (circle, square, diamond, pentagram, hexagram, and the four triangles).

- none makes the interior of the marker transparent, allowing the background to show through.
- auto uses the axes Color for the marker face color.
- flat uses the CData value of the vertex to determine the color of the face.
- ColorSpec defines a single color to use for all markers on the surfaceplot (see ColorSpec for more information).

## MarkerSize

size in points

*Marker size.* A scalar specifying the size of the marker in points. The default value for MarkerSize is 6 points (1 point = 1/72 inch). Note that MATLAB draws the point marker (specified by the ' .' symbol) at one-third the specified size.

## MeshStyle

{both} | row | column

*Row and column lines.* This property specifies whether to draw all edge lines or just row or column edge lines.

- both draws edges for both rows and columns.
- row draws row edges only.
- column draws column edges only.

## NormalMode

{auto} | manual

*MATLAB generated or user-specified normal vectors.* When this property is auto, MATLAB calculates vertex normals based on the coordinate data. If you specify your own vertex normals,

MATLAB sets this property to `manual` and does not generate its own data. See also the `VertexNormals` property.

## Parent

handle of parent axes, `hggroup`, or `hgtransform`

*Parent of this object.* This property contains the handle of the object's parent. The parent is normally the axes, `hggroup`, or `hgtransform` object that contains the object.

See “Objects That Can Contain Other Objects” for more information on parenting graphics objects.

## Selected

`on` | `{off}`

*Is object selected?* When you set this property to `on`, MATLAB displays selection "handles" at the corners and midpoints if the `SelectionHighlight` property is also `on` (the default). You can, for example, define the `ButtonDownFcn` callback to set this property to `on`, thereby indicating that this particular object is selected. This property is also set to `on` when an object is manually selected in plot edit mode.

## SelectionHighlight

`{on}` | `off`

*Objects are highlighted when selected.* When the `Selected` property is `on`, MATLAB indicates the selected state by drawing four edge handles and four corner handles. When `SelectionHighlight` is `off`, MATLAB does not draw the handles except when in plot edit mode and objects are selected manually.

## SpecularColorReflectance

scalar in the range 0 to 1

*Color of specularly reflected light.* When this property is 0, the color of the specularly reflected light depends on both the color of the object from which it reflects and the color of the light source.

# Surfaceplot Properties

---

When set to 1, the color of the specularly reflected light depends only on the color of the light source (i.e., the light object `Color` property). The proportions vary linearly for values in between.

## SpecularExponent

scalar  $\geq 1$

*Harshness of specular reflection.* This property controls the size of the specular spot. Most materials have exponents in the range of 5 to 20.

## SpecularStrength

scalar  $\geq 0$  and  $\leq 1$

*Intensity of specular light.* This property sets the intensity of the specular component of the light falling on the surface. Specular light comes from light objects in the axes.

You can also set the intensity of the ambient and diffuse components of the light on the surfaceplot object. See the `AmbientStrength` and `DiffuseStrength` properties. Also see the `material` function.

## Tag

string

*User-specified object label.* The `Tag` property provides a means to identify graphics objects with a user-specified label. This is particularly useful when you are constructing interactive graphics programs that would otherwise need to define object handles as global variables or pass them as arguments between callbacks. You can define `Tag` as any string.

For example, you might create an `areaseries` object and set the `Tag` property.

```
t = area(Y, 'Tag', 'area1')
```



When you want to access objects of a given type, you can use `findobj` to find the object's handle. The following statement changes the `FaceColor` property of the object whose `Tag` is `area1`.

```
set(findobj('Tag','area1'),'FaceColor','red')
```

## Type

string (read only)

*Class of the graphics object.* The class of the graphics object. For surfaceplot objects, `Type` is always the string `'surface'`.

## UIContextMenu

handle of a `uicontextmenu` object

*Associate a context menu with this object.* Assign this property the handle of a `uicontextmenu` object created in the object's parent figure. Use the `uicontextmenu` function to create the context menu. MATLAB displays the context menu whenever you right-click over the object.

## UserData

array

*User-specified data.* This property can be any data you want to associate with this object (including cell arrays and structures). The object does not set values for this property, but you can access it using the `set` and `get` functions.

## VertexNormals

vector or matrix

*Surfaceplot normal vectors.* This property contains the vertex normals for the surfaceplot. MATLAB generates this data to perform lighting calculations. You can supply your own vertex normal data, even if it does not match the coordinate data. This can be useful to produce interesting lighting effects.

# Surfaceplot Properties

---

## Visible

{on} | off

*Visibility of this object and its children.* By default, a new object's visibility is on. This means all children of the object are visible unless the child object's `Visible` property is set to `off`. Setting an object's `Visible` property to `off` prevents the object from being displayed. However, the object still exists and you can set and query its properties.

## XData

vector or matrix

*X-coordinates.* The  $x$ -position of the surfaceplot data points. If you specify a row vector, MATLAB replicates the row internally until it has the same number of columns as `ZData`.

## XDataMode

{auto} | manual

*Use automatic or user-specified x-axis values.* If you specify `XData` (by setting the `XData` property or specifying the `x` input argument), MATLAB sets this property to `manual` and uses the specified values to label the  $x$ -axis.

If you set `XDataMode` to `auto` after having specified `XData`, MATLAB resets the  $x$ -axis ticks to `1:size(YData,1)` or to the column indices of the `ZData`, overwriting any previous values for `XData`.

## XDataSource

string (MATLAB variable)

*Link XData to MATLAB variable.* Set this property to a MATLAB variable that is evaluated in the base workspace to generate the `XData`.

MATLAB reevaluates this property only when you set it. Therefore, a change to workspace variables appearing in an expression does not change XData.

You can use the `refreshdata` function to force an update of the object's data. `refreshdata` also enables you to specify that the data source variable be evaluated in the workspace of a function from which you call `refreshdata`.

See the `refreshdata` reference page for more information.

---

**Note** If you change one data source property to a variable that contains data of a different dimension, you might cause the function to generate a warning and not render the graph until you have changed all data source properties to appropriate values.

---

## YData

vector or matrix

*Y-coordinates.* The  $y$ -position of the surfaceplot data points. If you specify a row vector, MATLAB replicates the row internally until it has the same number of rows as ZData.

## YDataMode

{auto} | manual

*Use automatic or user-specified x-axis values.* If you specify XData, MATLAB sets this property to manual.

If you set YDataMode to auto after having specified YData, MATLAB resets the  $y$ -axis ticks and  $y$ -tick labels to the row indices of the ZData, overwriting any previous values for YData.

## YDataSource

string (MATLAB variable)

# Surfaceplot Properties

---

*Link YData to MATLAB variable.* Set this property to a MATLAB variable that is evaluated in the base workspace to generate the YData.

MATLAB reevaluates this property only when you set it. Therefore, a change to workspace variables appearing in an expression does not change YData.

You can use the `refreshdata` function to force an update of the object's data. `refreshdata` also enables you to specify that the data source variable be evaluated in the workspace of a function from which you call `refreshdata`.

See the `refreshdata` reference page for more information.

---

**Note** If you change one data source property to a variable that contains data of a different dimension, you might cause the function to generate a warning and not render the graph until you have changed all data source properties to appropriate values.

---

ZData  
matrix

*Z-coordinates.* The *z*-position of the surfaceplot data points. See the Description section for more information.

ZDataSource  
string (MATLAB variable)

*Link ZData to MATLAB variable.* Set this property to a MATLAB variable that is evaluated in the base workspace to generate the ZData.

MATLAB reevaluates this property only when you set it. Therefore, a change to workspace variables appearing in an expression does not change ZData.

You can use the `refreshdata` function to force an update of the object's data. `refreshdata` also enables you to specify that the data source variable be evaluated in the workspace of a function from which you call `refreshdata`.

See the `refreshdata` reference page for more information.

---

**Note** If you change one data source property to a variable that contains data of a different dimension, you might cause the function to generate a warning and not render the graph until you have changed all data source properties to appropriate values.


---

## Purpose

Surface plot with colormap-based lighting



## GUI Alternatives

To graph selected variables, use the Plot Selector  in the Workspace Browser, or use the Figure Palette Plot Catalog. Manipulate graphs in *plot edit* mode with the Property Editor. For details, see [Plotting Tools — Interactive Plotting in the MATLAB Graphics documentation](#) and [Creating Graphics from the Workspace Browser in the MATLAB Desktop Tools documentation](#).

## Syntax

```
surf1(Z)
surf1(...,'light')
surf1(...,s)
surf1(X,Y,Z,s,k)
h = surf1(...)
```

## Description

The `surf1` function displays a shaded surface based on a combination of ambient, diffuse, and specular lighting models.

`surf1(Z)` and `surf1(X,Y,Z)` create three-dimensional shaded surfaces using the default direction for the light source and the default lighting coefficients for the shading model. `X`, `Y`, and `Z` are vectors or matrices that define the  $x$ ,  $y$ , and  $z$  components of a surface.

`surf1(...,'light')` produces a colored, lighted surface using a MATLAB light object. This produces results different from the default lighting method, `surf1(...,'cdata')`, which changes the color data for the surface to be the reflectance of the surface.

`surf1(...,s)` specifies the direction of the light source. `s` is a two- or three-element vector that specifies the direction from a surface to a light source. `s = [sx sy sz]` or `s = [azimuth elevation]`. The default `s` is 45° counterclockwise from the current view direction.

`surf1(X,Y,Z,s,k)` specifies the reflectance constant. `k` is a four-element vector defining the relative contributions of ambient light,

diffuse reflection, specular reflection, and the specular shine coefficient.  $k = [ka \ kd \ ks \ shine]$  and defaults to  $[.55, .6, .4, 10]$ .

$h = \text{surfl}(\dots)$  returns a handle to a surface graphics object.

## Remarks

`surfl` does not accept complex inputs.

For smoother color transitions, use colormaps that have linear intensity variations (e.g., `gray`, `copper`, `bone`, `pink`).

The ordering of points in the  $X$ ,  $Y$ , and  $Z$  matrices defines the inside and outside of parametric surfaces. If you want the opposite side of the surface to reflect the light source, use `surfl(X',Y',Z')`. Because of the way surface normal vectors are computed, `surfl` requires matrices that are at least 3-by-3.

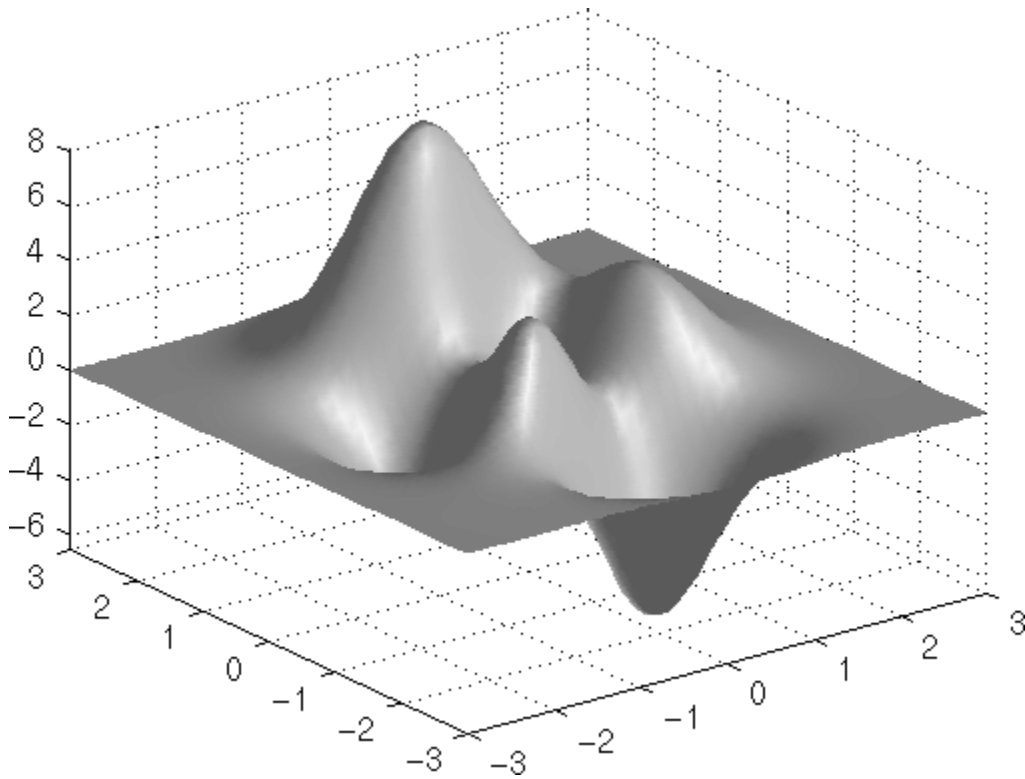
## Examples

View peaks using colormap-based lighting.

```
[x,y] = meshgrid(-3:1/8:3);
z = peaks(x,y);
surfl(x,y,z);
shading interp
colormap(gray);
axis([-3 3 -3 3 -8 8])
```

# surf1

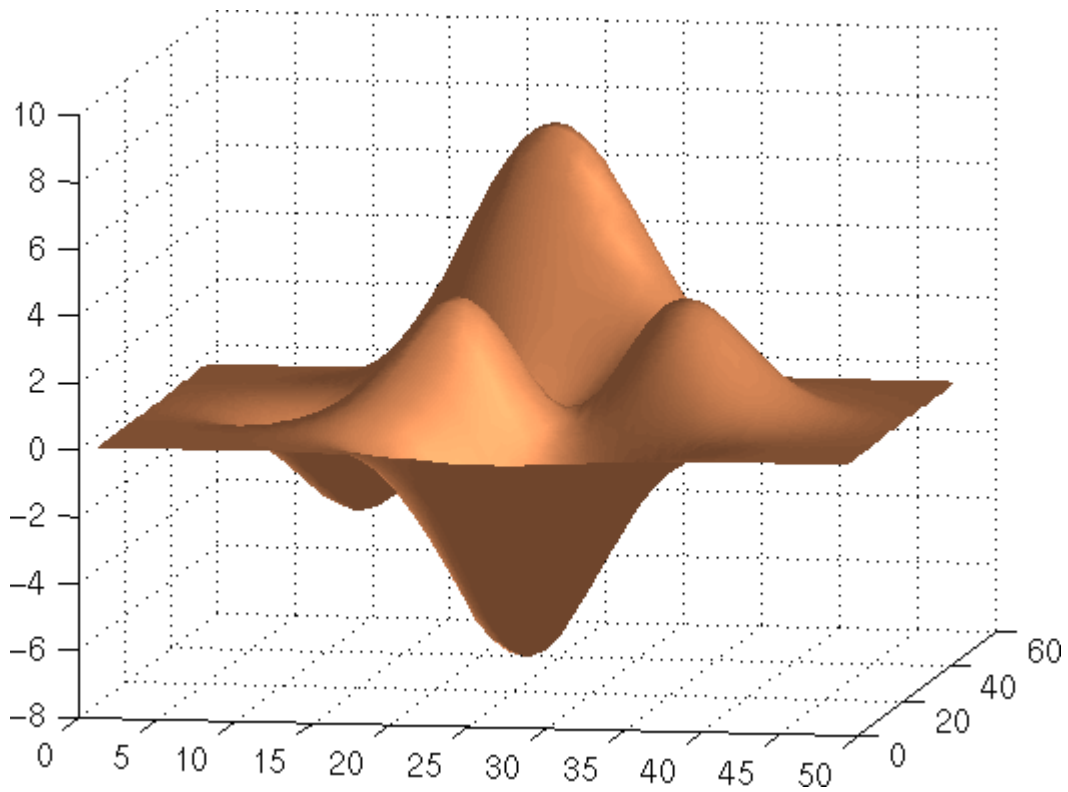
---



To plot a lighted surface from a view direction other than the default,

```
view([10 10])
grid on
hold on
surf1(peaks)
shading interp
colormap copper
hold off
```



**See Also**

`colormap`, `shading`, `light`

“Surface and Mesh Creation” on page 1-104 for functions related to surfaces

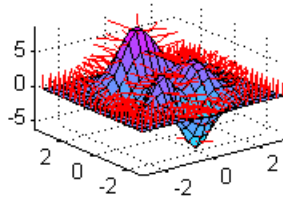
“Lighting” on page 1-108 for functions related to lighting

# surfnorm

---

## Purpose

Compute and display 3-D surface normals



## Syntax

```
surfnorm(Z)
surfnorm(X,Y,Z)
[Nx,Ny,Nz] = surfnorm(...)
```

## Description

The `surfnorm` function computes surface normals for the surface defined by  $X$ ,  $Y$ , and  $Z$ . The surface normals are unnormalized and valid at each vertex. Normals are not shown for surface elements that face away from the viewer.

`surfnorm(Z)` and `surfnorm(X,Y,Z)` plot a surface and its surface normals.  $Z$  is a matrix that defines the  $z$  component of the surface.  $X$  and  $Y$  are vectors or matrices that define the  $x$  and  $y$  components of the surface.

`[Nx,Ny,Nz] = surfnorm(...)` returns the components of the three-dimensional surface normals for the surface.

## Remarks

`surfnorm` does not accept complex inputs.

The direction of the normals is reversed by calling `surfnorm` with transposed arguments:

```
surfnorm(X',Y',Z')
```

`surf1` uses `surfnorm` to compute surface normals when calculating the reflectance of a surface.

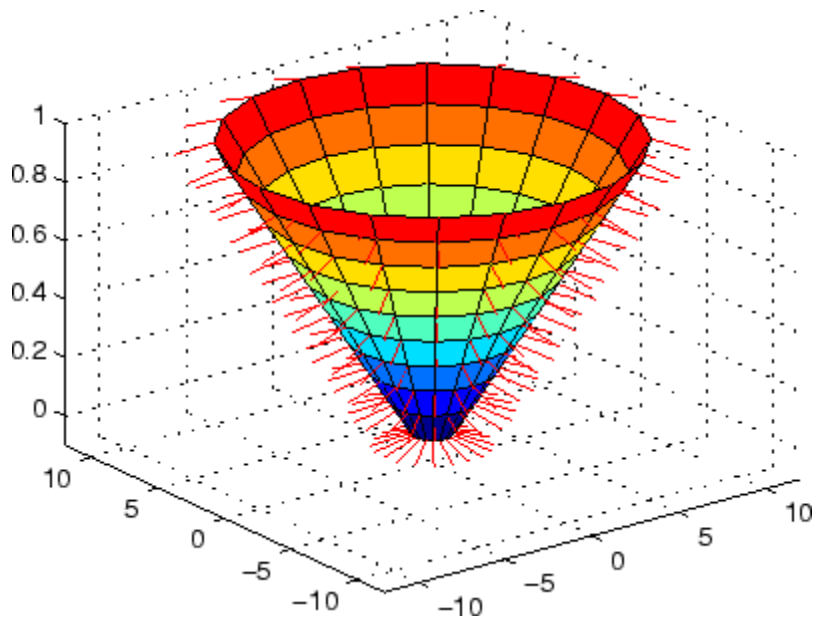
**Algorithm**

The surface normals are based on a bicubic fit of the data in X, Y, and Z. For each vertex, diagonal vectors are computed and crossed to form the normal.

**Examples**

Plot the normal vectors for a truncated cone.

```
[x,y,z] = cylinder(1:10);
surfnorm(x,y,z)
axis([-12 12 -12 12 -0.1 1])
```

**See Also**

surf, quiver3  
for related functions

# svd

---

**Purpose** Singular value decomposition

**Syntax**

```
s = svd(X)
[U,S,V] = svd(X)
[U,S,V] = svd(X,0)
[U,S,V] = svd(X,'econ')
```

**Description** The svd command computes the matrix singular value decomposition.

`s = svd(X)` returns a vector of singular values.

`[U,S,V] = svd(X)` produces a diagonal matrix **S** of the same dimension as **X**, with nonnegative diagonal elements in decreasing order, and unitary matrices **U** and **V** so that  $X = U*S*V'$ .

`[U,S,V] = svd(X,0)` produces the “economy size” decomposition. If **X** is *m*-by-*n* with  $m > n$ , then `svd` computes only the first *n* columns of **U** and **S** is *n*-by-*n*.

`[U,S,V] = svd(X,'econ')` also produces the “economy size” decomposition. If **X** is *m*-by-*n* with  $m \geq n$ , it is equivalent to `svd(X,0)`. For  $m < n$ , only the first *m* columns of **V** are computed and **S** is *m*-by-*m*.

## Examples

For the matrix

```
X =
 1 2
 3 4
 5 6
 7 8
```

the statement

```
[U,S,V] = svd(X)
```

produces

```
U =
-0.1525 -0.8226 -0.3945 -0.3800
```

|         |         |         |         |
|---------|---------|---------|---------|
| -0.3499 | -0.4214 | 0.2428  | 0.8007  |
| -0.5474 | -0.0201 | 0.6979  | -0.4614 |
| -0.7448 | 0.3812  | -0.5462 | 0.0407  |

S =

|         |        |
|---------|--------|
| 14.2691 | 0      |
| 0       | 0.6268 |
| 0       | 0      |
| 0       | 0      |

V =

|         |         |
|---------|---------|
| -0.6414 | 0.7672  |
| -0.7672 | -0.6414 |

The economy size decomposition generated by

$$[U, S, V] = \text{svd}(X, 0)$$

produces

U =

|         |         |
|---------|---------|
| -0.1525 | -0.8226 |
| -0.3499 | -0.4214 |
| -0.5474 | -0.0201 |
| -0.7448 | 0.3812  |

S =

|         |        |
|---------|--------|
| 14.2691 | 0      |
| 0       | 0.6268 |

V =

|         |         |
|---------|---------|
| -0.6414 | 0.7672  |
| -0.7672 | -0.6414 |

## Algorithm

svd uses the LAPACK routines listed in the following table to compute the singular value decomposition.

|          | <b>Real</b> | <b>Complex</b> |
|----------|-------------|----------------|
| X double | DGESVD      | ZGESVD         |
| X single | SGESVD      | CGESVD         |

## Diagnostics

If the limit of 75 QR step iterations is exhausted while seeking a singular value, this message appears:

Solution will not converge.

## References

[1] Anderson, E., Z. Bai, C. Bischof, S. Blackford, J. Demmel, J. Dongarra, J. Du Croz, A. Greenbaum, S. Hammarling, A. McKenney, and D. Sorensen, *LAPACK User's Guide* ([http://www.netlib.org/lapack/lug/lapack\\_lug.html](http://www.netlib.org/lapack/lug/lapack_lug.html)), Third Edition, SIAM, Philadelphia, 1999.

**Purpose** Find singular values and vectors

**Syntax**

```
s = svds(A)
s = svds(A,k)
s = svds(A,k,sigma)
s = svds(A,k,'L')
s = svds(A,k,sigma,options)
[U,S,V] = svds(A,...)
[U,S,V,flag] = svds(A,...)
```

**Description** `s = svds(A)` computes the six largest singular values and associated singular vectors of matrix A. If A is m-by-n, `svds(A)` manipulates eigenvalues and vectors returned by `eigs(B)`, where `B = [sparse(m,m) A; A' sparse(n,n)]`, to find a few singular values and vectors of A. The positive eigenvalues of the symmetric matrix B are the same as the singular values of A.

`s = svds(A,k)` computes the k largest singular values and associated singular vectors of matrix A.

`s = svds(A,k,sigma)` computes the k singular values closest to the scalar shift sigma. For example, `s = svds(A,k,0)` computes the k smallest singular values and associated singular vectors.

`s = svds(A,k,'L')` computes the k largest singular values (the default).

`s = svds(A,k,sigma,options)` sets some parameters (see `eigs`):

### Option Structure Fields and Descriptions

| Field name                 | Parameter                                                                  | Default |
|----------------------------|----------------------------------------------------------------------------|---------|
| <code>options.tol</code>   | Convergence tolerance:<br><code>norm(AV-US,1) &lt;= tol * norm(A,1)</code> | 1e-10   |
| <code>options.maxit</code> | Maximum number of iterations                                               | 300     |
| <code>options.disp</code>  | Number of values displayed each iteration                                  | 0       |

`[U,S,V] = svds(A,...)` returns three output arguments, and if  $A$  is  $m$ -by- $n$ :

- $U$  is  $m$ -by- $k$  with orthonormal columns
- $S$  is  $k$ -by- $k$  diagonal
- $V$  is  $n$ -by- $k$  with orthonormal columns
- $U*S*V'$  is the closest rank  $k$  approximation to  $A$

`[U,S,V,flag] = svds(A,...)` returns a convergence flag. If `eigs` converged then  $\text{norm}(A*V-U*S,1) \leq \text{tol}*\text{norm}(A,1)$  and `flag` is 0. If `eigs` did not converge, then `flag` is 1.

---

**Note** `svds` is best used to find a few singular values of a large, sparse matrix. To find all the singular values of such a matrix, `svd(full(A))` will usually perform better than `svds(A,min(size(A)))`.

---

## Algorithm

`svds(A,k)` uses `eigs` to find the  $k$  largest magnitude eigenvalues and corresponding eigenvectors of  $B = [0 \ A; \ A' \ 0]$ .

`svds(A,k,0)` uses `eigs` to find the  $2k$  smallest magnitude eigenvalues and corresponding eigenvectors of  $B = [0 \ A; \ A' \ 0]$ , and then selects the  $k$  positive eigenvalues and their eigenvectors.

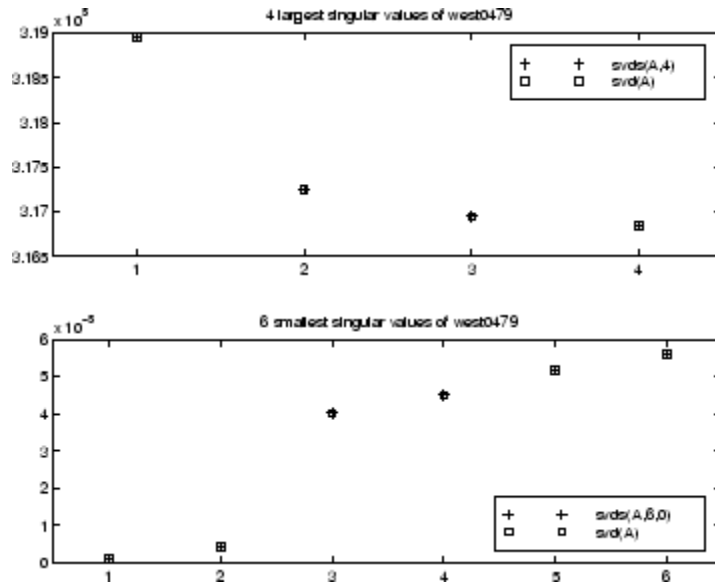
## Example

`west0479` is a real 479-by-479 sparse matrix. `svd` calculates all 479 singular values. `svds` picks out the largest and smallest singular values.

```
load west0479
s = svd(full(west0479))
s1 = svds(west0479,4)
ss = svds(west0479,6,0)
```

These plots show some of the singular values of `west0479` as computed by `svd` and `svds`.





The largest singular value of west0479 can be computed a few different ways:

```
svds(west0479, 1) =
 3.189517598808622e+05
max(svd(full(west0479))) =
 3.18951759880862e+05
norm(full(west0479)) =
 3.189517598808623e+05
```

and estimated:

```
normest(west0479) =
 3.189385666549991e+05
```

## See Also

`svd`, `eigs`

# swapbytes

---

**Purpose** Swap byte ordering

**Syntax** `Y = swapbytes(X)`

**Description** `Y = swapbytes(X)` reverses the byte ordering of each element in array `X`, converting little-endian values to big-endian (and vice versa). The input array must contain all full, noncomplex, numeric elements.

## **Examples** **Example 1**

Reverse the byte order for a scalar 32-bit value, changing hexadecimal 12345678 to 78563412:

```
A = uint32(hex2dec('12345678'));

B = dec2hex(swapbytes(A))
B =
 78563412
```

## **Example 2**

Reverse the byte order for each element of a 1-by-4 matrix:

```
X = uint16([0 1 128 65535])
X =
 0 1 128 65535

Y = swapbytes(X);
Y =
 0 256 32768 65535
```

Examining the output in hexadecimal notation shows the byte swapping:

```
format hex

X, Y
X =
 0000 0001 0080 ffff
```

```
Y =
 0000 0100 8000 ffff
```

### Example 3

Create a three-dimensional array A of 16-bit integers and then swap the bytes of each element:

```
format hex

A = uint16(magic(3) * 150);
A(:,:,2) = A * 40;

A
A(:,:,1) =
 04b0 0096 0384
 01c2 02ee 041a
 0258 0546 012c
A(:,:,2) =
 bb80 1770 8ca0
 4650 7530 a410
 5dc0 d2f0 2ee0

swapbytes(A)
ans(:,:,1) =
 b004 9600 8403
 c201 ee02 1a04
 5802 4605 2c01
ans(:,:,2) =
 80bb 7017 a08c
 5046 3075 10a4
 c05d f0d2 e02e
```

### See Also

typecast

# switch

---

**Purpose** Switch among several cases, based on expression

**Syntax**

```
switch switch_expr
 case case_expr
 statement, ..., statement
 case {case_expr1, case_expr2, case_expr3, ...}
 statement, ..., statement
 otherwise
 statement, ..., statement
end
```

**Discussion** The switch statement syntax is a means of conditionally executing code. In particular, `switch` executes one set of statements selected from an arbitrary number of alternatives. Each alternative is called a `case`, and consists of

- The case statement
- One or more case expressions
- One or more statements

In its basic syntax, `switch` executes the statements associated with the first case where `switch_expr == case_expr`. When the case expression is a cell array (as in the second case above), the `case_expr` matches if any of the elements of the cell array matches the switch expression. If no case expression matches the switch expression, then control passes to the `otherwise` case (if it exists). After the case is executed, program execution resumes with the statement after the `end`.

The `switch_expr` can be a scalar or a string. A scalar `switch_expr` matches a `case_expr` if `switch_expr==case_expr`. A string `switch_expr` matches a `case_expr` if `strcmp(switch_expr,case_expr)` returns logical 1 (true).

---

**Note for C Programmers** Unlike the C language switch construct, the MATLAB switch does not “fall through.” That is, switch executes only the first matching case; subsequent matching cases do not execute. Therefore, break statements are not used.

---

## Examples

To execute a certain block of code based on what the string, method, is set to,

```
method = 'Bilinear';

switch lower(method)
 case {'linear','bilinear'}
 disp('Method is linear')
 case 'cubic'
 disp('Method is cubic')
 case 'nearest'
 disp('Method is nearest')
 otherwise
 disp('Unknown method.')
end

Method is linear
```

## See Also

case, otherwise, end, if, else, elseif, while

# symamd

---

**Purpose** Symmetric approximate minimum degree permutation

**Syntax**  
`p = symamd(S)`  
`p = symamd(S,knobs)`  
`[p,stats] = symamd(...)`

**Description** `p = symamd(S)` for a symmetric positive definite matrix `S`, returns the permutation vector `p` such that `S(p,p)` tends to have a sparser Cholesky factor than `S`. To find the ordering for `S`, `symamd` constructs a matrix `M` such that `spones(M'*M) = spones(S)`, and then computes `p = colamd(M)`. The `symamd` function may also work well for symmetric indefinite matrices.

`S` must be square; only the strictly lower triangular part is referenced.

`p = symamd(S,knobs)` where `knobs` is a scalar. If `S` is `n`-by-`n`, rows and columns with more than `knobs*n` entries are removed prior to ordering, and ordered last in the output permutation `p`. If the `knobs` parameter is not present, then `knobs = spparms('wh_frac')`.

`[p,stats] = symamd(...)` produces the optional vector `stats` that provides data about the ordering and the validity of the matrix `S`.

|                       |                                                                                                                                                                     |
|-----------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <code>stats(1)</code> | Number of dense or empty rows ignored by <code>symamd</code>                                                                                                        |
| <code>stats(2)</code> | Number of dense or empty columns ignored by <code>symamd</code>                                                                                                     |
| <code>stats(3)</code> | Number of garbage collections performed on the internal data structure used by <code>symamd</code> (roughly of size <code>8.4*nnz(tril(S,-1)) + 9n</code> integers) |
| <code>stats(4)</code> | 0 if the matrix is valid, or 1 if invalid                                                                                                                           |
| <code>stats(5)</code> | Rightmost column index that is unsorted or contains duplicate entries, or 0 if no such column exists                                                                |
| <code>stats(6)</code> | Last seen duplicate or out-of-order row index in the column index given by <code>stats(5)</code> , or 0 if no such row index exists                                 |
| <code>stats(7)</code> | Number of duplicate and out-of-order row indices                                                                                                                    |

Although, MATLAB built-in functions generate valid sparse matrices, a user may construct an invalid sparse matrix using the MATLAB C or Fortran APIs and pass it to `symamd`. For this reason, `symamd` verifies that `S` is valid:

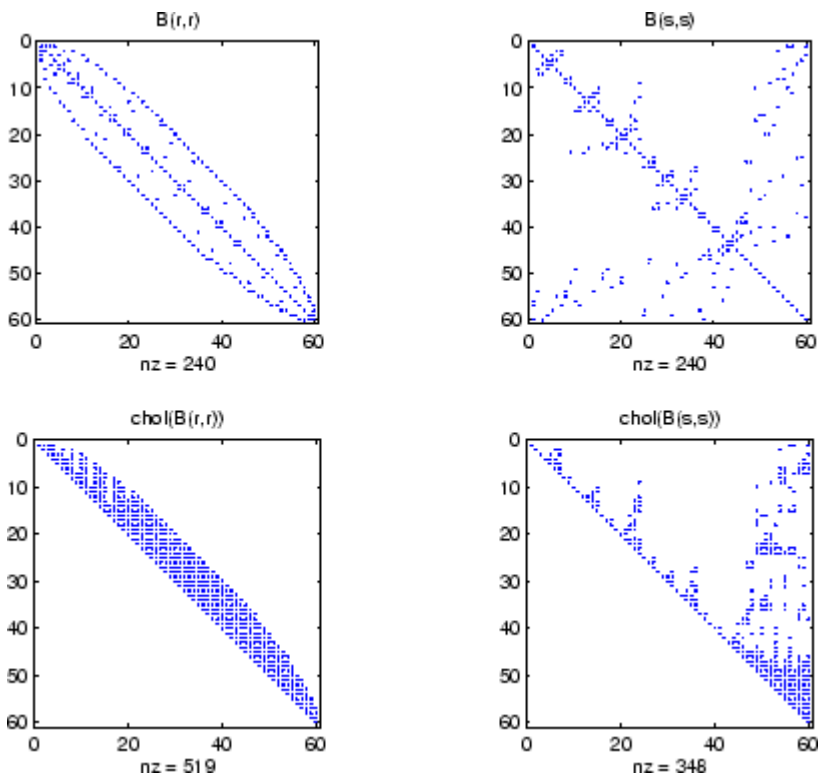
- If a row index appears two or more times in the same column, `symamd` ignores the duplicate entries, continues processing, and provides information about the duplicate entries in `stats(4:7)`.
- If row indices in a column are out of order, `symamd` sorts each column of its internal copy of the matrix `S` (but does not repair the input matrix `S`), continues processing, and provides information about the out-of-order entries in `stats(4:7)`.
- If `S` is invalid in any other way, `symamd` cannot continue. It prints an error message, and returns no output arguments (`p` or `stats`).

The ordering is followed by a symmetric elimination tree post-ordering.

## Examples

Here is a comparison of reverse Cuthill-McKee and minimum degree on the Bucky ball example mentioned in the `symrcm` reference page.

```
B = bucky+4*speye(60);
r = symrcm(B);
p = symamd(B);
R = B(r,r);
S = B(p,p);
subplot(2,2,1), spy(R,4), title('B(r,r)')
subplot(2,2,2), spy(S,4), title('B(s,s)')
subplot(2,2,3), spy(chol(R),4), title('chol(B(r,r))')
subplot(2,2,4), spy(chol(S),4), title('chol(B(s,s))')
```



Even though this is a very small problem, the behavior of both orderings is typical. RCM produces a matrix with a narrow bandwidth which fills in almost completely during the Cholesky factorization. Minimum degree produces a structure with large blocks of contiguous zeros which do not fill in during the factorization. Consequently, the minimum degree ordering requires less time and storage for the factorization.

## See Also

`colamd`, `colperm`, `spparms`, `symrcm`, `amd`

## References

The authors of the code for `symamd` are Stefan I. Larimore and Timothy A. Davis ([davis@cise.ufl.edu](mailto:davis@cise.ufl.edu)), University of Florida. The algorithm was developed in collaboration with John Gilbert,



Xerox PARC, and Esmond Ng, Oak Ridge National Laboratory.  
Sparse Matrix Algorithms Research at the University of Florida:  
<http://www.cise.ufl.edu/research/sparse/>

# symbfact

---

**Purpose** Symbolic factorization analysis

**Syntax**

```
count = symbfact(A)
count = symbfact(A, 'sym')
count = symbfact(A, 'col')
count = symbfact(A, 'row')
count = symbfact(A, 'lo')
[count,h,parent,post,R] = symbfact(...)
[count,h,parent,post,L] = symbfact(A,type,'lower')
```

**Description**

`count = symbfact(A)` returns the vector of row counts of  $R=\text{chol}(A'*A)$ . `symbfact` should be much faster than `chol(A)`.

`count = symbfact(A, 'sym')` is the same as `count = symbfact(A)`.

`count = symbfact(A, 'col')` returns row counts of  $R=\text{chol}(A'*A)$  (without forming it explicitly).

`count = symbfact(A, 'row')` returns row counts of  $R=\text{chol}(A*A')$ .

`count = symbfact(A, 'lo')` is the same as `count = symbfact(A)` and uses `tril(A)`.

`[count,h,parent,post,R] = symbfact(...)` has several optional return values.

The flop count for a subsequent Cholesky factorization is `sum(count.^2)`

| Return Value | Description                                                                                                                                                                |
|--------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| h            | Height of the elimination tree                                                                                                                                             |
| parent       | The elimination tree itself                                                                                                                                                |
| post         | Postordering of the elimination tree                                                                                                                                       |
| R            | 0-1 matrix having the structure of <code>chol(A)</code> for the symmetric case, <code>chol(A'*A)</code> for the 'col' case, or <code>chol(A*A')</code> for the 'row' case. |

`symbfact(A)` and `symbfact(A, 'sym')` use the upper triangular part of  $A$  (`triu(A)`) and assume the lower triangular part is the transpose of the upper triangular part. `symbfact(A, 'lo')` uses `tril(A)` instead.

`[count,h,parent,post,L] = symbfact(A,type,'lower')` where `type` is one of `'sym'`, `'col'`, `'row'`, or `'lo'` returns a lower triangular symbolic factor  $L=R'$ . This form is quicker and requires less memory.

## See Also

`chol`, `etree`, `treelayout`

# symmlq

---

## Purpose

Symmetric LQ method

## Syntax

```
x = symmlq(A,b)
symmlq(A,b,tol)
symmlq(A,b,tol,maxit)
symmlq(A,b,tol,maxit,M)
symmlq(A,b,tol,maxit,M1,M2)
symmlq(A,b,tol,maxit,M1,M2,x0)
[x,flag] = symmlq(A,b,...)
[x,flag,relres] = symmlq(A,b,...)
[x,flag,relres,iter] = symmlq(A,b,...)
[x,flag,relres,iter,resvec] = symmlq(A,b,...)
[x,flag,relres,iter,resvec,resvecg] = symmlq(A,b,...)
```

## Description

`x = symmlq(A,b)` attempts to solve the system of linear equations  $A*x=b$  for  $x$ . The  $n$ -by- $n$  coefficient matrix  $A$  must be symmetric but need not be positive definite. It should also be large and sparse. The column vector  $b$  must have length  $n$ .  $A$  can be a function handle `afun` such that `afun(x)` returns  $A*x$ . See “Function Handles” in the MATLAB Programming documentation for more information.

“Parametrizing Functions”, in the MATLAB Mathematics documentation, explains how to provide additional parameters to the function `afun`, as well as the preconditioner function `mfun` described below, if necessary.

If `symmlq` converges, a message to that effect is displayed. If `symmlq` fails to converge after the maximum number of iterations or halts for any reason, a warning message is printed displaying the relative residual  $\text{norm}(b-A*x) / \text{norm}(b)$  and the iteration number at which the method stopped or failed.

`symmlq(A,b,tol)` specifies the tolerance of the method. If `tol` is `[]`, then `symmlq` uses the default,  $1e-6$ .

`symmlq(A,b,tol,maxit)` specifies the maximum number of iterations. If `maxit` is `[]`, then `symmlq` uses the default,  $\min(n,20)$ .

`symmlq(A,b,tol,maxit,M)` and `symmlq(A,b,tol,maxit,M1,M2)` use the symmetric positive definite preconditioner  $M$  or  $M = M1*M2$  and effectively solve the system  $\text{inv}(\text{sqrt}(M))*A*\text{inv}(\text{sqrt}(M))*y = \text{inv}(\text{sqrt}(M))*b$  for  $y$  and then return  $x = \text{in}(\text{sqrt}(M))*y$ . If  $M$  is `[]` then `symmlq` applies no preconditioner.  $M$  can be a function handle `mfun` such that `mfun(x)` returns  $M \backslash x$ .

`symmlq(A,b,tol,maxit,M1,M2,x0)` specifies the initial guess. If `x0` is `[]`, then `symmlq` uses the default, an all-zero vector.

`[x,flag] = symmlq(A,b,...)` also returns a convergence flag.

| Flag | Convergence                                                                                                             |
|------|-------------------------------------------------------------------------------------------------------------------------|
| 0    | <code>symmlq</code> converged to the desired tolerance <code>tol</code> within <code>maxit</code> iterations.           |
| 1    | <code>symmlq</code> iterated <code>maxit</code> times but did not converge.                                             |
| 2    | Preconditioner $M$ was ill-conditioned.                                                                                 |
| 3    | <code>symmlq</code> stagnated. (Two consecutive iterates were the same.)                                                |
| 4    | One of the scalar quantities calculated during <code>symmlq</code> became too small or too large to continue computing. |
| 5    | Preconditioner $M$ was not symmetric positive definite.                                                                 |

Whenever `flag` is not 0, the solution  $x$  returned is that with minimal norm residual computed over all the iterations. No messages are displayed if the `flag` output is specified.

`[x,flag,relres] = symmlq(A,b,...)` also returns the relative residual  $\text{norm}(b-A*x) / \text{norm}(b)$ . If `flag` is 0, `relres`  $\leq$  `tol`.

`[x,flag,relres,iter] = symmlq(A,b,...)` also returns the iteration number at which  $x$  was computed, where  $0 \leq \text{iter} \leq \text{maxit}$ .

`[x,flag,relres,iter,resvec] = symmlq(A,b,...)` also returns a vector of estimates of the `symmlq` residual norms at each iteration, including  $\text{norm}(b-A*x0)$ .

`[x,flag,relres,iter,resvec,resvecg] = symmlq(A,b,...)` also returns a vector of estimates of the conjugate gradients residual norms at each iteration.

## Examples

### Example 1

```
n = 100;
on = ones(n,1);
A = spdiags([-2*on 4*on -2*on],-1:1,n,n);
b = sum(A,2);
tol = 1e-10;
maxit = 50; M1 = spdiags(4*on,0,n,n);

x = symmlq(A,b,tol,maxit,M1);
symmlq converged at iteration 49 to a solution with relative
residual 4.3e-015
```

### Example 2

This example replaces the matrix *A* in Example 1 with a handle to a matrix-vector product function *afun*. The example is contained in an M-file `run_symmlq` that

- Calls `symmlq` with the function handle `@afun` as its first argument.
- Contains *afun* as a nested function, so that all variables in `run_symmlq` are available to *afun*.

The following shows the code for `run_symmlq`:

```
function x1 = run_symmlq
n = 100;
on = ones(n,1);
A = spdiags([-2*on 4*on -on],-1:1,n,n);
b = sum(A,2);
tol = 1e-8;
maxit = 15;
M1 = spdiags([on/(-2) on],-1:0,n,n);
M2 = spdiags([4*on -on],0:1,n,n);
```

```

x1 = symmlq(@afun,b,tol,maxit,M1);

function y = afun(x)
 y = 4 * x;
 y(2:n) = y(2:n) - 2 * x(1:n-1);
 y(1:n-1) = y(1:n-1) - 2 * x(2:n);
end
end

```

When you enter

```
x1=run_symmlq;
```

MATLAB software displays the message

```

symmlq converged at iteration 49 to a solution with relative
residual 4.3e-015

```

### Example 3

Use a symmetric indefinite matrix that fails with pcg.

```

A = diag([20:-1:1,-1:-1:-20]);
b = sum(A,2); % The true solution is the vector of all ones.
x = pcg(A,b); % Errors out at the first iteration.
pcg stopped at iteration 1 without converging to the desired
tolerance 1e-006 because a scalar quantity became too small or
too large to continue computing.
The iterate returned (number 0) has relative residual 1

```

However, symmlq can handle the indefinite matrix A.

```

x = symmlq(A,b,1e-6,40);
symmlq converged at iteration 39 to a solution with relative
residual 1.3e-007

```

### See Also

bicg, bicgstab, cgs, lsqr, gmres, minres, pcg, qmr  
function\_handle (@), mldivide (\)

## References

- [1] Barrett, R., M. Berry, T. F. Chan, et al., *Templates for the Solution of Linear Systems: Building Blocks for Iterative Methods*, SIAM, Philadelphia, 1994.
- [2] Paige, C. C. and M. A. Saunders, "Solution of Sparse Indefinite Systems of Linear Equations." *SIAM J. Numer. Anal.*, Vol.12, 1975, pp. 617-629.

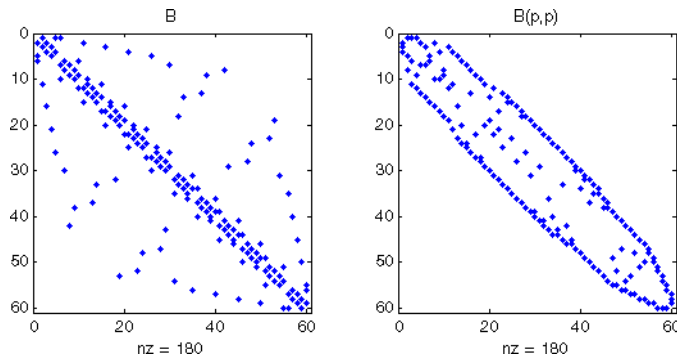


|                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|--------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Purpose</b>     | Sparse reverse Cuthill-McKee ordering                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| <b>Syntax</b>      | <code>r = symrcm(S)</code>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| <b>Description</b> | <p><code>r = symrcm(S)</code> returns the symmetric reverse Cuthill-McKee ordering of <code>S</code>. This is a permutation <code>r</code> such that <code>S(r,r)</code> tends to have its nonzero elements closer to the diagonal. This is a good reordering for LU or Cholesky factorization of matrices that come from long, skinny problems. The ordering works for both symmetric and nonsymmetric <code>S</code>.</p> <p>For a real, symmetric sparse matrix, <code>S</code>, the eigenvalues of <code>S(r,r)</code> are the same as those of <code>S</code>, but <code>eig(S(r,r))</code> probably takes less time to compute than <code>eig(S)</code>.</p>                                                                             |
| <b>Algorithm</b>   | The algorithm first finds a pseudoperipheral vertex of the graph of the matrix. It then generates a level structure by breadth-first search and orders the vertices by decreasing distance from the pseudoperipheral vertex. The implementation is based closely on the SPARSPAK implementation described by George and Liu.                                                                                                                                                                                                                                                                                                                                                                                                                   |
| <b>Examples</b>    | <p>The statement</p> <pre>B = bucky;</pre> <p>uses an M-file in the demos toolbox to generate the adjacency graph of a truncated icosahedron. This is better known as a soccer ball, a Buckminster Fuller geodesic dome (hence the name <code>bucky</code>), or, more recently, as a 60-atom carbon molecule. There are 60 vertices. The vertices have been ordered by numbering half of them from one hemisphere, pentagon by pentagon; then reflecting into the other hemisphere and gluing the two halves together. With this numbering, the matrix does not have a particularly narrow bandwidth, as the first spy plot shows</p> <pre>subplot(1,2,1), spy(B), title('B')</pre> <p>The reverse Cuthill-McKee ordering is obtained with</p> |

```
p = symrcm(B);
R = B(p,p);
```

The spy plot shows a much narrower bandwidth.

```
subplot(1,2,2), spy(R), title('B(p,p)')
```



This example is continued in the reference pages for `symamd`.

The bandwidth can also be computed with

```
[i,j] = find(B);
bw = max(i-j) + 1;
```

The bandwidths of `B` and `R` are 35 and 12, respectively.

## See Also

`colamd`, `colperm`, `symamd`

## References

[1] George, Alan and Joseph Liu, *Computer Solution of Large Sparse Positive Definite Systems*, Prentice-Hall, 1981.

[2] Gilbert, John R., Cleve Moler, and Robert Schreiber, "Sparse Matrices in MATLAB: Design and Implementation," *SIAM Journal on Matrix Analysis*, 1992. A slightly expanded version is also available as a technical report from the Xerox Palo Alto Research Center.

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|                    |                                                                                                                                                                                                                                                                                                                                                                                    |
|--------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Purpose</b>     | Determine symbolic variables in expression                                                                                                                                                                                                                                                                                                                                         |
| <b>Syntax</b>      | <pre>symvar 'expr'<br/>s = symvar('expr')</pre>                                                                                                                                                                                                                                                                                                                                    |
| <b>Description</b> | <p>symvar 'expr' searches the expression, expr, for identifiers other than i, j, pi, inf, nan, eps, and common functions. symvar displays those variables that it finds or, if no such variable exists, displays an empty cell array, {}.</p> <p>s = symvar('expr') returns the variables in a cell array of strings, s. If no such variable exists, s is an empty cell array.</p> |
| <b>Examples</b>    | <p>symvar finds variables beta1 and x, but skips pi and the cos function.</p> <pre>symvar 'cos(pi*x - beta1)'<br/><br/>ans =<br/><br/>    'beta1'<br/>    'x'</pre>                                                                                                                                                                                                                |
| <b>See Also</b>    | findstr                                                                                                                                                                                                                                                                                                                                                                            |

# synchronize

---

**Purpose** Synchronize and resample two `timeseries` objects using common time vector

**Syntax** `[ts1 ts2] = synchronize(ts1,ts2,'SynchronizeMethod')`

**Description** `[ts1 ts2] = synchronize(ts1,ts2,'SynchronizeMethod')` creates two new `timeseries` objects by synchronizing `ts1` and `ts2` using a common time vector. The string `'SynchronizeMethod'` defines the method for synchronizing the `timeseries` and can be one of the following:

- `'Union'` — Resample `timeseries` objects using a time vector that is a union of the time vectors of `ts1` and `ts2` on the time range where the two time vectors overlap.
- `'Intersection'` — Resample `timeseries` objects on a time vector that is the intersection of the time vectors of `ts1` and `ts2`.
- `'Uniform'` — Requires an additional argument as follows:

```
[ts1 ts2] = synchronize(ts1,ts2,'Uniform','Interval',value)
```

This method resamples time series on a uniform time vector, where `value` specifies the time interval between the two samples. The uniform time vector is the overlap of the time vectors of `ts1` and `ts2`. The interval units are assumed to be the smaller units of `ts1` and `ts2`.

You can specify additional arguments by using property-value pairs:

- `'InterpMethod'`: Forces the specified interpolation method (over the default method) for this `synchronize` operation. Can be either a string, `'linear'` or `'zoh'`, or a `tsdata.interpolation` object that contains a user-defined interpolation method.
- `'QualityCode'`: Integer (between -128 and 127) used as the quality code for both time series after the synchronization.

- 'KeepOriginalTimes': Logical value (true or false) indicating whether the new time series should keep the original time values. For example,

```
ts1 = timeseries([1 2],[datestr(now); datestr(now+1)]);
ts2 = timeseries([1 2],[datestr(now-1); datestr(now)]);
```

Note that `ts1.timeinfo.StartDate` is one day after `ts2.timeinfo.StartDate`. If you use

```
[ts1 ts2] = synchronize(ts1,ts2,'union');
```

the `ts1.timeinfo.StartDate` is changed to match `ts2.TimeInfo.StartDate` and `ts1.Time` changes to 1.

But if you use

```
[ts1 ts2] =
synchronize(ts1,ts2,'union','KeepOriginalTimes',true);
```

`ts1.timeinfo.StartDate` is unchanged and `ts1.Time` is still 0.

- 'tolerance': Real number used as the tolerance for differentiating two time values when comparing the `ts1` and `ts2` time vectors. The default tolerance is  $1e-10$ . For example, when the sixth time value in `ts1` is  $5+(1e-12)$  and the sixth time value in `ts2` is  $5-(1e-13)$ , both values are treated as 5 by default. To differentiate those two times, you can set 'tolerance' to a smaller value such as  $1e-15$ , for example.

## See Also

`timeseries`

**Purpose** Two ways to call MATLAB functions

**Description** You can call MATLAB functions using either *command syntax* or *function syntax*, as described below.

## **Command Syntax**

A function call in this syntax consists of the function name followed by one or more arguments separated by spaces:

```
functionname arg1 arg2 ... argn
```

Command syntax does not allow you to obtain any values that might be returned by the function. Attempting to assign output from the function to a variable using command syntax generates an error. Use function syntax instead.

Examples of command syntax:

```
save mydata.mat x y z
import java.awt.Button java.lang.String
```

Arguments are treated as string literals. See the examples below, under “Argument Passing” on page 2-3651.

## **Function Syntax**

A function call in this syntax consists of the function name followed by one or more arguments separated by commas and enclosed in parentheses:

```
functionname(arg1, arg2, ..., argn)
```

You can assign the output of the function to one or more output values. When assigning to more than one output variable, separate the variables by commas or spaces and enclose them in square brackets ([ ]):

```
[out1,out2,...,outn] = functionname(arg1, arg2, ..., argn)
```

Examples of function syntax:

```
copyfile('srcfile', '..\mytests', 'writable')
[x1,x2,x3,x4] = deal(A{:})
```

Arguments are passed to the function by value. See the examples below, under “Argument Passing” on page 2-3651.

### Argument Passing

When calling a function using command syntax, MATLAB passes the arguments as string literals. When using function syntax, arguments are passed by value.

In the following example, assign a value to A and then call `disp` on the variable to display the value passed. Calling `disp` with command syntax passes the variable name, 'A':

```
A = pi;
disp A
 A
```

while function syntax passes the value assigned to A:

```
A = pi;
disp(A)
 3.1416
```

The next example passes two strings to `strcmp` for comparison. Calling the function with command syntax compares the variable names, 'str1' and 'str2':

```
str1 = 'one'; str2 = 'one';
strcmp str1 str2
ans =
 0 (unequal)
```

while function syntax compares the values assigned to the variables, 'one' and 'one':

```
str1 = 'one'; str2 = 'one';
strcmp(str1, str2)
```

```
ans =
 1 (equal)
```

## Passing Strings

When using the function syntax to pass a string literal to a function, you must enclose the string in single quotes, ('string'). For example, to create a new directory called `myapptests`, use

```
mkdir('myapptests')
```

On the other hand, variables that contain strings do not need to be enclosed in quotes:

```
dirname = 'myapptests';
mkdir(dirname)
```

## See Also

`mlint`



**Purpose** Execute operating system command and return result

**Syntax**  
`system('command')`  
`[status, result] = system('command')`

# system

---

## Description

`system('command')` calls upon the operating system to run `command`, for example `dir` or `ls` or a UNIX<sup>26</sup> shell script, and directs the output to the MATLAB software. If `command` runs successfully, `ans` is 0. If `command` fails or does not exist on your operating system, `ans` is a nonzero value and an explanatory message appears.

`[status, result] = system('command')` calls upon the operating system to run `command`, and directs the output to MATLAB. If `command` runs successfully, `status` is 0 and `result` contains the output from `command`. If `command` fails or does not exist on your operating system, `status` is a nonzero value and `result` contains an explanatory message.

---

**Note** Running `system` on a Microsoft Windows platform with a command that relies on the current directory fails when the current directory is specified using a UNC pathname because DOS does not support UNC pathnames. When this happens, MATLAB returns the error:

```
??? Error using ==> system DOS commands may not be
executed when the current directory is a UNC pathname.
```

To work around this limitation, change the directory to a mapped drive prior to running `system` or a function that calls `system`.

---

## Examples

On a Windows system, display the current directory by accessing the operating system.

```
[status currdir] = system('cd')
status =
 0
currdir =
 D:\work\matlab\test
```

## See Also

`!` (bang), `computer`, `dos`, `perl`, `unix`, `winopen`

26. UNIX is a registered trademark of The Open Group in the United States and other countries.

“Running External Programs” in the MATLAB Desktop Tools and  
Development Environment documentation

# tan

---

**Purpose** Tangent of argument in radians

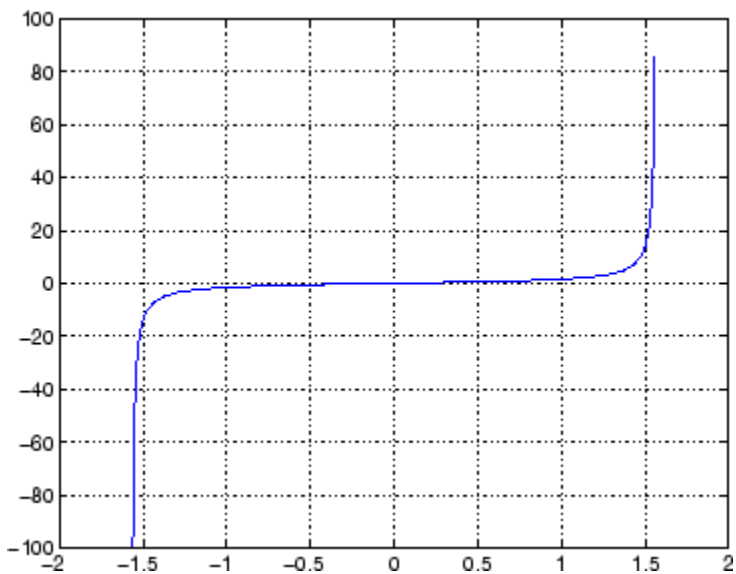
**Syntax**  $Y = \tan(X)$

**Description** The tan function operates element-wise on arrays. The function's domains and ranges include complex values. All angles are in radians.

$Y = \tan(X)$  returns the circular tangent of each element of  $X$ .

**Examples** Graph the tangent function over the domain  $-\pi/2 < x < \pi/2$ .

```
x = (-pi/2)+0.01:0.01:(pi/2)-0.01;
plot(x,tan(x)), grid on
```



The expression  $\tan(\pi/2)$  does not evaluate as infinite but as the reciprocal of the floating point accuracy `eps` since `pi` is only a floating-point approximation to the exact value of  $\pi$ .

**Definition** The tangent can be defined as

---

$$\tan(z) = \frac{\sin(z)}{\cos(z)}$$

**Algorithm**

tan uses FDLIBM, which was developed at SunSoft, a Sun Microsystems, Inc. business, by Kwok C. Ng, and others. For information about FDLIBM, see <http://www.netlib.org>.

**See Also**

tand, tanh, atan, atan2, atand, atanh

# tand

---

**Purpose** Tangent of argument in degrees

**Syntax**  $Y = \text{tand}(X)$

**Description**  $Y = \text{tand}(X)$  is the tangent of the elements of  $X$ , expressed in degrees. For odd integers  $n$ ,  $\text{tand}(n*90)$  is infinite, whereas  $\tan(n*\pi/2)$  is large but finite, reflecting the accuracy of the floating point value of  $\pi$ .

**See Also** `tan`, `tanh`, `atan`, `atan2`, `atand`, `atanh`

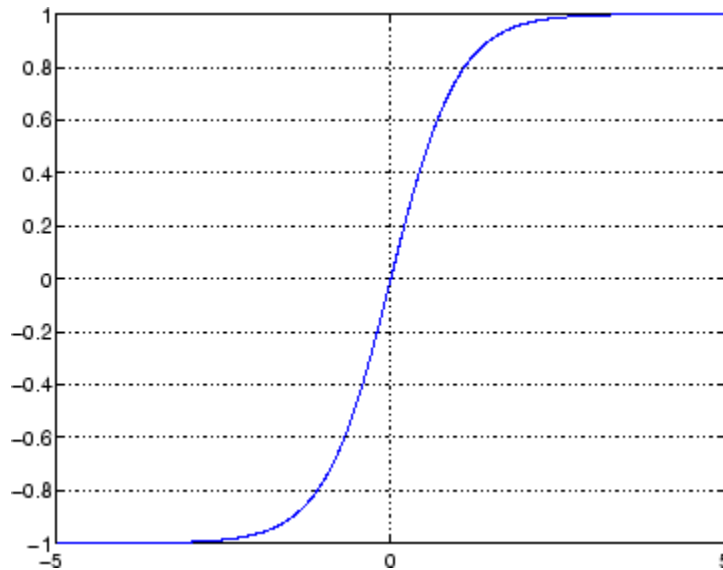
**Purpose** Hyperbolic tangent

**Syntax**  $Y = \tanh(X)$

**Description** The tanh function operates element-wise on arrays. The function's domains and ranges include complex values. All angles are in radians.  $Y = \tanh(X)$  returns the hyperbolic tangent of each element of  $X$ .

**Examples** Graph the hyperbolic tangent function over the domain  $-5 \leq x \leq 5$ .

```
x = -5:0.01:5;
plot(x,tanh(x)), grid on
```



**Definition** The hyperbolic tangent can be defined as

$$\tanh(z) = \frac{\sinh(z)}{\cosh(z)}$$

# tanh

---

**Algorithm**

tanh uses FDLIBM, which was developed at SunSoft, a Sun Microsystems, Inc. business, by Kwok C. Ng, and others. For information about FDLIBM, see <http://www.netlib.org>.

**See Also**

atan, atan2, tan



**Purpose**

Compress files into tar file

**Syntax**

```
tar(tarfilename,files)
tar(tarfilename,files,rootdir)
entrynames = tar(...)
```

**Description**

`tar(tarfilename,files)` creates a tar file named `tarfilename` from the list of files and directories specified in `files`. Relative paths are stored in the tar file, but absolute paths are not. Directories recursively include all of their content.

`tarfilename` is a string specifying the name of the tar file. MATLAB appends the `.tar` extension if `tarfilename` has no extension. The `tarfilename` extension can end in `.tgz` or `.gz`. In this case, `tarfilename` is gzipped.

`files` is a string or cell array of strings containing the list of files or directories included in `tarfilename`. Individual files that are on the MATLAB path can be specified as partial path names. Otherwise an individual file can be specified relative to the current directory or with an absolute path.

Directories must be specified relative to the current directory or with absolute paths. On UNIX<sup>27</sup> systems, directories can also start with `~/` or `~username/`, which expands to the current user's home directory or the specified user's home directory, respectively. The wildcard character `*` can be used when specifying files or directories, except when relying on the MATLAB path to resolve a file name or partial path name.

`tar(tarfilename, files, rootdir)` allows the path for `files` to be specified relative to `rootdir` rather than the current directory.

`entrynames = tar(...)` returns a string cell array of the names of the files contained in `tarfilename`. If `files` contains a relative path, `entrynames` also contains the relative path.

## Example

Tar all files in the current directory to the file `backup.tgz`.

```
tar('backup.tgz', '.');
```

## See Also

`gzip`, `gunzip`, `untar`, `unzip`, `zip`

27. UNIX is a registered trademark of The Open Group in the United States and other countries.

**Purpose** Name of system's temporary directory

**Syntax** `tmp_dir = tempdir`

**Description** `tmp_dir = tempdir` returns the name of the system's temporary directory, if one exists. This function does not create a new directory. See "Opening Temporary Files and Directories" for more information.

**See Also** `tempname`

# tempname

---

**Purpose** Unique name for temporary file

**Syntax** `tmp_nam = tempname`

**Description** `tmp_nam = tempname` returns a unique string, `tmp_nam`, suitable for use as a temporary filename.

---

**Note** The filename that `tempname` generates is not guaranteed to be unique; however, it is likely to be so.

---

See “Opening Temporary Files and Directories” for more information.

**See Also** `tempdir`

**Purpose**

Tetrahedron mesh plot

**Syntax**

```
tetramesh(T,X,c)
tetramesh(T,X)
h = tetramesh(...)
tetramesh(...,'param','value','param','value'...)
```

**Description**

`tetramesh(T,X,c)` displays the tetrahedrons defined in the  $m$ -by-4 matrix  $T$  as mesh.  $T$  is usually the output of `delaunayn`. A row of  $T$  contains indices into  $X$  of the vertices of a tetrahedron.  $X$  is an  $n$ -by-3 matrix, representing  $n$  points in 3 dimension. The tetrahedron colors are defined by the vector  $C$ , which is used as indices into the current colormap.

---

**Note** If  $T$  is the output of `delaunay3`, then  $X$  is the concatenation of the `delaunay3` input arguments  $x$ ,  $y$ ,  $z$  interpreted as column vectors, i.e.,  $X = [x(:) \ y(:) \ z(:)]$ .

---

`tetramesh(T,X)` uses  $C = 1:m$  as the color for the  $m$  tetrahedrons. Each tetrahedron has a different color (modulo the number of colors available in the current colormap).

`h = tetramesh(...)` returns a vector of tetrahedron handles. Each element of  $h$  is a handle to the set of patches forming one tetrahedron. You can use these handles to view a particular tetrahedron by turning the patch 'Visible' property 'on' or 'off'.

`tetramesh(...,'param','value','param','value'...)` allows additional patch property name/property value pairs to be used when displaying the tetrahedrons. For example, the default transparency parameter is set to 0.9. You can overwrite this value by using the property name/property value pair ('FaceAlpha',value) where value is a number between 0 and 1. See [Patch Properties](#) for information about the available properties.

# tetramesh

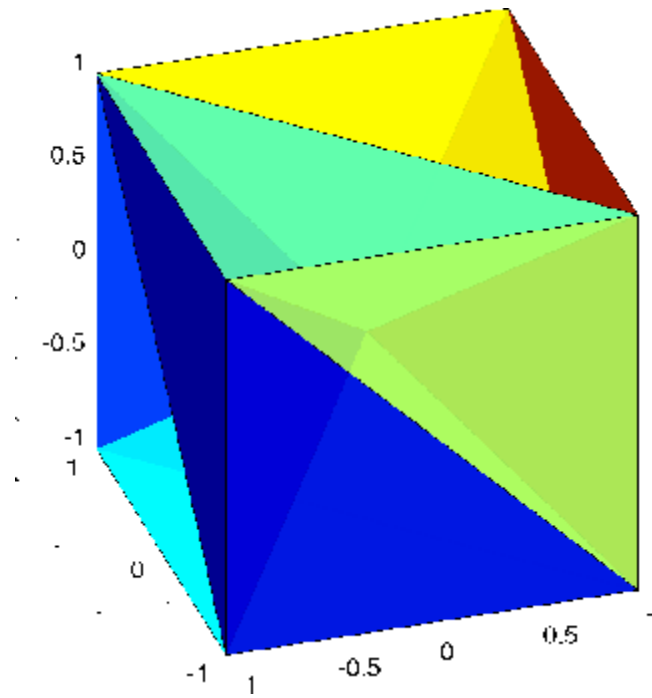
---

## Examples

Generate a 3-dimensional Delaunay tessellation, then use `tetramesh` to visualize the tetrahedrons that form the corresponding simplex.

```
d = [-1 1];
[x,y,z] = meshgrid(d,d,d); % A cube
x = [x(:);0];
y = [y(:);0];
z = [z(:);0];
% [x,y,z] are corners of a cube plus the center.
X = [x(:) y(:) z(:)];
Tes = delaunayn(X)
```

```
Tes =
 9 1 5 6
 3 9 1 5
 2 9 1 6
 2 3 9 4
 2 3 9 1
 7 9 5 6
 7 3 9 5
 8 7 9 6
 8 2 9 6
 8 2 9 4
 8 3 9 4
 8 7 3 9
tetramesh(Tes,X);camorbit(20,0)
```



## See Also

`delaunayn`, `patch`, `Patch Properties`, `trimesh`, `trisurf`

# texlabel

---

**Purpose** Produce TeX format from character string

**Syntax** `texlabel(f)`  
`texlabel(f, 'literal')`

**Description** `texlabel(f)` converts the MATLAB expression `f` into the TeX equivalent for use in text strings. It processes Greek variable names (e.g., `lambda`, `delta`, etc.) into a string that is displayed as actual Greek letters.

`texlabel(f, 'literal')` prints Greek variable names as literals.

If the string is too long to fit into a figure window, then the center of the expression is replaced with a tilde ellipsis (~~~).

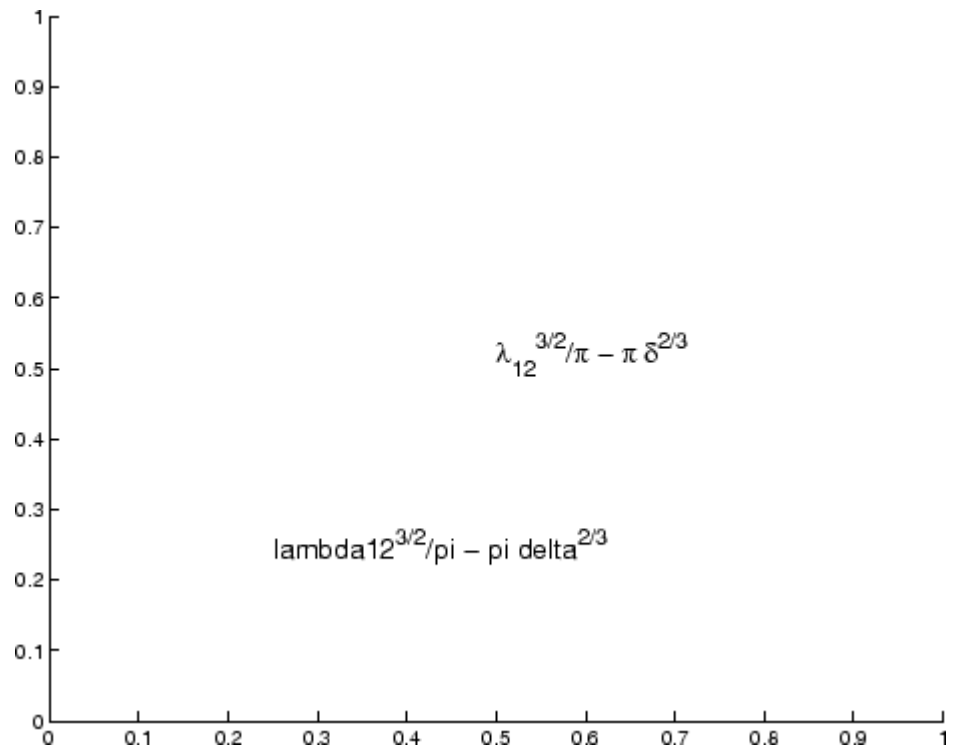
**Examples** You can use `texlabel` as an argument to the `title`, `xlabel`, `ylabel`, `zlabel`, and `text` commands. For example,

```
title(texlabel('sin(sqrt(x^2 + y^2))/sqrt(x^2 + y^2)'))
```

By default, `texlabel` translates Greek variable names to the equivalent Greek letter. You can select literal interpretation by including the `literal` argument. For example, compare these two commands.

```
text(.5,.5,...
 texlabel('lambda12^(3/2)/pi - pi*delta^(2/3)'))
text(.25,.25,...
 texlabel('lambda12^(3/2)/pi - pi*delta^(2/3)', 'literal'))
```





**See Also**

text, title, xlabel, ylabel, zlabel, the text String property  
 “Annotating Plots” on page 1-94 for related functions

# text

---

**Purpose** Create text object in current axes

**Syntax**

```
text(x,y,'string')
text(x,y,z,'string')
text(x,y,z,'string','PropertyName',PropertyValue....)
text('PropertyName',PropertyValue....)
h = text(...)
```

**Description** `text` is the low-level function for creating text graphics objects. Use `text` to place character strings at specified locations.

`text(x,y,'string')` adds the string in quotes to the location specified by the point  $(x,y)$   $x$  and  $y$  must be numbers of class `double`.

`text(x,y,z,'string')` adds the string in 3-D coordinates.  $x$ ,  $y$  and  $z$  must be numbers of class `double`.

`text(x,y,z,'string','PropertyName',PropertyValue....)` adds the string in quotes to the location defined by the coordinates and uses the values for the specified text properties. See the text property list section at the end of this page for a list of text properties.

`text('PropertyName',PropertyValue....)` omits the coordinates entirely and specifies all properties using property name/property value pairs.

`h = text(...)` returns a column vector of handles to text objects, one handle per object. All forms of the `text` function optionally return this output argument.

See the String property for a list of symbols, including Greek letters.

**Remarks** **Position Text Within the Axes**

The default text units are the units used to plot data in the graph. Specify the text location coordinates (the  $x$ ,  $y$ , and  $z$  arguments) in the data units of the current graph (see “Examples” on page 2-3672). You can use other units to position the text by setting the text `Units` property to `normalized` or one of the nonrelative units (`pixels`, `inches`, `centimeters`, `points`).

Note that the Axes Units property controls the positioning of the Axes within the figure and is not related to the axes data units used for graphing.

The Extent, VerticalAlignment, and HorizontalAlignment properties control the positioning of the character string with regard to the text location point.

If the coordinates are vectors, text writes the string at all locations defined by the list of points. If the character string is an array the same length as x, y, and z, text writes the corresponding row of the string array at each point specified.

### **Multiline Text**

When specifying strings for multiple text objects, the string can be

- A cell array of strings
- A padded string matrix

Each element of the specified string array creates a different text object.

When specifying the string for a single text object, cell arrays of strings and padded string matrices result in a text object with a multiline string, while vertical slash characters are not interpreted as separators and result in a single line string containing vertical slashes.

### **Behavior of the Text Function**

text is a low-level function that accepts property name/property value pairs as input arguments. However, the convenience form,

```
text(x,y,z,'string')
```

is equivalent to

```
text('Position',[x,y,z],'String','string')
```

You can specify other properties only as property name/property value pairs. See the text property list at the end of this page for a description

# text

---

of each property. You can specify properties as property name/property value pairs, structure arrays, and cell arrays (see the `set` and `get` reference pages for examples of how to specify these data types).

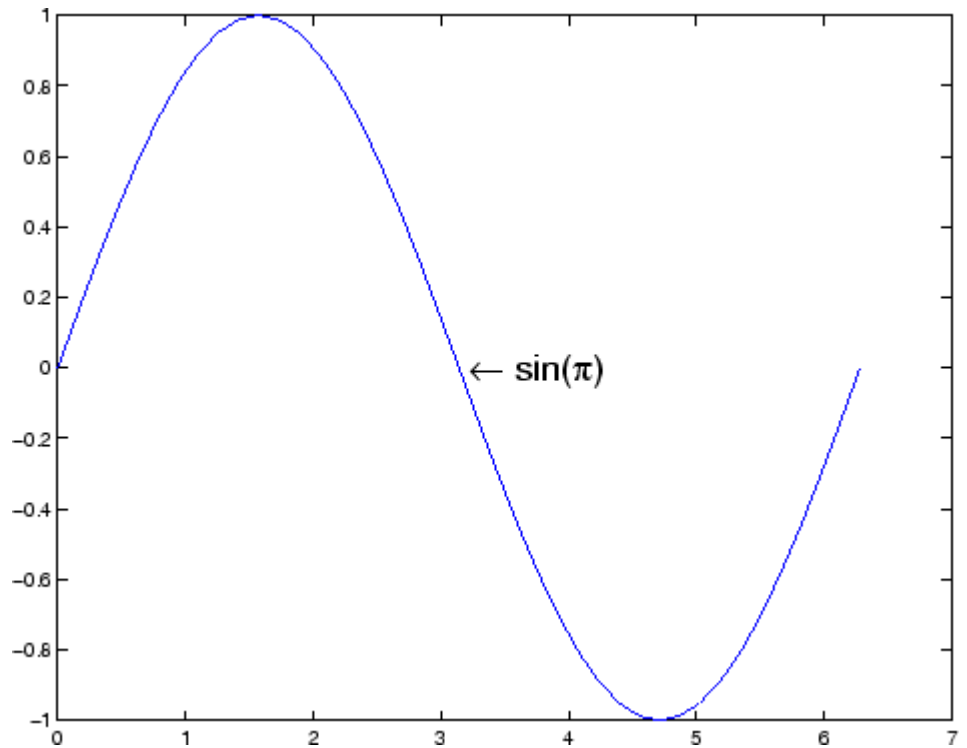
`text` does not respect the setting of the figure or axes `NextPlot` property. This allows you to add text objects to an existing axes without setting `hold` to on.

## Examples

The statements

```
plot(0:pi/20:2*pi,sin(0:pi/20:2*pi))
text(pi,0,' \leftarrow sin(\pi)', 'FontSize',18)
```

annotate the point at  $(\pi,0)$  with the string  $\sin(\pi)$



The statement

```
text(x,y,'\ite^{i\omega\tau} = cos(\omega\tau) + i sin(\omega\tau)')
```

uses embedded TeX sequences to produce

$$e^{i\omega\tau} = \cos(\omega\tau) + i \sin(\omega\tau)$$

## Setting Default Properties

You can set default text properties on the axes, figure, and root objectlevels:

```
set(0,'DefaulttextProperty',PropertyValue...)
set(gcf,'DefaulttextProperty',PropertyValue...)
```

## text

---

```
set(gca, 'DefaulttextProperty', PropertyValue...)
```

Where *Property* is the name of the text property and *PropertyValue* is the value you are specifying. Use `set` and `get` to access text properties.

### See Also

`annotation`, `gtext`, `int2str`, `num2str`, `strings`, `title`, `xlabel`,  
`ylabel`, `zlabel`

“Object Creation” on page 1-101 for related functions

Text Properties for property descriptions

## Purpose

Text properties

## Modifying Properties

You can set and query graphics object properties using the property editor or the `set` and `get` commands.

- The Property Editor is an interactive tool that enables you to see and change object property values.
- The `set` and `get` commands enable you to set and query the values of properties.

To change the default values of properties, see [Setting Default Property Values](#).

See [Core Objects](#) for general information about this type of object.

## Text Property Descriptions

This section lists property names along with the types of values each accepts. Curly braces `{ }` enclose default values.

### Annotation

`hg.Annotation` object Read Only

*Control the display of text objects in legends.* The `Annotation` property enables you to specify whether this text object is represented in a figure legend.

Querying the `Annotation` property returns the handle of an `hg.Annotation` object. The `hg.Annotation` object has a property called `LegendInformation`, which contains an `hg.LegendEntry` object.

Once you have obtained the `hg.LegendEntry` object, you can set its `IconDisplayStyle` property to control whether the text object is displayed in a figure legend:

# Text Properties

---

| IconDisplayStyle Value | Purpose                                              |
|------------------------|------------------------------------------------------|
| on                     | Represent this text object in a legend (default)     |
| off                    | Do not include this text object in a legend          |
| children               | Same as on because text objects do not have children |

## Setting the IconDisplayStyle property

These commands set the IconDisplayStyle of a graphics object with handle `hobj` to off:

```
hAnnotation = get(hobj,'Annotation');
hLegendEntry = get(hAnnotation,'LegendInformation');
set(hLegendEntry,'IconDisplayStyle','off')
```

## Using the IconDisplayStyle property

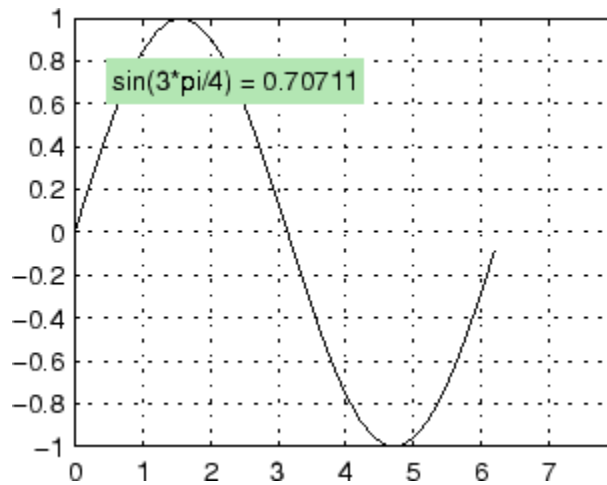
See “Controlling Legends” for more information and examples.

BackgroundColor  
ColorSpec | {none}

*Color of text extent rectangle.* This property enables you to define a color for the rectangle that encloses the text Extent plus the text Margin. For example, the following code creates a text object that labels a plot and sets the background color to light green.

```
text(3*pi/4,sin(3*pi/4),...
['sin(3*pi/4) = ',num2str(sin(3*pi/4))],...
'HorizontalAlignment','center',...
'BackgroundColor',[.7 .9 .7]);
```





For additional features, see the following properties:

- `EdgeColor` — Color of the rectangle's edge (none by default).
- `LineStyle` — Style of the rectangle's edge line (first set `EdgeColor`)
- `LineWidth` — Width of the rectangle's edge line (first set `EdgeColor`)
- `Margin` — Increase the size of the rectangle by adding a margin to the existing text extent rectangle. This margin is added to the text extent rectangle to define the text background area that is enclosed by the `EdgeColor` rectangle. Note that the text extent does not change when you change the margin; only the rectangle displayed when you set the `EdgeColor` property and the area defined by the `BackgroundColor` change.

See also [Drawing Text in a Box](#) in the MATLAB Graphics documentation for an example using background color with contour labels.

# Text Properties

---

## BeingDeleted

on | {off} read only

*This object is being deleted.* The `BeingDeleted` property provides a mechanism that you can use to determine if objects are in the process of being deleted. MATLAB software sets the `BeingDeleted` property to `on` when the object's delete function callback is called (see the `DeleteFcn` property). It remains set to `on` while the delete function executes, after which the object no longer exists.

For example, an object's delete function might call other functions that act on a number of different objects. These functions may not need to perform actions on objects that are going to be deleted, and therefore can check the object's `BeingDeleted` property before acting.

## BusyAction

cancel | {queue}

*Callback routine interruption.* The `BusyAction` property enables you to control how MATLAB handles events that potentially interrupt executing callback routines. If there is a callback routine executing, callback routines invoked subsequently always attempt to interrupt it. If the `Interruptible` property of the object whose callback is executing is set to `on` (the default), then interruption occurs at the next point where the event queue is processed. If the `Interruptible` property is set to `off`, the `BusyAction` property (of the object owning the executing callback) determines how MATLAB handles the event. The choices are

- `cancel` — Discard the event that attempted to execute a second callback routine.
- `queue` — Queue the event that attempted to execute a second callback routine until the current callback finishes.

## ButtonDownFcn

function handle, cell array containing function handle and additional arguments, or string (not recommended)

*Button press callback function.* A callback function that executes whenever you press a mouse button while the pointer is over the text object.

See the figure's `SelectionType` property to determine if modifier keys were also pressed.

Set this property to a function handle that references the callback. The function must define at least two input arguments (handle of object associated with the button down event and an event structure, which is empty for this property). For example, the following function takes different action depending on what type of selection was made:

```
function button_down(src, evnt)
% src - the object that is the source of the event
% evnt - empty for this property
 sel_typ = get(gcf, 'SelectionType')
 switch sel_typ
 case 'normal'
 disp('User clicked left-mouse button')
 set(src, 'Selected', 'on')
 case 'extend'
 disp('User did a shift-click')
 set(src, 'Selected', 'on')
 case 'alt'
 disp('User did a control-click')
 set(src, 'Selected', 'on')
 set(src, 'SelectionHighlight', 'off')
 end
end
```

# Text Properties

---

Suppose `h` is the handle of a text object and that the `button_down` function is on your MATLAB path. The following statement assigns the function above to the `ButtonDownFcn`:

```
set(h, 'ButtonDownFcn', @button_down)
```

See “Function Handle Callbacks” for information on how to use function handles to define the callback function.

## Children

matrix (read only)

The empty matrix; text objects have no children.

## Clipping

on | {off}

*Clipping mode.* When `Clipping` is on, MATLAB does not display any portion of the text that is outside the axes.

## Color

ColorSpec

*Text color.* A three-element RGB vector or one of the predefined names, specifying the text color. The default value is black. See `ColorSpec` for more information on specifying color.

## CreateFcn

function handle, cell array containing function handle and additional arguments, or string (not recommended)

*Callback function executed during object creation.* A callback function that executes when MATLAB creates a text object. You must define this property as a default value for text or in a call to the `text` function that creates a new text object. For example, the statement

```
set(0, 'DefaultTextCreateFcn', @text_create)
```

defines a default value on the root level that sets the figure `Pointer` property to crosshairs whenever you create a text object. The callback function must be on your MATLAB path when you execute the above statement.

```
function text_create(src,evtnt)
% src - the object that is the source of the event
% evtnt - empty for this property
 set(gcf,'Pointer','crosshair')
end
```

MATLAB executes this function after setting all text properties. Setting this property on an existing text object has no effect. The function must define at least two input arguments (handle of object created and an event structure, which is empty for this property).

The handle of the object whose `CreateFcn` is being executed is passed by MATLAB as the first argument to the callback function and is also accessible through the root `CallbackObject` property, which you can query using `gcbo`.

See “Function Handle Callbacks” for information on how to use function handles to define the callback function.

## DeleteFcn

function handle, cell array containing function handle and additional arguments, or string (not recommended)

*Delete text callback function.* A callback function that executes when you delete the text object (e.g., when you issue a `delete` command or clear the axes `cla` or figure `clf`). For example, the following function displays object property data before the object is deleted.

```
function delete_fcn(src,evtnt)
% src - the object that is the source of the event
% evtnt - empty for this property
```

# Text Properties

---

```
obj_tp = get(src, 'Type');
disp([obj_tp, ' object deleted'])
disp('Its user data is:')
disp(get(src, 'UserData'))
end
```

MATLAB executes the function before deleting the object's properties so these values are available to the callback function. The function must define at least two input arguments (handle of object being deleted and an event structure, which is empty for this property)

The handle of the object whose `DeleteFcn` is being executed is passed by MATLAB as the first argument to the callback function and is also accessible through the root `CallbackObject` property, which you can query using `gcbo`.

See [Function Handle Callbacks](#) for information on how to use function handles to define the callback function.

**DisplayName**  
string (default is empty string)

*String used by legend for this text object.* The `legend` function uses the string defined by the `DisplayName` property to label this text object in the legend.

- If you specify string arguments with the `legend` function, `DisplayName` is set to this text object's corresponding string and that string is used for the legend.
- If `DisplayName` is empty, legend creates a string of the form, `['data' n]`, where  $n$  is the number assigned to the object based on its location in the list of legend entries. However, legend does not set `DisplayName` to this string.
- If you edit the string directly in an existing legend, `DisplayName` is set to the edited string.

- If you specify a string for the `DisplayName` property and create the legend using the figure toolbar, then MATLAB uses the string defined by `DisplayName`.
- To add programmatically a legend that uses the `DisplayName` string, call `legend` with the `toggle` or `show` option.

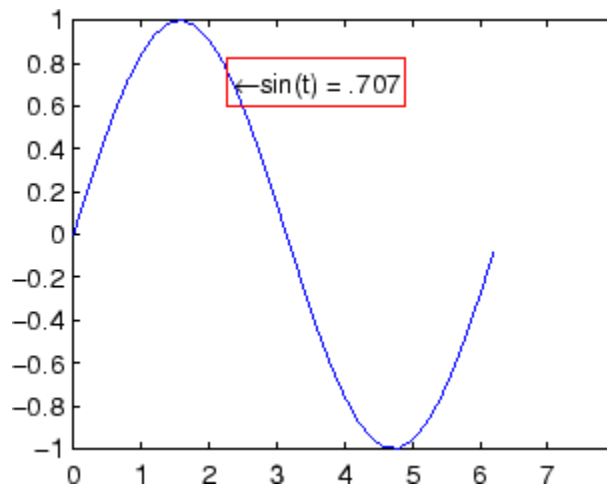
See “Controlling Legends” for more examples.

## EdgeColor

ColorSpec | {none}

*Color of edge drawn around text extent rectangle plus margin.* This property enables you to specify the color of a box drawn around the text `Extent` plus the text `Margin`. For example, the following code draws a red rectangle around text that labels a plot.

```
text(3*pi/4,sin(3*pi/4),...
'\leftarrow sin(t) = .707',...
'EdgeColor','red');
```



For additional features, see the following properties:

# Text Properties

---

- `BackgroundColor` — Color of the rectangle's interior (none by default)
- `LineStyle` — Style of the rectangle's edge line (first set `EdgeColor`)
- `LineWidth` — Width of the rectangle's edge line (first set `EdgeColor`)
- `Margin` — Increases the size of the rectangle by adding a margin to the area defined by the text extent rectangle. This margin is added to the text extent rectangle to define the text background area that is enclosed by the `EdgeColor` rectangle. Note that the text extent does not change when you change the margin; only the rectangle displayed when you set the `EdgeColor` property and the area defined by the `BackgroundColor` change.

## Editing

`on` | `{off}`

*Enable or disable editing mode.* When this property is set to the default `off`, you cannot edit the text string interactively (i.e., you must change the `String` property to change the text). When this property is set to `on`, MATLAB places an insert cursor at the end of the text string and enables editing. To apply the new text string,

- 1 Press the **Esc** key.
- 2 Click in any figure window (including the current figure).
- 3 Reset the `Editing` property to `off`.

MATLAB then updates the `String` property to contain the new text and resets the `Editing` property to `off`. You must reset the `Editing` property to `on` to resume editing.

## EraseMode

`{normal}` | `none` | `xor` | `background`



*Erase mode.* This property controls the technique MATLAB uses to draw and erase text objects. Alternative erase modes are useful for creating animated sequences where controlling the way individual objects are redrawn is necessary to improve performance and obtain the desired effect.

- **normal** — Redraw the affected region of the display, performing the three-dimensional analysis necessary to ensure that all objects are rendered correctly. This mode produces the most accurate picture, but is the slowest. The other modes are faster, but do not perform a complete redraw and are therefore less accurate.
- **none** — Do not erase the text when it is moved or destroyed. While the object is still visible on the screen after erasing with `EraseMode none`, you cannot print it because MATLAB stores no information about its former location.
- **xor** — Draw and erase the text by performing an exclusive OR (XOR) with each pixel index of the screen beneath it. When the text is erased, it does not damage the objects beneath it. However, when text is drawn in `xor` mode, its color depends on the color of the screen beneath it. It is correctly colored only when it is over axes background `Color`, or the figure background `Color` if the axes `Color` is set to `none`.
- **background** — Erase the text by drawing it in the axes background `Color`, or the figure background `Color` if the axes `Color` is set to `none`. This damages objects that are behind the erased text, but text is always properly colored.

## Printing with Nonnormal Erase Modes

MATLAB always prints figures as if the `EraseMode` of all objects is set to `normal`. This means graphics objects created with `EraseMode` set to `none`, `xor`, or `background` can look differently on screen than on paper. On screen, MATLAB may mathematically combine layers of colors (e.g., performing an XOR of a pixel color with that of the pixel behind it) and ignore three-dimensional

# Text Properties

---

sorting to obtain greater rendering speed. However, these techniques are not applied to the printed output.

You can use the MATLAB `getframe` command or other screen capture application to create an image of a figure containing nonnormal mode objects.

## Extent

position rectangle (read only)

*Position and size of text.* A four-element read-only vector that defines the size and position of the text string

[left,bottom,width,height]

If the `Units` property is set to `data` (the default), `left` and `bottom` are the  $x$ - and  $y$ -coordinates of the lower left corner of the text `Extent`.

For all other values of `Units`, `left` and `bottom` are the distance from the lower left corner of the axes `position` rectangle to the lower left corner of the text `Extent`. `width` and `height` are the dimensions of the `Extent` rectangle. All measurements are in units specified by the `Units` property.

## FontAngle

{normal} | italic | oblique

*Character slant.* MATLAB uses this property to select a font from those available on your particular system. Generally, setting this property to `italic` or `oblique` selects a slanted font.

## FontName

A name, such as `Courier`, or the string `FixedWidth`

*Font family.* A string specifying the name of the font to use for the text object. To display and print properly, this must be a font that your system supports. The default font is Helvetica.

## Specifying a Fixed-Width Font

If you want text to use a fixed-width font that looks good in any locale, you should set `FontName` to the string `FixedWidth`:

```
set(text_handle, 'FontName', 'FixedWidth')
```

This eliminates the need to hard-code the name of a fixed-width font, which may not display text properly on systems that do not use ASCII character encoding (such as in Japan where multibyte character sets are used). A properly written MATLAB application that needs to use a fixed-width font should set `FontName` to `FixedWidth` (note that this string is case sensitive) and rely on `FixedWidthFontName` to be set correctly in the end user's environment.

End users can adapt a MATLAB application to different locales or personal environments by setting the root `FixedWidthFontName` property to the appropriate value for that locale from `startup.m`.

Note that setting the root `FixedWidthFontName` property causes an immediate update of the display to use the new font.

### FontSize

size in `FontUnits`

*Font size.* A value specifying the font size to use for text in units determined by the `FontUnits` property. The default point size is 10 (1 point = 1/72 inch).

### FontWeight

light | {normal} | demi | bold

*Weight of text characters.* MATLAB uses this property to select a font from those available on your particular system. Generally, setting this property to `bold` or `demi` causes MATLAB to use a bold font.

### FontUnits

{points} | normalized | inches |  
centimeters | pixels

# Text Properties

---

*Font size units.* MATLAB uses this property to determine the units used by the `FontSize` property. Normalized units interpret `FontSize` as a fraction of the height of the parent axes. When you resize the axes, MATLAB modifies the screen `FontSize` accordingly. `pixels`, `inches`, `centimeters`, and `points` are absolute units (1 point = 1/72 inch).

Note that if you are setting both the `FontSize` and the `FontUnits` in one function call, you must set the `FontUnits` property first so that MATLAB can correctly interpret the specified `FontSize`.

## HandleVisibility

`{on} | callback | off`

*Control access to object's handle by command-line users and GUIs.* This property determines when an object's handle is visible in its parent's list of children. `HandleVisibility` is useful for preventing command-line users from accidentally drawing into or deleting a figure that contains only user interface devices (such as a dialog box).

Handles are always visible when `HandleVisibility` is set to `on`.

Setting `HandleVisibility` to `callback` causes handles to be visible from within callback routines or functions invoked by callback routines, but not from within functions invoked from the command line. This provides a means to protect GUIs from command-line users, while allowing callback routines to have complete access to object handles.

Setting `HandleVisibility` to `off` makes handles invisible at all times. This may be necessary when a callback routine invokes a function that might potentially damage the GUI (such as evaluating a user-typed string), and so temporarily hides its own handles during the execution of that function.

When a handle is not visible in its parent's list of children, it cannot be returned by functions that obtain handles by searching the object hierarchy or querying handle properties. This includes `get`, `findobj`, `gca`, `gcf`, `gco`, `newplot`, `cla`, `clf`, and `close`.

When a handle's visibility is restricted using `callback` or `off`,

- The object's handle does not appear in its parent's `Children` property.
- Figures do not appear in the root's `CurrentFigure` property.
- Objects do not appear in the root's `CallbackObject` property or in the figure's `CurrentObject` property.
- Axes do not appear in their parent's `CurrentAxes` property.

You can set the root `ShowHiddenHandles` property to `on` to make all handles visible regardless of their `HandleVisibility` settings (this does not affect the values of the `HandleVisibility` properties).

Handles that are hidden are still valid. If you know an object's handle, you can set and get its properties, and pass it to any function that operates on handles.

`HitTest`  
{on} | off

*Selectable by mouse click.* `HitTest` determines if the text can become the current object (as returned by the `gco` command and the figure `CurrentObject` property) as a result of a mouse click on the text. If `HitTest` is set to `off`, clicking the text selects the object below it (which is usually the axes containing it).

For example, suppose you define the `button down` function of an image (see the `ButtonDownFcn` property) to display text at the location you click with the mouse.

# Text Properties

---

First define the callback routine.

```
function bd_function
pt = get(gca,'CurrentPoint');
text(pt(1,1),pt(1,2),pt(1,3),...
 '{\fontsize{20}\oplus} The spot to label',...
 'HitTest','off')
```

Now display an image, setting its `ButtonDownFcn` property to the callback routine.

```
load earth
image(X,'ButtonDownFcn','bd_function'); colormap(map)
```

When you click the image, MATLAB displays the text string at that location. With `HitTest` set to `off`, existing text cannot intercept any subsequent button down events that occur over the text. This enables the image's button down function to execute.

`HorizontalAlignment`  
{left} | center | right

*Horizontal alignment of text.* This property specifies the horizontal justification of the text string. It determines where MATLAB places the string with regard to the point specified by the `Position` property. The following picture illustrates the alignment options.

`HorizontalAlignment` viewed with the `VerticalAlignment` set to `middle` (the default).



See the `Extent` property for related information.

## Interpreter

latex | {tex} | none

*Interpret T<sub>E</sub>X instructions.* This property controls whether MATLAB interprets certain characters in the String property as T<sub>E</sub>X instructions (default) or displays all characters literally. The options are:

- latex — Supports the full L<sub>A</sub>T<sub>E</sub>X markup language.
- tex — Supports a subset of plain T<sub>E</sub>X markup language. See the String property for a list of supported T<sub>E</sub>X instructions.
- none — Displays literal characters.

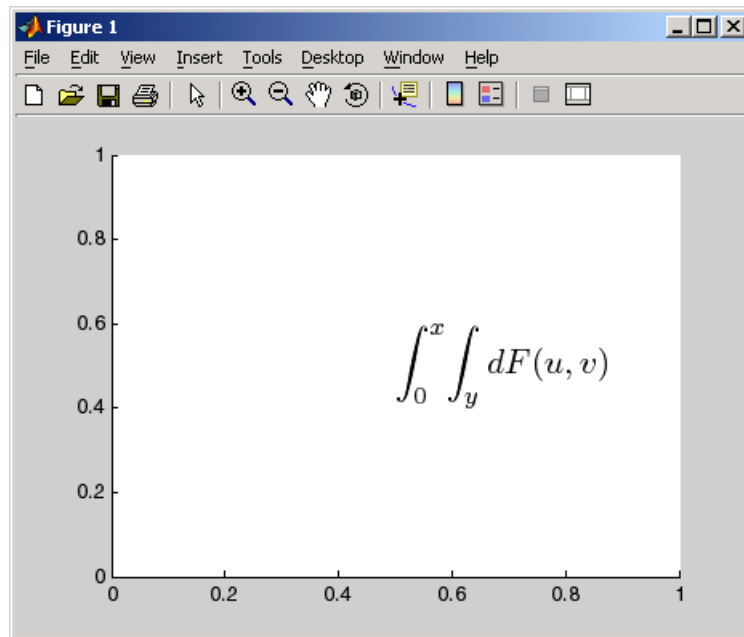
## Latex Interpreter

To enable the L<sub>A</sub>T<sub>E</sub>X interpreter for text objects, set the Interpreter property to latex. For example, the following statement displays an equation in a figure at the point [.5 .5], and enlarges the font to 16 points.

```
text('Interpreter','latex',...
 'String','$$\int_0^x \! \! \int_y dF(u,v)$$',...
 'Position',[.5 .5],...
 'FontSize',16)
```

# Text Properties

---



## Information About Using TEX

The following references may be useful to people who are not familiar with T<sub>E</sub>X.

- Donald E. Knuth, *The T<sub>E</sub>Xbook*, Addison Wesley, 1986.
- The T<sub>E</sub>X Users Group home page: <http://www.tug.org>

Interruptible  
{on} | off

*Callback routine interruption mode.* The Interruptible property controls whether a text callback routine can be interrupted by subsequently invoked callback routines. Text objects have three properties that define callback routines: ButtonDownFcn,



CreateFcn, and DeleteFcn. See the BusyAction property for information on how MATLAB executes callback routines.

## LineStyle

{-} | -- | : | -. | none

*Edge line type.* This property determines the line style used to draw the edges of the text Extent. The available line styles are shown in the following table.

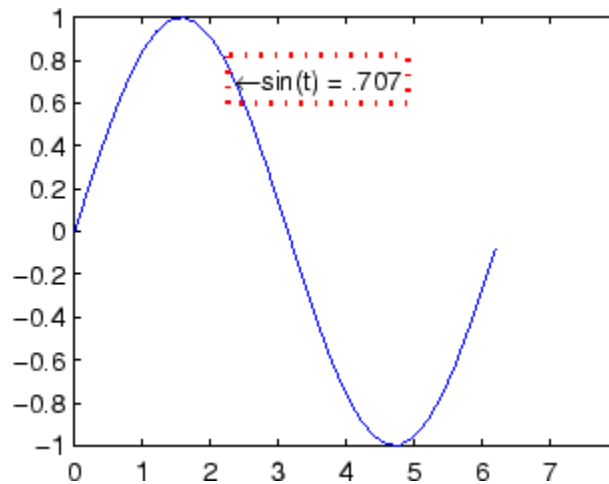
| Symbol | Line Style           |
|--------|----------------------|
| -      | Solid line (default) |
| --     | Dashed line          |
| :      | Dotted line          |
| -.     | Dash-dot line        |
| none   | No line              |

For example, the following code draws a red rectangle with a dotted line style around text that labels a plot.

```
text(3*pi/4,sin(3*pi/4),...
 '\leftarrowsin(t) = .707',...
 'EdgeColor','red',...
 'LineWidth',2,...
 'LineStyle',':');
```

# Text Properties

---



For additional features, see the following properties:

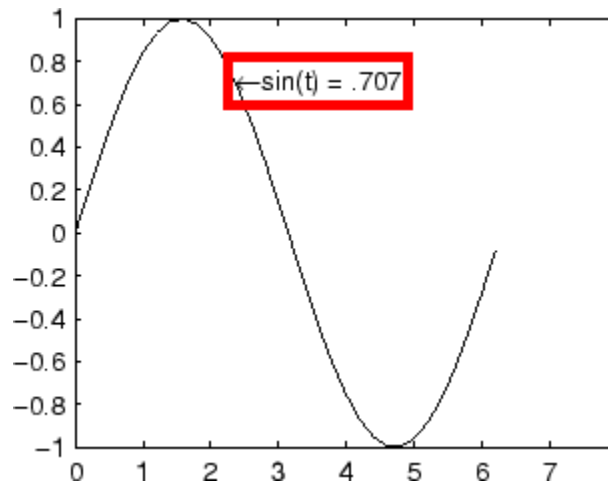
- **BackgroundColor** — Color of the rectangle's interior (none by default)
- **EdgeColor** — Color of the rectangle's edge (none by default)
- **LineWidth** — Width of the rectangle's edge line (first set **EdgeColor**)
- **Margin** — Increases the size of the rectangle by adding a margin to the existing text extent rectangle. This margin is added to the text extent rectangle to define the text background area that is enclosed by the **EdgeColor** rectangle. Note that the text extent does not change when you change the margin; only the rectangle displayed when you set the **EdgeColor** property and the area defined by the **BackgroundColor** change.

**LineWidth**  
scalar (points)

*Width of line used to draw text extent rectangle.* When you set the text **EdgeColor** property to a color (the default is none), MATLAB

displays a rectangle around the text Extent. Use the LineWidth property to specify the width of the rectangle edge. For example, the following code draws a red rectangle around text that labels a plot and specifies a line width of 3 points:

```
text(3*pi/4, sin(3*pi/4), ...
'\leftarrow sin(t) = .707', ...
'EdgeColor', 'red', ...
'LineWidth', 3);
```



For additional features, see the following properties:

- BackgroundColor — Color of the rectangle's interior (none by default)
- EdgeColor — Color of the rectangle's edge (none by default)
- LineStyle — Style of the rectangle's edge line (first set EdgeColor)
- Margin — Increases the size of the rectangle by adding a margin to the existing text extent rectangle. This margin is added to the text extent rectangle to define the text background

# Text Properties

---

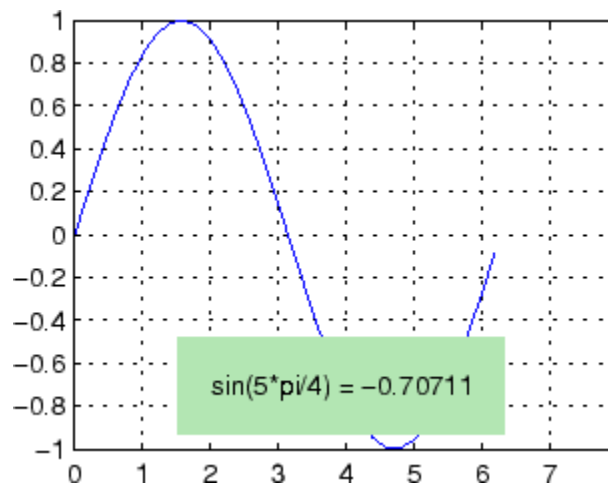
area that is enclosed by the `EdgeColor` rectangle. Note that the text extent does not change when you change the margin; only the rectangle displayed when you set the `EdgeColor` property and the area defined by the `BackgroundColor` change.

## Margin

scalar (pixels)

*Distance between the text extent and the rectangle edge.* When you specify a color for the `BackgroundColor` or `EdgeColor` text properties, MATLAB draws a rectangle around the area defined by the text `Extent` plus the value specified by the `Margin`. For example, the following code displays a light green rectangle with a 10-pixel margin.

```
text(5*pi/4, sin(5*pi/4), ...
 ['sin(5*pi/4) = ', num2str(sin(5*pi/4))], ...
 'HorizontalAlignment', 'center', ...
 'BackgroundColor', [.7 .9 .7], ...
 'Margin', 10);
```



For additional features, see the following properties:

- `BackgroundColor` — Color of the rectangle's interior (none by default)
- `EdgeColor` — Color of the rectangle's edge (none by default)
- `LineStyle` — Style of the rectangle's edge line (first set `EdgeColor`)
- `LineWidth` — Width of the rectangle's edge line (first set `EdgeColor`)

## See how margin affects text extent properties

This example enables you to change the values of the `Margin` property and observe the effects on the `BackgroundColor` area and the `EdgeColor` rectangle.

Click to view in editor — This link opens the MATLAB editor with the following example.

Click to run example — Use your scroll wheel to vary the `Margin`.

### Parent

handle of axes, `hgroup`, or `hgtransform`

*Parent of text object.* This property contains the handle of the text object's parent. The parent of a text object is the axes, `hgroup`, or `hgtransform` object that contains it.

See [Objects That Can Contain Other Objects](#) for more information on parenting graphics objects.

### Position

`[x,y,[z]]`

*Location of text.* A two- or three-element vector, `[x y [z]]`, that specifies the location of the text in three dimensions. If you

# Text Properties

---

omit the z value, it defaults to 0. All measurements are in units specified by the Units property. Initial value is [0 0 0].

## Rotation

scalar (default = 0)

*Text orientation.* This property determines the orientation of the text string. Specify values of rotation in degrees (positive angles cause counterclockwise rotation).

## Selected

on | {off}

*Is object selected?* When this property is set to on, MATLAB displays selection handles if the SelectionHighlight property is also set to on. You can, for example, define the ButtonDownFcn to set this property, allowing users to select the object with the mouse.

## SelectionHighlight

{on} | off

*Objects are highlighted when selected.* When the Selected property is set to on, MATLAB indicates the selected state by drawing four edge handles and four corner handles. When SelectionHighlight is set to off, MATLAB does not draw the handles.

## String

string

*The text string.* Specify this property as a quoted string for single-line strings, or as a cell array of strings, or a padded string matrix for multiline strings. MATLAB displays this string at the specified location. Vertical slash characters are not interpreted as line breaks in text strings, and are drawn as part of the text string. See Mathematical Symbols, Greek Letters, and TeX Characters for an example.

**Note** The words `default`, `factory`, and `remove` are reserved words that will not appear in a figure when quoted as a normal string. In order to display any of these words individually, type `'\reserved_word'` instead of `'reserved_word'`.

When the text Interpreter property is set to `Tex` (the default), you can use a subset of TeX commands embedded in the string to produce special characters such as Greek letters and mathematical symbols. The following table lists these characters and the character sequences used to define them.

| Character Sequence     | Symbol     | Character Sequence    | Symbol     | Character Sequence           | Symbol            |
|------------------------|------------|-----------------------|------------|------------------------------|-------------------|
| <code>\alpha</code>    | $\alpha$   | <code>\upsilon</code> | $\upsilon$ | <code>\sim</code>            | $\sim$            |
| <code>\beta</code>     | $\beta$    | <code>\phi</code>     | $\Phi$     | <code>\leq</code>            | $\leq$            |
| <code>\gamma</code>    | $\gamma$   | <code>\chi</code>     | $\chi$     | <code>\infty</code>          | $\infty$          |
| <code>\delta</code>    | $\delta$   | <code>\psi</code>     | $\psi$     | <code>\clubsuit</code>       | $\clubsuit$       |
| <code>\epsilon</code>  | $\epsilon$ | <code>\omega</code>   | $\omega$   | <code>\diamondsuit</code>    | $\diamondsuit$    |
| <code>\zeta</code>     | $\zeta$    | <code>\Gamma</code>   | $\Gamma$   | <code>\heartsuit</code>      | $\heartsuit$      |
| <code>\eta</code>      | $\eta$     | <code>\Delta</code>   | $\Delta$   | <code>\spadesuit</code>      | $\spadesuit$      |
| <code>\theta</code>    | $\Theta$   | <code>\Theta</code>   | $\Theta$   | <code>\leftrightarrow</code> | $\leftrightarrow$ |
| <code>\vartheta</code> |            | <code>\Lambda</code>  | $\Lambda$  | <code>\leftarrow</code>      | $\leftarrow$      |
| <code>\iota</code>     | $\iota$    | <code>\Xi</code>      | $\Xi$      | <code>\uparrow</code>        | $\uparrow$        |
| <code>\kappa</code>    | $\kappa$   | <code>\Pi</code>      | $\Pi$      | <code>\rightarrow</code>     | $\rightarrow$     |
| <code>\lambda</code>   | $\lambda$  | <code>\Sigma</code>   | $\Sigma$   | <code>\downarrow</code>      | $\downarrow$      |
| <code>\mu</code>       | $\mu$      | <code>\Upsilon</code> |            | <code>\circ</code>           | $\circ$           |

# Text Properties

| Character Sequence     | Symbol      | Character Sequence     | Symbol      | Character Sequence      | Symbol       |
|------------------------|-------------|------------------------|-------------|-------------------------|--------------|
| <code>\nu</code>       | $\nu$       | <code>\Phi</code>      | $\Phi$      | <code>\pm</code>        | $\pm$        |
| <code>\xi</code>       | $\xi$       | <code>\Psi</code>      | $\Psi$      | <code>\geq</code>       | $\geq$       |
| <code>\pi</code>       | $\pi$       | <code>\Omega</code>    | $\Omega$    | <code>\propto</code>    | $\propto$    |
| <code>\rho</code>      | $\rho$      | <code>\forall</code>   | $\forall$   | <code>\partial</code>   | $\partial$   |
| <code>\sigma</code>    | $\sigma$    | <code>\exists</code>   | $\exists$   | <code>\bullet</code>    | $\bullet$    |
| <code>\varsigma</code> | $\varsigma$ | <code>\ni</code>       | $\ni$       | <code>\div</code>       | $\div$       |
| <code>\tau</code>      | $\tau$      | <code>\cong</code>     | $\cong$     | <code>\neq</code>       | $\neq$       |
| <code>\equiv</code>    | $\equiv$    | <code>\approx</code>   | $\approx$   | <code>\aleph</code>     |              |
| <code>\Im</code>       | $\Im$       | <code>\Re</code>       | $\Re$       | <code>\wp</code>        | $\wp$        |
| <code>\otimes</code>   | $\otimes$   | <code>\oplus</code>    | $\oplus$    | <code>\oslash</code>    | $\oslash$    |
| <code>\cap</code>      | $\cap$      | <code>\cup</code>      | $\cup$      | <code>\supseteq</code>  | $\supseteq$  |
| <code>\supset</code>   | $\supset$   | <code>\subseteq</code> | $\subseteq$ | <code>\subset</code>    | $\subset$    |
| <code>\int</code>      | $\int$      | <code>\in</code>       | $\in$       | <code>\o</code>         | $\circ$      |
| <code>\rfloor</code>   | $\lfloor$   | <code>\lceil</code>    | $\lceil$    | <code>\nabla</code>     | $\nabla$     |
| <code>\lfloor</code>   | $\lfloor$   | <code>\cdot</code>     | $\cdot$     | <code>\ldots</code>     | $\dots$      |
| <code>\perp</code>     | $\perp$     | <code>\neg</code>      | $\neg$      | <code>\prime</code>     | $'$          |
| <code>\wedge</code>    | $\wedge$    | <code>\times</code>    | $\times$    | <code>\emptyset</code>  | $\emptyset$  |
| <code>\rceil</code>    | $\lceil$    | <code>\sqrt</code>     | $\sqrt$     | <code>\mid</code>       | $ $          |
| <code>\vee</code>      | $\vee$      | <code>\varpi</code>    | $\varpi$    | <code>\copyright</code> | $\copyright$ |
| <code>\langle</code>   | $\langle$   | <code>\rangle</code>   | $\rangle$   |                         |              |

You can also specify stream modifiers that control font type and color. The first four modifiers are mutually exclusive. However,



you can use `\fontname` in combination with one of the other modifiers:

- `\bf` — Bold font
- `\it` — Italic font
- `\sl` — Oblique font (rarely available)
- `\rm` — Normal font
- `\fontname{fontname}` — Specify the name of the font family to use.
- `\fontsize{fontsize}` — Specify the font size in FontUnits.
- `\color{colorSpec}` — Specify color for succeeding characters

Stream modifiers remain in effect until the end of the string or only within the context defined by braces `{}`.

## Specifying Text Color in TeX Strings

Use the `\color` modifier to change the color of characters following it from the previous color (which is black by default). Syntax is:

- `\color{colorname}` for the eight basic named colors (red, green, yellow, magenta, blue, black, white), and plus the four Simulink colors (gray, darkGreen, orange, and lightBlue)

Note that short names (one-letter abbreviations) for colors are not supported by the `\color` modifier.

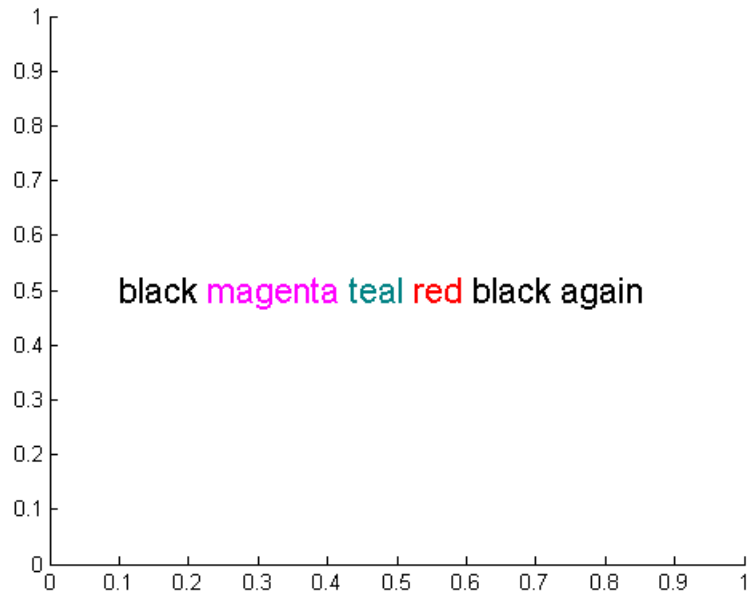
- `\color[rgb]{r g b}` to specify an RGB triplet with values between 0 and 1 as a cell array

For example,

```
text(.1,.5,['\fontsize{16}black {\color{magenta}magenta '...
'\color[rgb]{0 .5 .5}teal \color{red}red} black again'])
```

# Text Properties

---



## Specifying Subscript and Superscript Characters

The subscript character “`_`” and the superscript character “`^`” modify the character or substring defined in braces immediately following.

To print the special characters used to define the TeX strings when Interpreter is `TeX`, prefix them with the backslash “`\`” character: `\{`, `\}`, `\_`, `\^`.

See the “Examples” on page 2-3672 in the text reference page for more information.

When Interpreter is set to `none`, no characters in the `String` are interpreted, and all are displayed when the text is drawn.

When Interpreter is set to `latex`, MATLAB provides a complete  $\text{La}_T\text{E}_X$  interpreter for text objects. See the `Interpreter` property for more information.

## Tag

string

*User-specified object label.* The `Tag` property provides a means to identify graphics objects with a user-specified label. This is particularly useful when you are constructing interactive graphics programs that would otherwise need to define object handles as global variables or pass them as arguments between callback routines. You can define `Tag` as any string.

## Type

string (read only)

*Class of graphics object.* For text objects, `Type` is always the string `'text'`.

## Units

pixels | normalized | inches |  
centimeters | points | {data}

*Units of measurement.* This property specifies the units MATLAB uses to interpret the `Extent` and `Position` properties. All units are measured from the lower left corner of the axes plot box.

- Normalized units map the lower left corner of the rectangle defined by the axes to (0,0) and the upper right corner to (1.0,1.0).
- pixels, inches, centimeters, and points are absolute units (1 point =  $\frac{1}{72}$  inch).
- data refers to the data units of the parent axes as determined by the data graphed (not the axes `Units` property, which controls the positioning of the axes within the figure window).

If you change the value of `Units`, it is good practice to return it to its default value after completing your computation so as not to affect other functions that assume `Units` is set to the default value.

# Text Properties

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**UserData**  
matrix

*User-specified data.* Any data you want to associate with the text object. MATLAB does not use this data, but you can access it using `set` and `get`.

**UIContextMenu**  
handle of a `uicontextmenu` object

*Associate a context menu with the text.* Assign this property the handle of a `uicontextmenu` object created in the same figure as the text. Use the `uicontextmenu` function to create the context menu. MATLAB displays the context menu whenever you right-click over the text.

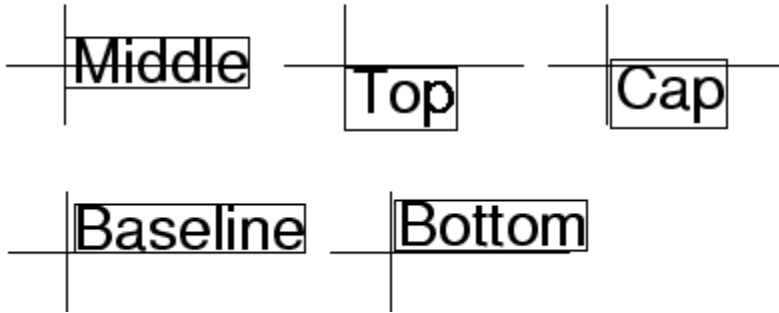
**VerticalAlignment**  
`top` | `cap` | `{middle}` | `baseline` | `bottom`

*Vertical alignment of text.* This property specifies the vertical justification of the text string. It determines where MATLAB places the string with regard to the value of the `Position` property. The possible values mean

- `top` — Place the top of the string's `Extent` rectangle at the specified *y*-position.
- `cap` — Place the string so that the top of a capital letter is at the specified *y*-position.
- `middle` — Place the middle of the string at the specified *y*-position.
- `baseline` — Place font baseline at the specified *y*-position.
- `bottom` — Place the bottom of the string's `Extent` rectangle at the specified *y*-position.

The following picture illustrates the alignment options.

**Text VerticalAlignment** property viewed with the **HorizontalAlignment** property set to left (the default).



**Visible**  
{on} | off

*Text visibility.* By default, all text is visible. When set to off, the text is not visible, but still exists, and you can query and set its properties.

# textread

---

## Purpose

Read data from text file; write to multiple outputs

---

**Note** `textread` is not recommended. Use `textscan` to read data from a text file.

---

## Graphical Interface

As an alternative to `textread`, use the Import Wizard. To activate the Import Wizard, select **Import Data** from the **File** menu.

## Syntax

```
[A,B,C,...] = textread('filename','format')
[A,B,C,...] = textread('filename','format',N)
[...] = textread(...,'param','value',...)
```

## Description

`[A,B,C,...] = textread('filename','format')` reads data from the file `'filename'` into the variables `A,B,C`, and so on, using the specified format, until the entire file is read. The `filename` and `format` inputs are strings, each enclosed in single quotes. `textread` is useful for reading text files with a known format. `textread` handles both fixed and free format files.

---

**Note** When reading large text files, reading from a specific point in a file, or reading file data into a cell array rather than multiple outputs, you might prefer to use the `textscan` function.

---

`textread` matches and converts groups of characters from the input. Each input field is defined as a string of non-white-space characters that extends to the next white-space or delimiter character, or to the maximum field width. Repeated delimiter characters are significant, while repeated white-space characters are treated as one.

The format string determines the number and types of return arguments. The number of return arguments is the number of items in the format string. The format string supports a subset of the conversion specifiers and conventions of the C language `fscanf` routine.

Values for the format string are listed in the table below. White-space characters in the format string are ignored.

| <b>format</b>                     | <b>Action</b>                                                                                                                                                                                   | <b>Output</b>         |
|-----------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|
| Literals<br>(ordinary characters) | Ignore the matching characters. For example, in a file that has Dept followed by a number (for department number), to skip the Dept and read only the number, use 'Dept ' in the format string. | None                  |
| %d                                | Read a signed integer value.                                                                                                                                                                    | Double array          |
| %u                                | Read an integer value.                                                                                                                                                                          | Double array          |
| %f                                | Read a floating-point value.                                                                                                                                                                    | Double array          |
| %s                                | Read a white-space or delimiter-separated string.                                                                                                                                               | Cell array of strings |
| %q                                | Read a double quoted string, ignoring the quotes.                                                                                                                                               | Cell array of strings |
| %C                                | Read characters, including white space.                                                                                                                                                         | Character array       |
| %[...]                            | Read the longest string containing characters specified in the brackets.                                                                                                                        | Cell array of strings |
| %[^...]                           | Read the longest nonempty string containing characters that are not specified in the brackets.                                                                                                  | Cell array of strings |
| %*...<br>instead of %             | Ignore the matching characters specified by *.                                                                                                                                                  | No output             |
| %w...<br>instead of %             | Read field width specified by w. The %f format supports %w.pf, where w is the field width and p is the precision.                                                                               |                       |

`[A,B,C,...] = textread('filename','format',N)` reads the data, reusing the format string N times, where N is an integer greater than zero. If N is smaller than zero, `textread` reads the entire file.

`[...] = textread(...,'param','value',...)` customizes `textread` using param/value pairs, as listed in the table below.

# textread

---

| param        | value                                                                                                                                                                | Action                                                                    |
|--------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------|
| bufsize      | Positive integer                                                                                                                                                     | Specifies the maximum string length, in bytes. Default is 4095.           |
| commentstyle | matlab                                                                                                                                                               | Ignores characters after %.                                               |
| commentstyle | shell                                                                                                                                                                | Ignores characters after #.                                               |
| commentstyle | c                                                                                                                                                                    | Ignores characters between /* and */.                                     |
| commentstyle | c++                                                                                                                                                                  | Ignores characters after //.                                              |
| delimiter    | One or more characters                                                                                                                                               | Act as delimiters between elements. Default is none.                      |
| emptyvalue   | Scalar double                                                                                                                                                        | Value given to empty cells when reading delimited files. Default is 0.    |
| endofline    | Single character or '\r\n'                                                                                                                                           | Character that denotes the end of a line. Default is determined from file |
| expchars     | Exponent characters                                                                                                                                                  | Default is eEdD.                                                          |
| headerlines  | Positive integer                                                                                                                                                     | Ignores the specified number of lines at the beginning of the file.       |
| whitespace   | Any from the list below:<br>' '           Space<br>\b            Backspace<br>\n            Newline<br>\r            Carriage return<br>\t            Horizontal tab | Treats vector of characters as white space. Default is '\b\t'.            |

---

**Note** When `textread` reads a consecutive series of `whitespace` values, it treats them as one white space. When it reads a consecutive series of `delimiter` values, it treats each as a separate delimiter.

---



**Remarks**

If you want to preserve leading and trailing spaces in a string, use the `whitespace` parameter as shown here:

```
textread('myfile.txt', '%s', 'whitespace', '')
ans =
 ' An example of preserving spaces '
```

**Examples****Example 1 – Read All Fields in Free Format File Using %**

The first line of `mydata.dat` is

```
Sally Level1 12.34 45 Yes
```

Read the first line of the file as a free format file using the % format.

```
[names, types, x, y, answer] = textread('mydata.dat', ...
 '%s %s %f %d %s', 1)
```

returns

```
names =
 'Sally'
types =
 'Level1'
x =
 12.340000000000000
y =
 45
answer =
 'Yes'
```

**Example 2 – Read as Fixed Format File, Ignoring the Floating Point Value**

The first line of `mydata.dat` is

```
Sally Level1 12.34 45 Yes
```

Read the first line of the file as a fixed format file, ignoring the floating-point value.

```
[names, types, y, answer] = textread('mydata.dat', ...
'%9c %5s %*f %2d %3s', 1)

returns

names =
Sally
types =
'Level1'
y =
45
answer =
'Yes'
```

`%*f` in the format string causes `textread` to ignore the floating point value, in this case, 12.34.

### **Example 3 – Read Using Literal to Ignore Matching Characters**

The first line of `mydata.dat` is

```
Sally Type1 12.34 45 Yes
```

Read the first line of the file, ignoring the characters `Type` in the second field.

```
[names, typenum, x, y, answer] = textread('mydata.dat', ...
'%s Type%d %f %d %s', 1)

returns

names =
'Sally'
typenum =
1
x =
12.340000000000000
y =
45
```

```
answer =
 'Yes'
```

Type%d in the format string causes the characters Type in the second field to be ignored, while the rest of the second field is read as a signed integer, in this case, 1.

#### Example 4 – Specify Value to Fill Empty Cells

For files with empty cells, use the emptyvalue parameter. Suppose the file data.csv contains:

```
1,2,3,4,,6
7,8,9,,11,12
```

Read the file using NaN to fill any empty cells:

```
data = textread('data.csv', '', 'delimiter', ',', ...
 'emptyvalue', NaN);
```

#### Example 5 – Read M-File into a Cell Array of Strings

Read the file fft.m into cell array of strings.

```
file = textread('fft.m', '%s', 'delimiter', '\n', ...
 'whitespace', '');
```

### See Also

textscan, dlmread, csvread, fscanf

# textscan

---

**Purpose** Read formatted data from text file or string

**Syntax**

```
C = textscan(fid, 'format')
C = textscan(fid, 'format', N)
C = textscan(fid, 'format', param, value, ...)
C = textscan(fid, 'format', N, param, value, ...)
C = textscan(str, ...)
[C, position] = textscan(...)
```

## Description

---

**Note** Before reading a file with `textscan`, you must open the file with the `fopen` function. `fopen` supplies the `fid` input required by `textscan`. When you are finished reading from the file, close the file by calling `fclose(fid)`.

---

`C = textscan(fid, 'format')` reads data from an open text file identified by file identifier `fid` into cell array `C`. The `format` input is a string of conversion specifiers enclosed in single quotation marks. The number of specifiers determines the number of cells in the cell array `C`.

`C = textscan(fid, 'format', N)` reads data from the file, using the `format` `N` times, where `N` is a positive integer. You can read additional data from the file after `N` cycles by calling `textscan` again using the original `fid`.

`C = textscan(fid, 'format', param, value, ...)` reads data from the file using nondefault parameter settings specified by one or more pairs of `param` and `value` arguments. For a list of all valid parameter strings, value descriptions, and defaults, see “User Configurable Options” on page 2-3716.

`C = textscan(fid, 'format', N, param, value, ...)` reads data from the file, using the `format` `N` times, and using nondefault parameter settings specified by pairs of `param` and `value` arguments.

`C = textscan(str, ...)` reads data from string `str`. You can use the `format`, `N`, and parameter/value arguments described above with this syntax. However, for strings, repeated calls to `textscan` restart the

scan from the beginning each time. (See “Example 10 — Resuming a Text Scan of a String” on page 2-3725.)

[C, position] = textscan(...) returns the file or string position at the end of the scan as the second output argument. For a file, this is the value that ftell(fid) would return after calling textscan. For a string, position indicates how many characters textscan read.

## Remarks

When textscan reads a specified file or string, it attempts to match the data to the format string. If textscan fails to convert a data field, it stops reading and returns all fields read before the failure.

### Basic Conversion Specifiers

The format input is a string of one or more conversion specifiers. The following table lists the basic specifiers.

| Field Type            | Specifier                         | Details                                                                                 |
|-----------------------|-----------------------------------|-----------------------------------------------------------------------------------------|
| Integer, signed       | %d<br>%d8<br>%d16<br>%d32<br>%d64 | 32-bit<br>8-bit<br>16-bit<br>32-bit<br>64-bit                                           |
| Integer, unsigned     | %u<br>%u8<br>%u16<br>%u32<br>%u64 | 32-bit<br>8-bit<br>16-bit<br>32-bit<br>64-bit                                           |
| Floating-point number | %f<br>%f32<br>%f64<br>%n          | 64-bit (double)<br>32-bit (single)<br>64-bit (double)<br>64-bit (double)                |
| Character strings     | %s<br>%q<br>%c                    | String<br>String, possibly double-quoted<br>Any single character, including a delimiter |

| Field Type               | Specifier            | Details                                                                                                                                                                                             |
|--------------------------|----------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Pattern-matching strings | <code>%[...]</code>  | Read only characters in the brackets, until the first nonmatching character. Use <code>%[...]...</code> to include <code>]</code> .<br><br>Example: <code>%[mus]</code> reads 'summer ' as 'summ'.  |
|                          | <code>%[^...]</code> | Read only characters not in the brackets, until the first matching character. Use <code>%[^]...</code> to exclude <code>]</code> .<br><br>Example: <code>%[^xrg]</code> reads 'summer ' as 'summe'. |

For each numeric conversion specifier, `textscan` returns a K-by-1 MATLAB numeric vector to the output cell array `C`, where K is the number of times that `textscan` finds a field matching the specifier. For each string conversion specifier, `textscan` returns a K-by-1 cell vector of strings. For each character conversion of the form `%Nc` (see “Field Length” on page 2-3714), `textscan` returns a K-by-N character array.

## Field Length

You can specify the number of characters or digits to read by inserting a number between the percent character (%) and the format specifier. For floating-point numbers (`%n`, `%f`, `%f32`, `%f64`), you also can specify the number of digits read to the right of the decimal point.

| Specifier        | Action Taken                                                                                                   |
|------------------|----------------------------------------------------------------------------------------------------------------|
| <code>%Nc</code> | Read N characters, including delimiter characters. Example: <code>%9c</code> reads 'Let's Go!' as 'Let's Go!'. |

| Specifier                                                            | Action Taken                                                                                                                                                                                       |
|----------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| %Ns      %Nn<br>%Nq      %Nd...<br>%N[...] %Nu...<br>%N[^...] %Nf... | Read N characters or digits (counting a decimal point as a digit), or up to the first delimiter, whichever comes first.<br><br>Example: %5f32 reads '473.238' as 473.2.                            |
| %N.Dn<br>%N.Df...                                                    | Read N digits (counting a decimal point as a digit), or up to the first delimiter, whichever comes first. Return D decimal digits in the output.<br><br>Example: %7.2f reads '473.238' as 473.23 . |

### Skipping Fields or Parts of Fields

The `textscan` function reads all characters in your file in sequence unless you tell it to ignore a particular field or a portion of a field.

Use the following format specifiers to skip or read portions of fields:

| Specifier | Action Taken                                                                                                                                                                                                                                                                                        |
|-----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| %*...     | Skip the field. <code>textscan</code> does not create an output cell for any field that it skips.<br><br>Example: '%s %*s %s %s %*s %*s %s' (spaces are optional) converts the string 'Blackbird singing in the dead of night' to four output cells with the strings 'Blackbird' 'in' 'the' 'night' |

| Specifier           | Action Taken                                                                                                                                                                                          |
|---------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <code>%*n...</code> | Ignore <code>n</code> characters of the field, where <code>n</code> is an integer less than or equal to the number of characters in the field.<br>Example: <code>%*4s</code> reads 'summer ' as 'er'. |
| literal             | Ignore the specified characters of the field.<br>Example: <code>Level%u8</code> reads 'Level11' as 1.<br>Example: <code>%u8Step</code> reads '2Step' as 2.                                            |

The `textscan` function does not include leading white-space characters in the processing of any data fields. When processing numeric data, `textscan` also ignores trailing white space.

## User Configurable Options

This table shows the valid `param-value` options and their default values. Parameter names are not case sensitive.

| Parameter                  | Value                                                                                                             | Default   |
|----------------------------|-------------------------------------------------------------------------------------------------------------------|-----------|
| <code>BufSize</code>       | Maximum string length in bytes                                                                                    | 4095      |
| <code>CollectOutput</code> | If true, <code>textscan</code> concatenates consecutive output cells with the same data type into a single array. | 0 (false) |



| Parameter           | Value                                                                                                                                                                                                                                              | Default                                      |
|---------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------|
| CommentStyle        | Symbol(s) designating text to ignore.<br>Specify a single string (such as '%') to ignore characters following the string on the same line.<br>Specify a cell array of two strings (such as {'/*', '*/'}) to ignore characters between the strings. | None                                         |
| Delimiter           | Field delimiter character(s)                                                                                                                                                                                                                       | White space                                  |
| EmptyValue          | Value to return for empty numeric fields in delimited files                                                                                                                                                                                        | NaN                                          |
| EndOfLine           | End-of-line character                                                                                                                                                                                                                              | Determined from the file:<br>\n, \r, or \r\n |
| ExpChars            | Exponent characters                                                                                                                                                                                                                                | 'eEdD'                                       |
| HeaderLines         | Number of lines to skip. (Includes the remainder of the current line.)                                                                                                                                                                             | 0                                            |
| MultipleDelimsAsOne | If true, textscan treats consecutive delimiters as a single delimiter. Only valid if you specify the delimiter option.                                                                                                                             | 0 (false)                                    |

| Parameter     | Value                                                                                                                                                                                                                                                                                           | Default                 |
|---------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|
| ReturnOnError | Determines behavior when <code>textscan</code> fails to read or convert. If <code>true</code> , <code>textscan</code> terminates without an error and returns all fields read. If <code>false</code> , <code>textscan</code> terminates with an error and does not return an output cell array. | 1 ( <code>true</code> ) |
| TreatAsEmpty  | String(s) in the data file to treat as an empty value. Can be a single string or cell array of strings. Only applies to numeric fields.                                                                                                                                                         | None                    |
| Whitespace    | White-space characters                                                                                                                                                                                                                                                                          | ' \b\t'                 |

## Field and Row Delimiters

Within each row, the default field delimiter is white space. White space can be any combination of space (' '), backspace ('\b'), or tab ('\t') characters.

If you use the default (white space) field delimiter, `textscan` interprets repeated white-space characters as a single delimiter. If you specify a nondefault delimiter, `textscan` interprets repeated delimiter characters as separate delimiters, and returns an empty value to the output cell. (See “Example 5 — Specifying Delimiter and Empty Value Conversion” on page 2-3721 and “Example 7 — Handling Repeated Delimiters” on page 2-3722.)

Rows delimiters are end-of-line (EOL) character sequences. The default end-of-line setting depends on the format of your file, and can include a newline character ('\n'), a carriage return ('\r'), or a combination of the two ('\r\n').

For more information, see “Example 9 — Using Nondefault Control Characters” on page 2-3724.

### Numeric Fields

`textscan` converts numeric fields to the specified output type according to MATLAB rules regarding overflow, truncation, and the use of NaN, Inf, and -Inf.

For example, MATLAB represents an integer NaN as zero. If `textscan` finds an empty field associated with an integer format specifier (such as `%d` or `%u`), it returns the empty value as zero and not NaN. (See “Example 2 — Reading Different Types of Data” on page 2-3720 and “Example 5 — Specifying Delimiter and Empty Value Conversion” on page 2-3721.)

`textscan` imports any complex number as a whole into a complex numeric field, converting the real and imaginary parts to the specified numeric type. Valid forms for a complex number are as follows:

| Form                                       | Example               |
|--------------------------------------------|-----------------------|
| <code>±&lt;real&gt;±&lt;imag&gt;i j</code> | <code>5.7-3.1i</code> |
| <code>±&lt;imag&gt;i j</code>              | <code>-7j</code>      |

Do not include embedded white space in a complex number. `textscan` interprets embedded white space as a field delimiter.

## Examples

---

**Note** The following examples include spaces between the conversion specifiers to make the format value easier to read. Spaces are not required.

---

### Example 1 — Reading a String

Read the following string, truncating each value to one decimal digit. The specifier `%*1d` tells `textscan` to skip the remaining digit:

```
str = '0.41 8.24 3.57 6.24 9.27';
```

```
C = textscan(str, '%3.1f %*1d');
```

textscan returns a 1-by-1 cell array C:

```
C{1} = [0.4; 8.2; 3.5; 6.2; 9.2]
```

## Example 2 – Reading Different Types of Data

The text file scan1.dat contains data in the following form:

```
Sally Level1 12.34 45 1.23e10 inf NaN Yes
Joe Level2 23.54 60 9e19 -inf 0.001 No
Bill Level3 34.90 12 2e5 10 100 No
```

Open the file, and read each column with the appropriate conversion specifier:

```
fid = fopen('scan1.dat');
C = textscan(fid, '%s %s %f32 %d8 %u %f %f %s');
fclose(fid);
```

textscan returns a 1-by-8 cell array C with the following cells:

```
C{1} = {'Sally'; 'Joe'; 'Bill'} class cell
C{2} = {'Level1'; 'Level2'; 'Level3'} class cell
C{3} = [12.34; 23.54; 34.9] class single
C{4} = [45; 60; 12] class int8
C{5} = [4294967295; 4294967295; 200000] class uint32
C{6} = [Inf; -Inf; 10] class double
C{7} = [NaN; 0.001; 100] class double
C{8} = {'Yes'; 'No'; 'No'} class cell
```

The first two elements of C{5} are the maximum values for a 32-bit unsigned integer, or intmax('uint32').

## Example 3 – Removing a Literal String

Remove the text 'Level1' from each field in the second column of the data from Example 2:

```
fid = fopen('scan1.dat');
```

```
C = textscan(fid, '%s Level%u8 %f32 %d8 %u %f %f %s');
fclose(fid);
```

textscan returns a 1-by-8 cell array, C, with

```
C{2} = [1; 2; 3] class uint8
```

#### Example 4 – Reading Only the First Field

Read the first column of the file in Example 2 into a cell array, skipping the rest of the line:

```
fid = fopen('scan1.dat');
names = textscan(fid, '%s %*[^\\n]');
fclose(fid);
```

textscan returns a 1-by-1 cell array names:

```
names{1} = {'Sally'; 'Joe'; 'Bill'}
```

#### Example 5 – Specifying Delimiter and Empty Value Conversion

The comma-delimited file data.csv contains

```
1, 2, 3, 4, , 6
7, 8, 9, , 11, 12
```

Read the file, converting empty cells to -Inf:

```
fid = fopen('data.csv');
C = textscan(fid, '%f %f %f %f %u32 %f', 'delimiter', ',', ...
 'EmptyValue', -Inf);
fclose(fid);
```

textscan returns a 1-by-6 cell array C with the following cells:

```
C{1} = [1; 7] class double
C{2} = [2; 8] class double
C{3} = [3; 9] class double
```

```
C{4} = [4; -Inf] class double (empty converted to -Inf)
C{5} = [0; 11] class uint32 (empty converted to 0)
C{6} = [6; 12] class double
```

textscan converts the empty value in C{4}, associated with a floating-point format, to -Inf. Because MATLAB represents unsigned integer -Inf as 0, textscan converts the empty value in C{5} to 0 and not -Inf.

## Example 6 – Using Custom Empty Value Strings and Comments

The comma-delimited file data2.csv contains the lines

```
abc, 2, NA, 3, 4
// Comment Here
def, na, 5, 6, 7
```

Designate the input that textscan should treat as comments or empty values:

```
fid = fopen('data2.csv');
C = textscan(fid, '%s %n %n %n %n', 'delimiter', ',', ...
 'treatAsEmpty', {'NA', 'na'}, ...
 'commentStyle', '//');
fclose(fid);
```

textscan returns a 1-by-5 cell array C with the following cells:

```
C{1} = {'abc'; 'def'}
C{2} = [2; NaN]
C{3} = [NaN; 5]
C{4} = [3; 6]
C{5} = [4; 7]
```

## Example 7 – Handling Repeated Delimiters

The file data3.csv contains

```
1,2,3,,4
```

5,6,7,,8

To treat the repeated commas as a single delimiter, use the `MultipleDelimsAsOne` parameter, with a value of 1:

```
fid = fopen('data3.csv');
C = textscan(fid, '%f %f %f %f', 'delimiter', ',', ...
 'MultipleDelimsAsOne', 1);
fclose(fid);
```

`textscan` returns a 1-by-4 cell array `C` with the following cells:

```
C{1} = [1; 5]
C{2} = [2; 6]
C{3} = [3; 7]
C{4} = [4; 8]
```

### Example 8 – Using the CollectOutput Switch

The file `grades.txt` contains

| Student_ID | Test1 | Test2 | Test3 |
|------------|-------|-------|-------|
| 1          | 91.5  | 89.2  | 77.3  |
| 2          | 88.0  | 67.8  | 91.0  |
| 3          | 76.3  | 78.1  | 92.5  |
| 4          | 96.4  | 81.2  | 84.6  |

The default value for the `CollectOutput` switch is 0 (false), and `textscan` returns each column of the numeric data in a separate array:

```
fid = fopen('grades.txt');

% read column headers
C_text = textscan(fid, '%s', 4, 'delimiter', '|');

% read numeric data
C_data0 = textscan(fid, '%d %f %f %f')

C_data0 =
```

```
[4x1 int32] [4x1 double] [4x1 double] [4x1 double]
```

Set `CollectOutput` to 1 (true) to collect the consecutive columns of the same class (the test scores, which are all double) into a single array:

```
frewind(fid);

C_text = textscan(fid, '%s', 4, 'delimiter', '|');

C_data1 = textscan(fid, '%d %f %f %f', ...
 'CollectOutput', 1)

C_data1 =
 [4x1 int32] [4x3 double]

fclose(fid);
```

## Example 9 – Using Nondefault Control Characters

When you specify one of the following escape sequences for any parameter value, `textscan` converts that sequence to the corresponding control character:

```
\b Backspace
\n Newline
\r Carriage return
\t Tab
\\ Backslash (\)
```

If your data uses a different control character, use the `sprintf` function to explicitly convert the escape sequence in your call to `textscan`.

For example, the following string includes a form feed character, `\f`:

```
lyric = sprintf('Blackbird\f\singing\f\n\fthe\fdead\fof\fnight');
```



To read the string using `textscan`, call the `sprintf` function to explicitly convert the form feed:

```
C = textscan(lyric, '%s', 'delimiter', sprintf('\f'));
```

`textscan` returns a 1-by-1 cell array `C`:

```
C{1} =
 {'Blackbird'; 'singing'; 'in'; 'the'; 'dead'; 'of'; 'night'}
```

### Example 10 – Resuming a Text Scan of a String

If you resume a text scan of a file by calling `textscan` with the same file identifier (`fid`), `textscan` automatically resumes reading at the point where it terminated the last read.

If your input is a string rather than a file, `textscan` reads from the beginning of the string each time. To resume a scan from any other position in the string, you must use the two-output argument syntax in your initial call to `textscan`. For example, given the string

```
lyric = 'Blackbird singing in the dead of night'
```

Read the first word of the string:

```
[firstword, pos] = textscan(lyric, '%9c', 1);
```

Resume the scan:

```
lastpart = textscan(lyric(pos+1:end), '%s');
```

### See Also

`load`, `type`, `importdata`, `uiimport`, `dlmread`, `xlsread`, `fscanf`, `fread`  
“Importing Large Data Sets” in the MATLAB Programming Fundamentals documentation

# textwrap

---

**Purpose**            Wrapped string matrix for given uicontrol

**Syntax**            `outstring = textwrap(h,instring)`  
`[outstring,position]=textwrap(h,instring)`

**Description**       `outstring = textwrap(h,instring)` returns a wrapped string cell array, `outstring`, that fits inside the uicontrol with handle `h`. `instring` is a cell array, with each cell containing a single line of text. `outstring` is the wrapped string matrix in cell array format. Each cell of the input string is considered a paragraph.

`[outstring,position]=textwrap(h,instring)` returns the recommended position of the uicontrol in the units of the uicontrol. `position` considers the extent of the multiline text in the *x* and *y* directions.

**Remarks**           When programming a GUI, do not call `copyobj` or `textwrap` (which calls `copyobj`) inside a `CreateFcn`. The act of copying the uicontrol object fires the `CreateFcn` repeatedly, which raises a series of error messages after exceeding the root object's `RecursionLimit` property.

**Example**            Place a text-wrapped string in a uicontrol:

```
pos = [10 10 100 10];
h = uicontrol('Style','Text','Position',pos);
string = {'This is a string for the uicontrol.',
 'It should be correctly wrapped inside.'};
[outstring,newpos] = textwrap(h,string);
pos(4) = newpos(4);
set(h,'String',outstring,'Position',[pos(1),pos(2),pos(3)+10,po
s(4)])
```

**See Also**            `uicontrol`

**Purpose** Transpose-free quasi-minimal residual method

**Syntax**

```
x = tfqmr(A,b)
x = tfqmr(afun,b)
x = tfqmr(a,b,tol)
x = tfqmr(a,b,tol,maxit)
x = tfqmr(a,b,tol,maxit,m)
x = tfqmr(a,b,tol,maxit,m1,m2,x0)
[x,flag] = tfqmr(A,B,...)
[x,flag,relres] = tfqmr(A,b,...)
[x,flag,relres,y]y(A,b,...)
[x,flag,relres,iter,resvec] = tfqmr(A,b,...)
```

**Description** `x = tfqmr(A,b)` attempts to solve the system of linear equations  $A*x=b$  for  $x$ . The  $n$ -by- $n$  coefficient matrix  $A$  must be square and the right-hand side column vector  $b$  must have length  $n$ .

`x = tfqmr(afun,b)` accepts a function handle `afun` instead of the matrix  $A$ . `afun(x)` accepts a vector input  $x$  and returns the matrix-vector product  $A*x$ . In all of the following syntaxes, you can replace  $A$  by `afun`. See “Function Handles” in the MATLAB Programming documentation for more information. “Parametrizing Functions”, in the MATLAB Mathematics documentation, explains how to provide additional parameters to the function `afun`.

`x = tfqmr(a,b,tol)` specifies the tolerance of the method. If `tol` is `[]` then `tfqmr` uses the default,  $1e-6$ .

`x = tfqmr(a,b,tol,maxit)` specifies the maximum number of iterations. If `maxit` is `[]` then `tfqmr` uses the default,  $\min(N,20)$ .

`x = tfqmr(a,b,tol,maxit,m)` and `x = tfqmr(a,b,tol,maxit,m1,m2)` use preconditioners  $m$  or  $m=m1*m2$  and effectively solve the system  $A*inv(M)*x = B$  for  $x$ . If  $M$  is `[]` then a preconditioner is not applied.  $M$  may be a function handle `mfun` such that `mfun(x)` returns  $m\backslash x$ .

`x = tfqmr(a,b,tol,maxit,m1,m2,x0)` specifies the initial guess. If `x0` is `[]` then `tfqmr` uses the default, an all zero vector.

`[x,flag] = tfqmr(A,B,...)` also returns a convergence flag:

| Flag | Convergence                                                                                               |
|------|-----------------------------------------------------------------------------------------------------------|
| 0    | tfqmr converged to the desired tolerance <code>tol</code> within <code>maxit</code> iterations.           |
| 1    | tfqmr iterated <code>maxit</code> times but did not converge.                                             |
| 2    | Preconditioner <code>m</code> was ill-conditioned.                                                        |
| 3    | tfqmr stagnated. (Two consecutive iterates were the same.)                                                |
| 4    | One of the scalar quantities calculated during tfqmr became too small or too large to continue computing. |

`[x,flag,relres] = tfqmr(A,b,...)` also returns the relative residual norm  $\text{norm}(b-A*x)/\text{norm}(b)$ . If `flag` is 0, then `relres`  $\leq$  `tol`.

`[x,flag,relres,y]y(A,b,...)` also returns the iteration number at which `x` was computed:  $0 \leq \text{iter} \leq \text{maxit}$ .

`[x,flag,relres,iter,resvec] = tfqmr(A,b,...)` also returns a vector of the residual norms at each iteration, including  $\text{norm}(b-A*x_0)$ .

## Examples

```
n = 100; on = ones(n,1);
A = spdiags([-2*on 4*on -on],-1:1,n,n);
b = sum(A,2);
tol = 1e-8;
maxit = 15;
M1 = spdiags([on/(-2) on],-1:0,n,n);
M2 = spdiags([4*on -on],0:1,n,n);
x = tfqmr(A,b,tol,maxit,M1,M2,[]);
```

You can also use a matrix-vector product function as input:

```
function y = afun(x,n)
y = 4 * x;
y(2:n) = y(2:n) - 2 * x(1:n-1);
```

```
y(1:n-1) = y(1:n-1) - x(2:n);
x1 = tfqmr(@(x)afun(x,n),b,tol,maxit,M1,M2);
```

If `applyOp` is a function suitable for use with `qmr`, it may be used with `tfqmr` by wrapping it in an anonymous function:

```
x1 = tfqmr(@(x)applyOp(x,'notransp'),b,tol,maxit,M1,M2);
```

### See Also

`qmr`, `bicg`, `bicgstab`, `bicgstablcs`, `gmres`, `lsqr`, `luinc`, `minres`, `pcg`, `symmlq`, `mldivide` (`\`)

# throw (MException)

---

**Purpose** Terminate function and issue exception

**Syntax** throw(ME)

**Description** throw(ME) terminates the currently running function, issues an exception based on MException object ME, and returns control to the keyboard or to any enclosing catch block. A thrown MException displays a message in the Command Window unless it is caught by try-catch. throw also sets the MException stack field to the location from which the throw method was called.

## Examples

### Example 1

This example tests the output of M-file evaluate\_plots and throws an exception if it is not acceptable:

```
[minval, maxval] = evaluate_plots(p24, p28, p41);
if minval < lower_bound || maxval > upper_bound
 ME = MException('VerifyOutput:OutOfBounds', ...
 'Results are outside the allowable limits');
 throw(ME);
end
```

### Example 2

This example attempts to open a file in a directory that is not on the MATLAB path. It uses a nested try-catch block to give the user the opportunity to extend the path. If the file still cannot be found, the program issues an exception with the first error appended to the second:

```
function data = read_it(filename);
try
 fid = fopen(filename, 'r');
 data = fread(fid);
catch eObj1
 if strcmp(eObj1.identifier, 'MATLAB:FileIO:InvalidFid')
 msg = sprintf('\n%s%s%s', 'Cannot open file ', ...
 filename, '. Try another location? ');
```

```
reply = input(msg, 's')
if reply(1) == 'y'
 newdir = input('Enter directory name: ', 's');
else
 throw(eObj1);
end
addpath(newdir);
try
 fid = fopen(filename, 'r');
 data = fread(fid);
catch eObj2
 eObj3 = addCause(eObj2, eObj1)
 throw(eObj3);
end
rmpath(newdir);
end
end
fclose(fid);
```

If you run this function in a try-catch block at the command line, you can look at the MException object by assigning it to a variable (e) with the catch command.

```
try
 d = read_it('anytextfile.txt');
catch e
end

e
e =
MException object with properties:

 identifier: 'MATLAB:FileIO:InvalidFid'
 message: 'Invalid file identifier. Use fopen to
generate a valid file identifier.'
 stack: [1x1 struct]
 cause: {[1x1 MException]}
```

## throw (MException)

---

```
Cannot open file anytextfile.txt. Try another location?y
Enter directory name: xxxxxxx
Warning: Name is nonexistent or not a directory: xxxxxxx.
> In path at 110
 In addpath at 89
```

### See Also

error, try, catch, assert, MException, rethrow(MException),  
throwAsCaller(MException), addCause(MException),  
getReport(MException), disp(MException), isequal(MException),  
eq(MException), ne(MException), last(MException),



# throwAsCaller (MException)

---

**Purpose** Throw exception, as if from calling function

**Syntax** `throwAsCaller(ME)`

**Description** `throwAsCaller(ME)` throws an exception from the currently running M-file based on `MException` object `ME`. The MATLAB software exits the currently running function and returns control to either the keyboard or an enclosing catch block in a calling function. Unlike the `throw` function, MATLAB omits the current stack frame from the stack field of the `MException`, thus making the exception look as if it is being thrown by the caller of the function.

In some cases, it is not relevant to show the person running your program the true location that generated an exception, but is better to point to the calling function where the problem really lies. You might also find `throwAsCaller` useful when you want to simplify the error display, or when you have code that you do not want made public.

**Examples** The function `klein_bottle`, in this example, generates a Klein Bottle figure by revolving the figure-eight curve defined by `XYKLEIN`. It defines a few variables and calls the function `draw_klein`, which executes three functions in a try-catch block. If there is an error, the catch block issues an exception using either `throw` or `throwAsCaller`:

```
function klein_bottle(ab, pq)
 rtr = [2 0.5 1];
 box = [-3 3 -3 3 -2 2];
 vue = [55 60];
 draw_klein(ab, rtr, pq, box, vue)
```

```
function draw_klein(ab, rtr, pq, box, vue)
 clf
 try
 tube('xyklein',ab, rtr, pq, box, vue);
 shading interp
 colormap(pink);
```

## throwAsCaller (MException)

---

```
catch ME
 throw(ME)
% throwAsCaller(ME)
end
```

Call the `klein_bottle` function, passing an incorrect value for the second argument. (The correct value would be a vector, such as [40 40].) Because the catch block issues the exception using `throw`, MATLAB displays error messages for line 15 of function `draw_klein`, and for line 5 of function `klein_bottle`:

```
klein_bottle(ab, pi)
??? Attempted to access pq(2); index out of bounds because
 numel(pq)=1.
```

```
Error in ==> klein_bottle>draw_klein at 15
 throw(ME);
```

```
Error in ==> klein_bottle at 5
draw_figure(ab, rtr, pq, box, vue)
```

Run the function again, this time changing the `klein_bottle.m` file so that the catch block uses `throwAsCaller` instead of `throw`. This time, MATLAB only displays the error at line 5 of the main program:

```
klein_bottle(ab, pi)
??? Attempted to access pq(2); index out of bounds because
 numel(pq)=1.
```

```
Error in ==> klein_bottle at 5
draw_figure(ab, rtr, pq, box, vue)
```

### See Also

`error`, `try`, `catch`, `assert`, `MException`, `throw(MException)`, `rethrow(MException)`, `addCause(MException)`, `getReport(MException)`, `disp(MException)`, `isequal(MException)`, `eq(MException)`, `ne(MException)`, `last(MException)`

---

|                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
|--------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Purpose</b>     | Measure performance using stopwatch timer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| <b>Syntax</b>      | <pre>tic; any_statements; toc; tic; any_statements; tElapsed=toc; tStart=tic; any_statements; toc(tStart); tStart=tic; any_statements; tElapsed=toc(tStart);</pre>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| <b>Description</b> | <p><code>tic; any_statements; toc;</code> measures the time it takes the MATLAB software to execute the one or more lines of MATLAB code shown here as <code>any_statements</code>. The <code>tic</code> command starts a stopwatch timer, MATLAB executes the block of statements, and <code>toc</code> stops the timer, displaying the time elapsed in seconds.</p> <p><code>tic; any_statements; tElapsed=toc;</code> makes the same time measurement, but assigns the elapsed time output to a variable, <code>tElapsed</code>. MATLAB does not display the elapsed time unless you omit the terminating semicolon. The value returned by <code>toc</code> is a scalar double that represents the elapsed time in seconds.</p> <p><code>tStart=tic; any_statements; toc(tStart);</code> makes the same time measurement, but allows you the option of running more than one stopwatch timer concurrently. You assign the output of <code>tic</code> to a variable <code>tStart</code> and then use that same variable when calling <code>toc</code>. MATLAB measures the time elapsed between the <code>tic</code> and its related <code>toc</code> command and displays the time elapsed in seconds. This syntax enables you to time multiple concurrent operations, including the timing of nested operations.</p> <p><code>tStart=tic; any_statements; tElapsed=toc(tStart);</code> is the same as the command shown above, except that MATLAB assigns the elapsed time output to a variable, <code>tElapsed</code>. MATLAB does not display the elapsed time unless you omit the terminating semicolon. The value returned by <code>toc</code> is a scalar double that represents the elapsed time in seconds.</p> |
| <b>Remarks</b>     | Using the third syntax shown above, you can nest <code>tic-toc</code> pairs.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |

When using the simpler `tic` and `toc` syntax, avoid using consecutive `tics` as they merely overwrite the internally-recorded starting time. Consecutive `toCs` however, may be useful as each `toc` returns the increasing time that has elapsed since the most recent `tic`. Using this mechanism, you can take multiple measurements from a single point in time.

When using the `tStart=tic` and `toc(tStart)` syntax, it is advisable to select a unique variable for `tStart`. If you accidentally overwrite this variable prior to the `toc` for which it is needed, you will get inaccurate results for the time measurement.

`tStart` is a 64-bit unsigned integer, scalar value. This value is only useful as an input argument for a subsequent call to `toc`.

The `clear` function does not reset the starting time recorded by a `tic` command.

### Examples

Measure how the time required to solve a linear system varies with the order of a matrix:

```
for n = 1:100
 A = rand(n,n);
 b = rand(n,1);
 tic
 x = A\b;
 t(n) = toc;
end
plot(t)
```

Measure the minimum and average time to compute a summation of Bessel functions:

```
REPS = 1000; minTime = Inf; nsum = 10;
tic;

for i=1:REPS
 tStart = tic; total = 0;
 for j=1:nsum,
```

```
 total = total + besselj(j,REPS);
 end

 tElapsed = toc(tStart);
 minTime = min(tElapsed, minTime);
end
averageTime = toc/REPS;
```

**See Also** [clock](#), [cputime](#), [etime](#), [profile](#)

# timer

---

|                                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
|--------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Purpose</b>                 | Construct timer object                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| <b>Syntax</b>                  | <pre>T = timer T = timer('PropertyName1', PropertyValue1, 'PropertyName2',           PropertyValue2,...)</pre>                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| <b>Description</b>             | <p>T = timer constructs a timer object with default attributes.</p> <p>T = timer('PropertyName1', PropertyValue1, 'PropertyName2', PropertyValue2,...) constructs a timer object in which the given property name/value pairs are set on the object. See “Timer Object Properties” on page 2-3738 for a list of all the properties supported by the timer object.</p> <p>Note that the property name/property value pairs can be in any format supported by the set function, i.e., property/value string pairs, structures, and property/value cell array pairs.</p> |
| <b>Examples</b>                | <p>This example constructs a timer object with a timer callback function handle, mycallback, and a 10 second interval.</p> <pre>t = timer('TimerFcn',@mycallback, 'Period', 10.0);</pre>                                                                                                                                                                                                                                                                                                                                                                              |
| <b>See Also</b>                | <pre>delete(timer), disp(timer), get(timer), invalid(timer), set(timer), start, startat, stop, timerfind, timerfindall, wait</pre>                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| <b>Timer Object Properties</b> | <p>The timer object supports the following properties that control its attributes. The table includes information about the data type of each property and its default value.</p> <p>To view the value of the properties of a particular timer object, use the <code>get(timer)</code> function. To set the value of the properties of a timer object, use the <code>set(timer)</code> function.</p>                                                                                                                                                                  |

| Property Name | Property Description                                                                                                                                                                                                                                                            | Data Types, Values, Defaults, Access |                                             |
|---------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------|---------------------------------------------|
| AveragePeriod | Average time between TimerFcn executions since the timer started.<br><br>Note: Value is NaN until timer executes two timer callbacks.                                                                                                                                           | Data type                            | double                                      |
|               |                                                                                                                                                                                                                                                                                 | Default                              | NaN                                         |
|               |                                                                                                                                                                                                                                                                                 | Read only                            | Always                                      |
| BusyMode      | Action taken when a timer has to execute TimerFcn before the completion of previous execution of TimerFcn.<br><br>'drop' — Do not execute the function.<br><br>'error' — Generate an error. Requires ErrorFcn to be set.<br><br>'queue' — Execute function at next opportunity. | Data type                            | Enumerated string                           |
|               |                                                                                                                                                                                                                                                                                 | Values                               | 'drop'<br>'error'<br>'queue'                |
|               |                                                                                                                                                                                                                                                                                 | Default                              | 'drop'                                      |
|               |                                                                                                                                                                                                                                                                                 | Read only                            | While Running = 'on'                        |
| ErrorFcn      | Function that the timer executes when an error occurs. This function executes before the StopFcn. See “Creating Callback Functions” for more information.                                                                                                                       | Data type                            | Text string, function handle, or cell array |
|               |                                                                                                                                                                                                                                                                                 | Default                              | None                                        |
|               |                                                                                                                                                                                                                                                                                 | Read only                            | Never                                       |

# timer

| Property Name | Property Description                                                                                             | Data Types, Values, Defaults, Access |                                                                                                                                                                                      |
|---------------|------------------------------------------------------------------------------------------------------------------|--------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| ExecutionMode | Determines how the timer object schedules timer events. See “Timer Object Execution Modes” for more information. | Data type                            | Enumerated string                                                                                                                                                                    |
|               |                                                                                                                  | Values                               | 'singleShot'<br>'fixedDelay'<br>'fixedRate'<br>'fixedSpacing'                                                                                                                        |
|               |                                                                                                                  | Default                              | 'singleShot'                                                                                                                                                                         |
|               |                                                                                                                  | Read only                            | While Running = 'on'                                                                                                                                                                 |
| InstantPeriod | The time between the last two executions of TimerFcn.                                                            | Data type                            | double                                                                                                                                                                               |
|               |                                                                                                                  | Default                              | NaN                                                                                                                                                                                  |
|               |                                                                                                                  | Read only                            | Always                                                                                                                                                                               |
| Name          | User-supplied name.                                                                                              | Data type                            | Text string                                                                                                                                                                          |
|               |                                                                                                                  | Default                              | 'timer- <i>i</i> ', where <i>i</i> is a number indicating the <i>i</i> th timer object created this session. To reset <i>i</i> to 1, execute the <code>clear classes</code> command. |
|               |                                                                                                                  | Read only                            | Never                                                                                                                                                                                |



| Property Name    | Property Description                                                                                                                                                                                                                                                                                                                                                                                                  | Data Types, Values, Defaults, Access |                         |
|------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------|-------------------------|
| ObjectVisibility | Provides a way for application developers to prevent end-user access to the timer objects created by their application. The <code>timerfind</code> function does not return an object whose <code>ObjectVisibility</code> property is set to 'off'. Objects that are not visible are still valid. If you have access to the object (for example, from within the M-file that created it), you can set its properties. | Data type                            | Enumerated string       |
|                  |                                                                                                                                                                                                                                                                                                                                                                                                                       | Values                               | 'off'<br>'on'           |
|                  |                                                                                                                                                                                                                                                                                                                                                                                                                       | Default                              | 'on'                    |
|                  |                                                                                                                                                                                                                                                                                                                                                                                                                       | Read only                            | Never                   |
| Period           | Specifies the delay, in seconds, between executions of <code>TimerFcn</code> .                                                                                                                                                                                                                                                                                                                                        | Data type                            | double                  |
|                  |                                                                                                                                                                                                                                                                                                                                                                                                                       | Value                                | Any number $\geq 0.001$ |
|                  |                                                                                                                                                                                                                                                                                                                                                                                                                       | Default                              | 1.0                     |
|                  |                                                                                                                                                                                                                                                                                                                                                                                                                       | Read only                            | While Running = 'on'    |
| Running          | Indicates whether the timer is currently executing.                                                                                                                                                                                                                                                                                                                                                                   | Data type                            | Enumerated string       |
|                  |                                                                                                                                                                                                                                                                                                                                                                                                                       | Values                               | 'off'<br>'on'           |
|                  |                                                                                                                                                                                                                                                                                                                                                                                                                       | Default                              | 'off'                   |
|                  |                                                                                                                                                                                                                                                                                                                                                                                                                       | Read only                            | Always                  |

## timer

---

| Property Name | Property Description                                                                                                           | Data Types, Values, Defaults, Access |                                             |
|---------------|--------------------------------------------------------------------------------------------------------------------------------|--------------------------------------|---------------------------------------------|
| StartDelay    | Specifies the delay, in seconds, between the start of the timer and the first execution of the function specified in TimerFcn. | Data type                            | double                                      |
|               |                                                                                                                                | Values                               | Any number $\geq 0$                         |
|               |                                                                                                                                | Default                              | 0                                           |
|               |                                                                                                                                | Read only                            | While Running = 'on'                        |
| StartFcn      | Function the timer calls when it starts. See “Creating Callback Functions” for more information.                               | Data type                            | Text string, function handle, or cell array |
|               |                                                                                                                                | Default                              | None                                        |
|               |                                                                                                                                | Read only                            | Never                                       |

| Property Name | Property Description                                                                                                                                                                                                                                                                                                                                                                                                      | Data Types, Values, Defaults, Access |                                             |
|---------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------|---------------------------------------------|
| StopFcn       | Function the timer calls when it stops. The timer stops when <ul style="list-style-type: none"> <li>• You call the timer stop function</li> <li>• The timer finishes executing TimerFcn, i.e., the value of TasksExecuted reaches the limit set by TasksToExecute.</li> <li>• An error occurs (The ErrorFcn is called first, followed by the StopFcn.)</li> </ul> See “Creating Callback Functions” for more information. | Date type                            | Text string, function handle, or cell array |
|               |                                                                                                                                                                                                                                                                                                                                                                                                                           | Default                              | None                                        |
|               |                                                                                                                                                                                                                                                                                                                                                                                                                           | Read only                            | Never                                       |
| Tag           | User supplied label.                                                                                                                                                                                                                                                                                                                                                                                                      | Data type                            | Text string                                 |
|               |                                                                                                                                                                                                                                                                                                                                                                                                                           | Default                              | Empty string ( ' ' )                        |
|               |                                                                                                                                                                                                                                                                                                                                                                                                                           | Read only                            | Never                                       |

# timer

| Property Name  | Property Description                                                                                    | Data Types, Values, Defaults, Access |                                             |
|----------------|---------------------------------------------------------------------------------------------------------|--------------------------------------|---------------------------------------------|
|                |                                                                                                         |                                      |                                             |
| TasksToExecute | Specifies the number of times the timer should execute the function specified in the TimerFcn property. | Data type                            | double                                      |
|                |                                                                                                         | Values                               | Any number > 0                              |
|                |                                                                                                         | Default                              | 1                                           |
|                |                                                                                                         | Read only                            | Never                                       |
| TasksExecuted  | The number of times the timer has called TimerFcn since the timer was started.                          | Data type                            | double                                      |
|                |                                                                                                         | Values                               | Any number >= 0                             |
|                |                                                                                                         | Default                              | 0                                           |
|                |                                                                                                         | Read only                            | Always                                      |
| TimerFcn       | Timer callback function. See “Creating Callback Functions” for more information.                        | Data type                            | Text string, function handle, or cell array |
|                |                                                                                                         | Default                              | None                                        |
|                |                                                                                                         | Read only                            | Never                                       |
| Type           | Identifies the object type.                                                                             | Data type                            | Text string                                 |
|                |                                                                                                         | Values                               | 'timer'                                     |
|                |                                                                                                         | Read only                            | Always                                      |
| UserData       | User-supplied data.                                                                                     | Data type                            | User-defined                                |
|                |                                                                                                         | Default                              | []                                          |
|                |                                                                                                         | Read only                            | Never                                       |

**Purpose**

Find timer objects

**Syntax**

```
out = timerfind
out = timerfind('P1', V1, 'P2', V2,...)
out = timerfind(S)
out = timerfind(obj, 'P1', V1, 'P2', V2,...)
```

**Description**

`out = timerfind` returns an array, `out`, of all the timer objects that exist in memory.

`out = timerfind('P1', V1, 'P2', V2,...)` returns an array, `out`, of timer objects whose property values match those passed as parameter/value pairs, `P1`, `V1`, `P2`, `V2`. Parameter/value pairs may be specified as a cell array.

`out = timerfind(S)` returns an array, `out`, of timer objects whose property values match those defined in the structure, `S`. The field names of `S` are timer object property names and the field values are the corresponding property values.

`out = timerfind(obj, 'P1', V1, 'P2', V2,...)` restricts the search for matching parameter/value pairs to the timer objects listed in `obj`. `obj` can be an array of timer objects.

---

**Note** When specifying parameter/value pairs, you can use any mixture of strings, structures, and cell arrays in the same call to `timerfind`.

---

Note that, for most properties, `timerfind` performs case-sensitive searches of property values. For example, if the value of an object's `Name` property is `'MyObject'`, `timerfind` will not find a match if you specify `'myobject'`. Use the `get` function to determine the exact format of a property value. However, properties that have an enumerated list of possible values are not case sensitive. For example, `timerfind` will find an object with an `ExecutionMode` property value of `'singleShot'` or `'singleshot'`.

# timerfind

---

## Examples

These examples use `timerfind` to find timer objects with the specified property values.

```
t1 = timer('Tag', 'broadcastProgress', 'Period', 5);
t2 = timer('Tag', 'displayProgress');
out1 = timerfind('Tag', 'displayProgress')
out2 = timerfind({'Period', 'Tag'}, {5, 'broadcastProgress'})
```

## See Also

`get(timer)`, `timer`, `timerfindall`

**Purpose** Find timer objects, including invisible objects

**Syntax**

```
out = timerfindall
out = timerfindall('P1', V1, 'P2', V2,...)
out = timerfindall(S)
out = timerfindall(obj, 'P1', V1, 'P2', V2,...)
```

**Description** `out = timerfindall` returns an array, `out`, containing all the timer objects that exist in memory, regardless of the value of the object's `ObjectVisibility` property.

`out = timerfindall('P1', V1, 'P2', V2,...)` returns an array, `out`, of timer objects whose property values match those passed as parameter/value pairs, `P1`, `V1`, `P2`, `V2`. Parameter/value pairs may be specified as a cell array.

`out = timerfindall(S)` returns an array, `out`, of timer objects whose property values match those defined in the structure, `S`. The field names of `S` are timer object property names and the field values are the corresponding property values.

`out = timerfindall(obj, 'P1', V1, 'P2', V2,...)` restricts the search for matching parameter/value pairs to the timer objects listed in `obj`. `obj` can be an array of timer objects.

---

**Note** When specifying parameter/value pairs, you can use any mixture of strings, structures, and cell arrays in the same call to `timerfindall`.

---

Note that, for most properties, `timerfindall` performs case-sensitive searches of property values. For example, if the value of an object's `Name` property is `'MyObject'`, `timerfindall` will not find a match if you specify `'myobject'`. Use the `get` function to determine the exact format of a property value. However, properties that have an enumerated list of possible values are not case sensitive. For example, `timerfindall` will find an object with an `ExecutionMode` property value of `'singleShot'` or `'singleshot'`.

# timerfindall

---

## Examples

Create several timer objects.

```
t1 = timer;
t2 = timer;
t3 = timer;
```

Set the `ObjectVisibility` property of one of the objects to 'off'.

```
t2.ObjectVisibility = 'off';
```

Use `timerfind` to get a listing of all the timer objects in memory. Note that the listing does not include the timer object (`timer-2`) whose `ObjectVisibility` property is set to 'off'.

```
timerfind
```

Timer Object Array

| Index: | ExecutionMode: | Period: | TimerFcn: | Name:   |
|--------|----------------|---------|-----------|---------|
| 1      | singleShot     | 1       | ''        | timer-1 |
| 2      | singleShot     | 1       | ''        | timer-3 |

Use `timerfindall` to get a listing of all the timer objects in memory. This listing includes the timer object whose `ObjectVisibility` property is set to 'off'.

```
timerfindall
```

Timer Object Array

| Index: | ExecutionMode: | Period: | TimerFcn: | Name:   |
|--------|----------------|---------|-----------|---------|
| 1      | singleShot     | 1       | ''        | timer-1 |
| 2      | singleShot     | 1       | ''        | timer-2 |
| 3      | singleShot     | 1       | ''        | timer-3 |

## See Also

`get(timer)`, `timer`, `timerfind`



**Purpose**

Create timeseries object

**Syntax**

```
ts = timeseries
ts = timeseries(Data)
ts = timeseries(Name)
ts = timeseries(Data,Time)
ts = timeseries(Data,Time,Quality)
ts = timeseries(Data,...,'Parameter',Value,...)
```

**Description**

`ts = timeseries` creates an empty time-series object.

`ts = timeseries(Data)` creates a time series with the specified `Data`. `ts` has a default time vector that ranges from 0 to N-1 with a 1-second interval, where N is the number of samples. The default name of the timeseries object is 'unnamed'.

`ts = timeseries(Name)` creates an empty time series with the name specified by a string `Name`. This name can differ from the time-series variable name.

`ts = timeseries(Data,Time)` creates a time series with the specified `Data` array and `Time`. When time values are date strings, you must specify `Time` as a cell array of date strings.

`ts = timeseries(Data,Time,Quality)` creates a timeseries object. The `Quality` attribute is an integer vector with values -128 to 127 that specifies the quality in terms of codes defined by `QualityInfo.Code`.

`ts = timeseries(Data,...,'Parameter',Value,...)` creates a timeseries object with optional parameter-value pairs after the `Data`, `Time`, and `Quality` arguments. You can specify the following parameters:

- `Name` — Time-series name entered as a string
- `IsTimeFirst` — Logical value (true or false) specifying whether the first or last dimension of the data array is aligned with the time vector. You can set this property when the data array is square and, therefore, the dimension that is aligned with time is ambiguous.

## Remarks

### Definition: timeseries

The time-series object, called `timeseries`, is a MATLAB variable that contains time-indexed data and properties in a single, coherent structure. For example, in addition to data and time values, you can also use the time-series object to store events, descriptive information about data and time, data quality, and the interpolation method.

### Definition: Data Sample

A time-series *data sample* consists of one or more values recorded at a specific time. The number of data samples in a time series is the same as the length of the time vector.

For example, suppose that `ts.data` has the size 5-by-4-by-3 and the time vector has the length 5. Then, the number of samples is 5 and the total number of data values is  $5 \times 4 \times 3 = 60$ .

### Notes About Quality

When `Quality` is a vector, it must have the same length as the time vector. In this case, each `Quality` value applies to the corresponding data sample. When `Quality` is an array, it must have the same size as the data array. In this case, each `Quality` value applies to the corresponding data value of the `ts.data` array.

## Examples

### Example 1 – Using Default Time Vector

Create a `timeseries` object called 'LaunchData' that contains four data sets, each stored as a column of length 5 and using the default time vector:

```
b = timeseries(rand(5, 4), 'Name', 'LaunchData')
```

### Example 2 – Using Uniform Time Vector

Create a `timeseries` object containing a single data set of length 5 and a time vector starting at 1 and ending at 5:

```
b = timeseries(rand(5,1), [1 2 3 4 5])
```

### Example 3

Create a `timeseries` object called 'FinancialData' containing five data points at a single time point:

```
b = timeseries(rand(1,5),1,'Name','FinancialData')
```

### See Also

`addsample`, `tscollection`, `tsdata.event`, `tsprops`


# title

---

## Purpose

Add title to current axes

## GUI Alternative

To create or modify a plot's title from a GUI, use **Insert Title** from the figure menu. Use the Property Editor, one of the plotting tools , to modify the position, font, and other properties of a legend. For details, see *The Property Editor* in the MATLAB Graphics documentation.

## Syntax

```
title('string')
title(fname)
title(...,'PropertyName',PropertyValue,...)
title(axes_handle,...)
h = title(...)
```

## Description

Each axes graphics object can have one title. The title is located at the top and in the center of the axes.

`title('string')` outputs the string at the top and in the center of the current axes.

`title(fname)` evaluates the function that returns a string and displays the string at the top and in the center of the current axes.

`title(...,'PropertyName',PropertyValue,...)` specifies property name and property value pairs for the text graphics object that `title` creates. Do not use the 'String' text property to set the title string; the content of the title should be given by the first argument.

`title(axes_handle,...)` adds the title to the specified axes.

`h = title(...)` returns the handle to the text object used as the title.

---

**Note** The words `default`, `factory`, and `remove` are reserved words that will not appear in a title when quoted as a normal string. In order to display any of these words individually, type `'\reserved_word'` instead of `'reserved_word'`.

---

**Examples**

Display today's date in the current axes:

```
title(date)
```

Include a variable's value in a title:

```
f = 70;
c = (f-32)/1.8;
title(['Temperature is ',num2str(c),'C'])
```

Include a variable's value in a title and set the color of the title to yellow:

```
n = 3;
title(['Case number #',int2str(n)],'Color','y')
```

Include Greek symbols in a title:

```
title('\ite^{\omega\tau} = cos(\omega\tau) + isin(\omega\tau)')
```

Include a superscript character in a title:

```
title('\alpha^2')
```

Include a subscript character in a title:

```
title('X_1')
```

The text object `String` property lists the available symbols.

Create a multiline title using a multiline cell array.

```
title({'First line';'Second line'})
```

**Remarks**

`title` sets the `Title` property of the current axes graphics object to a new text graphics object. See the text `String` property for more information.

**See Also**

`gtext`, `int2str`, `num2str`, `text`, `xlabel`, `ylabel`, `zlabel`

# title

---

“Annotating Plots” on page 1-94 for related functions

Text Properties for information on setting parameter/value pairs in titles

Adding Titles to Graphs for more information on ways to add titles

**Purpose** Convert CDF epoch object to MATLAB datenum

**Syntax** `n = todatenum(obj)`

**Description** `n = todatenum(obj)` converts the CDF epoch object `ep_obj` into a MATLAB serial date number. Note that a CDF epoch is the number of milliseconds since 01-Jan-0000 whereas a MATLAB datenum is the number of days since 00-Jan-0000.

**Examples** Construct a CDF epoch object from a date string, and then convert the object back into a MATLAB date string:

```
dstr = datestr(today)
dstr =
 08-Oct-2003

obj = cdfepoch(dstr)
obj =
 cdfepoch object:
 08-Oct-2003 00:00:00

dstr2 = datestr(todatenum(obj))
dstr2 =
 08-Oct-2003
```

**See Also** `cdfepoch`, `cdfinfo`, `cdfread`, `cdfwrite`, `datenum`

# toeplitz

---

**Purpose** Toeplitz matrix

**Syntax** `T = toeplitz(c,r)`  
`T = toeplitz(r)`

**Description** A *Toeplitz* matrix is defined by one row and one column. A *symmetric Toeplitz* matrix is defined by just one row. `toeplitz` generates Toeplitz matrices given just the row or row and column description.

`T = toeplitz(c,r)` returns a nonsymmetric Toeplitz matrix `T` having `c` as its first column and `r` as its first row. If the first elements of `c` and `r` are different, a message is printed and the column element is used.

For a real vector `r`, `T = toeplitz(r)` returns the symmetric Toeplitz matrix formed from vector `r`, where `r` defines the first row of the matrix. For a complex vector `r` with a real first element, `T = toeplitz(r)` returns the Hermitian Toeplitz matrix formed from `r`, where `r` defines the first row of the matrix and `r'` defines the first column. When the first element of `r` is not real, the resulting matrix is Hermitian off the main diagonal, i.e.,  $T_{ij} = \text{conj}(T_{ji})$  for  $i \neq j$ .

**Examples** A Toeplitz matrix with diagonal disagreement is

```
c = [1 2 3 4 5];
r = [1.5 2.5 3.5 4.5 5.5];
toeplitz(c,r)
Column wins diagonal conflict:
ans =
 1.000 2.500 3.500 4.500 5.500
 2.000 1.000 2.500 3.500 4.500
 3.000 2.000 1.000 2.500 3.500
 4.000 3.000 2.000 1.000 2.500
 5.000 4.000 3.000 2.000 1.000
```

**See Also** `hankel`, `kron`



|                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
|--------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Purpose</b>     | Root directory for specified toolbox                                                                                                                                                                                                                                                                                                                                                                                                                  |
| <b>Syntax</b>      | <pre>toolboxdir('tbxdirname')<br/>s = toolboxdir('tbxdirname')<br/>s = toolboxdir tbxdirname</pre>                                                                                                                                                                                                                                                                                                                                                    |
| <b>Description</b> | <p><code>toolboxdir('tbxdirname')</code> returns a string that is the absolute path to the specified toolbox, <code>tbxdirname</code>, where <code>tbxdirname</code> is the directory name for the toolbox.</p> <p><code>s = toolboxdir('tbxdirname')</code> returns the absolute path to the specified toolbox to the output argument, <code>s</code>.</p> <p><code>s = toolboxdir tbxdirname</code> is the command form of the syntax.</p>          |
| <b>Remarks</b>     | <p><code>toolboxdir</code> is particularly useful for MATLAB Compiler software. The base directory of all toolboxes installed with MATLAB software is:</p> <pre>matlabroot/toolbox/tbxdirname</pre> <p>However, in deployed mode, the base directories of the toolboxes are different. <code>toolboxdir</code> returns the correct root directory, whether running from MATLAB or from an application deployed with the MATLAB Compiler software.</p> |
| <b>Example</b>     | <p>To obtain the path for the Control System Toolbox software, run</p> <pre>s = toolboxdir('control')</pre> <p>MATLAB returns</p> <pre>s = \\myhome\r2009a\matlab\toolbox\control</pre>                                                                                                                                                                                                                                                               |
| <b>See Also</b>    | <p><code>ctfroot</code> (in the MATLAB Compiler product), <code>fullfile</code>, <code>matlabroot</code>, <code>partialpath</code>, <code>path</code>,</p> <p>“Managing Files and Working with the Current Directory”</p>                                                                                                                                                                                                                             |

# trace

---

|                    |                                                                                    |
|--------------------|------------------------------------------------------------------------------------|
| <b>Purpose</b>     | Sum of diagonal elements                                                           |
| <b>Syntax</b>      | <code>b = trace(A)</code>                                                          |
| <b>Description</b> | <code>b = trace(A)</code> is the sum of the diagonal elements of the matrix A.     |
| <b>Algorithm</b>   | <code>trace</code> is a single-statement M-file.<br><code>t = sum(diag(A));</code> |
| <b>See Also</b>    | <code>det</code> , <code>eig</code>                                                |

**Purpose** Transpose timeseries object

**Syntax** `ts1 = transpose(ts)`

**Description** `ts1 = transpose(ts)` returns a new `timeseries` object `ts1` with `IsTimeFirst` value set to the opposite of what it is for `ts`. For example, if `ts` has the first data dimension aligned with the time vector, `ts1` has the last data dimension aligned with the time vector.

**Remarks** The `transpose` function that is overloaded for the `timeseries` objects does not transpose the data. Instead, this function changes whether the first or the last dimension of the data is aligned with the time vector.

---

**Note** To transpose the data, you must transpose the `Data` property of the time series. For example, you can use the syntax `transpose(ts.Data)` or `(ts.Data).'`. `Data` must be a 2-D array.

---

Consider a time series with 10 samples with the property `IsTimeFirst = True`. When you transpose this time series, the data size is changed from 10-by-1 to 1-by-1-by-10. Note that the first dimension of the `Data` property is shown explicitly.

The following table summarizes how the size for time-series data (up to three dimensions) display before and after transposing.

### Data Size Before and After Transposing

| Size of Original Data | Size of Transposed Data |
|-----------------------|-------------------------|
| N-by-1                | 1-by-1-by-N             |
| N-by-M                | M-by-1-by-N             |
| N-by-M-by-L           | M-by-L-by-N             |

## transpose (timeseries)

---

### Examples

Suppose that a `timeseries` object `ts` has `ts.Data` size 10-by-3-by-2 and its time vector has a length of 10. The `IsTimeFirst` property of `ts` is set to `true`, which means that the first dimension of the data is aligned with the time vector. `transpose(ts)` modifies the `timeseries` object such that the last dimension of the data is now aligned with the time vector. This permutes the data such that the size of `ts.Data` becomes 3-by-2-by-10.

### See Also

`ctranspose (timeseries)`, `tsprops`

**Purpose**

Trapezoidal numerical integration

**Syntax**

```
Z = trapz(Y)
Z = trapz(X,Y)
Z = trapz(...,dim)
```

**Description**

`Z = trapz(Y)` computes an approximation of the integral of `Y` via the trapezoidal method (with unit spacing). To compute the integral for spacing other than one, multiply `Z` by the spacing increment. Input `Y` can be complex.

If `Y` is a vector, `trapz(Y)` is the integral of `Y`.

If `Y` is a matrix, `trapz(Y)` is a row vector with the integral over each column.

If `Y` is a multidimensional array, `trapz(Y)` works across the first nonsingleton dimension.

`Z = trapz(X,Y)` computes the integral of `Y` with respect to `X` using trapezoidal integration. Inputs `X` and `Y` can be complex.

If `X` is a column vector and `Y` an array whose first nonsingleton dimension is `length(X)`, `trapz(X,Y)` operates across this dimension.

`Z = trapz(...,dim)` integrates across the dimension of `Y` specified by scalar `dim`. The length of `X`, if given, must be the same as `size(Y,dim)`.

**Examples****Example 1**

The exact value of  $\int_0^{\pi} \sin(x) dx$  is 2.

To approximate this numerically on a uniformly spaced grid, use

```
X = 0:pi/100:pi;
Y = sin(X);
```

Then both

```
Z = trapz(X,Y)
```

and

```
Z = pi/100*trapz(Y)
```

produce

```
Z =
 1.9998
```

## Example 2

A nonuniformly spaced example is generated by

```
X = sort(rand(1,101)*pi);
Y = sin(X);
Z = trapz(X,Y);
```

The result is not as accurate as the uniformly spaced grid. One random sample produced

```
Z =
 1.9984
```

## Example 3

This example uses two complex inputs:

```
z = exp(1i*pi*(0:100)/100);

trapz(z, 1./z)
ans =
 0.0000 + 3.1411i
```

## See Also

cumsum, cumtrapz

**Purpose** Lay out tree or forest

**Syntax** `[x,y] = treelayout(parent,post)`  
`[x,y,h,s] = treelayout(parent,post)`

**Description** `[x,y] = treelayout(parent,post)` lays out a tree or a forest. `parent` is the vector of parent pointers, with 0 for a root. `post` is an optional postorder permutation on the tree nodes. If you omit `post`, `treelayout` computes it. `x` and `y` are vectors of coordinates in the unit square at which to lay out the nodes of the tree to make a nice picture.

`[x,y,h,s] = treelayout(parent,post)` also returns the height of the tree `h` and the number of vertices `s` in the top-level separator.

**See Also** `etree`, `treepplot`, `etreeplot`, `sympfact`

# treeplot

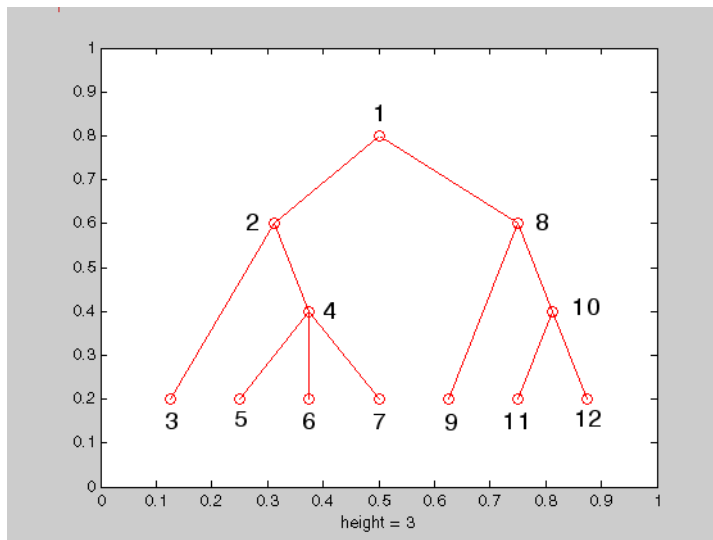
**Purpose** Plot picture of tree

**Syntax** `treeplot(p)`  
`treeplot(p,nodeSpec,edgeSpec)`

**Description** `treeplot(p)` plots a picture of a tree given a vector of parent pointers, with  $p(i) = 0$  for a root.

`treeplot(p,nodeSpec,edgeSpec)` allows optional parameters `nodeSpec` and `edgeSpec` to set the node or edge color, marker, and linestyle. Use `' '` to omit one or both.

**Examples** To plot a tree with 12 nodes, call `treeplot` with a 12-element input vector. The index of each element in the vector is shown adjacent to each node in the figure below. (These indices are shown only for the point of illustrating the example; they are not part of the `treeplot` output.)



To generate this plot, set the value of each element in the nodes vector to the index of its parent, (setting the parent of the root node to zero).



The node marked 1 in the figure is represented by `nodes(1)` in the input vector, and because this is the root node which has a parent of zero, you set its value to zero:

```
nodes(1) = 0; % Root node
```

`nodes(2)` and `nodes(8)` are children of `nodes(1)`, so set these elements of the input vector to 1:

```
nodes(2) = 1; nodes(8) = 1;
```

`nodes(5:7)` are children of `nodes(4)`, so set these elements to 4:

```
nodes(5) = 4; nodes(6) = 4; nodes(7) = 4;
```

Continue in this manner until each element of the vector identifies its parent. For the plot shown above, the `nodes` vector now looks like this:

```
nodes = [0 1 2 2 4 4 4 1 8 8 10 10];
```

Now call `treeplot` to generate the plot:

```
treeplot(nodes)
```

## See Also

`etree`, `etreeplot`, `treelayout`

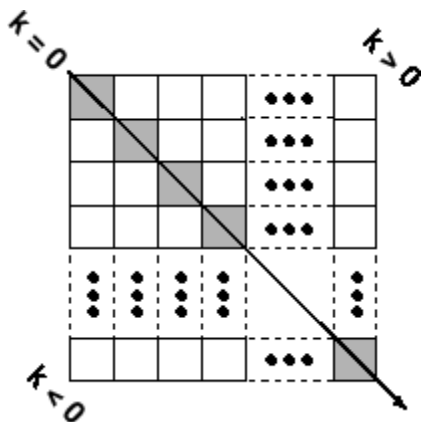
# tril

---

**Purpose** Lower triangular part of matrix

**Syntax**  
`L = tril(X)`  
`L = tril(X,k)`

**Description** `L = tril(X)` returns the lower triangular part of `X`.  
`L = tril(X,k)` returns the elements on and below the `k`th diagonal of `X`. `k = 0` is the main diagonal, `k > 0` is above the main diagonal, and `k < 0` is below the main diagonal.



**Examples** `tril(ones(4,4), -1)`

```
ans =

0 0 0 0
1 0 0 0
1 1 0 0
1 1 1 0
```

**See Also** `diag`, `triu`

---

|                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|--------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Purpose</b>     | Triangular mesh plot                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| <b>Syntax</b>      | <pre>trimesh(Tri,X,Y,Z) trimesh(Tri,X,Y,Z,C) trimesh(...'PropertyName',PropertyValue...) h = trimesh(...)</pre>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| <b>Description</b> | <p><code>trimesh(Tri,X,Y,Z)</code> displays triangles defined in the <math>m</math>-by-3 face matrix <code>Tri</code> as a mesh. Each row of <code>Tri</code> defines a single triangular face by indexing into the vectors or matrices that contain the <math>X</math>, <math>Y</math>, and <math>Z</math> vertices.</p> <p><code>trimesh(Tri,X,Y,Z,C)</code> specifies color defined by <code>C</code> in the same manner as the <code>surf</code> function. The MATLAB software performs a linear transformation on this data to obtain colors from the current colormap.</p> <p><code>trimesh(...'PropertyName',PropertyValue...)</code> specifies additional patch property names and values for the patch graphics object created by the function.</p> <p><code>h = trimesh(...)</code> returns a handle to a patch graphics object.</p> |
| <b>Example</b>     | <p>Create vertex vectors and a face matrix, then create a triangular mesh plot.</p> <pre>x = rand(1,50); y = rand(1,50); z = peaks(6*x-3,6*x-3); tri = delaunay(x,y); trimesh(tri,x,y,z)</pre>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| <b>See Also</b>    | <p><code>patch</code>, <code>tetramesh</code>, <code>triplot</code>, <code>trisurf</code>, <code>delaunay</code></p> <p>“Surface and Mesh Creation” on page 1-104 for related functions</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |

# triplequad

---

**Purpose** Numerically evaluate triple integral

**Syntax**  
`triplequad(fun,xmin,xmax,ymin,ymax,zmin,zmax)`  
`triplequad(fun,xmin,xmax,ymin,ymax,zmin,zmax,tol)`  
`triplequad(fun,xmin,xmax,ymin,ymax,zmin,zmax,tol,method)`

**Description** `triplequad(fun,xmin,xmax,ymin,ymax,zmin,zmax)` evaluates the triple integral  $\int_{xmin}^{xmax} \int_{ymin}^{ymax} \int_{zmin}^{zmax} fun(x,y,z)$  over the three dimensional rectangular region  $xmin \leq x \leq xmax$ ,  $ymin \leq y \leq ymax$ ,  $zmin \leq z \leq zmax$ . `fun` is a function handle. See “Function Handles” in the MATLAB Programming documentation for more information. `fun(x,y,z)` must accept a vector `x` and scalars `y` and `z`, and return a vector of values of the integrand.

“Parametrizing Functions”, in the MATLAB Mathematics documentation, explains how to provide additional parameters to the function `fun`, if necessary.

`triplequad(fun,xmin,xmax,ymin,ymax,zmin,zmax,tol)` uses a tolerance `tol` instead of the default, which is  $1.0e-6$ .

`triplequad(fun,xmin,xmax,ymin,ymax,zmin,zmax,tol,method)` uses the quadrature function specified as `method`, instead of the default `quad`. Valid values for `method` are `@quad1` or the function handle of a user-defined quadrature method that has the same calling sequence as `quad` and `quad1`.

**Examples** Pass M-file function handle `@integrnd` to `triplequad`:P

```
Q = triplequad(@integrnd,0,pi,0,1,-1,1);
```

where the M-file `integrnd.m` is

```
function f = integrnd(x,y,z)
f = y*sin(x)+z*cos(x);
```

Pass anonymous function handle `F` to `triplequad`:

```
F = @(x,y,z)y*sin(x)+z*cos(x);
```

```
Q = triplequad(F,0,pi,0,1,-1,1);
```

This example integrates  $y*\sin(x)+z*\cos(x)$  over the region  $0 \leq x \leq \pi, 0 \leq y \leq 1, -1 \leq z \leq 1$ . Note that the integrand can be evaluated with a vector  $x$  and scalars  $y$  and  $z$ .

## See Also

dblquad, quad2d, quad, quadgk, quadl, function handle (@),  
“Anonymous Functions”

# triplot

---

**Purpose** 2-D triangular plot

**Syntax**

```
triplot(TRI,x,y)
triplot(TRI,x,y,color)
h = triplot(...)
triplot(...,'param','value','param','value'...)
```

**Description** `triplot(TRI,x,y)` displays the triangles defined in the m-by-3 matrix TRI. A row of TRI contains indices into the vectors x and y that define a single triangle. The default line color is blue.

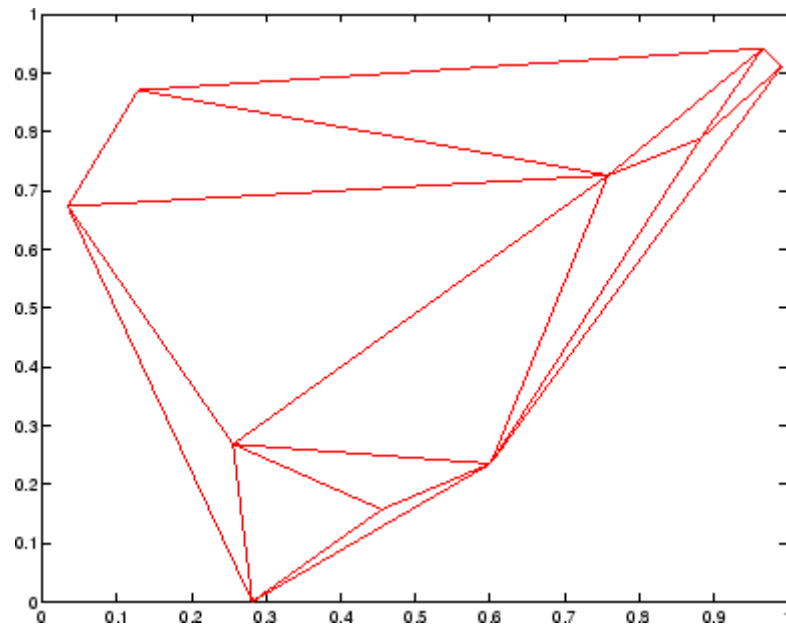
`triplot(TRI,x,y,color)` uses the string color as the line color. color can also be a line specification. See `ColorSpec` for a list of valid color strings. See `LineStyle` for information about line specifications.

`h = triplot(...)` returns a vector of handles to the displayed triangles.

`triplot(...,'param','value','param','value'...)` allows additional line property name/property value pairs to be used when creating the plot. See `Line Properties` for information about the available properties.

**Examples** This code plots the Delaunay triangulation for 10 randomly generated points.

```
rand('state',7);
x = rand(1,10);
y = rand(1,10);
TRI = delaunay(x,y);
triplot(TRI,x,y,'red')
```



**See Also**

ColorSpec, delaunay, line, Line Properties, LineSpec, plot, trimesh, trisurf

# TriRep class

---

**Purpose** Triangulation representation

**Description** TriRep provides topological and geometric queries for triangulations in 2-D and 3-D space. For example, for triangular meshes you can query triangles attached to a vertex, triangles that share an edge, neighbor information, circumcenters, or other features. You can create a TriRep directly using existing triangulation data. Alternatively, you can create a Delaunay triangulation, via DelaunayTri, which provides access to the TriRep functionality.

**Construction** TriRep Triangulation representation

**Methods**

|                 |                                                          |
|-----------------|----------------------------------------------------------|
| baryToCart      | Converts point coordinates from barycentric to Cartesian |
| cartToBary      | Convert point coordinates from cartesian to barycentric  |
| circumcenters   | Circumcenters of specified simplices                     |
| edgeAttachments | Simplices attached to specified edges                    |
| edges           | Triangulation edges                                      |
| faceNormals     | Unit normals to specified triangles                      |
| featureEdges    | Sharp edges of surface triangulation                     |
| freeBoundary    | Facets referenced by only one simplex                    |
| incenters       | Incenters of specified simplices                         |
| isEdge          | Test if vertices are joined by edge                      |



|                   |                                                 |
|-------------------|-------------------------------------------------|
| neighbors         | Simplex neighbor information                    |
| size              | Size of triangulation matrix                    |
| vertexAttachments | Return simplices attached to specified vertices |

## Properties

|               |                                                |
|---------------|------------------------------------------------|
| X             | Coordinates of the points in the triangulation |
| Triangulation | Triangulation data structure                   |

## Copy Semantics

Value. To learn how this affects your use of the class, see [Comparing Handle and Value Classes in the MATLAB Object-Oriented Programming documentation](#).

## Indexing

TriRep objects support indexing into the triangulation using parentheses (). The syntax is the same as for arrays.

## Examples

Load a 2-D triangulation and use the TriRep constructor to build an array of the free boundary edges:

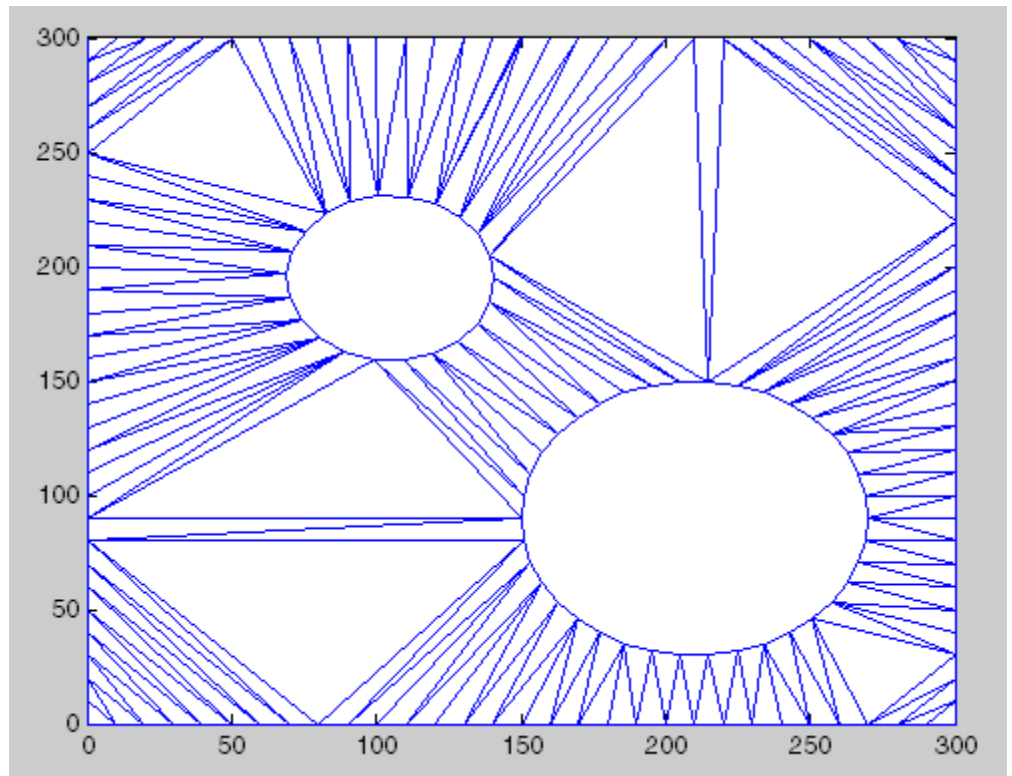
```
load trimesh2d
```

This loads triangulation `tri` and vertex coordinates `x`, `y`:

```
trep = TriRep(tri, x,y);
fe = freeBoundary(trep)';
triplot(trep);
```

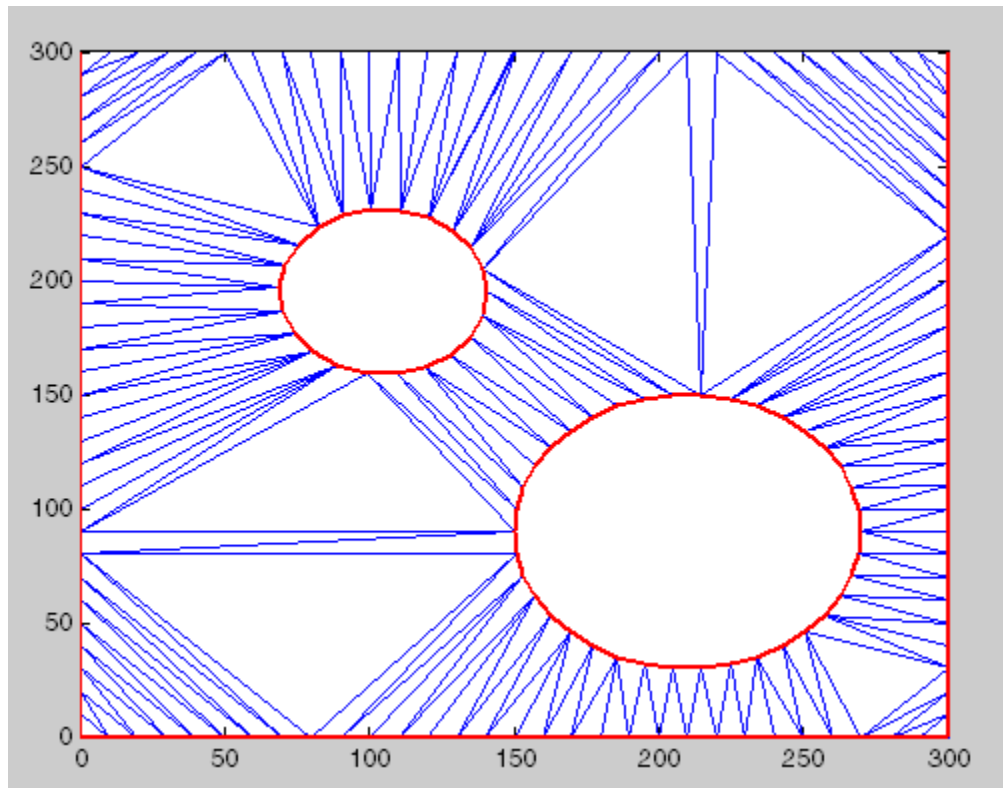
## TriRep class

---



You can add the free edges `fe` to the plot:

```
hold on;
plot(x(fe), y(fe), 'r','LineWidth',2);
hold off;
axis([-50 350 -50 350]);
axis equal;
```



## See Also

“Triangulation Representations” — How to use triangulation representations

`DelaunayTri` class

`TriScatteredInterp` class

# TriRep

---

**Purpose** Triangulation representation

**Syntax**  
TR = TriRep(TRI, X, Y)  
TR = TriRep(TRI, X, Y, Z)  
TR = TriRep(TRI, X)

**Description** TR = TriRep(TRI, X, Y) creates a 2-D triangulation representation from the triangulation matrix TRI and the vertex coordinates (X, Y). TRI is an m-by-3 matrix that defines the triangulation in face-vertex format, where m is the number of triangles. Each row of TRI is a triangle defined by indices into the column vector of vertex coordinates (X, Y).

TR = TriRep(TRI, X, Y, Z) creates a 3-D triangulation representation from the triangulation matrix TRI and the vertex coordinates (X, Y, Z). TRI is an m-by-3 or m-by-4 matrix that defines the triangulation in simplex-vertex format, where m is the number of simplices; triangles or tetrahedra in this case. Each row of TRI is a simplex defined by indices into the column vector of vertex coordinates (X, Y, Z).

TR = TriRep(TRI, X) creates a triangulation representation from the triangulation matrix TRI and the vertex coordinates X. TRI is an m-by-n matrix that defines the triangulation in simplex-vertex format, where m is the number of simplices and n is the number of vertices per simplex. Each row of TRI is a simplex defined by indices into the array of vertex coordinates X. X is an mpts-by-ndim matrix where mpts is the number of points and ndim is the dimension of the space where the points reside, where  $2 \leq \text{ndim} \leq 3$ .

**Examples** Load a 3-D tetrahedral triangulation compute the free boundary. First, load triangulation tet and vertex coordinates X.

```
load tetmesh
```

Create the triangulation representation and compute the free boundary.

```
trep = TriRep(tet, X);
[tri, Xb] = freeBoundary(trep);
```

**See Also**

TriScatteredInterp

“Computational Geometry”— A guide to MATLAB’s object-oriented and functional capabilities for computational geometry.

# TriScatteredInterp class

---

**Purpose** Interpolate scattered data

**Description** A scattered data set defined by locations  $X$  and corresponding values  $V$  can be interpolated using a Delaunay triangulation of  $X$ . This produces a surface of the form  $V = F(X)$ . The surface can be evaluated at any query location  $QX$ , using  $QV = F(QX)$ , where  $QX$  lies within the convex hull of  $X$ . The interpolant  $F$  always goes through the data points specified by the sample.

**Definitions** The *Delaunay triangulation* of a set of points is a triangulation such that the unique circle circumscribed about each triangle contains no other points in the set. The *convex hull* of a set of points is the smallest convex set containing all points of the original set. These definitions extend naturally to higher dimensions.

**Construction** TriScatteredInterp

|                   |         |                                                                 |                                |
|-------------------|---------|-----------------------------------------------------------------|--------------------------------|
| <b>Properties</b> | X       | Defines locations of scattered data points in 2-D or 3-D space. |                                |
|                   | V       | Defines value associated with each data point.                  |                                |
|                   | Method  | Defines method used to interpolate the data .                   |                                |
|                   |         | natural                                                         | Natural neighbor interpolation |
| linear            |         | Linear interpolation (default)                                  |                                |
|                   | nearest | Nearest neighbor interpolation                                  |                                |

**Copy Semantics** Value. To learn how this affects your use of the class, see Comparing Handle and Value Classes in the MATLAB Object-Oriented Programming documentation.

## Examples

Create a data set:

```
x = rand(100,1)*4-2;
y = rand(100,1)*4-2;
z = x.*exp(-x.^2-y.^2);
```

Construct the interpolant:

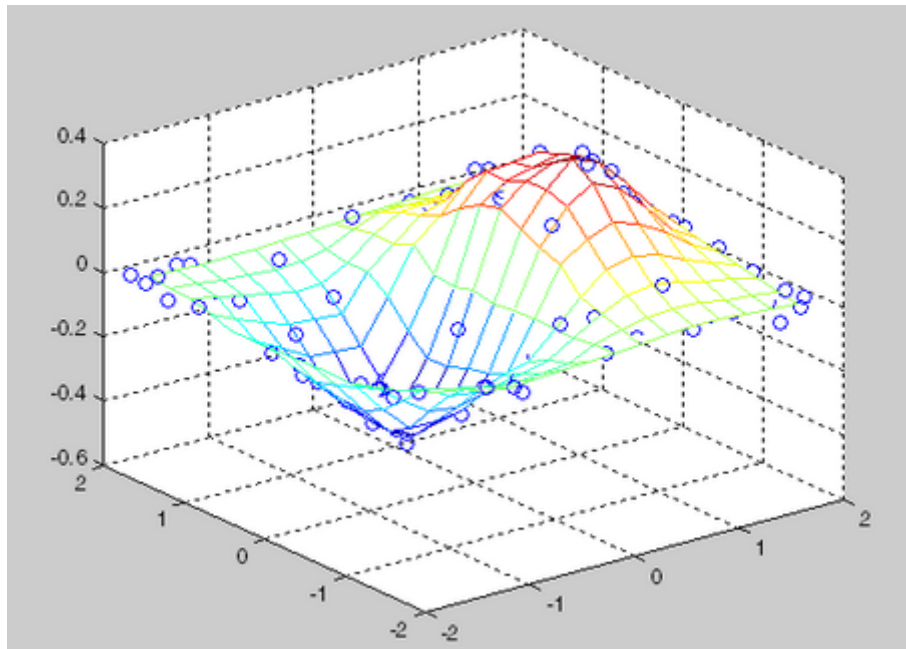
```
F = TriScatteredInterp(x,y,z);
```

Evaluate the interpolant at the locations (qx, qy). The corresponding value at these locations is qz:

```
ti = -2:.25:2;
[qx,qy] = meshgrid(ti,ti);
qz = F(qx,qy);
mesh(qx,qy,qz);
hold on;
plot3(x,y,z,'o');
```

# TriScatteredInterp class

---



## See Also

“Triangulation-Based Interpolation”—Object-oriented syntax for interpolation.

“Triangulations and Scattered Data”—Functional syntax for interpolation.

`DelaunayTri`

`interp1`

`interp2`

`interp3`

`meshgrid`



## Syntax

```
F = TriScatteredInterp()
F = TriScatteredInterp(X, V)
F = TriScatteredInterp(X, Y, V)
F = TriScatteredInterp(X, Y, Z, V)
F = TriScatteredInterp(DT, V)
F = TriScatteredInterp(..., method)
```

## Description

`F = TriScatteredInterp()` creates an empty scattered data interpolant. This can subsequently be initialized with sample data points and values (`Xdata`, `Vdata`) via `F.X = Xdata` and `F.V = Vdata`.

`F = TriScatteredInterp(X, V)` creates an interpolant that fits a surface of the form  $V = F(X)$  to the scattered data in  $(X, V)$ . `X` is a matrix of size `mpts-by-ndim`, where `mpts` is the number of points and `ndim` is the dimension of the space where the points reside,  $ndim \geq 2$ . The column vector `V` defines the values at `X`, where the length of `V` equals `mpts`.

`F = TriScatteredInterp(X, Y, V)` and `F = TriScatteredInterp(X, Y, Z, V)` allow the data point locations to be specified in alternative column vector format when working in 2-D and 3-D.

`F = TriScatteredInterp(DT, V)` uses the specified DelaunayTri object `DT` as a basis for computing the interpolant. The matrix `DT.X` is of size `mpts-by-ndim`, where `mpts` is the number of points and `ndim` is the dimension of the space where the points reside,  $2 \leq ndim \leq 3$ . `V` is a column vector that defines the values at `DT.X`, where the length of `V` equals `mpts`.

`F = TriScatteredInterp(..., method)` allows selection of the technique `method` used to interpolate the data.

## Inputs

|   |                                                                                                                                                                         |
|---|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| X | Matrix of size <code>mpts-by-ndim</code> , where <code>mpts</code> is the number of points and <code>ndim</code> is the dimension of the space where the points reside. |
| V | Column vector that defines the values at <code>X</code> , where the length of <code>V</code> equals <code>mpts</code> .                                                 |

# TriScatteredInterp

---

|        |                                                        |                                |
|--------|--------------------------------------------------------|--------------------------------|
| DT     | Delaunay triangulation of the scattered data locations |                                |
| method | natural                                                | Natural neighbor interpolation |
|        | linear                                                 | Linear interpolation (default) |
|        | nearest                                                | Nearest-neighbor interpolation |

## Outputs

|   |                                                                                          |
|---|------------------------------------------------------------------------------------------|
| F | Creates an interpolant that fits a surface of the form $V = F(X)$ to the scattered data. |
|---|------------------------------------------------------------------------------------------|

## Evaluation

To evaluate the interpolant, express the statement in Monge's form  $V=F(x)$ ,  $V=F(x,y)$ , or  $V=F(x,y,z)$ .

## Definitions

The *Delaunay triangulation* of a set of points is a triangulation such that the unique circle circumscribed about each triangle contains no other points in the set.

## Examples

Create a data set:

```
x = rand(100,1)*4-2;
y = rand(100,1)*4-2;
z = x.*exp(-x.^2-y.^2);
```

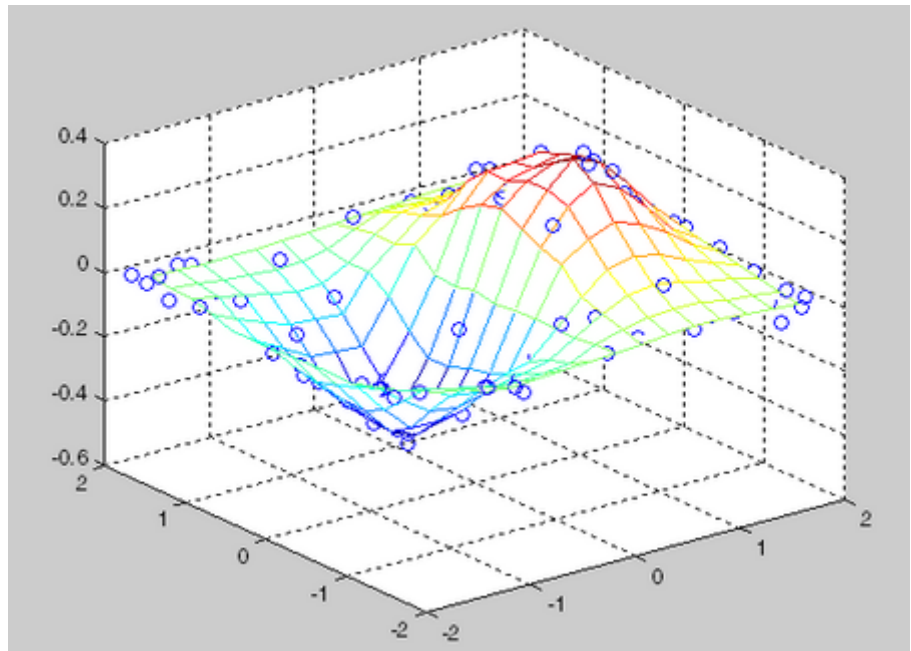
Construct the interpolant:

```
F = TriScatteredInterp(x,y,z);
```

Evaluate the interpolant at the locations (qx, qy). The corresponding value at these locations is qz .

```
ti = -2:.25:2;
[qx,qy] = meshgrid(ti,ti);
qz = F(qx,qy);
mesh(qx,qy,qz);
hold on;
```

```
plot3(x,y,z,'o');
```



## See Also

[DelaunayTri](#)  
[interp1](#)  
[interp2](#)  
[interp3](#)  
[meshgrid](#)

# trisurf

---

**Purpose** Triangular surface plot

**Syntax**

```
trisurf(Tri,X,Y,Z)
trisurf(Tri,X,Y,Z,C)
trisurf(...'PropertyName',PropertyValue...)
h = trisurf(...)
```

**Description**

`trisurf(Tri,X,Y,Z)` displays triangles defined in the  $m$ -by-3 face matrix `Tri` as a surface. Each row of `Tri` defines a single triangular face by indexing into the vectors or matrices that contain the  $X$ ,  $Y$ , and  $Z$  vertices.

`trisurf(Tri,X,Y,Z,C)` specifies color defined by `C` in the same manner as the `surf` function. The MATLAB software performs a linear transformation on this data to obtain colors from the current colormap.

`trisurf(...'PropertyName',PropertyValue...)` specifies additional patch property names and values for the patch graphics object created by the function.

`h = trisurf(...)` returns a patch handle.

**Example** Create vertex vectors and a face matrix, then create a triangular surface plot.

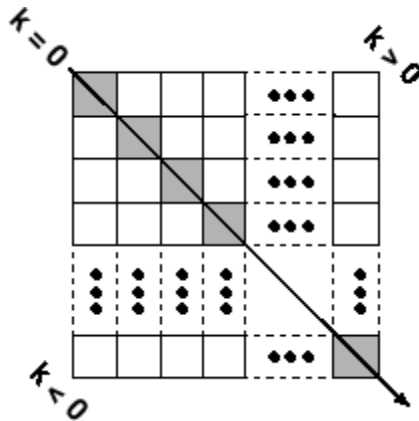
```
x = rand(1,50);
y = rand(1,50);
z = peaks(6*x-3,6*x-3);
tri = delaunay(x,y);
trisurf(tri,x,y,z)
```

**See Also** `patch`, `surf`, `tetramesh`, `trimesh`, `triplot`, `delaunay`  
“Surface and Mesh Creation” on page 1-104 for related functions

**Purpose** Upper triangular part of matrix

**Syntax**  
`U = triu(X)`  
`U = triu(X,k)`

**Description** `U = triu(X)` returns the upper triangular part of `X`.  
`U = triu(X,k)` returns the element on and above the `k`th diagonal of `X`.  
`k = 0` is the main diagonal, `k > 0` is above the main diagonal, and `k < 0` is below the main diagonal.



**Examples** `triu(ones(4,4), -1)`

`ans =`

```

1 1 1 1
1 1 1 1
0 1 1 1
0 0 1 1
```

**See Also** `diag`, `tril`

# true

---

**Purpose** Logical 1 (true)

**Syntax**  
true  
true(n)  
true(m, n)  
true(m, n, p, ...)  
true(size(A))

**Description** true is shorthand for logical 1.  
true(n) is an n-by-n matrix of logical ones.  
true(m, n) or true([m, n]) is an m-by-n matrix of logical ones.  
true(m, n, p, ...) or true([m n p ...]) is an m-by-n-by-p-by-... array of logical ones.

---

**Note** The size inputs m, n, p, ... should be nonnegative integers. Negative integers are treated as 0.

---

true(size(A)) is an array of logical ones that is the same size as array A.

**Remarks** true(n) is much faster and more memory efficient than logical(ones(n)).

**See Also** false, logical

**Purpose** Attempt to execute block of code, and catch errors

**Syntax** try

**Description** try marks the start of a *try block* in a try-catch statement. If the MATLAB software detects an error while executing code in the try block, it immediately jumps to the start of the respective *catch block* and executes the error handling code in that block.

A try-catch statement is a programming device that enables you to define how certain errors are to be handled in your program. This bypasses the default MATLAB error-handling mechanism when these errors are detected. The try-catch statement consists of two blocks of MATLAB code, a *try block* and a *catch block*, delimited by the keywords try, catch, and end:

```
try
 MATLAB commands % Try block
catch ME
 MATLAB commands % Catch block
end
```

Each of these blocks consists of one or more MATLAB commands. The try block is just another piece of your program code; the commands in this block execute just like any other part of your program. Any errors MATLAB encounters in the try block are dealt with by the respective catch block. This is where you write your error-handling code. If the try block executes without error, MATLAB skips the catch block entirely. If an error occurs while executing the catch block, the program terminates unless this error is caught by another try-catch block.

Specifying the try, catch, and end commands, as well as the commands that make up the try and catch blocks, on separate lines is recommended. If you combine any of these components on the same line, separate them with commas:

```
try, surf, catch ME, ME.stack, end
ans =
```

```
file: 'matlabroot\toolbox\matlab\graph3d\surf.m'
name: 'surf'
line: 54
```

where the term *matlabroot* represents the string returned by the `matlabroot` function.

## Examples

The catch block in this example checks to see if the specified file could not be found. If this is the case, the program allows for the possibility that a common variation of the filename extension (e.g., jpeg instead of jpg) was used by retrying the operation with a modified extension. This is done using a try-catch statement that is nested within the original try-catch.

```
function d_in = read_image(filename)
[path name ext] = fileparts(filename);
try
 fid = fopen(filename, 'r');
 d_in = fread(fid);
catch ME1
 % Get last segment of the error message identifier.
 idSegLast = regexp(ME1.identifier, ...
 '(?<=:\w+$', 'match');

 % Did the read fail because the file could not be found?
 if strcmp(idSegLast, 'InvalidFid') && ...
 ~exist(filename, 'file')

 % Yes. Try modifying the filename extension.
 switch ext
 case '.jpg' % Change jpg to jpeg
 filename = strrep(filename, '.jpg', '.jpeg')
 case '.jpeg' % Change jpeg to jpg
 filename = strrep(filename, '.jpeg', '.jpg')
 case '.tif' % Change tif to tiff
 filename = strrep(filename, '.tif', '.tiff')
 case '.tiff' % Change tiff to tif
```



```
 filename = strrep(filename, '.tiff', '.tif')
 otherwise
 fprintf('File %s not found\n', filename);
 rethrow(ME1);
 end

 % Try again, with modified filenames.
 try
 fid = fopen(filename, 'r');
 d_in = fread(fid);
 catch ME2
 fprintf('Unable to access file %s\n', filename);
 ME2 = addCause(ME2, ME1);
 rethrow(ME2)
 end
end
end
```

**See Also**

catch, rethrow, end, lasterror, eval, evalin

# tscollection

---

**Purpose** Create tscollection object

**Syntax**

```
tsc = tscollection(TimeSeries)
tsc = tscollection(Time)
tsc = tscollection(Time,TimeSeries,'Parameter',Value,...)
```

**Description** `tsc = tscollection(TimeSeries)` creates a `tscollection` object `tsc` with one or more `timeseries` objects already in the MATLAB workspace. The argument `TimeSeries` can be a

- Single `timeseries` object
- Cell array of `timeseries` objects

`tsc = tscollection(Time)` creates an empty `tscollection` object with the time vector `Time`. When time values are date strings, you must specify `Time` as a cell array of date strings.

`tsc = tscollection(Time,TimeSeries,'Parameter',Value,...)` creates a `tscollection` object with optional parameter-value pairs you enter after the `Time` and `TimeSeries` arguments. You can specify the following parameter:

- **Name** — String that specifies the name of this `tscollection` object

## Remarks

### Definition: Time Series Collection

A time series collection object is a MATLAB variable that groups several time series with a common time vector. The time series that you include in the collection are called members of this collection.

### Properties of Time Series Collection Objects

This table lists the properties of the `tscollection` object. You can specify the `Time`, `TimeSeries`, and `Name` properties as input arguments in the constructor.

| Property | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
|----------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Name     | tscollection name as a string. This can differ from the tscollection name in the MATLAB workspace.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| Time     | <p>When TimeInfo.StartDate is empty, values are measured relative to 0 . When TimeInfo.StartDate is defined, values represent date strings measured relative to the StartDate.</p> <p>The length of Time must be the same as the first or the last dimension of Data for each collection .</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| TimeInfo | <p>Contains fields for contextual information about Time:</p> <ul style="list-style-type: none"> <li>• <b>Units</b> — Time units with any of the following values: 'weeks', 'days', 'hours', 'minutes', 'seconds', 'milliseconds', 'microseconds', 'nanoseconds'</li> <li>• <b>Start</b> — Start time</li> <li>• <b>End</b> — End time (read only)</li> <li>• <b>Increment</b> — Interval between subsequent time values. NaN when times are not uniformly sampled.</li> <li>• <b>Length</b> — Length of the time vector (read only)</li> <li>• <b>Format</b> — String defining the date string display format. See datestr.</li> <li>• <b>StartDate</b> — Date string defining the reference date. See setabstime (tscollection).</li> <li>• <b>UserData</b> — Any additional user-defined information</li> </ul> |

## Examples

The following example shows how to create a tscollection object.

1 Import the sample data.

```
load count.dat
```

# tscollection

---

**2** Create three `timeseries` objects to store each set of data:

```
count1 = timeseries(count(:,1),1:24,'name', 'ts1');
count2 = timeseries(count(:,2),1:24,'name', 'ts2');
```

**3** Create a `tscollection` object named `tsc` and add to it two out of three time series already in the MATLAB workspace, by using the following syntax:

```
tsc = tscollection({count1 count2},'name','tsc')
```

## See Also

`addts`, `datestr`, `setabstime` (`tscollection`), `timeseries`, `tsprops`

**Purpose** Construct event object for `timeseries` object

**Syntax**

```
e = tsdata.event(Name,Time)
e = tsdata.event(Name,Time,'Datenum')
```

**Description**

`e = tsdata.event(Name,Time)` creates an event object with the specified `Name` that occurs at the time `Time`. `Time` can either be a real value or a date string.

`e = tsdata.event(Name,Time,'Datenum')` uses `'Datenum'` to indicate that the `Time` value is a serial date number generated by the `datenum` function. The `Time` value is converted to a date string after the event is created.

**Remarks** You add events by using the `addevent` method.

Fields of the `tsdata.event` object include the following:

- `EventData` — MATLAB array that stores any user-defined information about the event
- `Name` — String that specifies the name of the event
- `Time` — Time value when this event occurs, specified as a real number
- `Units` — Time units
- `StartDate` — A reference date, specified in MATLAB `datestr` format. `StartDate` is empty when you have a numerical (non-date-string) time vector.

# tsearch

---

**Purpose** Search for enclosing Delaunay triangle

**Syntax** `T = tsearch(x,y,TRI,xi,yi)`

**Description** `T = tsearch(x,y,TRI,xi,yi)` returns an index into the rows of `TRI` for each point in `xi, yi`. The `tsearch` command returns `NaN` for all points outside the convex hull. Requires a triangulation `TRI` of the points `x,y` obtained from `delaunay`.

**See Also** `delaunay`, `delaunayn`, `dsearch`, `tsearchn`

---

|                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
|--------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Purpose</b>     | N-D closest simplex search                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| <b>Syntax</b>      | $t = \text{tsearchn}(X, \text{TES}, XI)$<br>$[t, P] = \text{tsearchn}(X, \text{TES}, XI)$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| <b>Description</b> | <p><math>t = \text{tsearchn}(X, \text{TES}, XI)</math> returns the indices <math>t</math> of the enclosing simplex of the Delaunay tessellation <math>\text{TES}</math> for each point in <math>XI</math>. <math>X</math> is an <math>m</math>-by-<math>n</math> matrix, representing <math>m</math> points in <math>N</math>-dimensional space. <math>XI</math> is a <math>p</math>-by-<math>n</math> matrix, representing <math>p</math> points in <math>N</math>-dimensional space. <math>\text{tsearchn}</math> returns NaN for all points outside the convex hull of <math>X</math>. <math>\text{tsearchn}</math> requires a tessellation <math>\text{TES}</math> of the points <math>X</math> obtained from <code>delaunayn</code>.</p> <p><math>[t, P] = \text{tsearchn}(X, \text{TES}, XI)</math> also returns the barycentric coordinate <math>P</math> of <math>XI</math> in the simplex <math>\text{TES}</math>. <math>P</math> is a <math>p</math>-by-<math>n+1</math> matrix. Each row of <math>P</math> is the Barycentric coordinate of the corresponding point in <math>XI</math>. It is useful for interpolation.</p> |
| <b>Algorithm</b>   | $\text{tsearchn}$ is based on Qhull [1]. For information about Qhull, see <a href="http://www.qhull.org/">http://www.qhull.org/</a> . For copyright information, see <a href="http://www.qhull.org/COPYING.txt">http://www.qhull.org/COPYING.txt</a> .                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| <b>See Also</b>    | <code>delaunayn</code> , <code>griddatan</code> , <code>tsearch</code>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| <b>Reference</b>   | [1] Barber, C. B., D.P. Dobkin, and H.T. Huhdanpaa, "The Quickhull Algorithm for Convex Hulls," <i>ACM Transactions on Mathematical Software</i> , Vol. 22, No. 4, Dec. 1996, p. 469-483.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |

**Purpose** Help on timeseries object properties

**Syntax** help timeseries/tsprops

**Description** help timeseries/tsprops lists the properties of the timeseries object and briefly describes each property.

## Time Series Object Properties

| Property | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
|----------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Data     | <p>Time-series data, where each data sample corresponds to a specific time.</p> <p>The data can be a scalar, a vector, or a multidimensional array. Either the first or last dimension of the data must be aligned with Time.</p> <p>By default, NaNs are used to represent missing or unspecified data. Set the <code>TreatNaNasMissing</code> property to determine how missing data is treated in calculations.</p>                                                                                                                                                                                                                                                                                                                                                                                   |
| DataInfo | <p>Contains fields for storing contextual information about Data:</p> <ul style="list-style-type: none"><li>• <code>Unit</code> — String that specifies data units</li><li>• <code>Interpolation</code> — A <code>tsdata.interpolation</code> object that specifies the interpolation method for this time series.<br/>Fields of the <code>tsdata.interpolation</code> object include:<ul style="list-style-type: none"><li>▪ <code>Fhandle</code> — Function handle to a user-defined interpolation function</li><li>▪ <code>Name</code> — String that specifies the name of the interpolation method. Predefined methods include 'linear' and 'zoh' (zero-order hold). 'linear' is the default.</li></ul></li><li>• <code>UserData</code> — Any user-defined information entered as a string</li></ul> |



## Time Series Object Properties (Continued)

| Property | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
|----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Events   | <p>An array of <code>tsdata.event</code> objects that stores event information for this time series. You add events by using the <code>addevent</code> method.</p> <p>Fields of the <code>tsdata.event</code> object include the following:</p> <ul style="list-style-type: none"><li>• <code>EventData</code> — Any user-defined information about the event</li><li>• <code>Name</code> — String that specifies the name of the event</li><li>• <code>Time</code> — Time value when this event occurs, specified as a real number or a date string</li><li>• <code>Units</code> — Time units</li><li>• <code>StartDate</code> — A reference date specified in MATLAB date-string format. <code>StartDate</code> is empty when you have a numerical (non-date-string) time vector.</li></ul> |

## Time Series Object Properties (Continued)

| Property    | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
|-------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| IsTimeFirst | <p>Logical value (true or false) specifies whether the first or last dimension of the Data array is aligned with the time vector.</p> <p>You can set this property when the Data array is square and it is ambiguous which dimension is aligned with time. By default, the first Data dimension that matches the length of the time vector is aligned with the time vector.</p> <p>When you set this property to:</p> <ul style="list-style-type: none"> <li>• <b>true</b> — The first dimension of the data array is aligned with the time vector. For example:<br/> <code>ts=timeseries(rand(3,3),1:3, 'IsTimeFirst',true);</code></li> <li>• <b>false</b> — The last dimension of the data array is aligned with the time vector. For example:<br/> <code>ts=timeseries(rand(3,3),1:3, 'IsTimeFirst',false);</code></li> </ul> <p>After a time series is created, this property is read only.</p> |
| Name        | <p>Time-series name entered as a string. This name can differ from the name of the time-series variable in the MATLAB workspace.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| Quality     | <p>An integer vector or array containing values -128 to 127 that specifies the quality in terms of codes defined by <code>QualityInfo.Code</code>.</p> <p>When <code>Quality</code> is a vector, it must have the same length as the time vector. In this case, each <code>Quality</code> value applies to a corresponding data sample.</p> <p>When <code>Quality</code> is an array, it must have the same size as the data array. In this case, each <code>Quality</code> value applies to the corresponding value of the data array.</p>                                                                                                                                                                                                                                                                                                                                                          |

## Time Series Object Properties (Continued)

| Property    | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
|-------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| QualityInfo | <p>Provides a lookup table that converts numerical Quality codes to readable descriptions. QualityInfo fields include the following:</p> <ul style="list-style-type: none"><li>• <b>Code</b> — Integer vector containing values -128 to 127 that define the “dictionary” of quality codes, which you can assign to each Data value by using the Quality property</li><li>• <b>Description</b> — Cell vector of strings, where each element provides a readable description of the associated quality Code</li><li>• <b>UserData</b> — Stores any additional user-defined information</li></ul> <p>Lengths of Code and Description must match.</p> |
| Time        | <p>Array of time values.</p> <p>When TimeInfo.StartDate is empty, the numerical Time values are measured relative to 0 in specified units. When TimeInfo.StartDate is defined, the time values are date strings measured relative to the StartDate in specified units.</p> <p>The length of Time must be the same as either the first or the last dimension of Data.</p>                                                                                                                                                                                                                                                                          |

## Time Series Object Properties (Continued)

| Property          | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
|-------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| TimeInfo          | <p>Uses the following fields for storing contextual information about Time:</p> <ul style="list-style-type: none"><li>• <b>Units</b> — Time units can have any of following values: 'weeks', 'days', 'hours', 'minutes', 'seconds', 'milliseconds', 'microseconds', or 'nanoseconds'</li><li>• <b>Start</b> — Start time</li><li>• <b>End</b> — End time (read only)</li><li>• <b>Increment</b> — Interval between two subsequent time values</li><li>• <b>Length</b> — Length of the time vector (read only)</li><li>• <b>Format</b> — String defining the date string display format. See the MATLAB <code>datestr</code> function reference page for more information.</li><li>• <b>StartDate</b> — Date string defining the reference date. See the MATLAB <code>setabstime (timeseries)</code> function reference page for more information.</li><li>• <b>UserData</b> — Stores any additional user-defined information</li></ul> |
| TreatNaNasMissing | <p>Logical value that specifies how to treat NaN values in Data:</p> <ul style="list-style-type: none"><li>• <b>true</b> — (Default) Treat all NaN values as missing data except during statistical calculations.</li><li>• <b>false</b> — Include NaN values in statistical calculations, in which case NaN values are propagated to the result.</li></ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |

**See Also**

`datestr`, `get (timeseries)`, `set (timeseries)`, `setabstime (timeseries)`

# tstool

---

**Purpose** Open Time Series Tools GUI

**Syntax**

```
tstool
tstool(ts)
tstool(tsc)
tstool(sldata)
tstool(ModelDataLogs, 'replace')
```

**Description**

`tstool` starts the Time Series Tools GUI without loading any data.

`tstool(ts)` starts the Time Series Tools GUI and loads the time-series object `ts` from the MATLAB workspace.

`tstool(tsc)` starts the Time Series Tools GUI and loads the time-series collection object `tsc` from the MATLAB workspace.

`tstool(sldata)` starts the Time Series Tools GUI and loads the logged-signal data `sldata` from a Simulink model. If a Simulink logged signal `Name` property contains a `/`, the entire logged signal, including all levels of the signal hierarchy, is not imported into Time Series Tools.

`tstool(ModelDataLogs, 'replace')` replaces the logged-signal data object `ModelDataLogs` in the Time Series Tools GUI with an updated logged signal after you rerun the Simulink model. Use this command to update the `ModelDataLogs` object in the Time Series Tools GUI if you change the model or the logged-signal data settings.

**See Also** `timeseries`, `tscollection`

**Purpose** Display contents of file

**Syntax** `type('filename')`  
`type filename`

**Description** `type('filename')` displays the contents of the specified file in the MATLAB Command Window. Use the full path for `filename`, or use a MATLAB relative `partialpath`.

If you do not specify a file extension and there is no `filename` file without an extension, the `type` function adds the `.m` extension by default. The `type` function checks the directories specified in the MATLAB search path, which makes it convenient for listing the contents of M-files on the screen. Use `type` with `more on` to see the listing one screen at a time.

`type filename` is the command form of the syntax.

**Examples** `type('foo.bar')` lists the contents of the file `foo.bar`.

`type foo` lists the contents of the file `foo`. If `foo` does not exist, `type foo` lists the contents of the file `foo.m`.

**See Also** `cd`, `dbtype`, `delete`, `dir`, `more`, `partialpath`, `path`, `what`, `who`

# typecast

---

**Purpose** Convert data types without changing underlying data

**Syntax** `Y = typecast(X, type)`

**Description** `Y = typecast(X, type)` converts a numeric value in `X` to the data type specified by `type`. Input `X` must be a full, noncomplex, numeric scalar or vector. The `type` input is a string set to one of the following: 'uint8', 'int8', 'uint16', 'int16', 'uint32', 'int32', 'uint64', 'int64', 'single', or 'double'.

`typecast` is different from the MATLAB `cast` function in that it does not alter the input data. `typecast` always returns the same number of bytes in the output `Y` as were in the input `X`. For example, casting the 16-bit integer 1000 to `uint8` with `typecast` returns the full 16 bits in two 8-bit segments (3 and 232) thus keeping its original value ( $3 \times 256 + 232 = 1000$ ). The `cast` function, on the other hand, truncates the input value to 255.

The output of `typecast` can be formatted differently depending on what system you use it on. Some computer systems store data starting with its most significant byte (an ordering called *big-endian*), while others start with the least significant byte (called *little-endian*).

---

**Note** MATLAB issues an error if `X` contains fewer values than are needed to make an output value.

---

## Examples

### Example 1

This example converts between data types of the same size:

```
typecast(uint8(255), 'int8')
ans =
 -1
```

```
typecast(int16(-1), 'uint16')
ans =
```



65535

### Example 2

Set X to a 1-by-3 vector of 32-bit integers, then cast it to an 8-bit integer type:

```
X = uint32([1 255 256])
X =
 1 255 256
```

Running this on a little-endian system produces the following results. Each 32-bit value is divided up into four 8-bit segments:

```
Y = typecast(X, 'uint8')
Y =
 1 0 0 0 255 0 0 0 0 1 0 0
```

The third element of X, 256, exceeds the 8 bits that it is being converted to in Y(9) and thus overflows to Y(10):

```
Y(9:12)
ans =
 0 1 0 0
```

Note that `length(Y)` is equal to `4.*length(X)`. Also note the difference between the output of `typecast` versus that of `cast`:

```
Z = cast(X, 'uint8')
Z =
 1 255 255
```

### Example 3

This example casts a smaller data type (`uint8`) into a larger one (`uint16`). Displaying the numbers in hexadecimal format makes it easier to see just how the data is being rearranged:

```
format hex
X = uint8([44 55 66 77])
X =
```

# typecast

---

```
2c 37 42 4d
```

The first `typecast` is done on a big-endian system. The four 8-bit segments of the input data are combined to produce two 16-bit segments:

```
Y = typecast(X, 'uint16')
Y =
 2c37 424d
```

The second is done on a little-endian system. Note the difference in byte ordering:

```
Y = typecast(X, 'uint16')
Y =
 372c 4d42
```

You can format the little-endian output into big-endian (and vice versa) using the `swapbytes` function:

```
Y = swapbytes(typecast(X, 'uint16'))
Y =
 2c37 424d
```

## Example 4

This example attempts to make a 32-bit value from a vector of three 8-bit values. MATLAB issues an error because there are an insufficient number of bytes in the input:

```
format hex

typecast(uint8([120 86 52]), 'uint32')
??? Too few input values to make output type.

Error in ==> typecast at 29
out = typecastc(in, datatype);
```

Repeat the example, but with a vector of four 8-bit values, and it returns the expected answer:

```
typecast(uint8([120 86 52 18]), 'uint32')
ans =
 12345678
```

**See Also** [cast](#), [class](#), [swapbytes](#)

# uibuttongroup

---

**Purpose** Create container object to exclusively manage radio buttons and toggle buttons

**Syntax** `uibuttongroup('PropertyName1',Value1,'PropertyName2',Value2, ...)`  
`handle = uibuttongroup(...)`

**Description** A `uibuttongroup` groups components and manages exclusive selection behavior for radio buttons and toggle buttons that it contains. It can also contain other user interface controls, axes, `uipanel`s, and `uibuttongroup`s. It cannot contain ActiveX controls.

`uibuttongroup('PropertyName1',Value1,'PropertyName2',Value2,...)` creates a visible container component in the current figure window. This component manages exclusive selection behavior for `uicontrol`s of style `radiobutton` and `togglebutton`.

`handle = uibuttongroup(...)` creates a `uibuttongroup` object and returns a handle to it in `handle`.

A `uibuttongroup` object can have axes, `uicontrol`, `uipanel`, and `uibuttongroup` objects as children. However, only `uicontrol`s of style `radiobutton` and `togglebutton` are managed by the component.

When programming a button group, you do not code callbacks for the individual buttons; instead, use its `SelectionChangeFcn` callback to manage responses to selections. The following example illustrates how you use `uibuttongroup` event data to do this.

For the children of a `uibuttongroup` object, the `Position` property is interpreted relative to the button group. If you move the button group, the children automatically move with it and maintain their positions in the button group.

If you have a button group that contains a set of radio buttons and toggle buttons and you want:

- An immediate action to occur when a radio button or toggle button is selected, you must include the code to control the radio and toggle buttons in the button group's `SelectionChangeFcn` callback function,

not in the individual toggle button `Callback` functions. See the `SelectionChangeFcn` property and the example on this reference page for more information.

- Another component such as a push button to base its action on the selection, then that component's `Callback` callback can get the handle of the selected radio button or toggle button from the button group's `SelectedObject` property.

Use the `Parent` property to specify the parent as a figure, `uipanel`, or `uibuttongroup`. If you do not specify a parent, `uibuttongroup` adds the button group to the current figure. If no figure exists, one is created.

See the `Uibuttongroup Properties` reference page for more information.

After creating a `uibuttongroup`, you can set and query its property values using `set` and `get`. Run `get(handle)` to see a list of properties and their current values. Run `set(handle)` to see a list of object properties you can set and their legal values.

## Remarks

If you set the `Visible` property of a `uibuttongroup` object to `'off'`, any child objects it contains (buttons, button groups, etc.) become invisible along with the `uibuttongroup` panel itself. However, doing this does *not* affect the settings of the `Visible` property of any of its child objects, even though all of them remain invisible until the button group's visibility is set to `'on'`. `uipanel` components also behave in this manner.

## Examples

This example creates a `uibuttongroup` with three radiobuttons. It manages the radiobuttons with the `SelectionChangeFcn` callback, `selcbk`.

When you select a new radio button, `selcbk` displays the `uibuttongroup` handle on one line, the `EventName`, `OldValue`, and `NewValue` fields of the event data structure on a second line, and the value of the `SelectedObject` property on a third line.

```
% Create the button group.
h = uibuttongroup('visible','off','Position',[0 0 .2 1]);
```

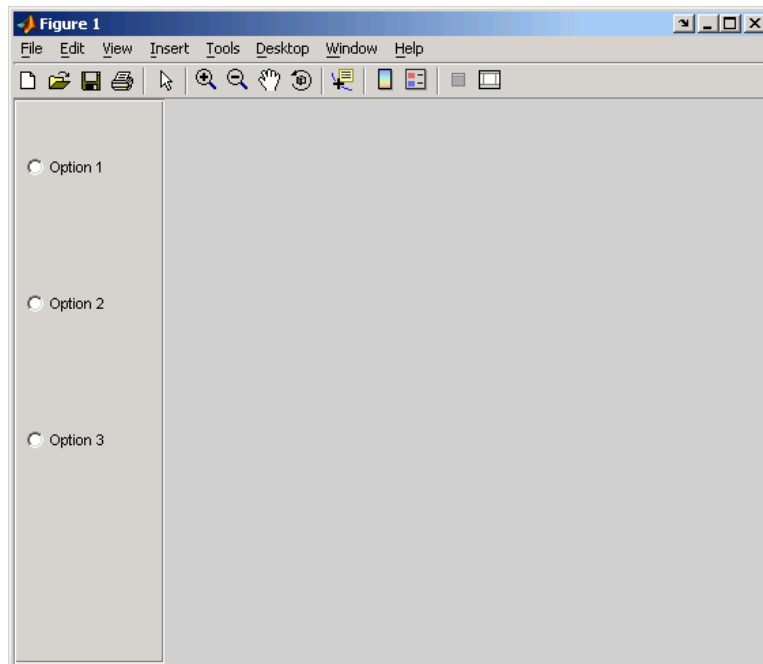
# uibbuttongroup

---

```
% Create three radio buttons in the button group.
u0 = uicontrol('Style','Radio','String','Option 1',...
 'pos',[10 350 100 30],'parent',h,'HandleVisibility','off');
u1 = uicontrol('Style','Radio','String','Option 2',...
 'pos',[10 250 100 30],'parent',h,'HandleVisibility','off');
u2 = uicontrol('Style','Radio','String','Option 3',...
 'pos',[10 150 100 30],'parent',h,'HandleVisibility','off');
% Initialize some button group properties.
set(h,'SelectionChangeFcn',@selcbk);
set(h,'SelectedObject',[]); % No selection
set(h,'Visible','on');
```

For the `SelectionChangeFcn` callback, `selcbk`, the source and event data structure arguments are available only if `selcbk` is called using a function handle. See `SelectionChangeFcn` for more information.

```
function selcbk(source,eventdata)
disp(source);
disp([eventdata.EventName, ' ',...
 get(eventdata.OldValue,'String'),' ', ...
 get(eventdata.NewValue,'String')]);
disp(get(get(source,'SelectedObject'),'String'));
```



If you click Option 2 with no option selected, the `SelectionChangeFcn` callback, `selcbk`, displays:

```
3.0011
```

```
SelectionChanged Option 2
Option 2
```

If you then click Option 1, the `SelectionChangeFcn` callback, `selcbk`, displays:

```
3.0011
```

```
SelectionChanged Option 2 Option 1
Option 1
```

# uibuttongroup

---

**See Also**      `uicontrol`, `uipanel`



**Purpose** Describe button group properties

## Modifying Properties

You can set and query graphics object properties in two ways:

- The Property Inspector is an interactive tool that enables you to see and change object property values. The Property inspector is available from GUIDE, or use the `inspect` function at the command line.
- The `set` and `get` functions enable you to set and query the values of properties.

Uibuttongroup takes its default property values from `uipanel`. To set a `uibuttongroup` default property value, set the default for the corresponding `uipanel` property. Note that you can set no default values for the `uibuttongroup` `SelectedObject` and `SelectionChangeFcn` properties.

For more information about changing the default value of a property see “Setting Default Property Values”. For an example, see the `CreateFcn` property.

**Uibuttongroup Properties** This section describes all properties useful to `uibuttongroup` objects and lists valid values. Curly braces `{ }` enclose default values.

| Property Name                | Description                                |
|------------------------------|--------------------------------------------|
| <code>BackgroundColor</code> | Color of the button group background       |
| <code>BorderType</code>      | Type of border around the button group     |
| <code>BorderWidth</code>     | Width of the button group border in pixels |
| <code>BusyAction</code>      | Interruption of other callback routines    |
| <code>ButtonDownFcn</code>   | Button-press callback routine              |
| <code>Children</code>        | All children of the button group           |

## Uibuttongroup Properties

---

| Property Name      | Description                                                                                                                      |
|--------------------|----------------------------------------------------------------------------------------------------------------------------------|
| Clipping           | Clipping of child axes, panels, and button groups to the button group. Does not affect child user interface controls (uicontrol) |
| CreateFcn          | Callback routine executed during object creation                                                                                 |
| DeleteFcn          | Callback routine executed during object deletion                                                                                 |
| FontAngle          | Title font angle                                                                                                                 |
| FontName           | Title font name                                                                                                                  |
| FontSize           | Title font size                                                                                                                  |
| FontUnits          | Title font units                                                                                                                 |
| FontWeight         | Title font weight                                                                                                                |
| ForegroundColor    | Title font color and color of 2-D border line                                                                                    |
| HandleVisibility   | Handle accessibility from command line and GUIs                                                                                  |
| HighlightColor     | 3-D frame highlight color                                                                                                        |
| Interruptible      | Callback routine interruption mode                                                                                               |
| Parent             | uibuttongroup object's parent                                                                                                    |
| Position           | Button group position relative to parent figure, panel, or button group                                                          |
| ResizeFcn          | User-specified resize routine                                                                                                    |
| Selected           | Whether object is selected                                                                                                       |
| SelectedObject     | Currently selected uicontrol of style radiobutton or togglebutton                                                                |
| SelectionChangeFcn | Callback routine executed when the selected radio button or toggle button changes                                                |
| SelectionHighlight | Object highlighted when selected                                                                                                 |

# Uibuttongroup Properties

| Property Name | Description                                                                                                                                                                                                    |
|---------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| ShadowColor   | 3-D frame shadow color                                                                                                                                                                                         |
| Tag           | User-specified object identifier                                                                                                                                                                               |
| Title         | Title string                                                                                                                                                                                                   |
| TitlePosition | Location of title string in relation to the button group                                                                                                                                                       |
| Type          | Object class                                                                                                                                                                                                   |
| UIContextMenu | Associate context menu with the button group                                                                                                                                                                   |
| Units         | Units used to interpret the position vector                                                                                                                                                                    |
| UserData      | User-specified data                                                                                                                                                                                            |
| Visible       | Button group visibility<br><br><b>Note</b> Controls the visibility of a uibuttongroup and of its child axes, uibuttongroups, uipanel, and child uicontrols. Setting it does not change their Visible property. |

BackgroundColor  
ColorSpec

*Color of the uibuttongroup background.* A three-element RGB vector or one of the MATLAB predefined names, specifying the background color. See the ColorSpec reference page for more information on specifying color.

BorderType  
none | {etchedin} | etchedout |  
beveledin | beveledout | line

*Border of the uibuttongroup area.* Used to define the button group area graphically. Etched and beveled borders provide a 3-D look.

# Uibuttongroup Properties

---

Use the `HighlightColor` and `ShadowColor` properties to specify the border color of etched and beveled borders. A line border is 2-D. Use the `ForegroundColor` property to specify its color.

`BorderWidth`  
integer

*Width of the button group border.* The width of the button group borders in pixels. The default border width is 1 pixel. 3-D borders wider than 3 may not appear correctly at the corners.

`BusyAction`  
cancel | {queue}

*Callback routine interruption.* If a callback is executing and the user triggers an event (such as a mouse click) on an object for which a callback is defined, the callback associated with the new event uses the value of `BusyAction` to decide whether or not to attempt to interrupt the executing callback.

- If the value is `cancel`, the event is discarded and the second callback does not execute.
- If the value is `queue`, and the `Interruptible` property of the first callback is `on`, the second callback is added to the event queue and executes in its turn after the first callback finishes execution.

---

**Note** If the interrupting callback is a `DeleteFcn` or `CreateFcn` callback or a figure's `CloseRequest` or `ResizeFcn` callback, it interrupts an executing callback regardless of the value of that object's `Interruptible` property. See the `Interruptible` property for information about controlling a callback's interruptibility.

---

`ButtonDownFcn`  
string or function handle

*Button-press callback routine.* A callback routine that executes when you press a mouse button while the pointer is in a 5-pixel wide border around the `uibuttongroup`. This is useful for implementing actions to interactively modify object properties, such as size and position, when they are clicked on (using the `selectmoveresize` function, for example).

If you define this routine as a string, the string can be a valid MATLAB expression or the name of an M-file. The expression executes in the MATLAB workspace.

## Children

vector of handles

*Children of the `uibuttongroup`.* A vector containing the handles of all children of the `uibuttongroup`. Although a `uibuttongroup` manages only `uicontrols` of style `radiobutton` and `togglebutton`, its children can be axes, `uipanel`s, `uibuttongroup`s, and other `uicontrol`s. You can use this property to reorder the children.

## Clipping

{on} | off

*Clipping mode.* By default, MATLAB clips a `uibuttongroup`'s child axes, `uipanel`s, and `uibuttongroup`s to the `uibuttongroup` rectangle. If you set `Clipping` to `off`, the axis, `uipanel`, or `uibuttongroup` is displayed outside the button group rectangle. This property does not affect child `uicontrol`s which, by default, can display outside the button group rectangle.

## CreateFcn

string or function handle

*Callback routine executed during object creation.* The specified function executes when MATLAB creates a `uibuttongroup` object. MATLAB sets all property values for the `uibuttongroup` before executing the `CreateFcn` callback so these values are available to

# Uibuttongroup Properties

---

the callback. Within the function, use `gcbo` to get the handle of the `uibuttongroup` being created.

Setting this property on an existing `uibuttongroup` object has no effect.

To define a default `CreateFcn` callback for all new `uibuttongroups` you must define the same default for all `uipanel`s. This default applies unless you override it by specifying a different `CreateFcn` callback when you call `uibuttongroup`. For example, the code

```
set(0,'DefaultUipanelCreateFcn','set(gcbo,...
 'FontSize','arial','FontSize',12)')
```

creates a default `CreateFcn` callback that runs whenever you create a new panel or button group. It sets the default font name and font size of the `uipanel` or `uibuttongroup` title.

To override this default and create a button group whose `FontName` and `FontSize` properties are set to different values, call `uibuttongroup` with code similar to

```
hpt = uibuttongroup(...,'CreateFcn','set(gcbo,...
 'FontName','times','FontSize',14)')
```

---

**Note** To override a default `CreateFcn` callback you must provide a new callback and not just provide different values for the specified properties. This is because the `CreateFcn` callback runs after the property values are set, and can override property values you have set explicitly in the `uibuttongroup` call. In the example above, if instead of redefining the `CreateFcn` property for this `uibuttongroup`, you had explicitly set `FontSize` to 14, the default `CreateFcn` callback would have set `FontSize` back to the system dependent default.

---

Do not call `copyobj` or `textwrap` (which calls `copyobj`) inside a `CreateFcn`. The act of copying the `uicontrol` object fires the `CreateFcn` repeatedly, which raises a series of error messages after exceeding the root object's `RecursionLimit` property.

See “Function Handle Callbacks” for information on how to use function handles to define a callback function.

## DeleteFcn

string or function handle

*Callback routine executed during object deletion.* A callback routine that executes when you delete the `uibuttongroup` object (e.g., when you issue a delete command or clear the figure containing the `uibuttongroup`). MATLAB executes the routine before destroying the object's properties so these values are available to the callback routine. The handle of the object whose `DeleteFcn` is being executed is accessible only through the root `CallbackObject` property, which you can query using `gcb0`.

## FontAngle

{normal} | italic | oblique

*Character slant used in the Title.* MATLAB uses this property to select a font from those available on your particular system. Setting this property to `italic` or `oblique` selects a slanted version of the font, when it is available on your system.

## FontName

string

*Font family used in the Title.* The name of the font in which to display the `Title`. To display and print properly, this must be a font that your system supports. The default font is system dependent. To eliminate the need to hard code the name of a fixed-width font, which may not display text properly on systems that do not use ASCII character encoding (such as in Japan), set

# Uibuttongroup Properties

---

FontName to the string FixedWidth. This string value is case insensitive.

```
set(uicontrol_handle, 'FontName', 'FixedWidth')
```

This then uses the value of the root FixedWidthFontName property, which can be set to the appropriate value for a locale from startup.m in the end user's environment. Setting the root FixedWidthFontName property causes an immediate update of the display to use the new font.

FontSize  
integer

*Title font size.* A number specifying the size of the font in which to display the Title, in units determined by the FontUnits property. The default size is system dependent.

FontUnits  
inches | centimeters | normalized |  
{points} | pixels

*Title font size units.* Normalized units interpret FontSize as a fraction of the height of the uibuttongroup. When you resize the uibuttongroup, MATLAB modifies the screen FontSize accordingly. pixels, inches, centimeters, and points are absolute units (1 point = 1/72 inch).

FontWeight  
light | {normal} | demi | bold

*Weight of characters in the title.* MATLAB uses this property to select a font from those available on your particular system. Setting this property to bold causes MATLAB to use a bold version of the font, when it is available on your system.

ForegroundColor  
ColorSpec



*Color used for title font and 2-D border line.* A three-element RGB vector or one of the MATLAB predefined names, specifying the font or line color. See the `ColorSpec` reference page for more information on specifying color.

## HandleVisibility

{on} | callback | off

*Control access to object's handle.* This property determines when an object's handle is visible in its parent's list of children. When a handle is not visible in its parent's list of children, it is not returned by functions that obtain handles by searching the object hierarchy or querying handle properties. This includes `get`, `findobj`, `gca`, `gcf`, `gco`, `newplot`, `cla`, `clf`, and `close`. Neither is the handle visible in the parent figure's `CurrentObject` property. Handles that are hidden are still valid. If you know an object's handle, you can `set` and `get` its properties, and pass it to any function that operates on handles.

- Handles are always visible when `HandleVisibility` is `on`.
- Setting `HandleVisibility` to `callback` causes handles to be visible from within callback routines or functions invoked by callback routines, but not from within functions invoked from the command line. This provides a means to protect GUIs from command-line users, while allowing callback routines to have complete access to object handles.
- Setting `HandleVisibility` to `off` makes handles invisible at all times. This may be necessary when a callback routine invokes a function that might potentially damage the GUI (such as evaluating a user-typed string), and so temporarily hides its own handles during the execution of that function.

# Uibuttongroup Properties

---

---

**Note** Uicontrols of style `radiobutton` and `togglebutton` that are managed by a `uibuttongroup` should not be accessed outside the button group. Set the `HandleVisibility` of such radio buttons and toggle buttons to `off` or `callback` to prevent inadvertent access.

---

You can set the root `ShowHiddenHandles` property to `on` to make all handles visible, regardless of their `HandleVisibility` settings. This does not affect the values of the `HandleVisibility` properties.

`HighlightColor`  
`ColorSpec`

*3-D frame highlight color.* A three-element RGB vector or one of the MATLAB predefined names, specifying the highlight color. See the `ColorSpec` reference page for more information on specifying color.

`Interruptible`  
{on} | off

*Callback routine interruption mode.* If a callback is executing and the user triggers an event (such as a mouse click) on an object for which a callback is defined, that callback attempts to interrupt the first callback. MATLAB processes the callbacks according to these factors:

- The `Interruptible` property of the object whose callback is executing
- Whether the executing callback contains `drawnow`, `figure`, `getframe`, `pause`, or `waitfor` statements
- The `BusyAction` property of the object whose callback is waiting to execute

If the `Interruptible` property of the object whose callback is executing is `on` (the default), the callback can be interrupted. Whenever the callback calls one of the `drawnow`, `figure`, `getframe`, `pause`, or `waitfor` functions, the function processes any events in the event queue, including the waiting callback, before performing its defined task.

If the `Interruptible` property of the object whose callback is executing is `off`, the callback cannot be interrupted (except by certain callbacks; see the note below). The `BusyAction` property of the object whose callback is waiting to execute determines what happens to the waiting callback.

---

**Note** If the interrupting callback is a `DeleteFcn` or `CreateFcn` callback or a figure's `CloseRequest` or `ResizeFcn` callback, it interrupts an executing callback regardless of the value of that object's `Interruptible` property. The interrupting callback starts execution at the next `drawnow`, `figure`, `getframe`, `pause`, or `waitfor` statement. A figure's `WindowButtonDownFcn` callback routine, or an object's `ButtonDownFcn` or `Callback` routine is processed according to the rules described above.

---

## Parent

`handle`

*Uibuttongroup parent.* The handle of the `uibuttongroup`'s parent figure, `uipanel`, or `uibuttongroup`. You can move a `uibuttongroup` object to another figure, `uipanel`, or `uibuttongroup` by setting this property to the handle of the new parent.

## Position

`position rectangle`

*Size and location of uibuttongroup relative to parent.* The rectangle defined by this property specifies the size and location

# Uibuttongroup Properties

---

of the button group within the parent figure window, uipanel, or uibuttongroup. Specify `Position` as

```
[left bottom width height]
```

`left` and `bottom` are the distance from the lower-left corner of the parent object to the lower-left corner of the `uibuttongroup` object. `width` and `height` are the dimensions of the `uibuttongroup` rectangle, including the title. All measurements are in units specified by the `Units` property.

## `ResizeFcn`

string or function handle

*Resize callback routine.* MATLAB executes this callback routine whenever a user resizes the `uibuttongroup` and the figure `Resize` property is set to `on`, or in GUIDE, the **Resize behavior** option is set to `Other`. You can query the `uibuttongroup Position` property to determine its new size and position. During execution of the callback routine, the handle to the figure being resized is accessible only through the root `CallbackObject` property, which you can query using `gcbo`.

You can use `ResizeFcn` to maintain a GUI layout that is not directly supported by the MATLAB `Position/Units` paradigm.

For example, consider a GUI layout that maintains an object at a constant height in pixels and attached to the top of the figure, but always matches the width of the figure. The following `ResizeFcn` accomplishes this; it keeps the `uicontrol` whose `Tag` is `'StatusBar'` 20 pixels high, as wide as the figure, and attached to the top of the figure. Note the use of the `Tag` property to retrieve the `uicontrol` handle, and the `gcbo` function to retrieve the figure handle. Also note the defensive programming regarding figure `Units`, which the callback requires to be in pixels in order to work correctly, but which the callback also restores to their previous value afterwards.

```
u = findobj('Tag','StatusBar');
fig = gcbo;
old_units = get(fig,'Units');
set(fig,'Units','pixels');
figpos = get(fig,'Position');
upos = [0, figpos(4) - 20, figpos(3), 20];
set(u,'Position',upos);
set(fig,'Units',old_units);
```

You can change the figure `Position` from within the `ResizeFcn` callback; however, the `ResizeFcn` is not called again as a result.

Note that the `print` command can cause the `ResizeFcn` to be called if the `PaperPositionMode` property is set to `manual` and you have defined a resize function. If you do not want your resize function called by `print`, set the `PaperPositionMode` to `auto`.

See “Function Handle Callbacks” for information on how to use function handles to define the callback function.

## Selected

on | off (read only)

*Is object selected?* This property indicates whether the button group is selected. When this property is on, MATLAB displays selection handles if the `SelectionHighlight` property is also on. You can, for example, define the `ButtonDownFcn` function to set this property, allowing users to select the object with the mouse.

## SelectedObject

scalar handle

*Currently selected radio button or toggle button uicontrol* in the managed group of components. Use this property to determine the currently selected component or to initialize selection of one of the radio buttons or toggle buttons. By default, `SelectedObject` is set to the first `uicontrol` radio button or toggle button that is added. Set it to `[]` if you want no selection. Note that

# Uibuttongroup Properties

---

SelectionChangeFcn does not execute when this property is set by the user.

SelectionChangeFcn  
string or function handle

Callback routine executed when the selected radio button or toggle button changes. If this routine is called as a function handle, uibuttongroup passes it two arguments. The first argument, source, is the handle of the uibuttongroup. The second argument, eventdata, is an event data structure that contains the fields shown in the following table.

| Event Data Structure Field | Description                                                               |
|----------------------------|---------------------------------------------------------------------------|
| EventName                  | 'SelectionChanged'                                                        |
| OldValue                   | Handle of the object selected before this event. [] if none was selected. |
| NewValue                   | Handle of the currently selected object.                                  |

If you have a button group that contains a set of radio buttons and/or toggle buttons and you want an immediate action to occur when a radio button or toggle button is selected, you must include the code to control the radio and toggle buttons in the button group's SelectionChangeFcn callback function, not in the individual toggle button Callback functions.

If you want another component such as a push button to base its action on the selection, then that component's Callback callback can get the handle of the selected radio button or toggle button from the button group's SelectedObject property.

---

**Note** For GUIDE GUIs, `hObject` contains the handle of the selected radio button or toggle button. See “Examples: Programming GUIDE GUI Components” for more information.

---

**SelectionHighlight**  
{on} | off

*Object highlighted when selected.* When the **Selected** property is on, MATLAB indicates the selected state by drawing four edge handles and four corner handles. When **SelectionHighlight** is off, MATLAB does not draw the handles.

**ShadowColor**  
ColorSpec

*3-D frame shadow color.* **ShadowColor** is a three-element RGB vector or one of the MATLAB predefined names, specifying the shadow color. See the **ColorSpec** reference page for more information on specifying color.

**Tag**  
string

*User-specified object identifier.* The **Tag** property provides a means to identify graphics objects with a user-specified label. You can define **Tag** as any string.

With the `findobj` function, you can locate an object with a given **Tag** property value. This saves you from defining object handles as global variables. For example, this function call returns the handles of all children (of the specified figures) that have the **Tag** value 'FormatTb'.

```
h = findobj(figurehandles,'Tag','FormatTb')
```

# Uibuttongroup Properties

---

## Title

string

*Title string.* The text displayed in the button group title. You can position the title using the `TitlePosition` property.

If the string value is specified as a cell array of strings or padded string matrix, only the first string in the cell array or padded string matrix is displayed; the rest are ignored. Vertical slash (`'\'`) characters are not interpreted as line breaks and instead show up in the text displayed in the `uibuttongroup` title.

Setting a property value to `default`, `remove`, or `factory` produces the effect described in “Defining Default Values”. To set `Title` to one of these words, you must precede the word with the backslash character. For example,

```
hp = uibuttongroup(...,'Title','\Default');
```

## TitlePosition

{lefttop} | centertop | righttop |  
leftbottom | centerbottom | rightbottom

*Location of the title.* This property determines the location of the title string, in relation to the `uibuttongroup`.

## Type

string (read-only)

*Object class.* This property identifies the kind of graphics object. For `uibuttongroup` objects, `Type` is always the string `'uibuttongroup'`.

## UIContextMenu

handle

*Associate a context menu with a uibuttongroup.* Assign this property the handle of a `Uicontextmenu` object. MATLAB displays



the context menu whenever you right-click the `uibuttongroup`. Use the `uicontextmenu` function to create the context menu.

## Units

`inches` | `centimeters` | `{normalized}` |  
`points` | `pixels` | `characters`

*Units of measurement.* MATLAB uses these units to interpret the `Position` property. For the button group itself, units are measured from the lower-left corner of its parent figure window, panel, or button group. For children of the button group, they are measured from the lower-left corner of the button group.

- Normalized units map the lower-left corner of the button group or figure window to (0,0) and the upper-right corner to (1.0,1.0).
- pixels, inches, centimeters, and points are absolute units (1 point = 1/72 inch).
- Character units are characters using the default system font; the width of one character is the width of the letter x, the height of one character is the distance between the baselines of two lines of text.

If you change the value of `Units`, it is good practice to return it to its default value after completing your computation so as not to affect other functions that assume `Units` is set to the default value.

## UserData

matrix

*User-specified data.* Any data you want to associate with the `uibuttongroup` object. MATLAB does not use this data, but you can access it using `set` and `get`.

## Visible

`{on}` | `off`

## Uibuttongroup Properties

---

*Uibuttongroup visibility.* By default, a `uibuttongroup` object is visible. When set to 'off', the `uibuttongroup` is not visible, as are all child objects of the button group. When a button group is hidden in this manner, you can still query and set its properties.

---

**Note** The value of a `uibuttongroup`'s `Visible` property determines whether its child components, such as axes, buttons, `uipanel`s, and other `uibuttongroup`s, are visible. However, changing the `Visible` property of a button group does *not* change the settings of the `Visible` property of its child components even though hiding the button group causes them to be hidden.

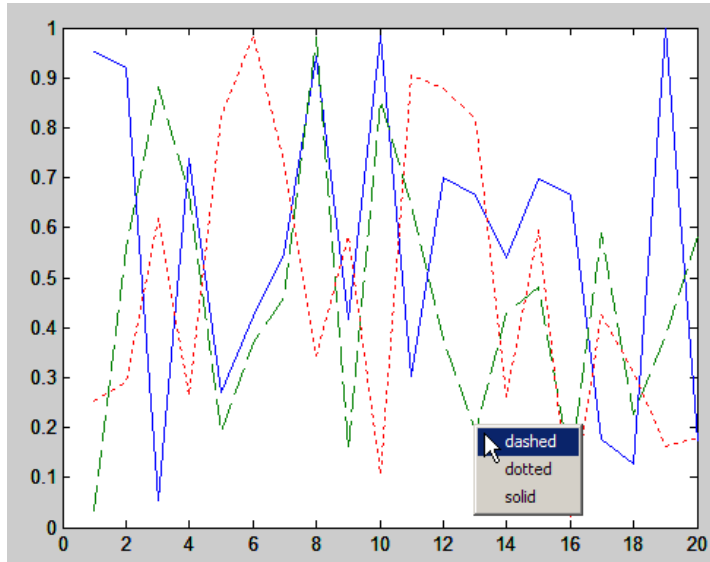
---

|                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
|--------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Purpose</b>     | Create context menu                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| <b>Syntax</b>      | <code>handle = uicontextmenu('PropertyName',PropertyValue,...)</code>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| <b>Description</b> | <p><code>handle = uicontextmenu('PropertyName',PropertyValue,...)</code> creates a context menu, which is a menu that appears when the user right-clicks on a graphics object. See the Uicontextmenu Properties reference page for more information.</p> <p>You create context menu items using the <code>uimenu</code> function. Menu items appear in the order the <code>uimenu</code> statements appear. You associate a context menu with an object using the <code>UIContextMenu</code> property for the object and specifying the context menu's handle as the property value.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| <b>Example</b>     | <p>These statements define a context menu associated with a line. When the user right clicks or presses <b>Alt+click</b> anywhere on the line, the menu appears. Menu items enable the user to change the line style.</p> <pre>% Create axes and save handle hax = axes; % Plot three lines plot(rand(20,3)); % Define a context menu; it is not attached to anything hcmenu = uicontextmenu; % Define callbacks for context menu items that change linestyle hcb1 = ['set(gcf, ''LineStyle'', ''--'')']; hcb2 = ['set(gcf, ''LineStyle'', '':'')']; hcb3 = ['set(gcf, ''LineStyle'', ''-'')']; % Define the context menu items and install their callbacks item1 = uimenu(hcmenu, 'Label', 'dashed', 'Callback', hcb1); item2 = uimenu(hcmenu, 'Label', 'dotted', 'Callback', hcb2); item3 = uimenu(hcmenu, 'Label', 'solid', 'Callback', hcb3); % Locate line objects hlines = findall(hax,'Type','line'); % Attach the context menu to each line for line = 1:length(hlines)     set(hlines(line),'uicontextmenu',hcmenu)</pre> |

# uicontextmenu

```
end
```

When the user right clicks or presses **Alt+click** on the line, the context menu appears, as shown in this figure:



Generally, you need to attach context menus to lines at the time they are plotted in order to be sure that the menus are available to users at once. Therefore, code such as the above could be placed in or called from the callbacks that perform plotting for the GUI.

You should only define callbacks as strings if they need to perform simple actions. For example, if you wanted to add check marks to menu items (using the `Checked` uimenu property) to indicate the current style for a each line, you should define the menu item callbacks as function handles and place the code for them in the GUI's M-file rather than placing callback strings in the figure.

## See Also

“Context Menus” in the MATLAB Creating Graphical User Interfaces documentation

`uibuttongroup, uicontrol, uimenu, uipanel`

# Uicontextmenu Properties

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## Purpose

Describe context menu properties

## Modifying Properties

You can set and query graphics object properties in two ways:

- The Property Inspector is an interactive tool that enables you to see and change object property values. The Property inspector is available from GUIDE, or use the `inspect` function at the command line.
- The `set` and `get` functions enable you to set and query the values of properties.

For more information about changing the default value of a property see “Setting Default Property Values”. For an example, see the `CreateFcn` property.

## Uicontextmenu Properties

This section lists all properties useful to `uicontextmenu` objects along with valid values and descriptions of their use. Curly braces `{}` enclose default values.

| Property                      | Purpose                                                              |
|-------------------------------|----------------------------------------------------------------------|
| <code>BusyAction</code>       | Callback routine interruption                                        |
| <code>Callback</code>         | Control action                                                       |
| <code>Children</code>         | The <code>uimenu</code> s defined for the <code>uicontextmenu</code> |
| <code>CreateFcn</code>        | Callback routine executed during object creation                     |
| <code>DeleteFcn</code>        | Callback routine executed during object deletion                     |
| <code>HandleVisibility</code> | Whether handle is accessible from command line and GUIs              |
| <code>Interruptible</code>    | Callback routine interruption mode                                   |
| <code>Parent</code>           | <code>Uicontextmenu</code> object’s parent                           |

# Uicontextmenu Properties

---

| Property | Purpose                                             |
|----------|-----------------------------------------------------|
| Position | Location of uicontextmenu when Visible is set to on |
| Tag      | User-specified object identifier                    |
| Type     | Class of graphics object                            |
| UserData | User-specified data                                 |
| Visible  | Uicontextmenu visibility                            |

## BusyAction

cancel | {queue}

*Callback routine interruption.* If a callback is executing and the user triggers an event (such as a mouse click) on an object for which a callback is defined, the callback associated with the new event uses the value of **BusyAction** to decide whether or not to attempt to interrupt the executing callback.

- If the value is **cancel**, the event is discarded and the second callback does not execute.
- If the value is **queue**, and the **Interruptible** property of the first callback is **on**, the second callback is added to the event queue and executes in its turn after the first callback finishes execution.

---

**Note** If the interrupting callback is a **DeleteFcn** or **CreateFcn** callback or a figure's **CloseRequest** or **ResizeFcn** callback, it interrupts an executing callback regardless of the value of that object's **Interruptible** property. See the **Interruptible** property for information about controlling a callback's interruptibility.

---

# Uicontextmenu Properties

---

Callback  
string

*Control action.* A routine that executes whenever you right-click an object for which a context menu is defined. The routine executes immediately before the context menu is posted. Define this routine as a string that is a valid MATLAB expression or the name of an M-file. The expression executes in the MATLAB workspace.

Children  
matrix

The uimenu items defined for the uicontextmenu.

CreateFcn  
string or function handle

*Callback routine executed during object creation.* The specified function executes when MATLAB creates a uicontextmenu object. MATLAB sets all property values for the uicontextmenu before executing the CreateFcn callback so these values are available to the callback. Within the function, use `gcbo` to get the handle of the uicontextmenu being created.

Setting this property on an existing uicontextmenu object has no effect.

You can define a default CreateFcn callback for all new uicontextmenus. This default applies unless you override it by specifying a different CreateFcn callback when you call `uicontextmenu`. For example, the code

```
set(0, 'DefaultUicontextmenuCreateFcn', 'set(gcbo, ...
 'Visible','on')')
```



creates a default `CreateFcn` callback that runs whenever you create a new context menu. It sets the default `Visible` property of a context menu.

To override this default and create a context menu whose `Visible` property is set to a different value, call `uicontextmenu` with code similar to

```
hpt = uicontextmenu(...,'CreateFcn','set(gcbo,...
 'Visible','off')')
```

---

**Note** To override a default `CreateFcn` callback you must provide a new callback and not just provide different values for the specified properties. This is because the `CreateFcn` callback runs after the property values are set, and can override property values you have set explicitly in the `uicontextmenu` call. In the example above, if instead of redefining the `CreateFcn` property for this `uicontextmenu`, you had explicitly set `Visible` to `off`, the default `CreateFcn` callback would have set `Visible` back to the default, i.e., `on`.

---

Do not call `copyobj` or `textwrap` (which calls `copyobj`) inside a `CreateFcn`. The act of copying the `uicontrol` object fires the `CreateFcn` repeatedly, which raises a series of error messages after exceeding the root object's `RecursionLimit` property.

See “Function Handle Callbacks” for information on how to use function handles to define a callback function.

### DeleteFcn

string or function handle

*Delete uicontextmenu callback routine.* A callback routine that executes when you delete the `uicontextmenu` object (e.g., when you issue a `delete` command or clear the figure containing the `uicontextmenu`). MATLAB executes the routine before destroying

# Uicontextmenu Properties

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the object's properties so these values are available to the callback routine.

The handle of the object whose `DeleteFcn` is being executed is accessible only through the root `CallbackObject` property, which you can query using `gcbo`.

See “Function Handle Callbacks” for information on how to use function handles to define a callback function.

## HandleVisibility

{on} | callback | off

*Control access to object's handle.* This property determines when an object's handle is visible in its parent's list of children. When a handle is not visible in its parent's list of children, it is not returned by functions that obtain handles by searching the object hierarchy or querying handle properties. This includes `get`, `findobj`, `gca`, `gcf`, `gco`, `newplot`, `cla`, `clf`, and `close`. Neither is the handle visible in the parent figure's `CurrentObject` property. Handles that are hidden are still valid. If you know an object's handle, you can `set` and `get` its properties, and pass it to any function that operates on handles.

- Handles are always visible when `HandleVisibility` is `on`.
- Setting `HandleVisibility` to `callback` causes handles to be visible from within callback routines or functions invoked by callback routines, but not from within functions invoked from the command line. This provides a means to protect GUIs from command-line users, while allowing callback routines to have complete access to object handles.
- Setting `HandleVisibility` to `off` makes handles invisible at all times. This may be necessary when a callback routine invokes a function that might potentially damage the GUI (such as evaluating a user-typed string), and so temporarily hides its own handles during the execution of that function.

You can set the root `ShowHiddenHandles` property to `on` to make all handles visible, regardless of their `HandleVisibility` settings. This does not affect the values of the `HandleVisibility` properties.

**Interruptible**  
{on} | off

*Callback routine interruption mode.* If a callback is executing and the user triggers an event (such as a mouse click) on an object for which a callback is defined, that callback attempts to interrupt the first callback. MATLAB processes the callbacks according to these factors:

- The `Interruptible` property of the object whose callback is executing
- Whether the executing callback contains `drawnow`, `figure`, `getframe`, `pause`, or `waitfor` statements
- The `BusyAction` property of the object whose callback is waiting to execute

If the `Interruptible` property of the object whose callback is executing is `on` (the default), the callback can be interrupted. Whenever the callback calls one of the `drawnow`, `figure`, `getframe`, `pause`, or `waitfor` functions, the function processes any events in the event queue, including the waiting callback, before performing its defined task.

If the `Interruptible` property of the object whose callback is executing is `off`, the callback cannot be interrupted (except by certain callbacks; see the note below). The `BusyAction` property of the object whose callback is waiting to execute determines what happens to the callback.

# Uicontextmenu Properties

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---

**Note** If the interrupting callback is a `DeleteFcn` or `CreateFcn` callback or a figure's `CloseRequest` or `ResizeFcn` callback, it interrupts an executing callback regardless of the value of that object's `Interruptible` property. The interrupting callback starts execution at the next `drawnow`, `figure`, `getframe`, `pause`, or `waitfor` statement. A figure's `WindowButtonDownFcn` callback routine, or an object's `ButtonDownFcn` or `Callback` routine are processed according to the rules described above.

---

Parent  
handle

*Uicontextmenu's parent.* The handle of the `uicontextmenu`'s parent object, which must be a figure.

Position  
vector

*Uicontextmenu's position.* A two-element vector that defines the location of a context menu posted by setting the `Visible` property value to `on`. Specify `Position` as

[x y]

where vector elements represent the horizontal and vertical distances in pixels from the bottom left corner of the figure window, panel, or button group to the top left corner of the context menu.

Tag  
string

*User-specified object label.* The `Tag` property provides a means to identify graphics objects with a user-specified label. This is particularly useful when constructing interactive graphics programs that would otherwise need to define object handles as

global variables or pass them as arguments between callback routines. You can define `Tag` as any string.

## Type

string

*Class of graphics object.* For `uicontextmenu` objects, `Type` is always the string `'uicontextmenu'`.

## UserData

matrix

*User-specified data.* Any data you want to associate with the `uicontextmenu` object. MATLAB does not use this data, but you can access it using `set` and `get`.

## Visible

on | {off}

*Uicontextmenu visibility.* The `Visible` property can be used in two ways:

- Its value indicates whether the context menu is currently posted. While the context menu is posted, the property value is `on`; when the context menu is not posted, its value is `off`.
- Its value can be set to `on` to force the posting of the context menu. Similarly, setting the value to `off` forces the context menu to be removed. When used in this way, the `Position` property determines the location of the posted context menu.

# uicontrol

---

**Purpose** Create user interface control object

**Syntax**

```
handle = uicontrol('PropertyName',PropertyValue,...)
handle = uicontrol(parent,'PropertyName',PropertyValue,...)
handle = uicontrol
uicontrol(uich)
```

**Description** `uicontrol` creates a `uicontrol` graphics objects (user interface controls), which you use to implement graphical user interfaces.

`handle = uicontrol('PropertyName',PropertyValue,...)` creates a `uicontrol` and assigns the specified properties and values to it. It assigns the default values to any properties you do not specify. The default `uicontrol` style is a pushbutton. The default parent is the current figure. See the `Uicontrol Properties` reference page for more information.

`handle = uicontrol(parent,'PropertyName',PropertyValue,...)` creates a `uicontrol` in the object specified by the `handle, parent`. If you also specify a different value for the `Parent` property, the value of the `Parent` property takes precedence. `parent` can be the handle of a figure, `uipanel`, or `uibbuttongroup`.

`handle = uicontrol` creates a pushbutton in the current figure. The `uicontrol` function assigns all properties their default values.

`uicontrol(uich)` gives focus to the `uicontrol` specified by the `handle, uich`.

When selected, most `uicontrol` objects perform a predefined action. MATLAB software supports numerous styles of `uicontrols`, each suited for a different purpose:

- Check boxes
- Editable text fields
- Frames
- List boxes

- Pop-up menus
- Push buttons
- Radio buttons
- Sliders
- Static text labels
- Toggle buttons

For information on using these uicontrols within GUIDE, the MATLAB GUI development environment, see Examples: Programming GUI Components in the MATLAB Creating GUIs documentation

### Specifying the Uicontrol Style

To create a specific type of uicontrol, set the `Style` property as one of the following strings:

- `'checkbox'` – Check boxes generate an action when selected. These devices are useful when providing the user with a number of independent choices. To activate a check box, click the mouse button on the object. The state of the device is indicated on the display.
- `'edit'` – Editable text fields enable users to enter or modify text values. Use editable text when you want text as input. If `Max-Min>1`, then multiple lines are allowed. For multi-line edit boxes, a vertical scrollbar enables scrolling, as do the arrow keys.
- `'frame'` – Frames are rectangles that provide a visual enclosure for regions of a figure window. Frames can make a user interface easier to understand by grouping related controls. Frames have no callback routines associated with them. Only other uicontrols can appear within frames.

Frames are opaque, not transparent, so the order in which you define uicontrols is important in determining whether uicontrols within a frame are covered by the frame or are visible. *Stacking order* determines the order objects are drawn: objects defined first are drawn first; objects defined later are drawn over existing objects. If

you use a frame to enclose objects, you must define the frame before you define the objects.

---

**Note** Most frames in existing GUIs can now be replaced with panels (`uipanel`) or button groups (`uibuttongroup`). GUIDE continues to support frames in those GUIs that contain them, but the frame component does not appear in the GUIDE Layout Editor component palette.

---

- 'listbox' – List boxes display a list of items and enable users to select one or more items. The `Min` and `Max` properties control the selection mode:

If `Max-Min>1`, then multiple selection is allowed.

If `Max-Min<=1`, then only single selection is allowed.

The `Value` property indicates selected entries and contains the indices into the list of strings; a vector value indicates multiple selections. MATLAB evaluates the list box's callback routine after any mouse button up event that changes the `Value` property. Therefore, you may need to add a "Done" button to delay action caused by multiple clicks on list items.

List boxes whose `Enable` property is on differentiate between single and double left clicks and set the figure `SelectionType` property to `normal` or `open` accordingly before evaluating the list box's `Callback` property. For such list boxes, **Ctrl**-left click and **Shift**-left click also set the figure `SelectionType` property to `normal` or `open` to indicate a single or double click.

- 'popupmenu' – Pop-up menus (also known as drop-down menus or combo boxes) open to display a list of choices when pressed. When not open, a pop-up menu indicates the current choice. Pop-up menus are useful when you want to provide users with a number of mutually exclusive choices, but do not want to take up the amount of space that a series of radio buttons requires.



- 'pushbutton' – Push buttons generate an action when pressed. To activate a push button, click the mouse button on the push button.
- 'radiobutton' – Radio buttons are similar to check boxes, but are intended to be mutually exclusive within a group of related radio buttons (i.e., only one is in a pressed state at any given time). To activate a radio button, click the mouse button on the object. The state of the device is indicated on the display. Note that your code can implement mutually exclusive behavior for radio buttons.
- 'slider' – Sliders accept numeric input within a specific range by enabling the user to move a sliding bar. Users move the bar by pressing the mouse button and dragging the pointer over the bar, or by clicking in the trough or on an arrow. The location of the bar indicates a numeric value, which is selected by releasing the mouse button. You can set the minimum, maximum, and current values of the slider.
- 'text' – Static text boxes display lines of text. Static text is typically used to label other controls, provide directions to the user, or indicate values associated with a slider. Users cannot change static text interactively and there is no way to invoke the callback routine associated with it.
- 'togglebutton' – Toggle buttons are controls that execute callbacks when clicked on and indicate their state, either on or off. Toggle buttons are useful for building toolbars.

## Remarks

- Adding a uicontrol to a figure removes the figure toolbar when the figure's `Toolbar` property is set to 'auto' (which is the default). To prevent this from happening, set the `Toolbar` property to 'figure'. The user can restore the toolbar by selecting **Figure Toolbar** from the **View** menu regardless of this property setting.
- The `uicontrol` function accepts property name/property value pairs, structures, and cell arrays as input arguments and optionally returns the handle of the created object. You can also set and query property values after creating the object using the `set` and `get` functions.

- A `uicontrol` object is a child of a `figure`, `uipanel`, or `uibuttongroup` and therefore does not require an axes to exist when placed in a figure window, `uipanel`, or `uibuttongroup`.
- When MATLAB is paused and a `uicontrol` has focus, pressing a keyboard key does not cause MATLAB to resume. Click anywhere outside a `uicontrol` and then press any key. See the `pause` function for more information.

## Examples

### Example 1

The following statement creates a push button that clears the current axes when pressed.

```
h = uicontrol('Style', 'pushbutton', 'String', 'Clear',...
 'Position', [20 150 100 70], 'Callback', 'cla');
```

This statement gives focus to the pushbutton.

```
uicontrol(h)
```

### Example 2

You can create a `uicontrol` object that changes figure colormaps by specifying a pop-up menu and supplying an M-file name as the object's `Callback`:

```
hpop = uicontrol('Style', 'popup',...
 'String', 'hsv|hot|cool|gray',...
 'Position', [20 320 100 50],...
 'Callback', 'setmap');
```

The above call to `uicontrol` defines four individual choices in the menu: `hsv`, `hot`, `cool`, and `gray`. You specify these choices with the `String` property, separating the choices with the `"|"` character.

The `Callback`, in this case `setmap`, is the name of an M-file that defines a more complicated set of instructions than a single MATLAB command. `setmap` contains these statements:

```
val = get(hpop, 'Value');
```

```
if val == 1
 colormap(hsv)
elseif val == 2
 colormap(hot)
elseif val == 3
 colormap(cool)
elseif val == 4
 colormap(gray)
end
```

The `Value` property contains a number that indicates the selected choice. The choices are numbered sequentially from one to four. The `setmap` M-file can get and then test the contents of the `Value` property to determine what action to take.

**See Also**

`textwrap`, `uibbuttongroup`, `uimenu`, `uipanel`

# Uicontrol Properties

---

## Purpose

Describe user interface control (`uicontrol`) properties

## Modifying Properties

You can set and query graphics object properties in two ways:

- The Property Inspector is an interactive tool that enables you to see and change object property values. The Property inspector is available from GUIDE, or use the `inspect` function at the command line.
- The `set` and `get` commands enable you to set and query the values of properties

To change the default value of properties see “Setting Default Property Values”. You can also set default `uicontrol` properties on the root and figure levels:

```
set(0, 'DefaultUicontrolProperty', PropertyValue...)
set(gcf, 'DefaultUicontrolProperty', PropertyValue...)
```

where *Property* is the name of the `uicontrol` property whose default value you want to set and *PropertyValue* is the value you are specifying as the default. Use `set` and `get` to access `uicontrol` properties.

For information on using these `uicontrols` within GUIDE, the MATLAB GUI development environment, see Programming GUI Components in the MATLAB Creating GUIs documentation.

## Uicontrol Properties

This section lists all properties useful to `uicontrol` objects along with valid values and descriptions of their use. Curly braces `{}` enclose default values.

| Property                     | Purpose                       |
|------------------------------|-------------------------------|
| <code>BackgroundColor</code> | Object background color       |
| <code>BusyAction</code>      | Callback routine interruption |
| <code>ButtonDownFcn</code>   | Button-press callback routine |
| <code>Callback</code>        | Control action                |

# Uicontrol Properties

| <b>Property</b>     | <b>Purpose</b>                                          |
|---------------------|---------------------------------------------------------|
| CData               | Truecolor image displayed on the control                |
| Children            | Uicontrol objects have no children                      |
| CreateFcn           | Callback routine executed during object creation        |
| DeleteFcn           | Callback routine executed during object deletion        |
| Enable              | Enable or disable the uicontrol                         |
| Extent              | position rectangle (read only)                          |
| FontAngle           | Character slant                                         |
| FontName            | Font family                                             |
| FontSize            | Font size                                               |
| FontUnits           | Font size units                                         |
| FontWeight          | Weight of text characters                               |
| ForegroundColor     | Color of text                                           |
| HandleVisibility    | Whether handle is accessible from command line and GUIs |
| HitTest             | Whether selectable by mouse click                       |
| HorizontalAlignment | Alignment of label string                               |
| Interruptible       | Callback routine interruption mode                      |
| KeyPressFcn         | Key press callback routine                              |
| ListboxTop          | Index of top-most string displayed in list box          |
| Max                 | Maximum value (depends on uicontrol object)             |
| Min                 | Minimum value (depends on uicontrol object)             |
| Parent              | Uicontrol object's parent                               |

# Uicontrol Properties

---

| Property           | Purpose                                                     |
|--------------------|-------------------------------------------------------------|
| Position           | Size and location of uicontrol object                       |
| Selected           | Whether object is selected                                  |
| SelectionHighlight | Object highlighted when selected                            |
| SliderStep         | Slider step size                                            |
| String             | Uicontrol object label, also list box and pop-up menu items |
| Style              | Type of uicontrol object                                    |
| Tag                | User-specified object identifier                            |
| TooltipString      | Content of object's tooltip                                 |
| Type               | Class of graphics object                                    |
| UIContextMenu      | Uicontextmenu object associated with the uicontrol          |
| Units              | Units to interpret position vector                          |
| UserData           | User-specified data                                         |
| Value              | Current value of uicontrol object                           |
| Visible            | Uicontrol visibility                                        |

BackgroundColor  
ColorSpec

*Object background color.* The color used to fill the uicontrol rectangle. Specify a color using a three-element RGB vector or one of the MATLAB predefined names. The default color is determined by system settings. See ColorSpec for more information on specifying color.

---

**Note** On Solaris 2 systems, setting the background color of a slider has no effect.

---

## BusyAction

cancel | {queue}

*Callback routine interruption.* If a callback is executing and the user triggers an event (such as a mouse click) on an object for which a callback is defined, the callback associated with the new event uses the value of `BusyAction` to decide whether or not to attempt to interrupt the executing callback.

- If the value is `cancel`, the event is discarded and the second callback does not execute.
- If the value is `queue`, and the `Interruptible` property of the first callback is `on`, the second callback is added to the event queue and executes in its turn after the first callback finishes execution.

---

**Note** If the interrupting callback is a `DeleteFcn` or `CreateFcn` callback or a figure's `CloseRequest` or `ResizeFcn` callback, it interrupts an executing callback regardless of the value of that object's `Interruptible` property. See the `Interruptible` property for information about controlling a callback's interruptibility.

---

## ButtonDownFcn

string or function handle (GUIDE sets this property)

*Button-press callback routine.* A callback routine that can execute when you press a mouse button while the pointer is on or near a uicontrol. Specifically:

# Uicontrol Properties

---

- If the uicontrol's `Enable` property is set to `on`, the `ButtonDownFcn` callback executes when you click the right or left mouse button in a 5-pixel border around the uicontrol or when you click the right mouse button on the control itself.
- If the uicontrol's `Enable` property is set to `inactive` or `off`, the `ButtonDownFcn` executes when you click the right or left mouse button in the 5-pixel border or on the control itself.

This is useful for implementing actions to interactively modify control object properties, such as size and position, when they are clicked on (using `selectmoveresize`, for example).

Define this routine as a string that is a valid MATLAB expression or the name of an M-file. The expression executes in the MATLAB workspace.

To add a `ButtonDownFcn` callback in GUIDE, select **View Callbacks** from the Layout Editor **View** menu, then select `ButtonDownFcn`. GUIDE sets this property to the appropriate string and adds the callback to the M-file the next time you save the GUI. Alternatively, you can set this property to the string `%automatic`. The next time you save the GUI, GUIDE sets this property to the appropriate string and adds the callback to the M-file.

Use the `Callback` property to specify the callback routine that executes when you activate the enabled uicontrol (e.g., click a push button).

## Callback

string or function handle (GUIDE sets this property)

*Control action.* A routine that executes whenever you activate the uicontrol object (e.g., when you click on a push button or move a slider). Define this routine as a string that is a valid MATLAB expression or the name of an M-file. The expression executes in the MATLAB workspace.



For examples of `Callback` callbacks for each style of component:

- For GUIDE GUIs, see “Examples: Programming GUIDE GUI Components”.
- For programmatically created GUIs, see “Examples: Programming GUI Components”.

Callback routines defined for static text do not execute because no action is associated with these objects.

To execute the callback routine for an edit text control, type in the desired text and then do one of the following:

- Click another component, the menu bar, or the background of the GUI.
- For a single line editable text box, press **Enter**.
- For a multiline editable text box, press **Ctrl+Enter**.

## `CData`

matrix

*Tricolor image displayed on control.* A three-dimensional matrix of RGB values that defines a tricolor image displayed on a control, which must be a **push button** or **toggle button**. Each value must be between 0.0 and 1.0. Setting `CData` on a **radio button** or **checkbox** will replace the default `CData` on these controls. The control will continue to work as expected, but its state is not reflected by its appearance when clicked.

For **push buttons** and **toggle buttons**, `CData` overlaps the `String`. In the case of **radio buttons** and **checkboxes**, `CData` takes precedence over `String` and, depending on its size, it can displace the text.

Setting `CData` to `[]` restores the default `CData` for **radio buttons** and **checkboxes**.

# Uicontrol Properties

---

Children  
matrix

The empty matrix; `uicontrol` objects have no children.

Clipping  
{on} | off

This property has no effect on `uicontrol` objects.

CreateFcn  
string or function handle

*Callback routine executed during object creation.* The specified function executes when MATLAB creates a `uicontrol` object. MATLAB sets all property values for the `uicontrol` before executing the `CreateFcn` callback so these values are available to the callback. Within the function, use `gcbo` to get the handle of the `uicontrol` being created.

Setting this property on an existing `uicontrol` object has no effect.

You can define a default `CreateFcn` callback for all new `uicontrols`. This default applies unless you override it by specifying a different `CreateFcn` callback when you call `uicontrol`. For example, the code

```
set(0, 'DefaultUicontrolCreateFcn', 'set(gcbo, ...
 'BackgroundColor', 'white')')
```

creates a default `CreateFcn` callback that runs whenever you create a new `uicontrol`. It sets the default background color of all new `uicontrols`.

To override this default and create a `uicontrol` whose `BackgroundColor` is set to a different value, call `uicontrol` with code similar to

```
hpt = uicontrol(..., 'CreateFcn', 'set(gcbo, ...
```

```
'BackgroundColor','blue'))
```

---

**Note** To override a default `CreateFcn` callback you must provide a new callback and not just provide different values for the specified properties. This is because the `CreateFcn` callback runs after the property values are set, and can override property values you have set explicitly in the `uicontrol` call. In the example above, if instead of redefining the `CreateFcn` property for this `uicontrol`, you had explicitly set `BackgroundColor` to `blue`, the default `CreateFcn` callback would have set `BackgroundColor` back to the default, i.e., `white`.

---

Do not call `copyobj` or `textwrap` (which calls `copyobj`) inside a `CreateFcn`. The act of copying the `uicontrol` object fires the `CreateFcn` repeatedly, which raises a series of error messages after exceeding the root object's `RecursionLimit` property.

See “Function Handle Callbacks” for information on how to use function handles to define a callback function.

## `DeleteFcn`

string or function handle

*Delete uicontrol callback routine.* A callback routine that executes when you delete the `uicontrol` object (e.g., when you issue a `delete` command or clear the figure containing the `uicontrol`). MATLAB executes the routine before destroying the object's properties so these values are available to the callback routine.

The handle of the object whose `DeleteFcn` is being executed is accessible only through the root `CallbackObject` property, which you can query using `gcbo`.

See “Function Handle Callbacks” for information on how to use function handles to define a callback function.

# Uicontrol Properties

---

## Enable

{on} | inactive | off

*Enable or disable the uicontrol.* This property controls how uicontrols respond to mouse button clicks, including which callback routines execute.

- **on** – The uicontrol is operational (the default).
- **inactive** – The uicontrol is not operational, but looks the same as when Enable is on.
- **off** – The uicontrol is not operational and its image (set by the Cdata property) is grayed out.

When you left-click on a uicontrol whose Enable property is on, MATLAB performs these actions in this order:

- 1** Sets the figure's SelectionType property.
- 2** Executes the uicontrol's ClickedCallback routine.
- 3** Does not set the figure's CurrentPoint property and does not execute either the control's ButtonDownFcn or the figure's WindowButtonDownFcn callback.

When you left-click on a uicontrol whose Enable property is off, or when you right-click a uicontrol whose Enable property has any value, MATLAB performs these actions in this order:

- 1** Sets the figure's SelectionType property.
- 2** Sets the figure's CurrentPoint property.
- 3** Executes the figure's WindowButtonDownFcn callback.

## Extent

position rectangle (read only)

*Size of uicontrol character string.* A four-element vector that defines the size and position of the character string used to label the uicontrol. It has the form:

[0,0,width,height]

The first two elements are always zero. `width` and `height` are the dimensions of the rectangle. All measurements are in units specified by the `Units` property.

Since the `Extent` property is defined in the same units as the uicontrol itself, you can use this property to determine proper sizing for the uicontrol with regard to its label. Do this by

- Defining the `String` property and selecting the font using the relevant properties.
- Getting the value of the `Extent` property.
- Defining the `width` and `height` of the `Position` property to be somewhat larger than the `width` and `height` of the `Extent`.

For multiline strings, the `Extent` rectangle encompasses all the lines of text. For single line strings, the `height` element of the `Extent` property returned always indicates the height of a single line, and its `width` element always indicates the width of the longest line, even if the string wraps when displayed on the control. Edit boxes are considered multiline if `Max - Min > 1`.

**FontAngle**

{normal} | italic | oblique

*Character slant.* MATLAB uses this property to select a font from those available on your particular system. Setting this property to `italic` or `oblique` selects a slanted version of the font, when it is available on your system.

**FontName**

string

*Font family.* The name of the font in which to display the `String`. To display and print properly, this must be a font that your system supports. The default font is system dependent.

# Uicontrol Properties

---

---

**Note** MATLAB GUIs do not support the Marlett and Symbol font families.

---

To use a fixed-width font that looks good in any locale (and displays properly in Japan, where multibyte character sets are used), set `FontName` to the string `FixedWidth` (this string value is case sensitive):

```
set(uicontrol_handle, 'FontName', 'FixedWidth')
```

This parameter value eliminates the need to hard code the name of a fixed-width font, which may not display text properly on systems that do not use ASCII character encoding (such as in Japan). A properly written MATLAB application that needs to use a fixed-width font should set `FontName` to `FixedWidth` and rely on the root `FixedWidthFontName` property to be set correctly in the end user's environment.

End users can adapt a MATLAB application to different locales or personal environments by setting the root `FixedWidthFontName` property to the appropriate value for that locale from `startup.m`. Setting the root `FixedWidthFontName` property causes an immediate update of the display to use the new font.

---

**Tip** To determine what fonts exist on your system (which can differ from the GUI user's system), use the `uisetfont` GUI to select a font and return its name and other characteristics in a MATLAB structure.

---

`FontSize`  
size in `FontUnits`

*Font size.* A number specifying the size of the font in which to display the String, in units determined by the FontUnits property. The default point size is system dependent.

## FontUnits

{points} | normalized | inches |  
centimeters | pixels

*Font size units.* This property determines the units used by the FontSize property. Normalized units interpret FontSize as a fraction of the height of the uicontrol. When you resize the uicontrol, MATLAB modifies the screen FontSize accordingly. pixels, inches, centimeters, and points are absolute units (1 point =  $1/72$  inch).

## FontWeight

light | {normal} | demi | bold

*Weight of text characters.* MATLAB uses this property to select a font from those available on your particular system. Setting this property to bold causes MATLAB to use a bold version of the font, when it is available on your system.

## ForegroundColor

ColorSpec

*Color of text.* This property determines the color of the text defined for the String property (the uicontrol label). Specify a color using a three-element RGB vector or one of the MATLAB predefined names. The default text color is black. See ColorSpec for more information on specifying color.

## HandleVisibility

{on} | callback | off

*Control access to object's handle.* This property determines when an object's handle is visible in its parent's list of children. When a handle is not visible in its parent's list of children, it is not returned by functions that obtain handles by searching the object

# Uicontrol Properties

---

hierarchy or querying handle properties. This includes `get`, `findobj`, `gca`, `gcf`, `gco`, `newplot`, `cla`, `clf`, and `close`. Neither is the handle visible in the parent figure's `CurrentObject` property. Handles that are hidden are still valid. If you know an object's handle, you can set and get its properties, and pass it to any function that operates on handles.

- Handles are always visible when `HandleVisibility` is on.
- Setting `HandleVisibility` to `callback` causes handles to be visible from within callback routines or functions invoked by callback routines, but not from within functions invoked from the command line. This provides a means to protect GUIs from command-line users, while allowing callback routines to have complete access to object handles.
- Setting `HandleVisibility` to `off` makes handles invisible at all times. This may be necessary when a callback routine invokes a function that might potentially damage the GUI (such as evaluating a user-typed string), and so temporarily hides its own handles during the execution of that function.

You can set the root `ShowHiddenHandles` property to `on` to make all handles visible, regardless of their `HandleVisibility` settings. This does not affect the values of the `HandleVisibility` properties.

---

**Note** Radio buttons and toggle buttons that are managed by a `uibuttongroup` should not be accessed outside the button group. Set the `HandleVisibility` of such radio buttons and toggle buttons to `off` to prevent inadvertent access.

---

```
HitTest
 {on} | off
```



*Selectable by mouse click.* This property has no effect on uicontrol objects.

## HorizontalAlignment

left | {center} | right

*Horizontal alignment of label string.* This property determines the justification of the text defined for the String property (the uicontrol label):

- left — Text is left justified with respect to the uicontrol.
- center — Text is centered with respect to the uicontrol.
- right — Text is right justified with respect to the uicontrol.

On Microsoft Windows systems, this property affects only edit and text uicontrols.

## Interruptible

{on} | off

*Callback routine interruption mode.* If a callback is executing and the user triggers an event (such as a mouse click) on an object for which a callback is defined, that callback attempts to interrupt the first callback. MATLAB processes the callbacks according to these factors:

- The Interruptible property of the object whose callback is executing
- Whether the executing callback contains drawnow, figure, getframe, pause, or waitfor statements
- The BusyAction property of the object whose callback is waiting to execute

If the Interruptible property of the object whose callback is executing is on (the default), the callback can be interrupted. Whenever the callback calls one of the drawnow, figure, getframe, pause, or waitfor functions, the function processes

# Uicontrol Properties

---

any events in the event queue, including the waiting callback, before performing its defined task.

If the `Interruptible` property of the object whose callback is executing is `off`, the callback cannot be interrupted (except by certain callbacks; see the note below). The `BusyAction` property of the object whose callback is waiting to execute determines what happens to the callback.

---

**Note** If the interrupting callback is a `DeleteFcn` or `CreateFcn` callback or a figure's `CloseRequest` or `ResizeFcn` callback, it interrupts an executing callback regardless of the value of that object's `Interruptible` property. The interrupting callback starts execution at the next `drawnow`, `figure`, `getframe`, `pause`, or `waitfor` statement. A figure's `WindowButtonDownFcn` callback routine, or an object's `ButtonDownFcn` or `Callback` routine are processed according to the rules described above.

---

## `KeyPressFcn`

string or function handle

*Key press callback function.* A callback routine invoked by a key press when the callback's uicontrol object has focus. Focus is denoted by a border or a dotted border, respectively, in UNIX and Microsoft Windows. If no uicontrol has focus, the figure's key press callback function, if any, is invoked. `KeyPressFcn` can be a function handle, the name of an M-file, or any legal MATLAB expression.

If the specified value is the name of an M-file, the callback routine can query the figure's `CurrentCharacter` property to determine what particular key was pressed and thereby limit the callback execution to specific keys.

If the specified value is a function handle, the callback routine can retrieve information about the key that was pressed from its event data structure argument.

| Event Data Structure Field | Description                                                                         | Examples:  |            |           |           |
|----------------------------|-------------------------------------------------------------------------------------|------------|------------|-----------|-----------|
|                            |                                                                                     | a          | =          | Shift     | Shift/a   |
| Character                  | Character interpretation of the key that was pressed.                               | 'a'        | '='        | ' '       | 'A'       |
| Modifier                   | Current modifier, such as 'control', or an empty cell array if there is no modifier | {1x0 cell} | {1x0 cell} | {'shift'} | {'shift'} |
| Key                        | Name of the key that was pressed.                                                   | 'a'        | 'equal'    | 'shift'   | 'a'       |

See “Function Handle Callbacks” for information on how to use function handles to define the callback function.

**ListboxTop**  
scalar

*Index of top-most string displayed in list box.* This property applies only to the `listbox` style of uicontrol. It specifies which string appears in the top-most position in a list box that is not large enough to display all list entries. `ListboxTop` is an index into the array of strings defined by the `String` property and must have a value between 1 and the number of strings. Noninteger values are fixed to the next lowest integer.

**Max**  
scalar

*Maximum value.* This property specifies the largest value allowed for the `Value` property. Different styles of uicontrols interpret `Max` differently:

# Uicontrol Properties

---

- Check boxes – Max is the setting of the Value property while the check box is selected.
- Editable text – The Value property does not apply. If Max - Min > 1, then editable text boxes accept multiline input. If Max - Min <= 1, then editable text boxes accept only single line input. The absolute values of Max and Min have no effect on the number of lines an edit box can contain; a multiline edit box can contain any number of lines.
- List boxes – If Max - Min > 1, then list boxes allow multiple item selection. If Max - Min <= 1, then list boxes do not allow multiple item selection. When they do, Value can be a vector of indices.
- Radio buttons – Max is the setting of the Value property when the radio button is selected.
- Sliders – Max is the maximum slider value and must be greater than the Min property. The default is 1.
- Toggle buttons – Max is the value of the Value property when the toggle button is selected. The default is 1.
- Pop-up menus, push buttons, and static text do not use the Max property.

Min

scalar

*Minimum value.* This property specifies the smallest value allowed for the Value property. Different styles of uicontrols interpret Min differently:

- Check boxes – Min is the setting of the Value property while the check box is not selected.
- Editable text – The Value property does not apply. If Max - Min > 1, then editable text boxes accept multiline input. If Max - Min <= 1, then editable text boxes accept only single line input. The absolute values of Max and Min have no effect on the number of

lines an edit box can contain; a multiline edit box can contain any number of lines.

- List boxes – If  $\text{Max} - \text{Min} > 1$ , then list boxes allow multiple item selection. If  $\text{Max} - \text{Min} \leq 1$ , then list boxes allow only single item selection. When they do, `Value` can be a vector of indices.
- Radio buttons – `Min` is the setting of the `Value` property when the radio button is not selected.
- Sliders – `Min` is the minimum slider value and must be less than `Max`. The default is 0.
- Toggle buttons – `Min` is the value of the `Value` property when the toggle button is not selected. The default is 0.
- Pop-up menus, push buttons, and static text do not use the `Min` property.

## Parent

`handle`

*Uicontrol parent.* The handle of the uicontrol's parent object. You can move a uicontrol object to another figure, uipanel, or uibuttongroup by setting this property to the handle of the new parent.

## Position

`position rectangle`

*Size and location of uicontrol.* The rectangle defined by this property specifies the size and location of the control within the parent figure window, uipanel, or uibuttongroup. Specify `Position` as

```
[left bottom width height]
```

`left` and `bottom` are the distance from the lower-left corner of the parent object to the lower-left corner of the uicontrol object. `width` and `height` are the dimensions of the uicontrol rectangle. All measurements are in units specified by the `Units` property.

# Uicontrol Properties

---

On Microsoft Windows systems, the height of pop-up menus is automatically determined by the size of the font. The value you specify for the height of the Position property has no effect.

The width and height values determine the orientation of sliders. If width is greater than height, then the slider is oriented horizontally. If height is greater than width, then the slider is oriented vertically.

---

**Note** The height of a pop-up menu is determined by the font size. The height you set in the position vector is ignored. The height element of the position vector is not changed.

On Mac platforms, the height of a horizontal slider is constrained. If the height you set in the position vector exceeds this constraint, the displayed height of the slider is the maximum allowed. The height element of the position vector is not changed.

---

Selected  
on | {off} (read only)

*Is object selected.* When this property is on, MATLAB displays selection handles if the SelectionHighlight property is also on. You can, for example, define the ButtonDownFcn to set this property, allowing users to select the object with the mouse.

SelectionHighlight  
{on} | off

*Object highlight when selected.* When the Selected property is on, MATLAB indicates the selected state by drawing four edge handles and four corner handles. When SelectionHighlight is off, MATLAB does not draw the handles.

SliderStep  
[min\_step max\_step]

*Slider step size.* This property controls the amount the slider Value changes when you click the mouse on the arrow button (`min_step`) or on the slider trough (`max_step`). Specify `SliderStep` as a two-element vector; each value must be in the range `[0, 1]`, and `min_step` should be less than `max_step`. Numbers outside `[0 1]` can cause the slider not to render or produce unexpected results. The actual step size is a function of the specified `SliderStep` and the total slider range (`Max - Min`). The default, `[0.01 0.10]`, provides a 1 percent change for clicks on the arrow button and a 10 percent change for clicks in the trough. and both should be positive numbers less than 1.

For example, if you create the following slider,

```
uicontrol('Style','slider','Min',1,'Max',7,...
 'Value',2,'SliderStep',[0.1 0.6])
```

clicking on the arrow button moves the indicator by,

```
0.1*(7-1)
ans =
 0.6000
```

and clicking in the trough moves the indicator by,

```
0.6*(7-1)
ans =
 3.6000
```

Note that if the specified step size moves the slider to a value outside the range, the indicator moves only to the `Max` or `Min` value.

See also the `Max`, `Min`, and `Value` properties.

String  
string

*Uicontrol label, list box items, pop-up menu choices.*

# Uicontrol Properties

---

**For check boxes, editable text, push buttons, radio buttons, static text, and toggle buttons**, the text displayed on the object. For list boxes and pop-up menus, the set of entries or items displayed in the object.

---

**Note** If you specify a numerical value for `String`, MATLAB converts it to `char` but the result may not be what you expect. If you have numerical data, you should first convert it to a string, e.g., using `num2str`, before assigning it to the `String` property.

---

**For uicontrol objects that display only one line of text** (check box, push button, radio button, toggle button), if the string value is specified as a cell array of strings or padded string matrix, only the first string of a cell array or of a padded string matrix is displayed; the rest are ignored. Vertical slash (`'|'`) characters are not interpreted as line breaks and instead show up in the text displayed in the uicontrol.

**For multiple line editable text or static text controls**, line breaks occur between each row of the string matrix, and each cell of a cell array of strings. Vertical slash (`'|'`) characters and `\n` characters are not interpreted as line breaks, and instead show up in the text displayed in the uicontrol.

**For multiple items on a list box or pop-up menu**, you can specify the items in any of the formats shown in the following table.

| String Property Format | Example               |
|------------------------|-----------------------|
| Cell array of strings  | {'one' 'two' 'three'} |



| String Property Format                                   | Example                   |
|----------------------------------------------------------|---------------------------|
| Padded string matrix                                     | ['one '; 'two '; 'three'] |
| String vector separated by vertical slash ( ) characters | ['one two three']         |

If you specify a component width that is too small to accommodate one or more of the specified strings, MATLAB truncates those strings with an ellipsis. Use the `Value` property to set the index of the initial item selected.

For **check boxes**, **push buttons**, **radio buttons**, **toggle buttons**, and the selected item in **popup menus**, when the specified text is clipped because it is too long for the uicontrol, an ellipsis (...) is appended to the text in the active GUI to indicate that it has been clipped.

For **push buttons** and **toggle buttons**, `CData` overlaps the `String`. In the case of **radio buttons** and **checkboxes**, `CData` takes precedence over `String` and, depending on its size, can displace the text.

For **editable text**, the `String` property value is set to the string entered by the user.

# Uicontrol Properties

---

---

**Reserved Words** There are three reserved words: `default`, `remove`, `factory` (case sensitive). If you want to use one of these reserved words in the `String` property, you must precede it with a backslash (`'\'`) character. For example,

```
h = uicontrol('Style','edit','String','\default');
```

---

## Style

{pushbutton} | togglebutton | radiobutton | checkbox |  
edit | text | slider | frame | listbox | popupmenu

*Style of uicontrol object to create.* The `Style` property specifies the kind of uicontrol to create. See the `uicontrol` Description section for information on each type.

## Tag

string (GUIDE sets this property)

*User-specified object label.* The `Tag` property provides a means to identify graphics objects with a user-specified label. This is particularly useful when constructing interactive graphics programs that would otherwise need to define object handles as global variables or pass them as arguments between callback routines. You can define `Tag` as any string.

## TooltipString

string

*Content of tooltip for object.* The `TooltipString` property specifies the text of the tooltip associated with the uicontrol. When the user moves the mouse pointer over the control and leaves it there, the tooltip is displayed.

## Type

string (read only)

*Class of graphics object.* For uicontrol objects, Type is always the string 'uicontrol'.

UIContextMenu  
handle

*Associate a context menu with uicontrol.* Assign this property the handle of a uicontextmenu object. MATLAB displays the context menu whenever you right-click over the uicontrol. Use the uicontextmenu function to create the context menu.

Units

{pixels} | normalized | inches | centimeters | points | characters (GUIDE default: normalized)

*Units of measurement.* MATLAB uses these units to interpret the Extent and Position properties. All units are measured from the lower-left corner of the parent object.

- Normalized units map the lower-left corner of the parent object to (0,0) and the upper-right corner to (1.0,1.0).
- pixels, inches, centimeters, and points are absolute units (1 point = 1/72 inch).
- Character units are characters using the default system font; the width of one character is the width of the letter x, the height of one character is the distance between the baselines of two lines of text.

If you change the value of Units, it is good practice to return it to its default value after completing your computation so as not to affect other functions that assume Units is set to the default value.

UserData  
matrix

# Uicontrol Properties

---

*User-specified data.* Any data you want to associate with the uicontrol object. MATLAB does not use this data, but you can access it using `set` and `get`.

## Value

scalar or vector

*Current value of uicontrol.* The uicontrol style determines the possible values this property can have:

- Check boxes set `Value` to `Max` when they are on (when selected) and `Min` when off (not selected).
- List boxes set `Value` to a vector of indices corresponding to the selected list entries, where 1 corresponds to the first item in the list.
- Pop-up menus set `Value` to the index of the item selected, where 1 corresponds to the first item in the menu. The Examples section shows how to use the `Value` property to determine which item has been selected.
- Radio buttons set `Value` to `Max` when they are on (when selected) and `Min` when off (not selected).
- Sliders set `Value` to the number indicated by the slider bar.
- Toggle buttons set `Value` to `Max` when they are down (selected) and `Min` when up (not selected).
- Editable text, push buttons, and static text do not set this property.

Set the `Value` property either interactively with the mouse or through a call to the `set` function. The display reflects changes made to `Value`.

## Visible

{on} | off

*Uicontrol visibility.* By default, all uicontrols are visible. When set to `off`, the uicontrol is not visible, but still exists and you can query and set its properties.

---

**Note** Setting `Visible` to `off` for uicontrols that are not displayed initially in the GUI, can result in faster startup time for the GUI.

---

# uigetdir

---

**Purpose** Open standard dialog box for selecting directory

**Syntax**

```
uigetdir
directory_name = uigetdir
directory_name = uigetdir(start_path)
directory_name = uigetdir(start_path,dialog_title)
```

**Description** `uigetdir` displays a modal dialog box enabling the user to browse through the directory structure and select a directory or type the name of a directory. If the directory exists, `uigetdir` returns the selected path when the user clicks **OK**. For Microsoft Windows platforms, `uigetdir` opens a dialog box in the base directory (the Windows desktop) with the current directory selected. See “Remarks” on page 2-3875 for information about UNIX and Mac platforms.

---

**Note** A modal dialog box prevents the user from interacting with other windows before responding. To block MATLAB program execution as well, use the `uiwait` function. For more information about modal dialog boxes, see `WindowState` in the MATLAB Figure Properties.

---

`directory_name = uigetdir` returns the path to the selected directory when the user clicks **OK**. If the user clicks **Cancel** or closes the dialog window, `directory_name` is set to 0.

`directory_name = uigetdir(start_path)` opens a dialog box with the directory specified by `start_path` selected. If `start_path` is a valid directory path, the dialog box opens in the specified directory.

If `start_path` is an empty string ( `' '` ), the dialog box opens in the current directory. If `start_path` is not a valid directory path, the dialog box opens in the base directory. For Windows, this is the Windows desktop. See “Remarks” on page 2-3875 for information about UNIX and Mac platforms.

`directory_name = uigetdir(start_path,dialog_title)` opens a dialog box with the specified title. On Windows platforms, the

string replaces the default caption inside the dialog box for specifying instructions to the user. The default `dialog_title` is `Select Directory to Open`. See “Remarks” on page 2-3875 for information about UNIX and Mac platforms.

---

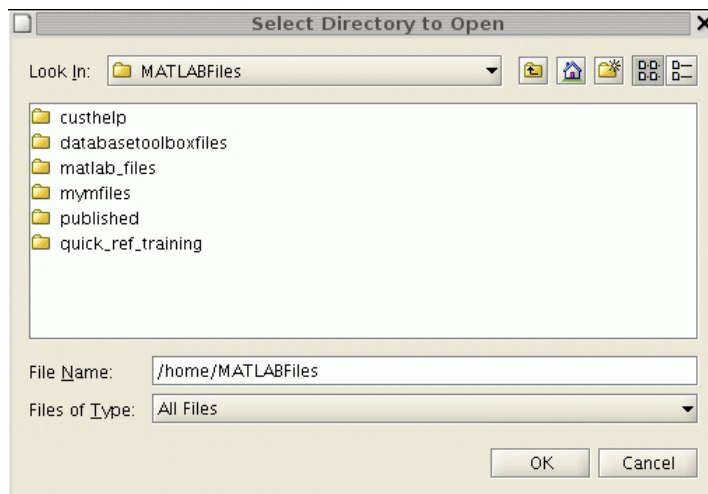
**Note** On Windows platforms, users can click the **New Folder** button to add a new directory to the directory structure displayed. Users can also drag and drop existing directories.

---

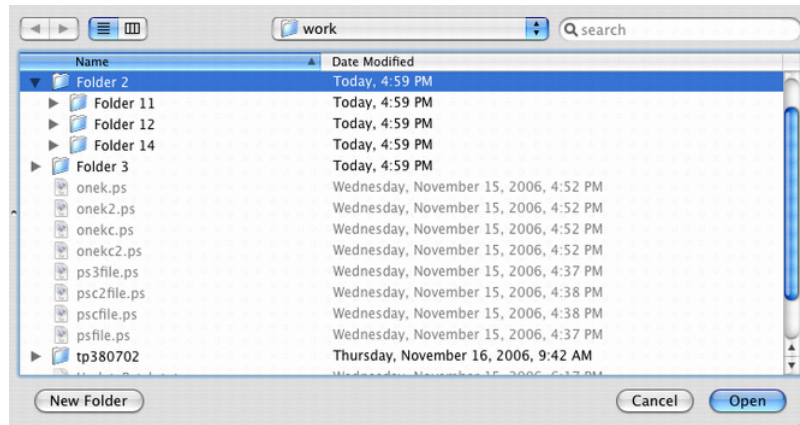
## Remarks

For Windows platforms, the dialog box is similar to those shown in the “Examples” on page 2-3876 below.

For UNIX platforms, `uigetdir` opens a dialog box in the base directory (the directory from which MATLAB is started) with the current directory selected. The `dialog_title` string replaces the default title of the dialog box. The dialog box is similar to the one shown in the following figure.



For Mac platforms, `uigetdir` opens a dialog box in the base directory (the current directory) with the current directory open. The `dialog_title` string, if any, is ignored. The dialog box is similar to the one shown in the following figure.



## Examples

### Example 1

The following statement displays directories on the C: drive.

```
dname = uigetdir('C:\');
```

The dialog box is shown in the following figure.





If the user selects the directory Desktop, as shown in the figure, and clicks **OK**, `uigetdir` returns

```
dname =
C:\WINNT\Profiles\All Users\Desktop
```

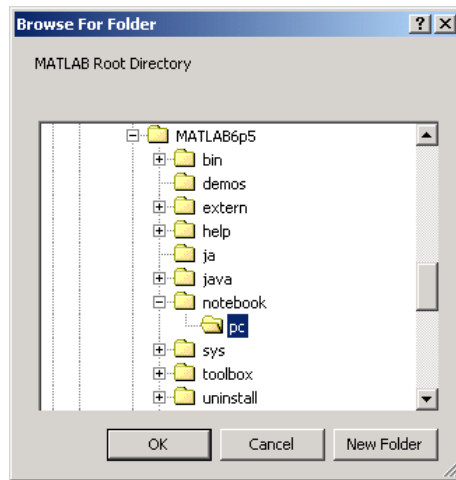
## Example 2

The following statement uses the `matlabroot` command to display the MATLAB root directory in the dialog box:

```
uigetdir(matlabroot, 'MATLAB Root Directory')
```

# uigetdir

---



If the user selects the directory MATLAB6.5/notebook/pc, as shown in the figure, `uigetdir` returns a string like

```
C:\MATLAB6.5\notebook\pc
```

assuming that MATLAB is installed on drive C:\.

## See Also

`uigetfile`, `uiputfile`

**Purpose** Open standard dialog box for retrieving files

**Syntax**

```
uigetfile
[FileName,PathName,FilterIndex] = uigetfile(FilterSpec)
[FileName,PathName,FilterIndex] = uigetfile(FilterSpec,
 DialogTitle)
[FileName,PathName,FilterIndex] = uigetfile(FilterSpec,
 DialogTitle,DefaultName)
[FileName,PathName,FilterIndex] = uigetfile(...,'MultiSelect',
 selectmode)
```

**Description** `uigetfile` displays a modal dialog box that lists files in the current directory and enables the user to select or type the name of a file to be opened. If the filename is valid and if the file exists, `uigetfile` returns the filename when the user clicks **Open**. Otherwise `uigetfile` displays an appropriate error message from which control returns to the dialog box. The user can then enter another filename or click **Cancel**. If the user clicks **Cancel** or closes the dialog window, `uigetfile` returns 0.

Successful execution of `uigetfile` does not open a file; it only returns the name of an existing file that the user designates.

---

**Note** A modal dialog box prevents the user from interacting with other windows before responding. To block MATLAB program execution, use the `uiwait` function. For more information about modal dialog boxes, see `WindowState` in the MATLAB Figure Properties.

---

```
[FileName,PathName,FilterIndex] = uigetfile(FilterSpec)
displays only those files with extensions that match FilterSpec.
The uigetfile function appends 'All Files' to the list of file
types.FilterSpec can be a string or a cell array of strings, and can
include the * wildcard.
```

- If `FilterSpec` is a string that contains a filename, the filename is displayed and selected in the **File name** field and the file's extension is used as the default filter.
- If `FilterSpec` is a string, it can include a path. That path can contain '.', '..', or '/'. For example, '../\*.\*m' lists all M-files in the directory above the current directory.
- If `FilterSpec` is a cell array of strings, the first column contains a list of file extensions. The optional second column contains a corresponding list of descriptions. These descriptions replace standard descriptions in the **Files of type** field. A description cannot be an empty string. “Example 2” on page 2-3884 and “Example 3” on page 2-3885 illustrate use of a cell array as `FilterSpec`.

If `FilterSpec` is not specified, `uigetfile` uses the default list of file types (i.e., all MATLAB files).

After the user clicks **Open** and if the filename exists, `uigetfile` returns the name of the file in `FileName` and its path in `PathName`. If the user clicks **Cancel** or closes the dialog window, `FileName` and `PathName` are set to 0.

`FilterIndex` is the index of the filter selected in the dialog box. Indexing starts at 1. If the user clicks **Cancel** or closes the dialog window, `FilterIndex` is set to 0.

```
[FileName,PathName,FilterIndex] =
uigetfile(FilterSpec,DialogTitle) displays a dialog box that
has the title DialogTitle. To use the default file types and specify a
dialog title, enter
```

```
uigetfile('',DialogTitle)
```

```
[FileName,PathName,FilterIndex] =
uigetfile(FilterSpec,DialogTitle,DefaultName) displays a dialog
box in which the filename specified by DefaultName appears in the
File name field. DefaultName can also be a path or a path/filename. In
this case, uigetfile opens the dialog box in the directory specified by
```

the path. See “Example 6” on page 2-3888 . Note that you can use '.', '..', or '/' in the `DefaultName` argument.

If the specified path does not exist, `uigetfile` opens the dialog box in the current directory.

```
[FileName,PathName,FilterIndex] =
uigetfile(...,'MultiSelect',selectmode)
```

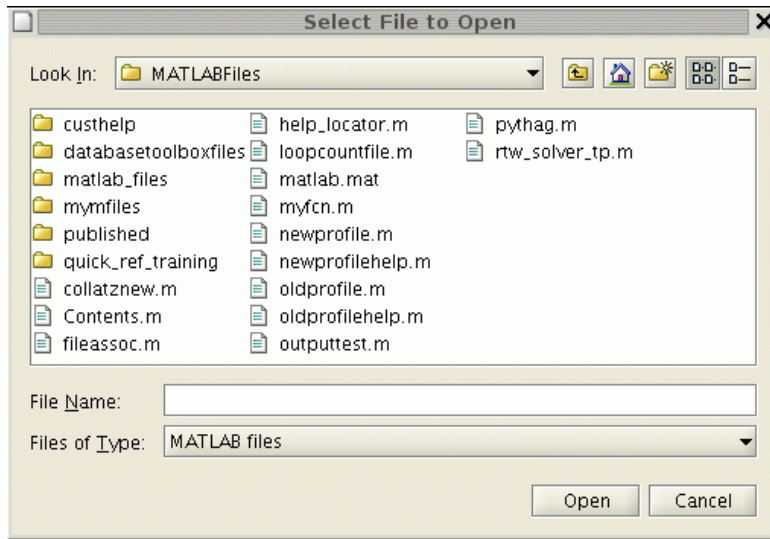
 sets the multiselect mode to specify if multiple file selection is enabled for the `uigetfile` dialog. Valid values for *selectmode* are 'on' and 'off' (default). If 'MultiSelect' is 'on' and the user selects more than one file in the dialog box, then `FileName` is a cell array of strings, each of which represents the name of a selected file. Filenames in the cell array are in the sort order native to your platform. Because multiple selections are always in the same directory, `PathName` is always a string that represents a single directory.

## Remarks

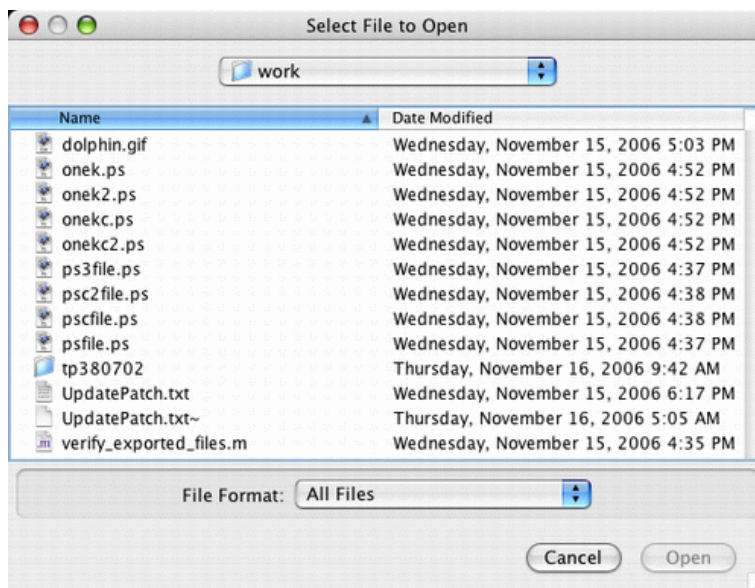
If the user includes either of the “wildcard” characters '\*' or '?' in a file name, `uigetfile` does not respond to clicking **Open**. The dialog box remains open until the user cancels it or removes the wildcard characters. This restriction applies to all platforms, even to file systems that permit these characters in file names.

For Microsoft Windows platforms, the dialog box is the Windows dialog box native to your platform. Because of this, it may differ from those shown in “Examples” on page 2-3883 below.

For UNIX platforms, the dialog box is similar to the one shown in the following figure.



For Mac platforms, the dialog box is similar to the one shown in the following figure.



## Examples

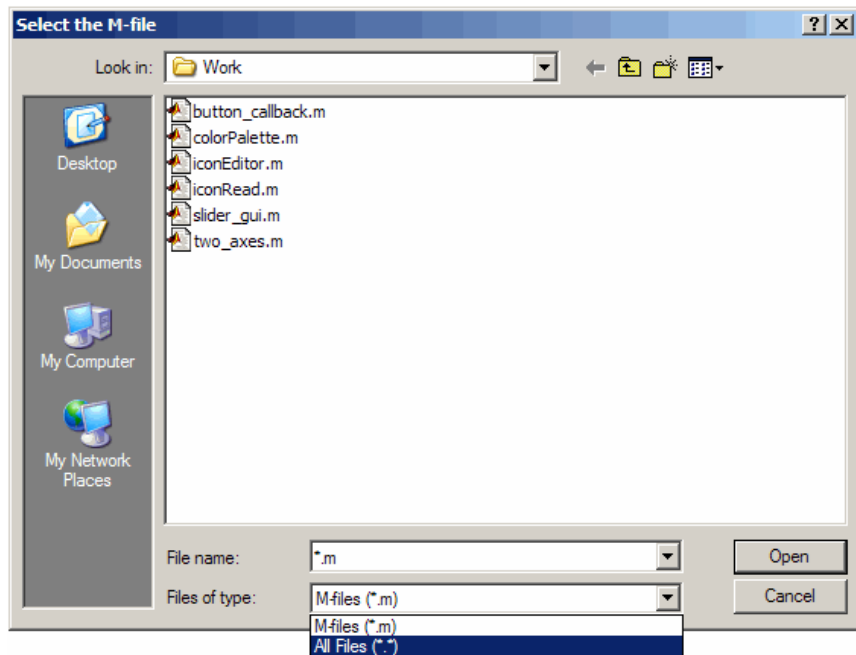
### Example 1

The following statement displays a dialog box that enables the user to retrieve a file. The statement lists all MATLAB M-files within a selected directory. The name and path of the selected file are returned in `FileName` and `PathName`. Note that `uigetfile` appends `All Files (*.*)` to the file types when `FilterSpec` is a string.

```
[FileName,PathName] = uigetfile('*.*','Select the M-file');
```

The dialog box is shown in the following figure.

# uigetfile

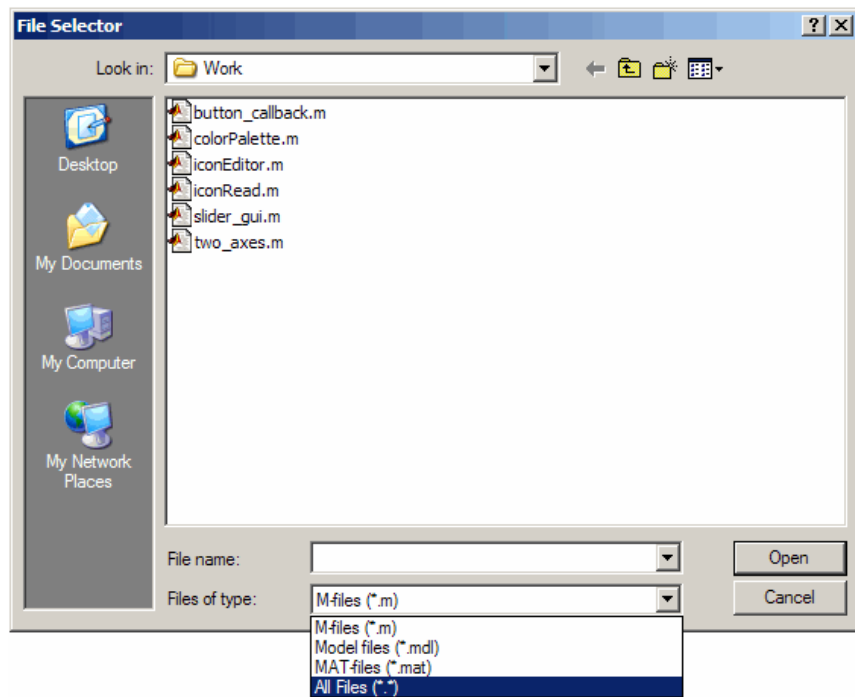


## Example 2

To create a list of file types that appears in the **Files of type** list box, separate the file extensions with semicolons, as in the following code. Note that `uigetfile` displays a default description for each known file type, such as "Simulink Models" for `.mdl` files.

```
[filename, pathname] = ...
 uigetfile({'*.m'; '*.mdl'; '*.mat'; '*.*'}, 'File Selector');
```



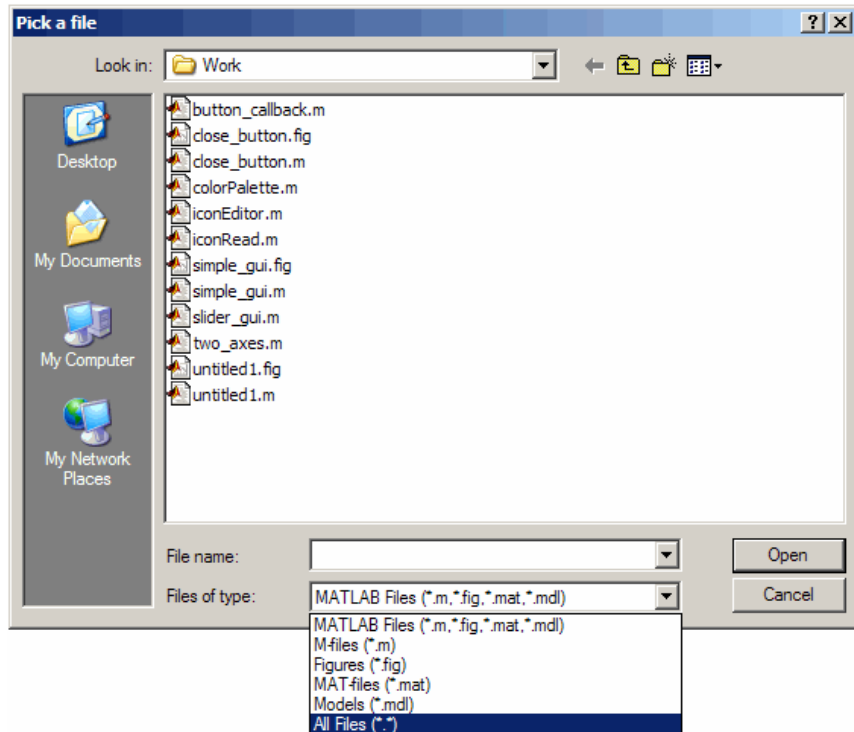


### Example 3

If you want to create a list of file types and give them descriptions that are different from the defaults, use a cell array, as in the following code. This example also associates multiple file types with the 'MATLAB Files' description.

```
[filename, pathname] = uigetfile(...
{'*.m;*.fig;*.mat;*.mdl','MATLAB Files (*.m,*.fig,*.mat,*.mdl)';
 '*.m', 'M-files (*.m)'; ...
 '*.fig','Figures (*.fig)'; ...
 '*.mat','MAT-files (*.mat)'; ...
 '*.mdl','Models (*.mdl)'; ...
 '*.*', 'All Files (*.*)'}, ...
'Pick a file');
```

The first column of the cell array contains the file extensions, while the second contains the descriptions you want to provide for the file types. Note that the first entry of column one contains several extensions, separated by semicolons, all of which are associated with the description 'MATLAB Files (\*.m;\*.fig;\*.mat;\*.mdl)'. The code produces the dialog box shown in the following figure.



## Example 4

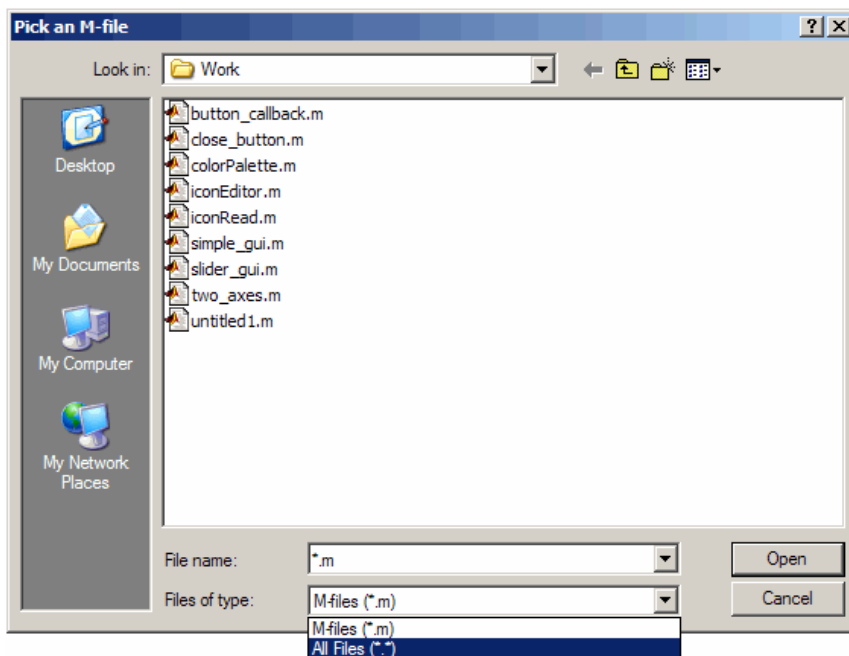
The following code checks for the existence of the file and displays a message about the result of the open operation.

```
[filename, pathname] = uigetfile('*.*', 'Pick an M-file');
```

```

if isequal(filename,0)
 disp('User selected Cancel')
else
 disp(['User selected', fullfile(pathname, filename)])
end

```



### Example 5

This example creates a list of file types and gives them descriptions that are different from the defaults, then enables multiple file selection. The user can select multiple files by holding down the **Shift** or **Ctrl** key and clicking on a file.

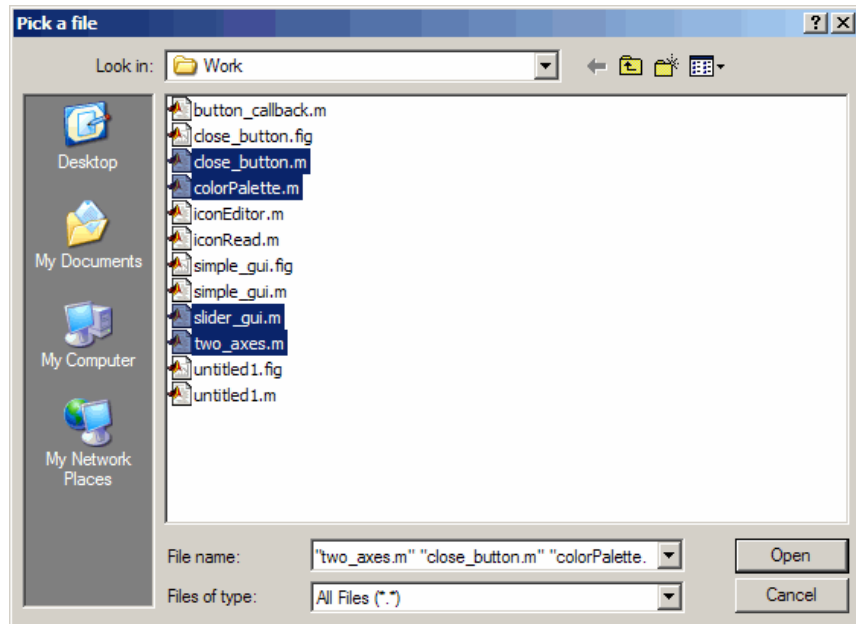
```

[filename, pathname, filterindex] = uigetfile(...
 { '*.mat', 'MAT-files (*.mat)'; ...
 '*.mdl', 'Models (*.mdl)'; ...
 '*.*', 'All Files (*.*)' }, ...

```

# uigetfile

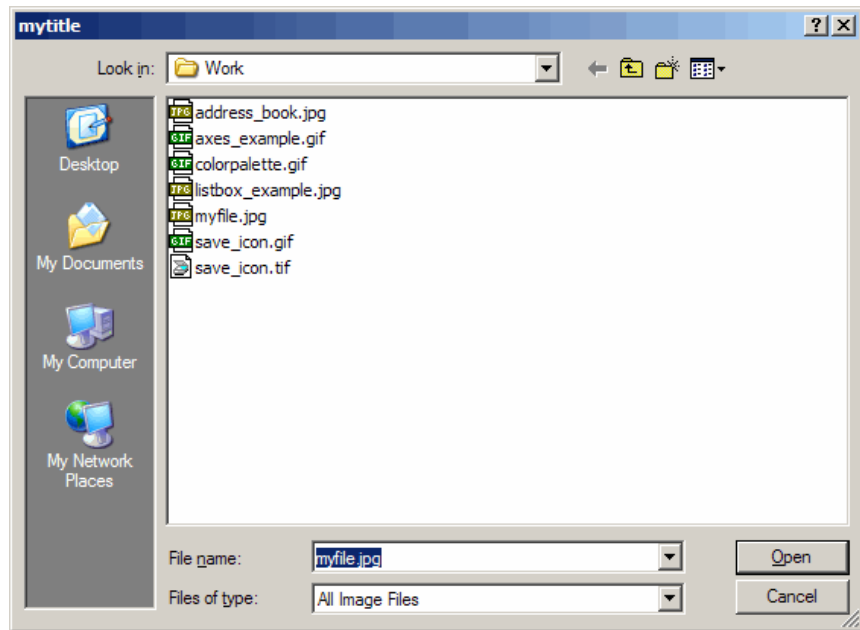
```
'Pick a file', ...
'MultiSelect', 'on');
```



## Example 6

This example uses the `DefaultName` argument to specify a start path and a default filename for the dialog box.

```
uigetfile({'*.jpg;*.tif;*.png;*.gif', 'All Image Files'; ...
 '*.*', 'All Files' }, 'mytitle', ...
 'C:\Work\myfile.jpg')
```



**See Also** `uigetdir`, `uiputfile`

# uigetpref

---

**Purpose** Open dialog box for retrieving preferences

**Syntax** `value = uigetpref(group,pref,title,question,pref_choices)`  
`[val,dlgshown] = uigetpref(...)`

**Description** `value = uigetpref(group,pref,title,question,pref_choices)` returns one of the strings in `pref_choices`, by doing one of the following:

- Prompting the user with a multiple-choice question dialog box
- Returning a previous answer stored in the preferences database

By default, the dialog box is shown, with each choice on a different pushbutton, and with a checkbox controlling whether the returned value should be stored in preferences and automatically reused in subsequent invocations.

If the user checks the checkbox before choosing one of the push buttons, the push button choice is stored in preferences and returned in `value`. Subsequent calls to `uigetpref` detect that the last choice was stored in preferences, and return that choice immediately without displaying the dialog.

If the user does not check the checkbox before choosing a pushbutton, the selected preference is not stored in preferences. Rather, a special value, 'ask', is stored, indicating that subsequent calls to `uigetpref` should display the dialog box.

---

**Note** `uigetpref` uses the same preference database as `addpref`, `getpref`, `ispref`, `rmpref`, and `setpref`. However, it registers the preferences it sets in a separate list so that it, and `uisetpref`, can distinguish those preferences that are being managed with `uigetpref`.

For preferences registered with `uigetpref`, you can use `setpref` and `uisetpref` to explicitly change preference values to 'ask'.

---

`group` and `pref` define the preference. If the preference does not already exist, `uigetpref` creates it.

`title` defines the string displayed in the dialog box titlebar.

`question` is a descriptive paragraph displayed in the dialog, specified as a string array or cell array of strings. This should contain the question the user is being asked, and should be detailed enough to give the user a clear understanding of their choice and its impact. `uigetpref` inserts line breaks between rows of the string array, between elements of the cell array of strings, or between `'|'` or newline characters in the string vector.

`pref_choices` is either a string, cell array of strings, or `'|'`-separated strings specifying the strings to be displayed on the push buttons. Each string element is displayed in a separate push button. The string on the selected pushbutton is returned.

Make `pref_choices` a 2-by-`n` cell array of strings if the internal preference values are different from the strings displayed on the pushbuttons. The first row contains the preference strings, and the second row contains the related pushbutton strings. Note that the preference values are returned in `value`, not the button labels.

`[val,dlgshown] = uigetpref(...)` returns whether or not the dialog was shown.

Additional arguments can be passed in as parameter-value pairs:

`(... 'CheckboxState',state)` sets the initial state of the checkbox, either checked or unchecked. `state` can be either 0 (unchecked) or 1 (checked). By default it is 0.

`(... 'CheckboxString',cbstr)` sets the string `cbstr` on the checkbox. By default it is 'Never show this dialog again'.

`(... 'HelpString',hstr)` sets the string `hstr` on the help button. By default the string is empty and there is no help button.

`(... 'HelpFcn',hfcn)` sets the callback that is executed when the help button is pressed. By default it is `doc('uigetpref')`. Note that if there is no 'HelpString' option, a button is not created.

(... 'ExtraOptions', eo) creates extra buttons which are not mapped to any preference settings. eo can be a string or a cell array of strings. By default it is {} and no extra buttons are created. If the user chooses one of these buttons, the dialog is closed and the string is returned in value.

(... 'DefaultButton', dbstr) sets the string value dbstr that is returned if the dialog is closed. By default, it is the first button. Note that dbstr does not have to correspond to a preference or ExtraOption.

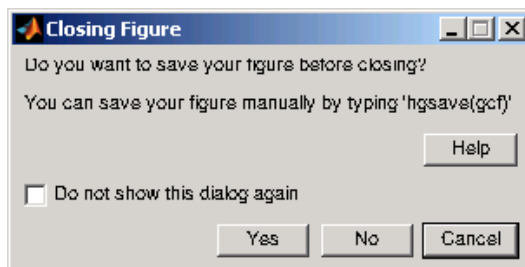
---

**Note** If the preference does not already exist in the preference database, `uigetpref` creates it. Preference values are persistent and maintain their values between MATLAB sessions. Where they are stored is system dependent.

---

## Examples

This example creates the following preference dialog for the 'savefigurebeforeclosing' preference in the 'mygraphics' group.



It uses the cell array {'always', 'never'; 'Yes', 'No'} to define the preference values as 'always' and 'never', and their corresponding button labels as 'Yes' and 'No'.

```
[selectedButton,dlgShown]=uigetpref('mygraphics',... % Group
 'savefigurebeforeclosing',... % Preference
 'Closing Figure',... % Window title
 {'Do you want to save your figure before closing?'
```



```
''
 'You can save your figure manually by typing ''hgsave(gcf)''},...
{'always','never';'Yes','No'},... % Values and button strings
'ExtraOptions','Cancel',... % Additional button
'DefaultButton','Cancel',... % Default choice
'HelpString','Help',... % String for Help button
'HelpFcn','doc(''closereq'');') % Callback for Help button
```

**See Also**

addpref, getpref, ispref, rmpref, setpref, uisetpref

# uiimport

---

**Purpose** Open Import Wizard to import data

**Syntax**

```
uiimport
uiimport(filename)
uiimport('-file')
uiimport('-pastespecial')
S = uiimport(...)
```

**Description** `uiimport` starts the Import Wizard in the current directory, presenting options to load data from a file or the clipboard.

`uiimport(filename)` starts the Import Wizard, opening the file specified in `filename`. The Import Wizard displays a preview of the data in the file.

`uiimport('-file')` works as above but presents the file selection dialog first.

`uiimport('-pastespecial')` works as above but presents the clipboard contents first.

`S = uiimport(...)` works as above with resulting variables stored as fields in the struct `S`.

---

**Note** For ASCII data, you must verify that the Import Wizard correctly identified the column delimiter.

---

**See Also** `load`, `importdata`, `clipboard`, `fileformats`

**Purpose**

Create menus on figure windows

**Syntax**

```
handle = uimenu('PropertyName',PropertyValue,...)
handle = uimenu(parent,'PropertyName',PropertyValue,...)
```

**Description**

`uimenu` creates a hierarchy of menus and submenus that are displayed in the figure window's menu bar. You also use `uimenu` to create menu items for context menus.

`handle = uimenu('PropertyName',PropertyValue,...)` creates a menu in the current figure's menu bar using the values of the specified properties and assigns the menu handle to `handle`.

See the [Uimenu Properties](#) reference page for more information.

`handle = uimenu(parent,'PropertyName',PropertyValue,...)` creates a submenu of a parent menu or a menu item on a context menu specified by `parent` and assigns the menu handle to `handle`. If `parent` refers to a figure instead of another `uimenu` object or a `uicontextmenu`, MATLAB software creates a new menu on the referenced figure's menu bar.

**Remarks**

MATLAB adds the new menu to the existing menu bar. If the figure does not have a menu bar, MATLAB creates one. Each menu choice can itself be a menu that displays its submenu when selected. `uimenu` accepts property name/property value pairs, as well as structures and cell arrays of properties as input arguments.

The `uimenu` `Callback` property defines the action taken when you activate the created menu item.

Uimenus only appear in figures whose `Window Style` is `normal`. If a figure containing `uimenu` children is changed to `modal`, the `uimenu` children still exist and are contained in the `Children` list of the figure, but are not displayed until the `WindowStyle` is changed to `normal`.

The value of the figure `MenuBar` property affects the content of the figure menu bar. When `MenuBar` is `figure`, a set of built-in menus precedes any user-created `uimenu`s on the menu bar (MATLAB controls the

# uimenu

---

built-in menus and their handles are not available to the user). When `MenuBar` is `none`, `uimenu`s are the only items on the menu bar (that is, the built-in menus do not appear).

You can set and query property values after creating the menu using `set` and `get`.

## Examples

This example creates a menu labeled **Workspace** whose choices allow users to create a new figure window, save workspace variables, and exit out of MATLAB. In addition, it defines an accelerator key for the Quit option.

```
f = uimenu('Label','Workspace');
 uimenu(f,'Label','New Figure','Callback','figure');
 uimenu(f,'Label','Save','Callback','save');
 uimenu(f,'Label','Quit','Callback','exit',...
 'Separator','on','Accelerator','Q');
```

## See Also

`uicontrol`, `uicontextmenu`, `gcbo`, `set`, `get`, `figure`

## Purpose

Describe menu properties

## Modifying Properties

You can set and query graphics object properties in two ways:

- The Property Inspector is an interactive tool that enables you to see and change object property values. The Property inspector is available from GUIDE, or use the `inspect` function at the command line.
- The `set` and `get` commands enable you to set and query the values of properties

You can set default Uimenu properties on the root, figure and menu levels:

```
set(0, 'DefaultUimenuPropertyName', PropertyValue...)
set(gcf, 'DefaultUimenuPropertyName', PropertyValue...)
set(menu_handle, 'DefaultUimenuPropertyName', PropertyValue...)
```

Where *PropertyName* is the name of the Uimenu property and *PropertyValue* is the value you specify as the default for that property.

For more information about changing the default value of property see “Setting Default Property Values”

## Uimenu Properties

This section lists all properties useful to uimenu objects along with valid values and instructions for their use. Curly braces { } enclose default values.

| Property Name | Property Description          |
|---------------|-------------------------------|
| Accelerator   | Keyboard equivalent           |
| BusyAction    | Callback routine interruption |
| Callback      | Control action                |
| Checked       | Menu check indicator          |
| Children      | Handles of submenus           |

# Uimenu Properties

---

| Property Name    | Property Description                                    |
|------------------|---------------------------------------------------------|
| CreateFcn        | Callback routine executed during object creation        |
| DeleteFcn        | Callback routine executed during object deletion        |
| Enable           | Enable or disable the uimenu                            |
| ForegroundColor  | Color of text                                           |
| HandleVisibility | Whether handle is accessible from command line and GUIs |
| Interruptible    | Callback routine interruption mode                      |
| Label            | Menu label                                              |
| Parent           | Uimenu object's parent                                  |
| Position         | Relative uimenu position                                |
| Separator        | Separator line mode                                     |
| Tag              | User-specified object identifier                        |
| Type             | Class of graphics object                                |
| UserData         | User-specified data                                     |
| Visible          | Uimenu visibility                                       |

Accelerator  
character

*Keyboard equivalent.* An alphabetic character specifying the keyboard equivalent for the menu item. This allows users to select a particular menu choice by pressing the specified character in conjunction with another key, instead of selecting the menu item with the mouse. The key sequence is platform specific:

- For Microsoft Windows systems, the sequence is **Ctrl+Accelerator**. These keys are reserved for default menu items: c, v, and x.
- For UNIX systems, the sequence is **Ctrl+Accelerator**. These keys are reserved for default menu items: o, p, s, and w.

You can define an accelerator only for menu items that do not have children menus. Accelerators work only for menu items that directly execute a callback routine, not items that bring up other menus.

Note that the menu item does not have to be displayed (e.g., a submenu) for the accelerator key to work. However, the window focus must be in the figure when the key sequence is entered.

To remove an accelerator, set `Accelerator` to an empty string, ''.

`BusyAction`  
`cancel | {queue}`

*Callback routine interruption.* If a callback is executing and the user triggers an event (such as a mouse click) on an object for which a callback is defined, the callback associated with the new event uses the value of `BusyAction` to decide whether or not to attempt to interrupt the executing callback.

- If the value is `cancel`, the event is discarded and the second callback does not execute.
- If the value is `queue`, and the `Interruptible` property of the first callback is `on`, the second callback is added to the event queue and executes in its turn after the first callback finishes execution.

# Uimenu Properties

---

---

**Note** If the interrupting callback is a `DeleteFcn` or `CreateFcn` callback or a figure's `CloseRequest` or `ResizeFcn` callback, it interrupts an executing callback regardless of the value of that object's `Interruptible` property. See the `Interruptible` property for information about controlling a callback's interruptibility.

---

## Callback

string or function handle

*Menu action.* A callback routine that executes whenever you select the menu. Define this routine as a string that is a valid MATLAB expression or the name of an M-file. The expression executes in the MATLAB workspace.

A menu with children (submenus) executes its callback routine before displaying the submenus. A menu without children executes its callback routine when you *release* the mouse button (i.e., on the button up event).

## Checked

on | {off}

*Menu check indicator.* Setting this property to `on` places a check mark next to the corresponding menu item. Setting it to `off` removes the check mark. You can use this feature to create menus that indicate the state of a particular option. For example, suppose you have a menu item called **Show axes** that toggles the visibility of an axes between visible and invisible each time the user selects the menu item. If you want a check to appear next to the menu item when the axes are visible, add the following code to the callback for the **Show axes** menu item:

```
if strcmp(get(gcbo, 'Checked'), 'on')
 set(gcbo, 'Checked', 'off');
else
```



```
 set(gcbo, 'Checked', 'on');
 end
```

This changes the value of the `Checked` property of the menu item from `on` to `off` or vice versa each time a user selects the menu item.

Note that there is no formal mechanism for indicating that an unchecked menu item will become checked when selected.

---

**Note** This property is ignored for top level and parent menus.

---

## Children

vector of handles

*Handles of submenus.* A vector containing the handles of all children of the `uimenu` object. The children objects of `uimenu`s are other `uimenu`s, which function as submenus. You can use this property to reorder the menus.

## CreateFcn

string or function handle

*Callback routine executed during object creation.* The specified function executes when MATLAB creates a `uimenu` object. MATLAB sets all property values for the `uimenu` before executing the `CreateFcn` callback so these values are available to the callback. Within the function, use `gcbo` to get the handle of the `uimenu` being created.

Setting this property on an existing `uimenu` object has no effect.

You can define a default `CreateFcn` callback for all new `uimenu`s. This default applies unless you override it by specifying a different `CreateFcn` callback when you call `uimenu`. For example, the code

# Uimenu Properties

---

```
set(0, 'DefaultUimenuCreateFcn', 'set(gcbo,...
 'Visible','on'))
```

creates a default `CreateFcn` callback that runs whenever you create a new menu. It sets the default `Visible` property of a `uimenu` object.

To override this default and create a menu whose `Visible` property is set to a different value, call `uimenu` with code similar to

```
hpt = uimenu(..., 'CreateFcn', 'set(gcbo,...
 'Visible','off'))
```

---

**Note** To override a default `CreateFcn` callback you must provide a new callback and not just provide different values for the specified properties. This is because the `CreateFcn` callback runs after the property values are set, and can override property values you have set explicitly in the `uimenu` call. In the example above, if instead of redefining the `CreateFcn` property for this `uimenu`, you had explicitly set `Visible` to `off`, the default `CreateFcn` callback would have set `Visible` back to the default, i.e., `on`.

---

Do not call `copyobj` or `textwrap` (which calls `copyobj`) inside a `CreateFcn`. The act of copying the `uicontrol` object fires the `CreateFcn` repeatedly, which raises a series of error messages after exceeding the root object's `RecursionLimit` property.

See “Function Handle Callbacks” for information on how to use function handles to define a callback function.

**DeleteFcn**  
string or function handle

*Delete uimenu callback routine.* A callback routine that executes when you delete the `uimenu` object (e.g., when you issue a `delete` command or cause the figure containing the `uimenu` to reset).

MATLAB executes the routine before destroying the object's properties so these values are available to the callback routine.

The handle of the object whose DeleteFcn is being executed is accessible only through the root CallbackObject property, which is more simply queried using `gcbo`.

See “Function Handle Callbacks” for information on how to use function handles to define a callback function.

## Enable

{on} | off

*Enable or disable the uimenu.* This property controls whether a menu item can be selected. When not enabled (set to `off`), the menu `Label` appears dimmed, indicating the user cannot select it.

## ForegroundColor

ColorSpec X-Windows only

*Color of menu label string.* This property determines color of the text defined for the `Label` property. Specify a color using a three-element RGB vector or one of the MATLAB predefined names. The default text color is black. See `ColorSpec` for more information on specifying color.

## HandleVisibility

{on} | callback | off

*Control access to object's handle.* This property determines when an object's handle is visible in its parent's list of children. When a handle is not visible in its parent's list of children, it is not returned by functions that obtain handles by searching the object hierarchy or querying handle properties. This includes `get`, `findobj`, `gca`, `gcf`, `gco`, `newplot`, `cla`, `clf`, and `close`. Neither is the handle visible in the parent figure's `CurrentObject` property. Handles that are hidden are still valid. If you know an object's

# Uimenu Properties

---

handle, you can set and get its properties, and pass it to any function that operates on handles.

- Handles are always visible when `HandleVisibility` is on.
- Setting `HandleVisibility` to `callback` causes handles to be visible from within callback routines or functions invoked by callback routines, but not from within functions invoked from the command line. This provides a means to protect GUIs from command-line users, while allowing callback routines to have complete access to object handles.
- Setting `HandleVisibility` to `off` makes handles invisible at all times. This may be necessary when a callback routine invokes a function that might potentially damage the GUI (such as evaluating a user-typed string), and so temporarily hides its own handles during the execution of that function.

You can set the root `ShowHiddenHandles` property to `on` to make all handles visible, regardless of their `HandleVisibility` settings. This does not affect the values of the `HandleVisibility` properties.

`Interruptible`  
{on} | off

*Callback routine interruption mode.* If a callback is executing and the user triggers an event (such as a mouse click) on an object for which a callback is defined, that callback attempts to interrupt the first callback. MATLAB processes the callbacks according to these factors:

- The `Interruptible` property of the object whose callback is executing
- Whether the executing callback contains `drawnow`, `figure`, `getframe`, `pause`, or `waitfor` statements
- The `BusyAction` property of the object whose callback is waiting to execute

If the `Interruptible` property of the object whose callback is executing is `on` (the default), the callback can be interrupted. Whenever the callback calls one of the `drawnow`, `figure`, `getframe`, `pause`, or `waitfor` functions, the function processes any events in the event queue, including the waiting callback, before performing its defined task.

If the `Interruptible` property of the object whose callback is executing is `off`, the callback cannot be interrupted (except by certain callbacks; see the note below). The `BusyAction` property of the object whose callback is waiting to execute determines what happens to the callback.

---

**Note** If the interrupting callback is a `DeleteFcn` or `CreateFcn` callback or a figure's `CloseRequest` or `ResizeFcn` callback, it interrupts an executing callback regardless of the value of that object's `Interruptible` property. The interrupting callback starts execution at the next `drawnow`, `figure`, `getframe`, `pause`, or `waitfor` statement. A figure's `WindowButtonDownFcn` callback routine, or an object's `ButtonDownFcn` or `Callback` routine are processed according to the rules described above.

---

## Label

string

*Menu label.* A string specifying the text label on the menu item. You can specify a mnemonic for the label using the `'&'` character. Except as noted below, the character that follows the `'&'` in the string appears underlined and selects the menu item when you type **Alt+** followed by that character while the menu is visible. The `'&'` character is not displayed. To display the `'&'` character in a label, use two `'&'` characters in the string:

`'O&&pen selection'` yields **Open selection**

# Uimenu Properties

---

'Save && Go' yields **Save & Go**

'Save&&Go' yields **Save & Go**

'Save& Go' yields **Save& Go** (the space is not a mnemonic)

There are three reserved words: `default`, `remove`, `factory` (case sensitive). If you want to use one of these reserved words in the `Label` property, you must precede it with a backslash ('\\') character. For example:

'\\remove' yields **remove**

'\\default' yields **default**

'\\factory' yields **factory**

## Parent

handle

*Uimenu's parent.* The handle of the uimenu's parent object. The parent of a uimenu object is the figure on whose menu bar it displays, or the uimenu of which it is a submenu. You can move a uimenu object to another figure by setting this property to the handle of the new parent.

## Position

scalar

*Relative menu position.* The value of `Position` indicates placement on the menu bar or within a menu. Top-level menus are placed from left to right on the menu bar according to the value of their `Position` property, with 1 representing the left-most position. The individual items within a given menu are placed from top to bottom according to the value of their `Position` property, with 1 representing the top-most position.

## Separator

on | {off}

*Separator line mode.* Setting this property to on draws a dividing line above the menu item.

## Tag

string

*User-specified object label.* The Tag property provides a means to identify graphics objects with a user-specified label. This is particularly useful when constructing interactive graphics programs that would otherwise need to define object handles as global variables or pass them as arguments between callback routines. You can define Tag as any string.

## Type

string (read only)

*Class of graphics object.* For uimenu objects, Type is always the string 'uimenu'.

## UserData

matrix

*User-specified data.* Any matrix you want to associate with the uimenu object. MATLAB does not use this data, but you can access it using the set and get commands.

## Visible

{on} | off

*Uimenu visibility.* By default, all uimenu are visible. When set to off, the uimenu is not visible, but still exists and you can query and set its properties.

# uint8, uint16, uint32, uint64

**Purpose** Convert to unsigned integer

**Syntax**

```
I = uint8(X)
I = uint16(X)
I = uint32(X)
I = uint64(X)
```

**Description** `I = uint*(X)` converts the elements of array `X` into unsigned integers. `X` can be any numeric object (such as a `double`). The results of a `uint*` operation are shown in the next table.

| Operation           | Output Range                    | Output Type             | Bytes per Element | Output Class        |
|---------------------|---------------------------------|-------------------------|-------------------|---------------------|
| <code>uint8</code>  | 0 to 255                        | Unsigned 8-bit integer  | 1                 | <code>uint8</code>  |
| <code>uint16</code> | 0 to 65,535                     | Unsigned 16-bit integer | 2                 | <code>uint16</code> |
| <code>uint32</code> | 0 to 4,294,967,295              | Unsigned 32-bit integer | 4                 | <code>uint32</code> |
| <code>uint64</code> | 0 to 18,446,744,073,709,551,615 | Unsigned 64-bit integer | 8                 | <code>uint64</code> |

`double` and `single` values are rounded to the nearest `uint*` value on conversion. A value of `X` that is above or below the range for an integer class is mapped to one of the endpoints of the range. For example,

```
uint16(70000)
ans =
 65535
```

If `X` is already an unsigned integer of the same class, then `uint*` has no effect.



You can define or overload your own methods for `uint*` (as you can for any object) by placing the appropriately named method in an `@uint*` directory within a directory on your path. Type `help datatypes` for the names of the methods you can overload.

## Remarks

Most operations that manipulate arrays without changing their elements are defined for integer values. Examples are `reshape`, `size`, the logical and relational operators, subscripted assignment, and subscripted reference.

Some arithmetic operations are defined for integer arrays on interaction with other integer arrays of the same class (e.g., where both operands are `uint16`). Examples of these operations are `+`, `-`, `.*`, `./`, `.\` and `.^`. If at least one operand is scalar, then `*`, `/`, `\`, and `^` are also defined. Integer arrays may also interact with scalar `double` variables, including constants, and the result of the operation is an integer array of the same class. Integer arrays saturate on overflow in arithmetic.

---

**Note** Only the lower order integer data types support math operations. Math operations are not supported for `int64` and `uint64`.

---

A particularly efficient way to initialize a large array is by specifying the data type (i.e., class name) for the array in the `zeros`, `ones`, or `eye` function. For example, to create a 100-by-100 `uint64` array initialized to zero, type

```
I = zeros(100, 100, 'uint64');
```

An easy way to find the range for any MATLAB integer type is to use the `intmin` and `intmax` functions as shown here for `uint32`:

```
intmin('uint32') intmax('uint32')
ans = ans =
 0 4294967295
```

## See Also

`double`, `single`, `int8`, `int16`, `int32`, `int64`, `intmax`, `intmin`

# uiopen

---

**Purpose** Open file selection dialog box with appropriate file filters

**Syntax**

```
uiopen
uiopen('MATLAB')
uiopen('LOAD')
uiopen('FIGURE')
uiopen('SIMULINK')
uiopen('EDITOR')
```

**Description** `uiopen` displays a modal file selection dialog from which a user can select a file to open. The dialog is the same as the one displayed when you select **Open** from the **File** menu in the MATLAB desktop.

Selecting a file in the dialog and clicking **Open** does the following:

- Gets the file using `uigetfile`
- Opens the file in the base workspace using the `open` command

---

**Note** A modal dialog box prevents the user from interacting with other windows before responding. For more information, see `WindowState` in the MATLAB Figure Properties.

---

---

**Note** Only the form `uiopen('LOAD')` can be compiled into a standalone application. You can create a file selection dialog that can be compiled using `uigetfile`.

---

`uiopen` or `uiopen('MATLAB')` displays the dialog with the file filter set to all MATLAB files.

`uiopen('LOAD')` displays the dialog with the file filter set to MAT-files (\*.mat).

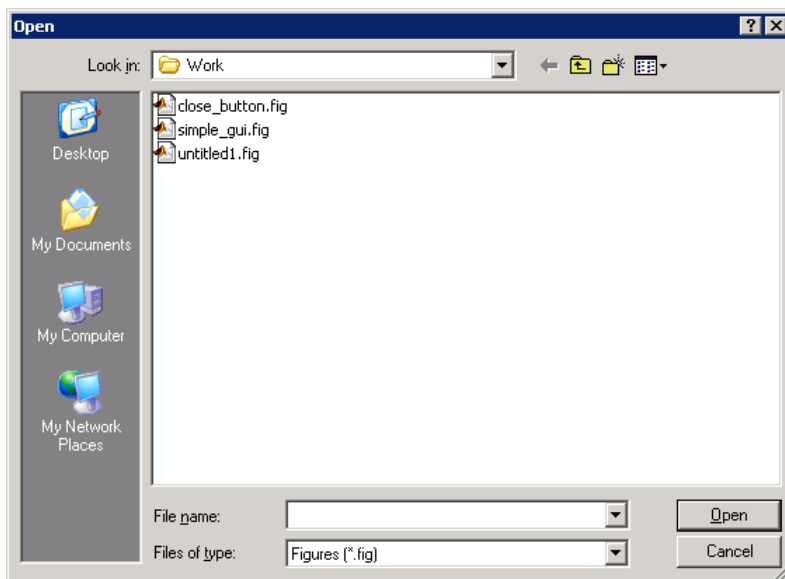
`uiopen('FIGURE')` displays the dialog with the file filter set to figure files (\*.fig).

`uiopen('SIMULINK')` displays the dialog with the file filter set to model files (\*.mdl).

`uiopen('EDITOR')` displays the dialog with the file filter set to all MATLAB files except for MAT-files and FIG-files. All files are opened in the MATLAB Editor.

## Examples

Typing `uiopen('figure')` sets the **Files of type** field to Figures (\*.fig):



## See Also

`uigetfile`, `uiputfile`, `uisave`

# uipanel

---

## Purpose

Create panel container object

## Syntax

```
h = uipanel('PropertyName1',value1,'PropertyName2',value2,
...)
h = uipanel(parent,'PropertyName1',value1,'PropertyName2',
value2,...)
```

## Description

A uipanel groups components. It can contain user interface controls with which the user interacts directly. It can also contain axes, other uipanel, and uibuttongroups. It cannot contain ActiveX controls.

```
h =
uipanel('PropertyName1',value1,'PropertyName2',value2,...)
creates a uipanel container object in a figure, uipanel, or
uibuttongroup. Use the Parent property to specify the parent figure,
uipanel, or uibuttongroup. If you do not specify a parent, uipanel adds
the panel to the current figure. If no figure exists, one is created. See
the Uipanel Properties reference page for more information.
```

```
h =
uipanel(parent,'PropertyName1',value1,'PropertyName2',value2,...)
creates a uipanel in the object specified by the handle, parent. If you
also specify a different value for the Parent property, the value
of the Parent property takes precedence. parent must be a
figure, uipanel, or uibuttongroup.
```

A uipanel object can have axes, uicontrol, uipanel, and uibuttongroup objects as children. For the children of a uipanel, the Position property is interpreted relative to the uipanel. If you move the panel, the children automatically move with it and maintain their positions relative to the panel.

After creating a uipanel object, you can set and query its property values using set and get.

## Remarks

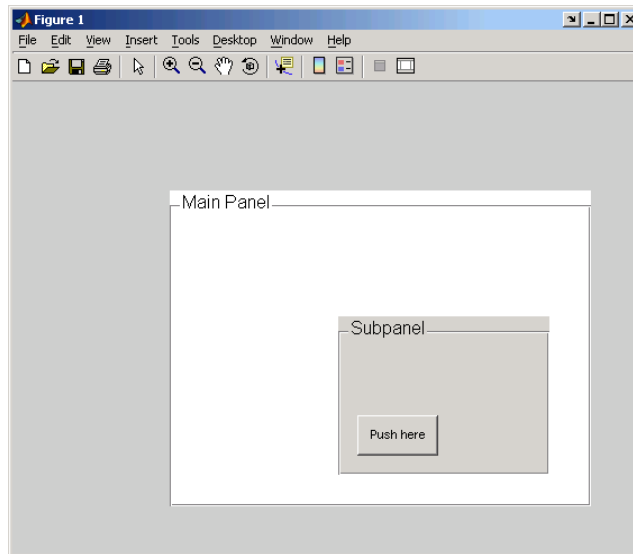
If you set the Visible property of a uipanel object to 'off', any child objects it contains (buttons, button groups, axes, etc.) become invisible along with the panel itself. However, doing this does *not* affect the

settings of the `Visible` property of any of its child objects, even though all of them remain invisible until the `uipanel`'s visibility is set to `'on'`. `uibuttongroup` components also behave in this manner.

## Examples

This example creates a `uipanel` in a figure, then creates a subpanel in the first panel. Finally, it adds a pushbutton to the subpanel. Both panels use the default `Units` property value, normalized. Note that default `Units` for the `uicontrol` pushbutton is pixels.

```
h = figure;
hp = uipanel('Title','Main Panel','FontSize',12,...
 'BackgroundColor','white',...
 'Position',[.25 .1 .67 .67]);
hsp = uipanel('Parent',hp,'Title','Subpanel','FontSize',12,...
 'Position',[.4 .1 .5 .5]);
hbsp = uicontrol('Parent',hsp,'String','Push here',...
 'Position',[18 18 72 36]);
```



# uipanel

---

## **See Also**

hgtransform, uibuttongroup, uicontrol

## Purpose

Describe panel properties

## Modifying Properties

You can set and query graphics object properties in two ways:

- The Property Inspector is an interactive tool that enables you to see and change object property values. The Property inspector is available from GUIDE, or use the `inspect` function at the command line.
- The `set` and `get` functions enable you to set and query the values of properties.

You can set default uipanel properties by typing:

```
set(h, 'DefaultUipanelPropertyName', PropertyValue...)
```

Where `h` can be the root handle (0), a figure handle, or a uipanel handle. *PropertyName* is the name of the uipanel property and *PropertyValue* is the value you specify as the default for that property.

---

**Note** Default properties you set for uipanel also apply to `uibuttongroups`.

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For more information about changing the default value of a property see “Setting Default Property Values”. For an example, see the `CreateFcn` property.

## Uipanel Properties

This section lists all properties useful to `uipanel` objects along with valid values and a descriptions of their use. Curly braces { } enclose default values.

| Property Name                | Description                             |
|------------------------------|-----------------------------------------|
| <code>BackgroundColor</code> | Color of the uipanel background         |
| <code>BorderType</code>      | Type of border around the uipanel area. |

# Uipanel Properties

---

| Property Name    | Description                                                                                           |
|------------------|-------------------------------------------------------------------------------------------------------|
| BorderWidth      | Width of the panel border.                                                                            |
| BusyAction       | Interruption of other callback routines                                                               |
| ButtonDownFcn    | Button-press callback routine                                                                         |
| Children         | All children of the uipanel                                                                           |
| Clipping         | Clipping of child axes, uipanel, and uibuttongroups to the uipanel. Does not affect child uicontrols. |
| CreateFcn        | Callback routine executed during object creation                                                      |
| DeleteFcn        | Callback routine executed during object deletion                                                      |
| FontAngle        | Title font angle                                                                                      |
| FontName         | Title font name                                                                                       |
| FontSize         | Title font size                                                                                       |
| FontUnits        | Title font units                                                                                      |
| FontWeight       | Title font weight                                                                                     |
| ForegroundColor  | Title font color and/or color of 2-D border line                                                      |
| HandleVisibility | Handle accessibility from commandline and GUIs                                                        |
| HighlightColor   | 3-D frame highlight color                                                                             |
| Interruptible    | Callback routine interruption mode                                                                    |
| Parent           | Uipanel object's parent                                                                               |
| Position         | Panel position relative to parent figure or uipanel                                                   |
| ResizeFcn        | User-specified resize routine                                                                         |
| Selected         | Whether object is selected                                                                            |



# Uipanel Properties

| Property Name      | Description                                                                                                                                                                                                  |
|--------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| SelectionHighlight | Object highlighted when selected                                                                                                                                                                             |
| ShadowColor        | 3-D frame shadow color                                                                                                                                                                                       |
| Tag                | User-specified object identifier                                                                                                                                                                             |
| Title              | Title string                                                                                                                                                                                                 |
| TitlePosition      | Location of title string in relation to the panel                                                                                                                                                            |
| Type               | Object class                                                                                                                                                                                                 |
| UIContextMenu      | Associates uicontextmenu with the uipanel                                                                                                                                                                    |
| Units              | Units used to interpret the position vector                                                                                                                                                                  |
| UserData           | User-specified data                                                                                                                                                                                          |
| Visible            | Uipanel visibility.<br><hr/> <b>Note</b> Controls the visibility of a uipanel and of its child axes, uibuttongroups, uipanel, and child uicontrols. Setting it does not change their Visible property. <hr/> |

BackgroundColor  
ColorSpec

*Color of the uipanel background.* A three-element RGB vector or one of the MATLAB predefined names, specifying the background color. See the ColorSpec reference page for more information on specifying color.

BorderType  
none | {etchedin} | etchedout | beveledin | beveledout  
| line

# Uipanel Properties

---

*Border of the uipanel area.* Used to define the panel area graphically. Etched and beveled borders provide a 3-D look. Use the `HighlightColor` and `ShadowColor` properties to specify the border color of etched and beveled borders. A line border is 2-D. Use the `ForegroundColor` property to specify its color.

`BorderWidth`  
integer

*Width of the panel border.* The width of the panel borders in pixels. The default border width is 1 pixel. 3-D borders wider than 3 may not appear correctly at the corners.

`BusyAction`  
cancel | {queue}

*Callback routine interruption.* If a callback is executing and the user triggers an event (such as a mouse click) on an object for which a callback is defined, the callback associated with the new event uses the value of `BusyAction` to decide whether or not to attempt to interrupt the executing callback.

- If the value is `cancel`, the event is discarded and the second callback does not execute.
- If the value is `queue`, and the `Interruptible` property of the first callback is `on`, the second callback is added to the event queue and executes in its turn after the first callback finishes execution.

---

**Note** If the interrupting callback is a `DeleteFcn` or `CreateFcn` callback or a figure's `CloseRequest` or `ResizeFcn` callback, it interrupts an executing callback regardless of the value of that object's `Interruptible` property. See the `Interruptible` property for information about controlling a callback's interruptibility.

---

## ButtonDownFcn

string or function handle

*Button-press callback routine.* A callback routine that executes when you press a mouse button while the pointer is in a 5-pixel wide border around the uipanel. This is useful for implementing actions to interactively modify control object properties, such as size and position, when they are clicked on (using the `selectmoveresize` function, for example).

If you define this routine as a string, the string can be a valid MATLAB expression or the name of an M-file. The expression executes in the MATLAB workspace.

## Children

vector of handles

*Children of the uipanel.* A vector containing the handles of all children of the uipanel. A `uipanel` object's children are axes, uipanels, `uibuttongroups`, and `uicontrols`. You can use this property to reorder the children.

## Clipping

{on} | off

*Clipping mode.* By default, MATLAB clips a uipanel's child axes, uipanels, and `uibuttongroups` to the uipanel rectangle. If you set `Clipping` to `off`, the axis, uipanel, or `uibuttongroup` is displayed outside the panel rectangle. This property does not affect child `uicontrols` which, by default, can display outside the panel rectangle.

## CreateFcn

string or function handle

*Callback routine executed during object creation.* The specified function executes when MATLAB creates a `uipanel` object. MATLAB sets all property values for the uipanel before executing

# Uipanel Properties

---

the `CreateFcn` callback so these values are available to the callback. Within the function, use `gcbo` to get the handle of the uipanel being created.

Setting this property on an existing uipanel object has no effect.

You can define a default `CreateFcn` callback for all new uipanel. This default applies unless you override it by specifying a different `CreateFcn` callback when you call `uipanel`. For example, the code

```
set(0, 'DefaultUipanelCreateFcn', 'set(gcbo, ...
 ' 'FontName', 'arial', 'FontSize', 12)')
```

creates a default `CreateFcn` callback that runs whenever you create a new panel. It sets the default font name and font size of the uipanel title.

---

**Note** `Uibuttongroup` takes its default property values from `uipanel`. Defining a default property for all uipanel defines the same default property for all `uibuttongroups`.

---

To override this default and create a panel whose `FontName` and `FontSize` properties are set to different values, call `uipanel` with code similar to

```
hpt = uipanel(..., 'CreateFcn', 'set(gcbo, ...
 ' 'FontName', 'times', 'FontSize', 14)')
```

---

**Note** To override a default `CreateFcn` callback you must provide a new callback and not just provide different values for the specified properties. This is because the `CreateFcn` callback runs after the property values are set, and can override property values you have set explicitly in the `uipushtool` call. In the example above, if instead of redefining the `CreateFcn` property for this uipanel, you had explicitly set `FontSize` to 14, the default `CreateFcn` callback would have set `FontSize` back to the system dependent default.

---

Do not call `copyobj` or `textwrap` (which calls `copyobj`) inside a `CreateFcn`. The act of copying the `uicontrol` object fires the `CreateFcn` repeatedly, which raises a series of error messages after exceeding the root object's `RecursionLimit` property.

See “Function Handle Callbacks” for information on how to use function handles to define a callback function.

## DeleteFcn

string or function handle

*Callback routine executed during object deletion.* A callback routine that executes when you delete the uipanel object (e.g., when you issue a delete command or clear the figure containing the uipanel). MATLAB executes the routine before destroying the object's properties so these values are available to the callback routine. The handle of the object whose `DeleteFcn` is being executed is accessible only through the root `CallbackObject` property, which you can query using `gcbo`.

## FontAngle

{normal} | italic | oblique

*Character slant used in the Title.* MATLAB uses this property to select a font from those available on your particular system. Setting this property to `italic` or `oblique` selects a slanted version of the font, when it is available on your system.

# Uipanel Properties

---

FontName  
string

*Font family used in the Title.* The name of the font in which to display the Title. To display and print properly, this must be a font that your system supports. The default font is system dependent. To eliminate the need to hard code the name of a fixed-width font, which may not display text properly on systems that do not use ASCII character encoding (such as in Japan), set FontName to the string FixedWidth (this string value is case insensitive).

```
set(uicontrol_handle, 'FontName', 'FixedWidth')
```

This then uses the value of the root FixedWidthFontName property which can be set to the appropriate value for a locale from startup.m in the end user's environment. Setting the root FixedWidthFontName property causes an immediate update of the display to use the new font

FontSize  
integer

*Title font size.* A number specifying the size of the font in which to display the Title, in units determined by the FontUnits property. The default size is system dependent.

FontUnits  
inches | centimeters | normalized | {points} | pixels

*Title font size units.* Normalized units interpret FontSize as a fraction of the height of the uipanel. When you resize the uipanel, MATLAB modifies the screen FontSize accordingly. pixels, inches, centimeters, and points are absolute units (1 point = 1/72 inch).

FontWeight  
light | {normal} | demi | bold

*Weight of characters in the title.* MATLAB uses this property to select a font from those available on your particular system. Setting this property to bold causes MATLAB to use a bold version of the font, when it is available on your system.

ForegroundColor  
ColorSpec

*Color used for title font and 2-D border line.* A three-element RGB vector or one of the MATLAB predefined names, specifying the font or line color. See the ColorSpec reference page for more information on specifying color.

HandleVisibility  
{on} | callback | off

*Control access to object's handle.* This property determines when an object's handle is visible in its parent's list of children. When a handle is not visible in its parent's list of children, it is not returned by functions that obtain handles by searching the object hierarchy or querying handle properties. This includes `get`, `findobj`, `gca`, `gcf`, `gco`, `newplot`, `cla`, `clf`, and `close`. Neither is the handle visible in the parent figure's `CurrentObject` property. Handles that are hidden are still valid. If you know an object's handle, you can `set` and `get` its properties, and pass it to any function that operates on handles.

- Handles are always visible when `HandleVisibility` is `on`.
- Setting `HandleVisibility` to `callback` causes handles to be visible from within callback routines or functions invoked by callback routines, but not from within functions invoked from the command line. This provides a means to protect GUIs from command-line users, while allowing callback routines to have complete access to object handles.
- Setting `HandleVisibility` to `off` makes handles invisible at all times. This may be necessary when a callback routine invokes a function that might potentially damage the GUI

# Uipanel Properties

---

(such as evaluating a user-typed string), and so temporarily hides its own handles during the execution of that function.

You can set the root `ShowHiddenHandles` property to `on` to make all handles visible, regardless of their `HandleVisibility` settings. This does not affect the values of the `HandleVisibility` properties.

`HighlightColor`  
`ColorSpec`

*3-D frame highlight color.* A three-element RGB vector or one of the MATLAB predefined names, specifying the highlight color. See the `ColorSpec` reference page for more information on specifying color.

`Interruptible`  
`{on} | off`

*Callback routine interruption mode.* If a callback is executing and the user triggers an event (such as a mouse click) on an object for which a callback is defined, that callback attempts to interrupt the first callback. MATLAB processes the callbacks according to these factors:

- The `Interruptible` property of the object whose callback is executing
- Whether the executing callback contains `drawnow`, `figure`, `getframe`, `pause`, or `waitfor` statements
- The `BusyAction` property of the object whose callback is waiting to execute

If the `Interruptible` property of the object whose callback is executing is `on` (the default), the callback can be interrupted. Whenever the callback calls one of the `drawnow`, `figure`, `getframe`, `pause`, or `waitfor` functions, the function processes



any events in the event queue, including the waiting callback, before performing its defined task.

If the `Interruptible` property of the object whose callback is executing is `off`, the callback cannot be interrupted (except by certain callbacks; see the note below). The `BusyAction` property of the object whose callback is waiting to execute determines what happens to the callback.

---

**Note** If the interrupting callback is a `DeleteFcn` or `CreateFcn` callback or a figure's `CloseRequest` or `ResizeFcn` callback, it interrupts an executing callback regardless of the value of that object's `Interruptible` property. The interrupting callback starts execution at the next `drawnow`, `figure`, `getframe`, `pause`, or `waitfor` statement. A figure's `WindowButtonDownFcn` callback routine, or an object's `ButtonDownFcn` or `Callback` routine are processed according to the rules described above.

---

## Parent

handle

*Uipanel parent.* The handle of the uipanel's parent figure, uipanel, or uibuttongroup. You can move a uipanel object to another figure, uipanel, or uibuttongroup by setting this property to the handle of the new parent.

## Position

position rectangle

*Size and location of uipanel relative to parent.* The rectangle defined by this property specifies the size and location of the panel within the parent figure window, uipanel, or uibuttongroup. Specify `Position` as

```
[left bottom width height]
```

# Uipanel Properties

---

`left` and `bottom` are the distance from the lower-left corner of the parent object to the lower-left corner of the `uipanel` object. `width` and `height` are the dimensions of the `uipanel` rectangle, including the title. All measurements are in units specified by the `Units` property.

`ResizeFcn`  
string or function handle

*Resize callback routine.* MATLAB executes this callback routine whenever a user resizes the `uipanel` and the figure `Resize` property is set to `on`, or in GUIDE, the `Resize` behavior option is set to `Other`. You can query the `uipanel` `Position` property to determine its new size and position. During execution of the callback routine, the handle to the figure being resized is accessible only through the root `CallbackObject` property, which you can query using `gcbo`.

All axes, `uipanel`, `uitable` and `uicontrol` objects that have their `Units` set to `normalized` automatically resize proportionally to the figure. You can define individual resize functions for any such object as needed. For example, you can use `ResizeFcn` to maintain a GUI layout that is not directly supported by the MATLAB `Position/Units` paradigm.

For example, consider a GUI layout that maintains an object at a constant height in pixels and attached to the top of the figure, but always matches the width of the figure. The following `ResizeFcn` accomplishes this; it keeps the `uicontrol` whose `Tag` is `'StatusBar'` 20 pixels high, as wide as the figure, and attached to the top of the figure. Note the use of the `Tag` property to retrieve the `uicontrol` handle, and the `gcbo` function to retrieve the figure handle. Also note the defensive programming regarding figure `Units`, which the callback requires to be in pixels in order to work correctly, but which the callback also restores to their previous value afterwards.

```
u = findobj('Tag','StatusBar');
```

```
fig = gcbo;
old_units = get(fig,'Units');
set(fig,'Units','pixels');
figpos = get(fig,'Position');
upos = [0, figpos(4) - 20, figpos(3), 20];
set(u,'Position',upos);
set(fig,'Units',old_units);
```

You can change the figure `Position` from within a uipanel `ResizeFcn` callback; however, the `ResizeFcn` is not called again as a result.

A figure's uipanel resize before the figure itself does. Nested uipanel resize from inner to outer, with child `ResizeFcns` being called before parent `ResizeFcns`.

Note that the `print` command can cause the `ResizeFcn` to be called if the `PaperPositionMode` property is set to `manual` and you have defined a resize function. If you do not want your resize function called by `print`, set the `PaperPositionMode` to `auto`.

See “Function Handle Callbacks” for information on how to use function handles to define the callback function.

See `Resize Behavior` for information on creating resize functions using `GUIDE`.

## Selected

on | off (read only)

*Is object selected?* This property indicates whether the panel is selected. When this property is on, MATLAB displays selection handles if the `SelectionHighlight` property is also on. You can, for example, define the `ButtonDownFcn` to set this property, allowing users to select the object with the mouse.

## SelectionHighlight

{on} | off

# Uipanel Properties

---

*Object highlighted when selected.* When the `Selected` property is on, MATLAB indicates the selected state by drawing four edge handles and four corner handles. When `SelectionHighlight` is off, MATLAB does not draw the handles.

`ShadowColor`  
`ColorSpec`

*3-D frame shadow color.* A three-element RGB vector or one of the MATLAB predefined names, specifying the shadow color. See the `ColorSpec` reference page for more information on specifying color.

`Tag`  
string

*User-specified object identifier.* The `Tag` property provides a means to identify graphics objects with a user-specified label. You can define `Tag` as any string.

With the `findobj` function, you can locate an object with a given `Tag` property value. This saves you from defining object handles as global variables. For example, this function call returns the handles of all children (of the specified figures) that have the `Tag` value `'FormatTb'`.

```
h = findobj(figurehandles,'Tag','FormatTb')
```

`Title`  
string

*Title string.* The text displayed in the panel title. You can position the title using the `TitlePosition` property.

If the string value is specified as a cell array of strings or padded string matrix, only the first string of a cell array or of a padded string matrix is displayed; the rest are ignored. Vertical slash (`'\'`)

characters are not interpreted as line breaks and instead show up in the text displayed in the uipanel title.

Setting a property value to `default`, `remove`, or `factory` produces the effect described in “Defining Default Values”. To set `Title` to one of these words, you must precede the word with the backslash character. For example,

```
hp = uipanel(...,'Title','\Default');
```

## TitlePosition

{lefttop} | centertop | righttop | leftbottom |  
centerbottom | rightbottom

*Location of the title.* This property determines the location of the title string, in relation to the uipanel.

## Type

string (read-only)

*Object class.* This property identifies the kind of graphics object. For uipanel objects, `Type` is always the string `'uipanel'`.

## UIContextMenu

handle

*Associate a context menu with a uipanel.* Assign this property the handle of a `Uicontextmenu` object. MATLAB displays the context menu whenever you right-click the uipanel. Use the `uicontextmenu` function to create the context menu.

## Units

inches | centimeters | {normalized} | points | pixels  
| characters

*Units of measurement.* MATLAB uses these units to interpret the `Position` property. For the panel itself, units are measured from the lower-left corner of the figure window. For children of the panel, they are measured from the lower-left corner of the panel.

# Uipanel Properties

---

- Normalized units map the lower-left corner of the panel or figure window to (0,0) and the upper-right corner to (1.0,1.0).
- pixels, inches, centimeters, and points are absolute units (1 point = 1/72 inch).
- Character units are characters using the default system font; the width of one character is the width of the letter x, the height of one character is the distance between the baselines of two lines of text.

If you change the value of `Units`, it is good practice to return it to its default value after completing your computation so as not to affect other functions that assume `Units` is set to the default value.

`UserData`  
matrix

*User-specified data.* Any data you want to associate with the `uipanel` object. MATLAB does not use this data, but you can access it using `set` and `get`.

`Visible`  
{on} | off

*Uipanel visibility.* By default, a `uipanel` object is visible. When set to 'off', the `uipanel` is not visible, as are all child objects of the panel. When a panel is hidden in this manner, you can still query and set its properties.

---

**Note** The value of a `uipanel`'s `Visible` property determines whether its child components, such as axes, buttons, `uibuttongroups`, and other `uipanel`s, are visible. However, changing the `Visible` property of a panel does *not* change the settings of the `Visible` property of its child components even though hiding the panel causes them to be hidden.

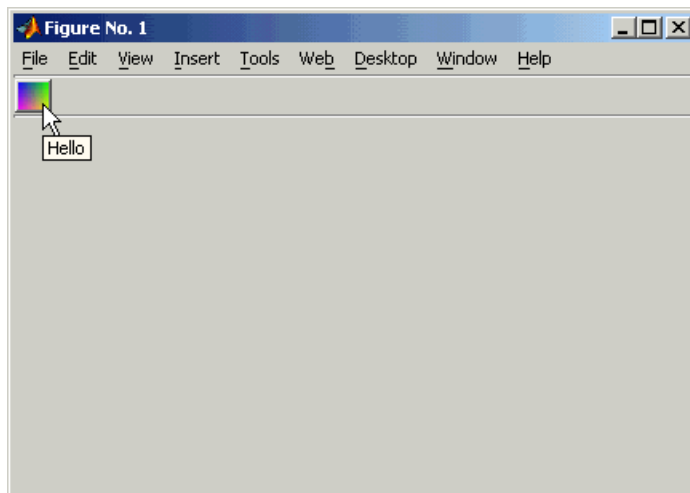
---

|                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
|--------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Purpose</b>     | Create push button on toolbar                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| <b>Syntax</b>      | <pre>hpt = uipushtool('PropertyName1',value1,'PropertyName2',     value2,...) hpt = uipushtool(ht,...)</pre>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| <b>Description</b> | <p><code>hpt = uipushtool('PropertyName1',value1,'PropertyName2',value2,...)</code> creates a push button on the <code>uitoolbar</code> at the top of the current figure window, and returns a handle to it. <code>uipushtool</code> assigns the specified property values, and assigns default values to the remaining properties. You can change the property values at a later time using the <code>set</code> function.</p> <p>Type <code>get(hpt)</code> to see a list of <code>uipushtool</code> object properties and their current values. Type <code>set(hpt)</code> to see a list of <code>uipushtool</code> object properties that you can set and their legal property values. See the <a href="#">Uipushtool Properties</a> reference page for more information.</p> <p><code>hpt = uipushtool(ht,...)</code> creates a button with <code>ht</code> as a parent. <code>ht</code> must be a <code>uitoolbar</code> handle.</p> |
| <b>Remarks</b>     | <p><code>uipushtool</code> accepts property name/property value pairs, as well as structures and cell arrays of properties as input arguments.</p> <p><code>Uipushtools</code> appear in figures whose <code>Window Style</code> is <code>normal</code> or <code>docked</code>. They do not appear in figures whose <code>WindowStyle</code> is <code>modal</code>. If the <code>WindowStyle</code> of a figure containing a <code>uitoolbar</code> and its <code>uipushtool</code> children is changed to <code>modal</code>, the <code>uipushtools</code> still exist and are contained in the <code>Children</code> list of the <code>uitoolbar</code>, but are not displayed until the figure <code>WindowStyle</code> is changed to <code>normal</code> or <code>docked</code>.</p>                                                                                                                                                   |
| <b>Examples</b>    | <p>This example creates a <code>uitoolbar</code> object and places a <code>uipushtool</code> object on it.</p> <pre>h = figure('ToolBar','none') ht = uitoolbar(h) a = [.20:.05:0.95];</pre>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |

# uipushtool

---

```
b(:,:,1) = repmat(a,16,1)';
b(:,:,2) = repmat(a,16,1);
b(:,:,3) = repmat(flipdim(a,2),16,1);
hpt = uipushtool(ht,'CData',b,'TooltipString','Hello')
```



## See Also

`get`, `set`, `uicontrol`, `uitoggletool`, `uitoolbar`



## Purpose

Describe push tool properties

## Modifying Properties

You can set and query graphics object properties in two ways:

- The Property Inspector is an interactive tool that enables you to see and change object property values. The Property inspector is available from GUIDE, or use the `inspect` function at the command line.
- The `set` and `get` functions enable you to set and query the values of properties.

You can set default Uipushtool properties by typing:

```
set(h, 'DefaultUipushtoolPropertyName', PropertyValue...)
```

Where `h` can be the root handle (0), a figure handle, a uicontrol handle, or a uipushtool handle. *PropertyName* is the name of the Uipushtool property and *PropertyValue* is the value you specify as the default for that property.

For more information about changing the default value of a property see Setting Default Property Values.

## Uipushtool Properties

This section lists all properties useful to uipushtool objects along with valid values and a descriptions of their use. Curly braces { } enclose default values.

| Property        | Purpose                                           |
|-----------------|---------------------------------------------------|
| BeingDeleted    | This object is being deleted.                     |
| BusyAction      | Callback routine interruption.                    |
| CData           | Truecolor image displayed on the control.         |
| ClickedCallback | Control action.                                   |
| CreateFcn       | Callback routine executed during object creation. |
| DeleteFcn       | Delete uipushtool callback routine.               |

# Uipushtool Properties

---

| Property         | Purpose                                             |
|------------------|-----------------------------------------------------|
| Enable           | Enable or disable the uipushtool.                   |
| HandleVisibility | Control access to object's handle.                  |
| HitTest          | Whether selectable by mouse click                   |
| Interruptible    | Callback routine interruption mode.                 |
| Parent           | Handle of uipushtool's parent.                      |
| Separator        | Separator line mode                                 |
| Tag              | User-specified object label.                        |
| TooltipString    | Content of object's tooltip.                        |
| Type             | Object class.                                       |
| UicontextMenu    | Uicontextmenu object associated with the uipushtool |
| UserData         | User specified data.                                |
| Visible          | Uipushtool visibility.                              |

**BeingDeleted**  
on | {off} (read only)

*This object is being deleted.* The **BeingDeleted** property provides a mechanism that you can use to determine if objects are in the process of being deleted. MATLAB software sets the **BeingDeleted** property to on when the object's delete function callback is called (see the **DeleteFcn** property). It remains set to on while the delete function executes, after which the object no longer exists.

For example, some functions may not need to perform actions on objects that are being deleted, and therefore, can check the object's **BeingDeleted** property before acting.

## BusyAction

cancel | {queue}

*Callback routine interruption.* If a callback is executing and the user triggers an event (such as a mouse click) on an object for which a callback is defined, the callback associated with the new event uses the value of **BusyAction** to decide whether or not to attempt to interrupt the executing callback.

- If the value is **cancel**, the event is discarded and the second callback does not execute.
- If the value is **queue**, and the **Interruptible** property of the first callback is **on**, the second callback is added to the event queue and executes in its turn after the first callback finishes execution.

---

**Note** If the interrupting callback is a **DeleteFcn** or **CreateFcn** callback or a figure's **CloseRequest** or **ResizeFcn** callback, it interrupts an executing callback regardless of the value of that object's **Interruptible** property. See the **Interruptible** property for information about controlling a callback's interruptibility.

---

## CData

3-dimensional array

*Truecolor image displayed on control.* An  $n$ -by- $m$ -by-3 array of RGB values that defines a truecolor image displayed on either a push button or toggle button. Each value must be between 0.0 and 1.0. If your **CData** array is larger than 16 in the first or second dimension, it may be clipped or cause other undesirable effects. If the array is clipped, only the center 16-by-16 part of the array is used.

# Uipushtool Properties

---

**ClickedCallback**  
string or function handle

*Control action.* A routine that executes when the uipushtool's Enable property is set to on, and you press a mouse button while the pointer is on the push tool itself or in a 5-pixel wide border around it.

**CreateFcn**  
string or function handle

*Callback routine executed during object creation.* The specified function executes when MATLAB creates a uipushtool object. MATLAB sets all property values for the uipushtool before executing the CreateFcn callback so these values are available to the callback. Within the function, use `gcb0` to get the handle of the push tool being created.

Setting this property on an existing uipushtool object has no effect.

You can define a default CreateFcn callback for all new uipushtools. This default applies unless you override it by specifying a different CreateFcn callback when you call `uipushtool`. For example, the code

```
imga(:,:,1) = rand(20);
imga(:,:,2) = rand(20);
imga(:,:,3) = rand(20);
set(0,'DefaultUipushtoolCreateFcn','set(gcb0, 'Cdata',imga)')
```

creates a default CreateFcn callback that runs whenever you create a new push tool. It sets the default image `imga` on the push tool.

To override this default and create a push tool whose `Cdata` property is set to a different image, call `uipushtool` with code similar to

```
a = [.05:.05:0.95];
imgb(:,:,1) = repmat(a,19,1)';
imgb(:,:,2) = repmat(a,19,1);
imgb(:,:,3) = repmat(flipdim(a,2),19,1);
hpt = uipushtool(...,'CreateFcn','set(gcbo,'CData',imgb)',...
```

---

**Note** To override a default `CreateFcn` callback you must provide a new callback and not just provide different values for the specified properties. This is because the `CreateFcn` callback runs after the property values are set, and can override property values you have set explicitly in the `uipushtool` call. In the example above, if instead of redefining the `CreateFcn` property for this push tool, you had explicitly set `CData` to `imgb`, the default `CreateFcn` callback would have set `CData` back to `imga`.

---

Do not call `copyobj` or `textwrap` (which calls `copyobj`) inside a `CreateFcn`. The act of copying the `uicontrol` object fires the `CreateFcn` repeatedly, which raises a series of error messages after exceeding the root object's `RecursionLimit` property.

See “Function Handle Callbacks” for information on how to use function handles to define a callback function.

## DeleteFcn

string or function handle

*Callback routine executed during object deletion.* A callback routine that executes when you delete the `uipushtool` object (e.g., when you call the `delete` function or cause the figure containing the `uipushtool` to reset). MATLAB executes the routine before destroying the object's properties so these values are available to the callback routine.

The handle of the object whose `DeleteFcn` is being executed is accessible only through the root `CallbackObject` property, which you can query using `gcbo`.

# Uipushtool Properties

---

See “Function Handle Callbacks” for information on how to use function handles to define a callback function.

## Enable

{on} | off

*Enable or disable the uipushtool.* This property controls how uipushtools respond to mouse button clicks, including which callback routines execute.

- on – The uipushtool is operational (the default).
- off – The uipushtool is not operational and its image (set by the Cdata property) is grayed out.

When you left-click on a uipushtool whose Enable property is on, MATLAB performs these actions in this order:

- 1 Sets the figure’s SelectionType property.
- 2 Executes the push tool’s ClickedCallback routine.
- 3 Does not set the figure’s CurrentPoint property and does not execute the figure’s WindowButtonDownFcn callback.

When you left-click on a uipushtool whose Enable property is off, or when you right-click a uipushtool whose Enable property has any value, MATLAB performs these actions in this order:

- 1 Sets the figure’s SelectionType property.
- 2 Sets the figure’s CurrentPoint property.
- 3 Executes the figure’s WindowButtonDownFcn callback.
- 4 Does not execute the push tool’s ClickedCallback routine.

## HandleVisibility

{on} | callback | off

*Control access to object’s handle.* This property determines when an object’s handle is visible in its parent’s list of children. When

a handle is not visible in its parent's list of children, it is not returned by functions that obtain handles by searching the object hierarchy or querying handle properties. This includes `get`, `findobj`, `gca`, `gcf`, `gco`, `newplot`, `cla`, `clf`, and `close`. Neither is the handle visible in the parent figure's `CurrentObject` property. Handles that are hidden are still valid. If you know an object's handle, you can `set` and `get` its properties, and pass it to any function that operates on handles.

- Handles are always visible when `HandleVisibility` is `on`.
- Setting `HandleVisibility` to `callback` causes handles to be visible from within callback routines or functions invoked by callback routines, but not from within functions invoked from the command line. This provides a means to protect GUIs from command-line users, while allowing callback routines to have complete access to object handles.
- Setting `HandleVisibility` to `off` makes handles invisible at all times. This may be necessary when a callback routine invokes a function that might potentially damage the GUI (such as evaluating a user-typed string), and so temporarily hides its own handles during the execution of that function.

You can set the root `ShowHiddenHandles` property to `on` to make all handles visible, regardless of their `HandleVisibility` settings. This does not affect the values of the `HandleVisibility` properties.

`HitTest`  
{on} | off

*Selectable by mouse click.* This property has no effect on uipushtool objects.

`Interruptible`  
{on} | off

# Uipushtool Properties

---

*Callback routine interruption mode.* If a callback is executing and the user triggers an event (such as a mouse click) on an object for which a callback is defined, that callback attempts to interrupt the first callback. MATLAB processes the callbacks according to these factors:

- The `Interruptible` property of the object whose callback is executing
- Whether the executing callback contains `drawnow`, `figure`, `getframe`, `pause`, or `waitfor` statements
- The `BusyAction` property of the object whose callback is waiting to execute

If the `Interruptible` property of the object whose callback is executing is `on` (the default), the callback can be interrupted. Whenever the callback calls one of the `drawnow`, `figure`, `getframe`, `pause`, or `waitfor` functions, the function processes any events in the event queue, including the waiting callback, before performing its defined task.

If the `Interruptible` property of the object whose callback is executing is `off`, the callback cannot be interrupted (except by certain callbacks; see the note below). The `BusyAction` property of the object whose callback is waiting to execute determines what happens to the callback.

---

**Note** If the interrupting callback is a `DeleteFcn` or `CreateFcn` callback or a figure's `CloseRequest` or `ResizeFcn` callback, it interrupts an executing callback regardless of the value of that object's `Interruptible` property. The interrupting callback starts execution at the next `drawnow`, `figure`, `getframe`, `pause`, or `waitfor` statement. A figure's `WindowButtonDownFcn` callback routine, or an object's `ButtonDownFcn` or `Callback` routine are processed according to the rules described above.

---



## Parent

handle

*Uipushtool parent.* The handle of the uipushtool's parent toolbar. You can move a uipushtool object to another toolbar by setting this property to the handle of the new parent.

## Separator

on | {off}

*Separator line mode.* Setting this property to on draws a dividing line to the left of the uipushtool.

## Tag

string

*User-specified object identifier.* The Tag property provides a means to identify graphics objects with a user-specified label. You can define Tag as any string.

With the `findobj` function, you can locate an object with a given Tag property value. This saves you from defining object handles as global variables. For example, this function call returns the handles of all children (of the specified toolbars) that have the Tag value 'Copy'.

```
h = findobj(uitoolbarhandles,'Tag','Copy')
```

## TooltipString

string

*Content of tooltip for object.* The TooltipString property specifies the text of the tooltip associated with the uipushtool. When the user moves the mouse pointer over the control and leaves it there, the tooltip is displayed.

## Type

string (read-only)

# Uipushtool Properties

---

Object class. This property identifies the kind of graphics object. For uipushtool objects, Type is always the string 'uipushtool'.

UIContextMenu  
handle

*Associate a context menu with uicontrol.* This property has no effect on uipushtool objects.

UserData  
array

*User specified data.* You can specify UserData as any array you want to associate with the uipushtool object. The object does not use this data, but you can access it using the set and get functions.

Visible  
{on} | off

*Uipushtool visibility.* By default, all uipushtools are visible. When set to off, the uipushtool is not visible, but still exists and you can query and set its properties.

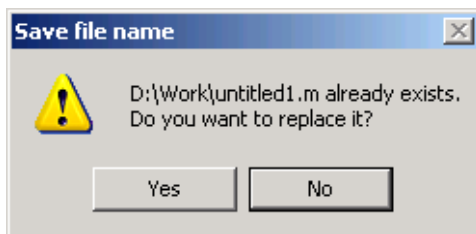
**Purpose** Open standard dialog box for saving files

**Syntax**

```
uiputfile
[FileName,PathName,FilterIndex] = uiputfile(FilterSpec)
[FileName,PathName,FilterIndex] = uiputfile(FilterSpec,
 DialogTitle)
[FileName,PathName,FilterIndex] = uiputfile(FilterSpec,
 DialogTitle,DefaultName)
```

**Description** uiputfile displays a modal dialog box used to select or specify a file for saving. The dialog box lists the files and directories in the current directory. If the selected or specified filename is valid, it is returned in ans.

If an existing filename is selected or specified, the following warning dialog box is displayed.



The user can select **Yes** to replace the existing file or **No** to return to the dialog to select another filename. If the user selects **Yes**, uiputfile returns the name of the file. If the user selects **No**, uiputfile returns 0.

Successful execution of uiputfile does not create a file; it only returns the name of a new or existing file that the user designates.

---

**Note** A modal dialog box prevents the user from interacting with other windows before responding. To block MATLAB program execution as well, use the uiwait function. For more information about modal dialog boxes, see WindowStyle in the MATLAB Figure Properties.

---

`[FileName,PathName,FilterIndex] = uiputfile(FilterSpec)` displays only those files with extensions that match `FilterSpec`. The `uiputfile` function appends 'All Files' to the list of file types. `FilterSpec` can be a string or a cell array of strings, and can include the \* wildcard. For example, '\*.m' lists all the MATLAB M-files.

- If `FilterSpec` is a string that contains a filename, the filename is displayed and selected in the **File name** field and the file's extension is used as the default filter.
- If `FilterSpec` is a string, it can include a path. That path can contain '.', '..', or '/'. For example, '../\*.m' lists all M-files in the directory above the current directory.
- If `FilterSpec` is a cell array of strings, the first column contains a list of file extensions. The optional second column contains a corresponding list of descriptions. These descriptions replace standard descriptions in the **Save as type** field. A description cannot be an empty string. “Example 3” on page 2-3949 and “Example 4” on page 2-3950 illustrate use of a cell array as `FilterSpec`.

If `FilterSpec` is not specified, `uiputfile` uses the default list of file types (i.e., all MATLAB files).

After the user clicks **Save** and if the filename is valid, `uiputfile` returns the name of the selected file in `FileName` and its path in `PathName`. If the user clicks the **Cancel** button, closes the dialog window, or if the filename is not valid, `FileName` and `PathName` are set to 0.

`FilterIndex` is the index of the filter selected in the dialog box. Indexing starts at 1. If the user clicks the **Cancel** button, closes the dialog window, or if the file does not exist, `FilterIndex` is set to 0.

If no output arguments are specified, the filename is returned in `ans`.

`[FileName,PathName,FilterIndex] = uiputfile(FilterSpec,DialogTitle)` displays a dialog box that has the title `DialogTitle`. To use the default file types and specify a dialog title, enter

```
uiputfile('',DialogTitle)
```

```
[FileName,PathName,FilterIndex] =
uiputfile(FilterSpec,DialogTitle,DefaultName) displays a dialog
box in which the filename specified by DefaultName appears in the
File name field. DefaultName can also be a path or a path/filename. In
this case, uiputfile opens the dialog box in the directory specified
by the path. See “Example 6” on page 2-3952. Note that you can use
'.', '..', or '/' in the DefaultName argument.
```

If the specified path does not exist, uiputfile opens the dialog box in the current directory.

## Remarks

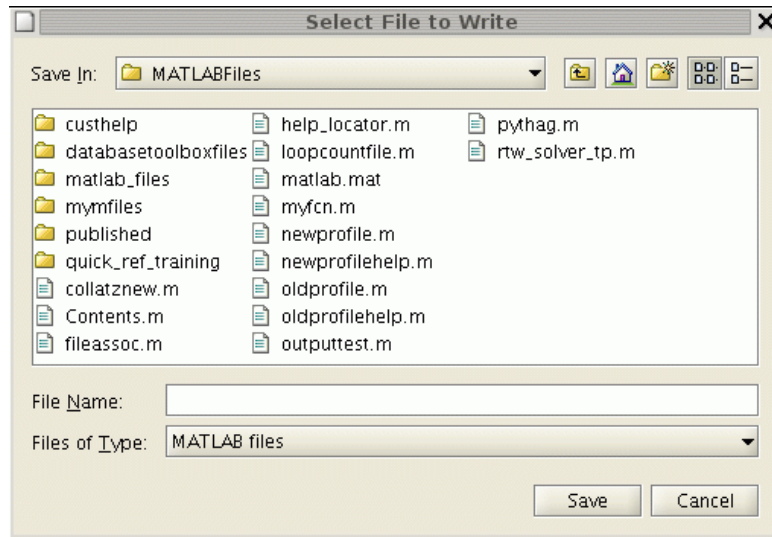
If the user includes either of the “wildcard” characters '\*' or '?' in a file name, uiputfile does not respond to clicking **Save**. The dialog box remains open until the user cancels it or removes the wildcard characters. This restriction applies to all platforms, even to file systems that permit these characters in file names.

For Microsoft Windows platforms, the dialog box is the Windows dialog box native to your platform. Because of this, it may differ from those shown in the examples below.

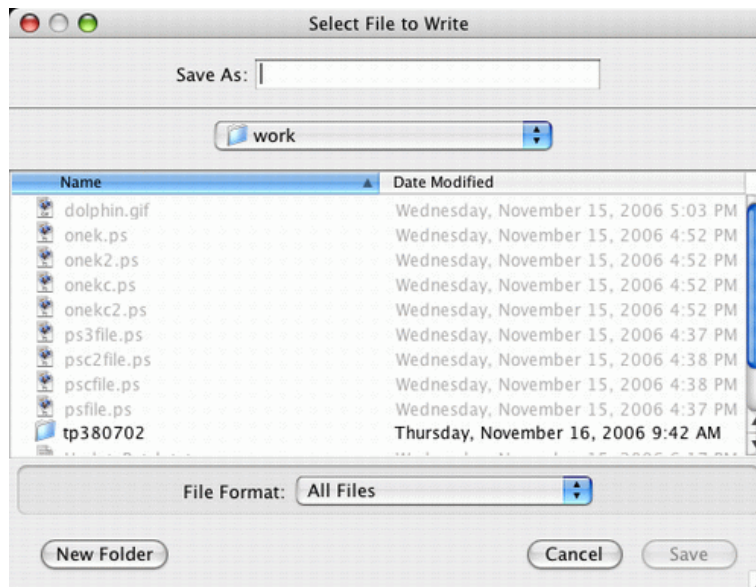
For UNIX platforms, the dialog box is similar to the one shown in the following figure.

# uiputfile

---



For Mac platforms, the dialog box is similar to the one shown in the following figure.

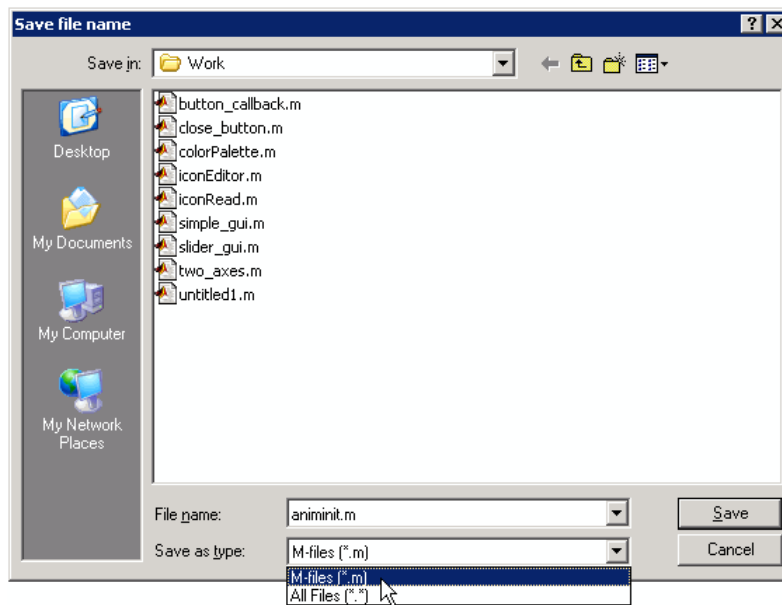


## Examples

### Example 1

The following statement displays a dialog box titled 'Save file name' with the **Filename** field set to `animinit.m` and the filter set to M-files (`*.m`). Because `FilterSpec` is a string, the filter also includes All Files (`*.*`)

```
[file,path] = uiputfile('animinit.m','Save file name');
```

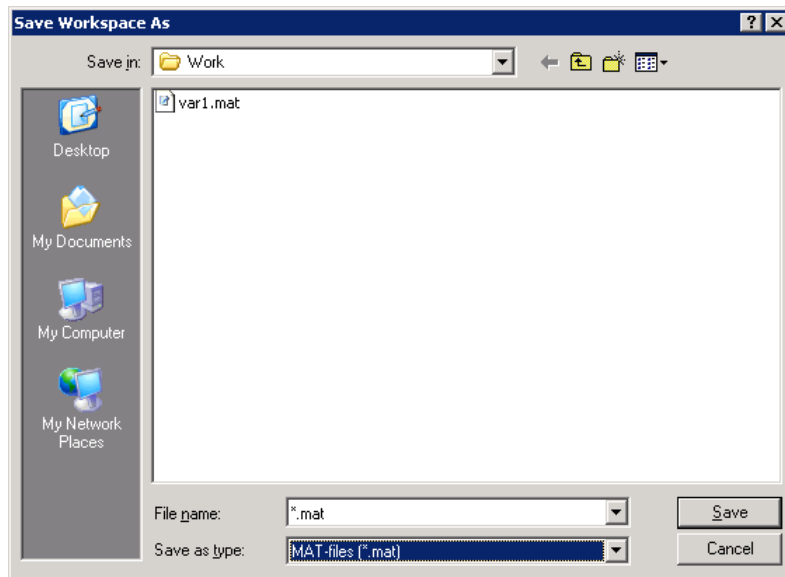


## Example 2

The following statement displays a dialog box titled 'Save Workspace As' with the filter specifier set to MAT-files.

```
[file,path] = uiputfile('*.mat','Save Workspace As');
```

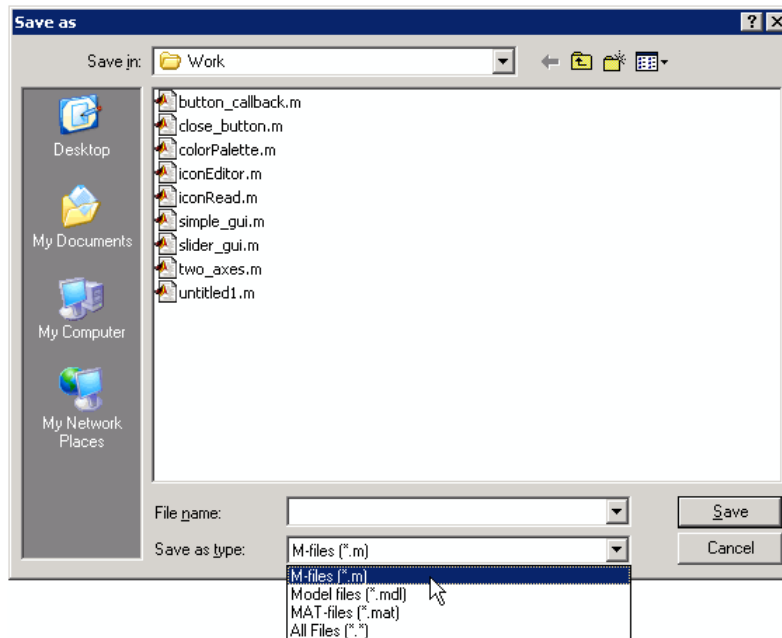




### Example 3

To display several file types in the **Save as type** list box, separate each file extension with a semicolon, as in the following code. Note that `uiputfile` displays a default description for each known file type, such as "Simulink Models" for `.mdl` files.

```
[filename, pathname] = uiputfile(...
 {'*.m'; '*.mdl'; '*.mat'; '*.*'}, ...
 'Save as');
```

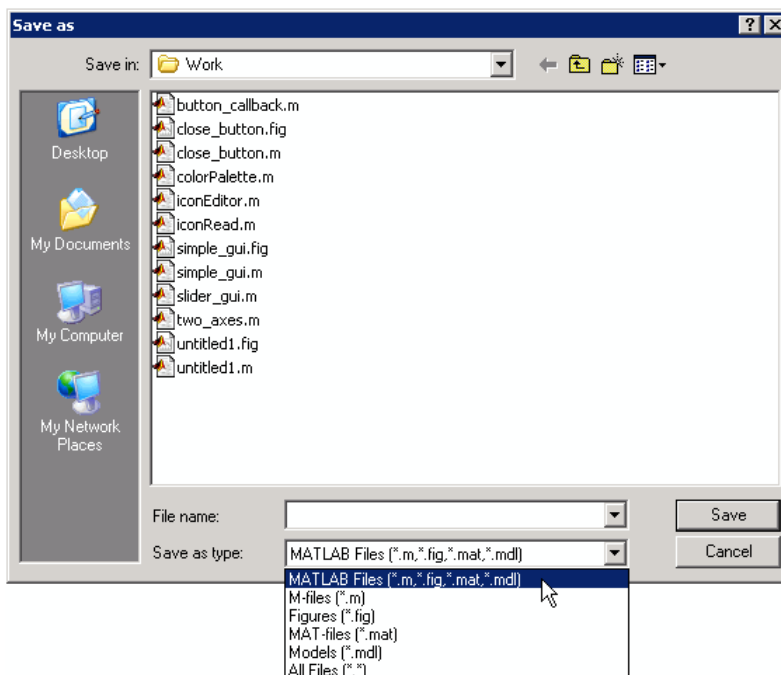


## Example 4

If you want to create a list of file types and give them descriptions that are different from the defaults, use a cell array, as in the following code. This example also associates multiple file types with the 'MATLAB Files' description.

```
[filename, pathname, filterindex] = uiputfile(...
{ '*.m'; '*.fig'; '*.mat'; '*.mdl', 'MATLAB Files (*.m,*.fig,*.mat,*.mdl)';
'*.m', 'M-files (*.m)'; ...
'*.fig', 'Figures (*.fig)'; ...
'*.mat', 'MAT-files (*.mat)'; ...
'*.mdl', 'Models (*.mdl)'; ...
'*.*', 'All Files (*.*)'}, ...
'Save as');
```

The first column of the cell array contains the file extensions, while the second contains the descriptions you want to provide for the file types. Note that the first entry of column one contains several extensions, separated by semicolons, all of which are associated with the description 'MATLAB Files (\*.m;\*.fig;\*.mat;\*.mdl)'. The code produces the dialog box shown in the following figure.



### Example 5

The following code checks for the existence of the file and displays a message about the result of the open operation.

```
[filename, pathname] = uiputfile('*.*','Pick an M-file');
if isequal(filename,0) || isequal(pathname,0)
 disp('User selected Cancel')
else
```

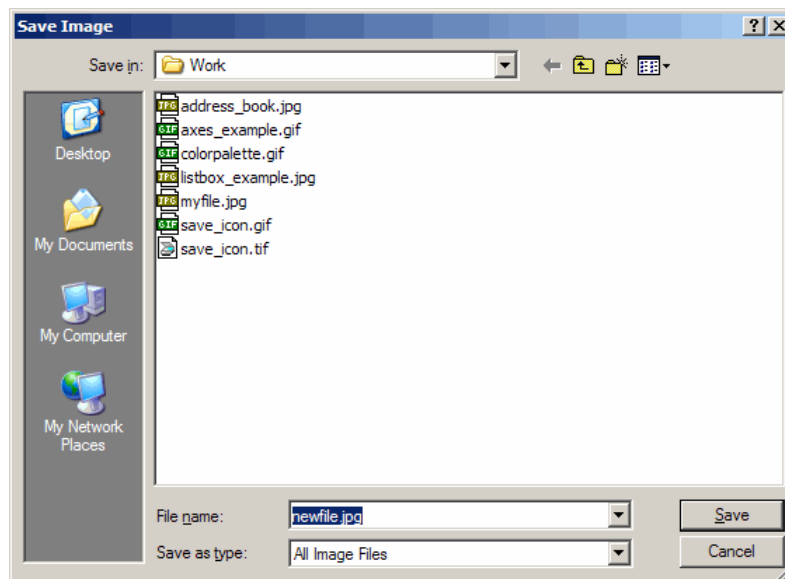
# uiputfile

---

```
 disp(['User selected',fullfile(pathname,filename)])
end
```

## Example 6

```
uiputfile({'*.jpg;*.tif;*.png;*.gif','All Image Files';...
 '*.','All Files' },'Save Image',...
 'C:\Work\newfile.jpg')
```



**See Also** [uigetdir](#), [uigetfile](#)

---

|                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|--------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Purpose</b>     | Resume execution of blocked M-file                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| <b>Syntax</b>      | <code>uiresume(h)</code>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| <b>Description</b> | <code>uiresume(h)</code> resumes the M-file execution that <code>uiwait</code> suspended.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| <b>Remarks</b>     | <p>The <code>uiwait</code> and <code>uiresume</code> functions block and resume MATLAB program execution. When creating a dialog, you should have a <code>uicontrol</code> component with a callback that calls <code>uiresume</code> or a callback that destroys the dialog box. These are the only methods that resume program execution after the <code>uiwait</code> function blocks execution.</p> <p>When used in conjunction with a modal dialog, <code>uiresume</code> can resume the execution of the M-file that <code>uiwait</code> suspended while presenting a dialog box.</p>                                                                                                                                                                                                                                                                                                                                    |
| <b>Example</b>     | <p>This example creates a GUI with a <b>Continue</b> push button. The example calls <code>uiwait</code> to block MATLAB execution until <code>uiresume</code> is called. This happens when the user clicks the <b>Continue</b> push button because the push button's <code>Callback</code> callback, which responds to the click, calls <code>uiresume</code>.</p> <pre>f = figure;<br/>h = uicontrol('Position',[20 20 200 40],'String','Continue',...<br/>             'Callback','uiresume(gcf)');<br/>disp('This will print immediately');<br/>uiwait(gcf);<br/>disp('This will print after you click Continue');<br/>close(f);</pre> <p><code>gcbf</code> is the handle of the figure that contains the object whose callback is executing.</p> <p>“Using a Modal Dialog Box to Confirm an Operation” is a more complex example for a GUIDE GUI. See “Icon Editor” for an example for a programmatically created GUI.</p> |

# uiresume

---

## See Also

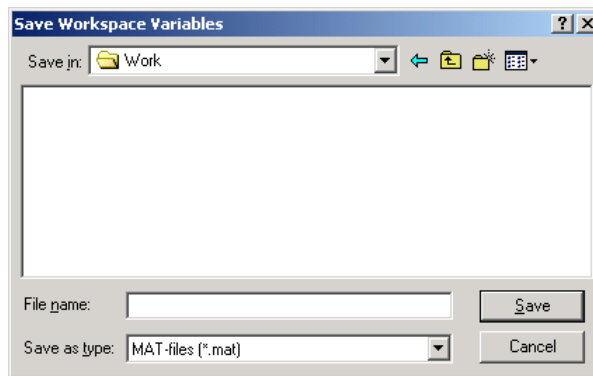
dialog, figure, uicontrol, uimenu, uiwait, waitfor

**Purpose** Open standard dialog box for saving workspace variables

**Syntax**

```
uisave
uisave(variables)
uisave(variables,filename)
```

**Description** `uisave` displays the Save Workspace Variables dialog box for saving workspace variables to a MAT-file, as shown in the figure below. By default, the dialog box opens in your current directory.



---

**Note** The `uisave` dialog box is modal. A modal dialog box prevents the user from interacting with other windows before responding. For more information, see `WindowStyle` in the MATLAB Figure Properties.

---

If you type a name in the **File name** field, such as `my_vars`, and click **Save**, the dialog saves all workspace variables in the file `my_vars.mat`. The default filename is `matlab.mat`.

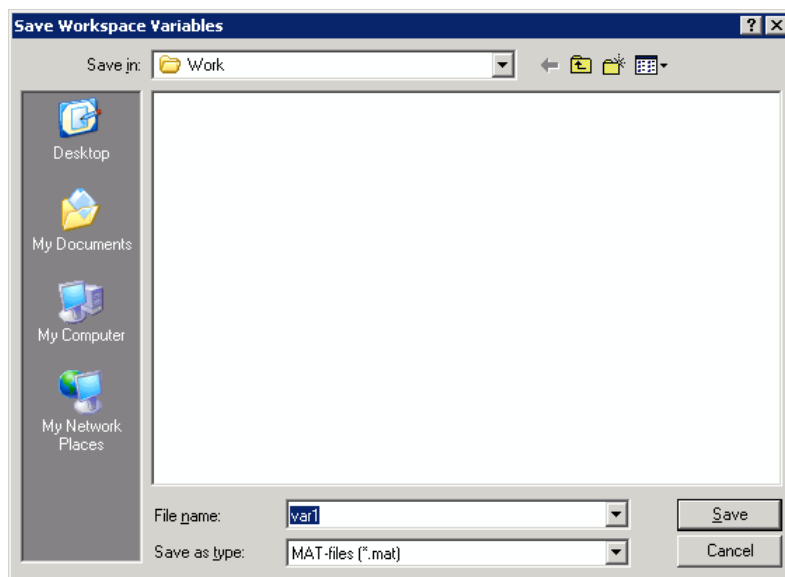
`uisave(variables)` saves only the variables listed in `variables`. For a single variable, `variables` can be a string. For more than one variable, `variables` must be a cell array of strings.

`uisave(variables,filename)` uses the specified filename as the default **File name** in the Save Workspace Variables dialog box.

## Example

This example creates workspace variables `h` and `g`, and then displays the Save Workspace Variables dialog box in the current directory with the default **File name** set to `var1`.

```
h = 365;
g = 52;
uisave({'h','g'}, 'var1');
```



Clicking **Save** stores the workspace variables `h` and `g` in the file `var1.mat` in the displayed directory.

## See Also

`uigetfile`, `uiputfile`, `uiopen`



**Purpose**

Open standard dialog box for setting object's ColorSpec

**Syntax**

```
c = uicolor
c = uicolor([r g b])
c = uicolor(h)
c = uicolor(...,'dialogTitle')
```

**Description**

`c = uicolor` displays a modal color selection dialog appropriate to the platform, and returns the color selected by the user. The dialog box is initialized to white.

`c = uicolor([r g b])` displays a dialog box initialized to the specified color, and returns the color selected by the user. `r`, `g`, and `b` must be values between 0 and 1.

`c = uicolor(h)` displays a dialog box initialized to the color of the object specified by handle `h`, returns the color selected by the user, and applies it to the object. `h` must be the handle to an object containing a color property.

`c = uicolor(...,'dialogTitle')` displays a dialog box with the specified title.

If the user presses **Cancel** from the dialog box, or if any error occurs, the output value is set to the input RGB triple, if provided; otherwise, it is set to 0.

---

**Note** A modal dialog box prevents the user from interacting with other windows before responding. For more information, see `WindowState` in the MATLAB Figure Properties.

---

**See Also**

ColorSpec

# uifont

---

**Purpose** Open standard dialog box for setting object's font characteristics

**Syntax**

```
uifont
uifont(h)
uifont(S)
uifont(...,'DialogTitle')
S = uifont(...)
```

**Description** `uifont` enables you to change font properties (`FontName`, `FontUnits`, `FontSize`, `FontWeight`, and `FontAngle`) for a `text`, `axes`, or `uicontrol` object. The function returns a structure consisting of font properties and values. You can specify an alternate title for the dialog box.

`uifont` displays a modal dialog box and returns the selected font properties.

---

**Note** A modal dialog box prevents the user from interacting with other windows before responding. For more information, see `WindowState` in the MATLAB Figure Properties.

---

`uifont(h)` displays a modal dialog box, initializing the font property values with the values of those properties for the object whose handle is `h`. Selected font property values are applied to the current object. If a second argument is supplied, it specifies a name for the dialog box.

`uifont(S)` displays a modal dialog box, initializing the font property values with the values defined for the specified structure (`S`). `S` must define legal values for one or more of these properties: `FontName`, `FontUnits`, `FontSize`, `FontWeight`, and `FontAngle` and the field names must match the property names exactly. If other properties are defined, they are ignored. If a second argument is supplied, it specifies a name for the dialog box.

`uisetfont(..., 'DialogTitle')` displays a modal dialog box with the title `DialogTitle` and returns the values of the font properties selected in the dialog box.

`S = uisetfont(...)` returns the properties `FontName`, `FontUnits`, `FontSize`, `FontWeight`, and `FontAngle` as fields in a structure. If the user presses **Cancel** from the dialog box or if an error occurs, the output value is set to 0.

## Example

These statements create a text object, then display a dialog box (labeled Update Font) that enables you to change the font characteristics:

```
h = text(.5,.5,'Figure Annotation');
uisetfont(h,'Update Font')
```

These statements create two push buttons, then set the font properties of one based on the values set for the other:

```
% Create push button with string ABC
c1 = uicontrol('Style', 'pushbutton', ...
 'Position', [10 10 100 20], 'String', 'ABC');
% Create push button with string XYZ
c2 = uicontrol('Style', 'pushbutton', ...
 'Position', [10 50 100 20], 'String', 'XYZ');
% Display set font dialog box for c1, make selections,
& and save to d
d = uisetfont(c1);
% Apply those settings to c2
set(c2, d)
```

## See Also

`axes`, `text`, `uicontrol`

# uisetpref

---

**Purpose** Manage preferences used in `uisetpref`

**Syntax** `uisetpref('clearall')`

**Description** `uisetpref('clearall')` resets the value of all preferences registered through `uisetpref` to 'ask'. This causes the dialog box to display when you call `uisetpref`.

---

**Note** Use `setpref` to set the value of a particular preference to 'ask'.

---

**See Also** `setpref`, `uisetpref`

**Purpose** Reorder visual stacking order of objects

**Syntax**

```
uistack(h)
uistack(h,stackopt)
uistack(h,stackopt,step)
```

**Description** `uistack(h)` raises the visual stacking order of the objects specified by the handles in `h` by one level (step of 1). All handles in `h` must have the same parent.

`uistack(h,stackopt)` moves the objects specified by `h` in the stacking order, where `stackopt` is one of the following:

- 'up' – moves `h` up one position in the stacking order
- 'down' – moves `h` down one position in the stacking order
- 'top' – moves `h` to the top of the current stack
- 'bottom' – moves `h` to the bottom of the current stack

`uistack(h,stackopt,step)` moves the objects specified by `h` up or down the number of levels specified by `step`.

---

**Note** In a GUI, axes objects are always at a lower level than `uicontrol` objects. You cannot stack an axes object on top of a `uicontrol` object.

---

See “Setting Tab Order” in the MATLAB documentation for information about changing the tab order.

**Example** The following code moves the child that is third in the stacking order of the figure handle `hObject` down two positions.

```
v = allchild(hObject)
uistack(v(3), 'down', 2)
```

# uitable

---

**Purpose** Create 2-D graphic table GUI component

**Syntax**

```
uitable
uitable('PropertyName1', value1, 'PropertyName2', value2, ...)
uitable(parent, ...)
handle = uitable(...)
```

**Description**

uitable creates a 1-by-1 uitable object in the current figure window, using default property values. If no figure exists, a new figure window opens.

uitable('PropertyName1', value1, 'PropertyName2', value2, ...) creates a uitable object with specified property values. Properties that you do not specify assume the default property values. See the Uitable Properties reference page for information about the available properties.

uitable(parent, ...) creates a uitable object as a child of the specified parent handle parent. The parent can be a figure or uipanel handle. If you also specify a different value for the Parent property, the value of the Parent property takes precedence.

handle = uitable(...) creates a uitable object and returns its handle.

After creating a uitable object, you can set and query its property values using the set and get functions.

**Remarks**

Users can change values in a table if the ColumnEditable property is true for the column they attempt to edit. By default, this property is false for all columns. If the column contains pop-up choices, only the current choice is visible (and not the pop-up menu control) when its column cannot be edited.

After editing a value, the edited value is displayed and the CellEditCallback fires when the user does any of the following:

- Types **Enter**
- Clicks another table cell

- Clicks anywhere else within the table
- Clicks another control or area within the same figure window

However, the `CellEditCallback` does not fire if the user edits a cell and clicks in another figure window or desktop tool. If the user then returns to the table to edit a different cell, the previous `CellEditCallback` still does not fire. Even though the table displays the results of the previous edit, the underlying data matrix (the table's `Data` property) is not updated to contain the value that appears in the cell.

---

**Note** If you attempt to create a `uitable` when running MATLAB on a Linux system without a Java virtual machine (`matlab -nojvm`) or without a display (`matlab nodisplay`), no table generates and you receive an error.

---

## Examples

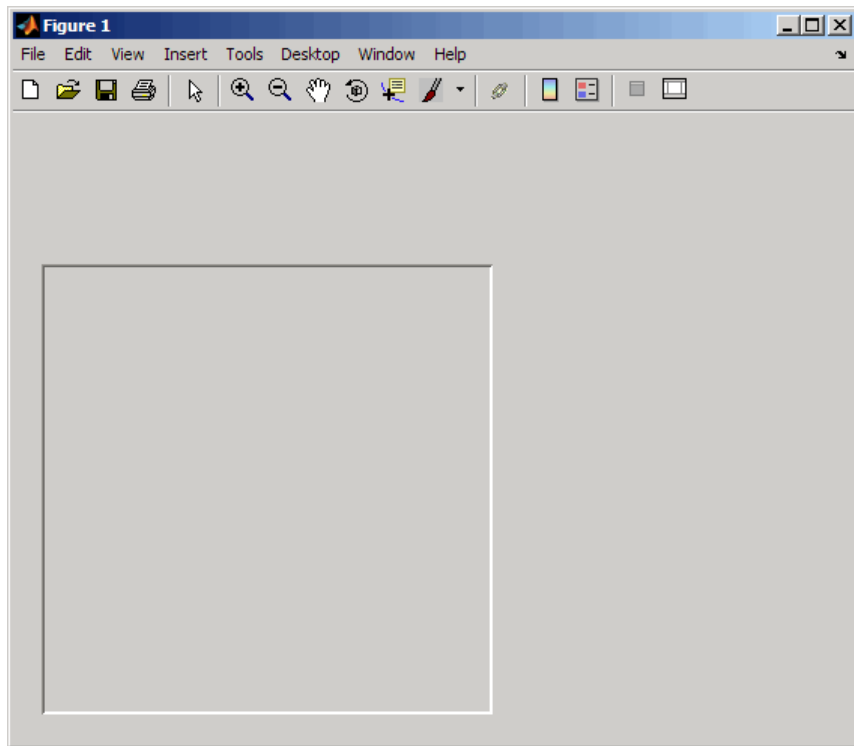
### Example 1

This example creates a table in the current figure. If no figure exists, one is created.

```
t = uitable;
```

# uitable

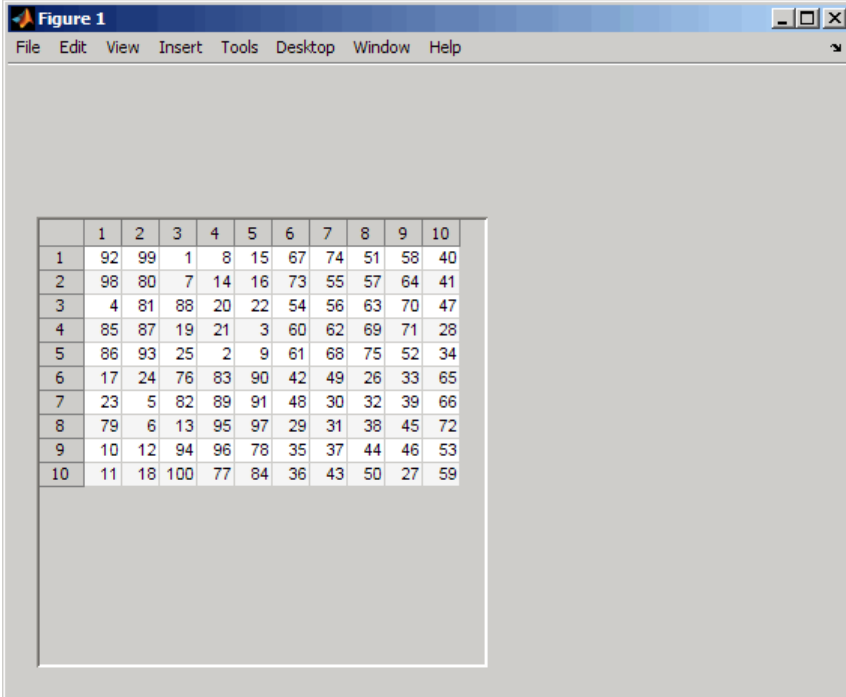
---



As the table has no content (its `Data` property is empty), it initially displays no rows or columns. Provide data (a magic square), and set column widths to 25 pixels uniformly to make the entire table visible.

```
set(t,'Data',magic(10))
set(t,'ColumnWidth',{25})
```





The screenshot shows a MATLAB window titled "Figure 1" with a menu bar (File, Edit, View, Insert, Tools, Desktop, Window, Help). The main area displays a table with 10 columns and 10 rows of numerical data. The table is enclosed in a white border within a larger gray frame.

|    | 1  | 2  | 3   | 4  | 5  | 6  | 7  | 8  | 9  | 10 |
|----|----|----|-----|----|----|----|----|----|----|----|
| 1  | 92 | 99 | 1   | 8  | 15 | 67 | 74 | 51 | 58 | 40 |
| 2  | 98 | 80 | 7   | 14 | 16 | 73 | 55 | 57 | 64 | 41 |
| 3  | 4  | 81 | 88  | 20 | 22 | 54 | 56 | 63 | 70 | 47 |
| 4  | 85 | 87 | 19  | 21 | 3  | 60 | 62 | 69 | 71 | 28 |
| 5  | 86 | 93 | 25  | 2  | 9  | 61 | 68 | 75 | 52 | 34 |
| 6  | 17 | 24 | 76  | 83 | 90 | 42 | 49 | 26 | 33 | 65 |
| 7  | 23 | 5  | 82  | 89 | 91 | 48 | 30 | 32 | 39 | 66 |
| 8  | 79 | 6  | 13  | 95 | 97 | 29 | 31 | 38 | 45 | 72 |
| 9  | 10 | 12 | 94  | 96 | 78 | 35 | 37 | 44 | 46 | 53 |
| 10 | 11 | 18 | 100 | 77 | 84 | 36 | 43 | 50 | 27 | 59 |

The `uitable` `ColumnWidth` property is specified as a cell array. It can contain:

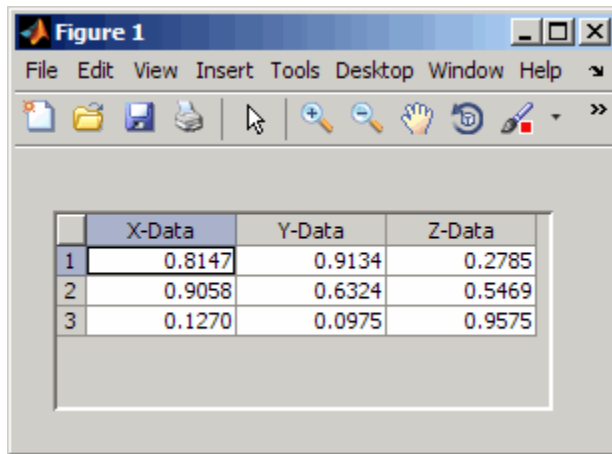
- One number (a width measured in pixels) or the string `'auto'`
- A cell array containing a list of pixel sizes having up to as many entries as the table has columns

If a list has  $n$  entries, where  $n$  is smaller than the number of columns, it sets the first  $n$  column widths only. You can substitute `'auto'` for any value in the cell array to have the width of that column calculated automatically.

## Example 2

This example creates a table with a 3-by-3 data matrix. This example specifies the column names, parent, and position of the table:

```
f = figure('Position',[100 100 300 150]);
dat = rand(3);
cnames = {'X-Data','Y-Data','Z-Data'};
t = uitable('Data',dat,'ColumnName',cnames,...
 'Parent',f,'Position',[20 20 250 100]);
```



The screenshot shows a MATLAB figure window titled "Figure 1". The window contains a table with three columns: "X-Data", "Y-Data", and "Z-Data". The table has three rows of data. The first row contains values 0.8147, 0.9134, and 0.2785. The second row contains values 0.9058, 0.6324, and 0.5469. The third row contains values 0.1270, 0.0975, and 0.9575.

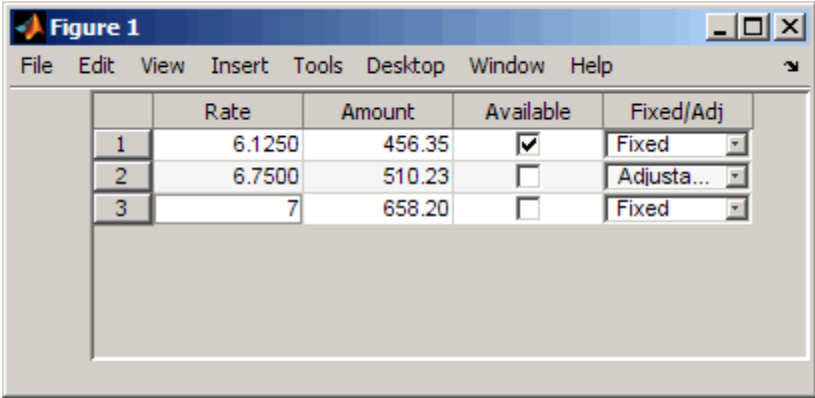
|   | X-Data | Y-Data | Z-Data |
|---|--------|--------|--------|
| 1 | 0.8147 | 0.9134 | 0.2785 |
| 2 | 0.9058 | 0.6324 | 0.5469 |
| 3 | 0.1270 | 0.0975 | 0.9575 |

## Example 3

This example creates a table with a 3-by-4 array that contains numeric, logical, and string data in the following columns:

- First column (**Rate**): Numeric, with three decimals (not editable)
- Second column (**Amount**): Currency (not editable)
- Third column (**Available**): Check box (editable)
- Fourth column (**Fixed/Adj**): Pop-up menu with two choices: Fixed and Adjustable (editable)

```
f = figure('Position',[100 100 400 150]);
dat = {6.125, 456.3457, true, 'Fixed';...
 6.75, 510.2342, false, 'Adjustable';...
 7, 658.2, false, 'Fixed'}};
columnname = {'Rate', 'Amount', 'Available', 'Fixed/Adj'};
columnformat = {'numeric', 'bank', [], {'Fixed' 'Adjustable'}};
columneditable = [false false true true];
t = uitable('Units','normalized','Position',...
 [0.1 0.1 0.9 0.9], 'Data', dat,...
 'ColumnName', columnname,...
 'ColumnFormat', columnformat,...
 'ColumnEditable', columneditable);
```



|   | Rate   | Amount | Available                           | Fixed/Adj  |
|---|--------|--------|-------------------------------------|------------|
| 1 | 6.1250 | 456.35 | <input checked="" type="checkbox"/> | Fixed      |
| 2 | 6.7500 | 510.23 | <input type="checkbox"/>            | Adjusta... |
| 3 | 7      | 658.20 | <input type="checkbox"/>            | Fixed      |

For more information about working with uitable, see the following examples in the MATLAB Creating Graphical User Interfaces documentation:

- “GUI to Interactively Explore Data in a Table” (GUIDE example)
- “GUI that Displays and Graphs Tabular Data” (programmatic example)

## See Also

figure, format, inspect, uicontrol, uimenu, uipanel

# Uitable Properties

---

## Purpose

Describe table properties

## Modifying Properties

You can set and query graphics object properties in two ways:

- The Property Inspector is an interactive tool that enables you to see and change object property values. The Property inspector is available from GUIDE, or use the `inspect` function at the command line.
- The `set` and `get` functions enable you to set and query the values of properties.

You can set default uitable properties by typing:

```
set(h, 'DefaultUitablePropertyName', PropertyValue...)
```

Where `h` can be the root handle (0), a figure handle, or a uitable handle. *PropertyName* is the name of the uitable property and *PropertyValue* is the value you specify as the default for that property.

For more information about changing the default value of a property see “Setting Default Property Values”. For an example, see the `CreateFcn` property.

## Uitable Properties

This section lists all properties useful to uitable objects along with valid values and descriptions of their use. In the property descriptions, curly braces { } enclose default values.

| Property Name                | Description                   |
|------------------------------|-------------------------------|
| <code>BackgroundColor</code> | Background color of cells.    |
| <code>BeingDeleted</code>    | This object is being deleted. |
| <code>BusyAction</code>      | Callback routine interruption |
| <code>ButtonDownFcn</code>   | Button-press callback routine |

# Uitable Properties

| Property Name         | Description                                   |
|-----------------------|-----------------------------------------------|
| CellEditCallback      | Callback when data in a cell is changed.      |
| CellSelectionCallback | Callback when cell is selected                |
| Children              | uitable objects have no children              |
| Clipping              | Does not apply to uitable objects             |
| ColumnEditable        | Determines data in a column as editable       |
| ColumnFormat          | Determines display and editability of columns |
| ColumnName            | Column header label                           |
| ColumnWidth           | Width of each column in pixels                |
| CreateFcn             | Callback routine during object creation       |
| Data                  | Table data                                    |
| DeleteFcn             | Callback routine during object deletion       |
| Enable                | Enable or disable the uitable                 |
| Extent                | Size of uitable rectangle                     |
| FontAngle             | Character slant of cell content               |
| FontName              | Font family for cell content                  |
| FontSize              | Font size of cell content                     |
| FontUnits             | Font size units for cell content              |
| FontWeight            | Weight of cell text characters                |
| ForegroundColor       | Color of text in cells                        |
| HandleVisibility      | Control access to object's handle             |
| HitTest               | Selectable by mouse click                     |
| Interruptible         | Callback routine interruption mode            |
| KeyPressFcn           | Key press callback function                   |

# Uitable Properties

---

| Property Name       | Description                         |
|---------------------|-------------------------------------|
| Parent              | uitable parent                      |
| Position            | Size and location of uitable        |
| RearrangeableColumn | Location of the column              |
| RowName             | Row header label names              |
| RowStriping         | Color striping of label rows        |
| Selected            | Is object selected?                 |
| SelectionHighlight  | Object highlight when selected      |
| Tag                 | Use-specified object label          |
| TooltipString       | Content of tooltip for object       |
| Type                | Class of graphics object            |
| UIContextMenu       | Associate context menu with uitable |
| Units               | Units of measurement                |
| UserData            | User-specified data                 |
| Visible             | uitable visibility                  |

## BackgroundColor

1-by-3 or 2-by-3 matrix of RGB triples

*Cell background color.* Color used to fill the uitable cells. Specify as an 1-by-3 or 2-by-3 matrix of RGB triples, such as [.8 .9 .8] or [1 1 .9; .9 1 1]. Each row is an RGB triplet of real numbers between 0.0 and 1.0 that defines one color. (Color names are not allowed.) The default is a 1-by-3 matrix of platform-dependent colors. See ColorSpec for information about RGB colors.

Row 2 of the matrix is used only if the `RowStriping` property is on. The table background is not striped unless both `RowStriping` is on and the `BackgroundColor` color matrix has two rows.

**BeingDeleted**  
on | {off} (read-only)

*This object is being deleted.* The `BeingDeleted` property provides a mechanism that you can use to determine if objects are in the process of being deleted. MATLAB software sets the `BeingDeleted` property to on when the object's delete function callback is called (see the `DeleteFcn` property). It remains set to on while the delete function executes, after which the object no longer exists.

For example, some functions may not need to perform actions on objects that are being deleted, and therefore, can check the object's `BeingDeleted` property before acting.

**BusyAction**  
cancel | {queue}

*Callback routine interruption.* If a callback is executing and the user triggers an event (such as a mouse click) on an object for which a callback is defined, the callback associated with the new event uses the value of `BusyAction` to decide whether or not to attempt to interrupt the executing callback.

- If the value is `cancel`, the new event is discarded and the second callback does not execute.
- If the value is `queue`, and the `Interruptible` property of the first callback is on, the second callback is added to the event queue and executes in its turn after the first callback finishes execution.

# Uitable Properties

---

---

**Note** If the interrupting callback is `DeleteFcn` or `CreateFcn` or a figure's `CloseRequest` or `ResizeFcn` callback, it interrupts an executing callback regardless of the value of that object's `Interruptible` property. See the `Interruptible` property for information about controlling a callback's interruptibility.

---

## `ButtonDownFcn`

string or function handle (GUIDE sets this property)

*Button-press callback routine.* A callback routine that can execute when you press a mouse button while the pointer is on or near a `uitable`. Specifically:

- If the `uitable Enable` property is set to `on`, the `ButtonDownFcn` callback executes when you click the right or left mouse button in a 5-pixel border around the `uitable` or when you click the right mouse button on the control itself.
- If the `uitable Enable` property is set to `inactive` or `off`, the `ButtonDownFcn` executes when you click the right or left mouse button in the 5-pixel border or on the control itself.

This is useful for implementing actions to interactively modify control object properties, such as size and position, when they are clicked on (using the `selectmoveresize` function, for example).

Define this routine as a string that is a valid MATLAB expression or the name of an M-file. The expression executes in the MATLAB workspace.

To add a `ButtonDownFcn` callback in GUIDE, select **View Callbacks** from the Layout Editor **View** menu, then select `ButtonDownFcn`. GUIDE sets this property to the appropriate string and adds the callback to the M-file the next time you save the GUI. Alternatively, you can set this property to the string `%automatic`. The next time you save the GUI, GUIDE sets this



property to the appropriate string and adds the callback to the M-file.

## CellEditCallback

function handle, cell array containing function handle and additional arguments, or string (not recommended)

*Callback to edit user-entered data*

Callback function executed when the user modifies a table cell. It can perform evaluations, validations, or other customizations. If this function is called as a function handle, `uitable` passes it two arguments. The first argument, `source`, is the handle of the `uitable`. The second argument, `eventdata`, is an event data structure that contains the fields shown in the following table. All fields in the event data structure are read only.

| Event Data Structure Field | Type                        | Description                                                                           |
|----------------------------|-----------------------------|---------------------------------------------------------------------------------------|
| Indices                    | 1-by-2 matrix               | Row index and column index of the cell the user edited.                               |
| PreviousData               | 1-by-1 matrix or cell array | Previous data for the changed cell. The default is an empty matrix, <code>[]</code> . |
| EditData                   | String                      | User-entered string.                                                                  |

# Uitable Properties

---

| <b>Event Data Structure Field</b> | <b>Type</b>                 | <b>Description</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
|-----------------------------------|-----------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| NewData                           | 1-by-1 matrix or cell array | <p>Value that <code>uitable</code> wrote to <code>Data</code>. It is either the same as <code>EditData</code> or a converted value, for example, 2 where <code>EditData</code> is '2' and the cell is numeric.</p> <p>Empty if <code>uitable</code> detected an error in the user-entered data and did not write it to <code>Data</code>.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| Error                             | String                      | <p>Error that occurred when <code>uitable</code> tried to convert the <code>EditData</code> string into a value appropriate for <code>Data</code>. For example, <code>uitable</code> could not convert the <code>EditData</code> string consistent with the <code>Column Format</code> property, if any, or the data type for the changed cell.</p> <p>Empty if <code>uitable</code> wrote the value to <code>Data</code>.</p> <p>If <code>Error</code> is not empty, the <code>CellEditCallback</code> can pass the error string to the user or can attempt to manipulate the data. For example, the string 'pi' would raise an error in a numeric cell but the <code>CellEditCallback</code> could convert it to its numerical equivalent and store it in <code>Data</code> without passing the error to the user.</p> |

When a user edits a cell, `uitable` first attempts to store the user-entered value in `Data`, converting the value if necessary. It then calls the `CellEditCallback` and passes it the event data structure. If there is no `CellEditCallback` and the user-entered data results in an error, the contents of the cell reverts to its previous value and no error is displayed.

---

**Note** In order for the `CellEditCallback` to be issued, after modifying a table cell the user must hit **Enter** or click somewhere else within the figure containing the table. Editing a cell's value and then clicking another figure or other window does not save the new value to the data table, and does not fire the `CellEditCallback`.

---

## `CellSelectionCallback`

function handle, cell array containing function handle and additional arguments, or string (not recommended)

*Callback that executes when cell is selected.* Callback function that executes when the user highlights a cell by navigating to it or clicking it. For multiple selection, this callback executes when new cells are added to the selection. The callback includes event data, a structure with one member

| Event Data Structure Field | Type          | Description                                                             |
|----------------------------|---------------|-------------------------------------------------------------------------|
| Indices                    | n-by-2 matrix | Row index and column index of the cells the user currently has selected |

Once a cell selection has been made, cells within it can be removed one at a time by **Ctrl**-clicking them.

## `Children`

matrix

The empty matrix; `uitable` objects have no children.

## `Clipping`

{on} | off

This property has no effect on `uitable` objects.

# Uitable Properties

---

## ColumnEditable

logical 1-by-n matrix | scalar logical value | { empty matrix ([]) }

*Determines if column is user-editable.*

Determines if the data can be edited by the end user. Each value in the cell array corresponds to a column. False is default because the developer needs to have control over changes users potentially might make to data.

Specify elements of a logical matrix as `true` if the data in a column is editable by the user or `false` if it is not. An empty matrix indicates that no columns are editable.

Columns that contain check boxes or pop-up menus must be editable for the user to manipulate these controls. If a column that contains pop-up menus is not editable, the currently selected choice appears without displaying the pop-up control. The Elements of the `ColumnEditable` matrix must be in the same order as columns in the `Data` property. If you do not specify `ColumnEditable`, the default is an empty matrix ( []).

## ColumnFormat

cell array of strings

*Cell display formatting.* Determines how the data in each column displays and is edited. Elements of the cell array must be in the same order as table columns in the `Data` property. If you do not want to specify a display format for a particular column, enter [ ] as a placeholder. If no format is specified for a column, the default display is determined by the data type of the data in the cell. Default `ColumnFormat` is an empty cell array ( {}). In most cases, the default is similar to the command window.

Elements of the cell array must be one of the strings described in the following table.

| Cell Format | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
|-------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 'char'      | <p>Displays a left-aligned string.</p> <p>To edit, the user types a string that replaces the existing string.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| 'logical'   | <p>Displays a check box.</p> <p>To edit, the user checks or unchecks the check box. <code>uitable</code> sets the corresponding <code>Data</code> value to <code>true</code> or <code>false</code> accordingly.</p> <p>Initially, the check box is checked if the corresponding <code>Data</code> value would produce</p>                                                                                                                                                                                                                                                                                                                                                                               |
| 'numeric'   | <p>Displays a right-aligned string equivalent to the command window, for numeric data. If the cell <code>Data</code> value is boolean, then 1 or 0 is displayed. If the cell <code>Data</code> value is not numeric and not boolean, then NaN is displayed.</p> <p>To edit, the user can enter any string. This enables a user to enter a value such as 'pi' that can be converted to its numeric equivalent by a <code>CellEditCallback</code>. The <code>uitable</code> function first attempts to convert the user-entered string to a numeric value and store it in <code>Data</code>. It then calls the <code>CellEditCallback</code>. See <code>CellEditCallback</code> for more information.</p> |

# Uitable Properties

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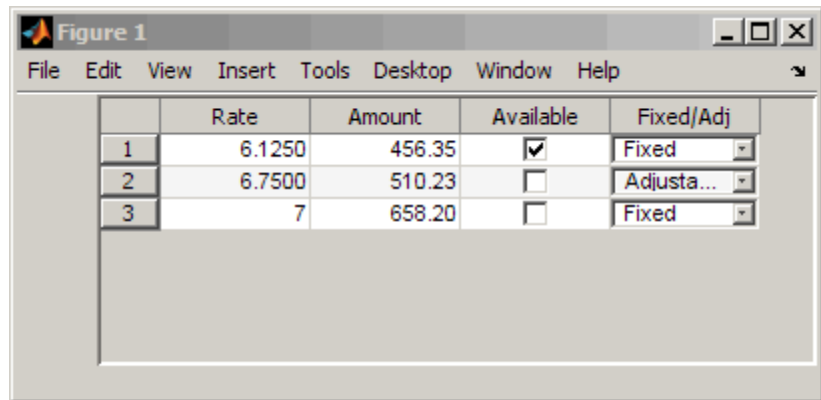
| Cell Format                                                                         | Description                                                                                                                                                                                                                                                                                                                                                                                                      |
|-------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1-by-n cell array of strings that define a pop-up menu, e.g., {'one' 'two' 'three'} | <p>Displays a pop-up menu.</p> <p>To edit, the user makes a selection from the pop-up menu. <code>uitable</code> sets the corresponding Data value to the selected menu item.</p> <p>The initial values for the pop-up menus in the column are the corresponding strings in Data. These initial values do not have to be items in the pop-up menu. See Example 3 on the <code>uitable</code> reference page.</p> |
| Valid string accepted by the format function, e.g., 'short' or 'bank'               | <p>Displays the Data value using the specified format. For example, for a two-column table, <code>set(htable, 'ColumnFormat', {'short', 'bank'})</code>.</p>                                                                                                                                                                                                                                                     |

In some cases, you may need to insert an appropriate column in Data. If Data is a numerical or logical matrix, you must first convert it to a cell array using the `mat2cell` function.

## Data and ColumnFormat

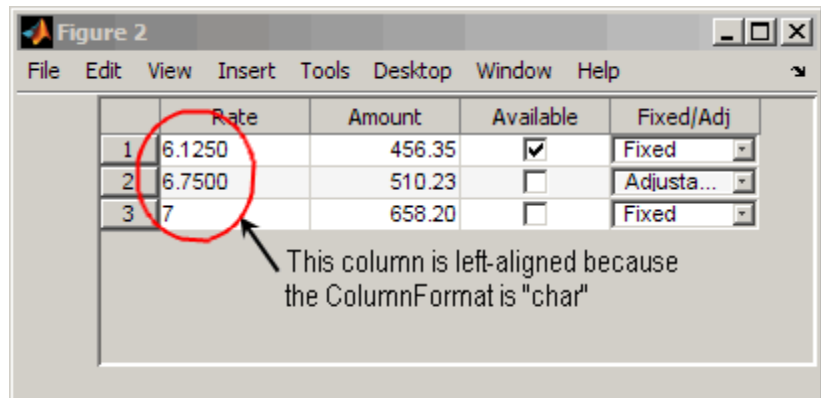
When you create a table, you must specify value of Data. The Data property dictates what type of data can exist in any given cell. By default, the value of the Data also dictates the display of the cell to the end user, unless you specify a different format using the `ColumnFormat` property.

# Uitable Properties



|   | Rate   | Amount | Available                           | Fixed/Adj  |
|---|--------|--------|-------------------------------------|------------|
| 1 | 6.1250 | 456.35 | <input checked="" type="checkbox"/> | Fixed      |
| 2 | 6.7500 | 510.23 | <input type="checkbox"/>            | Adjusta... |
| 3 | 7      | 658.20 | <input type="checkbox"/>            | Fixed      |

ColumnFormat controls the presentation of the Data to the end user. Therefore, if you specify a ColumnFormat of char (or pick **Text** from the Table Property Editor), you are asking the table to display the Data associated with that column as a string. For example, if the Data for a particular column is numeric, and you specify the ColumnFormat as char, then the display of the numeric data will be left-aligned

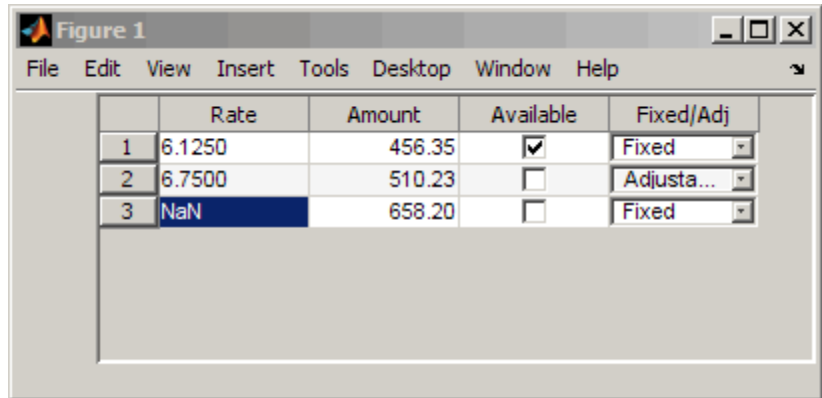


|   | Rate   | Amount | Available                           | Fixed/Adj  |
|---|--------|--------|-------------------------------------|------------|
| 1 | 6.1250 | 456.35 | <input checked="" type="checkbox"/> | Fixed      |
| 2 | 6.7500 | 510.23 | <input type="checkbox"/>            | Adjusta... |
| 3 | 7      | 658.20 | <input type="checkbox"/>            | Fixed      |

This column is left-aligned because the ColumnFormat is "char"

# Uitable Properties

If your column is editable and the user enters a number, the number will be left-aligned. However, if the user enters a text string, the table displays a **NaN**.



|   | Rate   | Amount | Available                           | Fixed/Adj  |
|---|--------|--------|-------------------------------------|------------|
| 1 | 6.1250 | 456.35 | <input checked="" type="checkbox"/> | Fixed      |
| 2 | 6.7500 | 510.23 | <input type="checkbox"/>            | Adjusta... |
| 3 | NaN    | 658.20 | <input type="checkbox"/>            | Fixed      |

Another possible scenario is that the value `Data` is `char` and you set the `ColumnFormat` to be a pop-up menu. Here, if the value of the `Data` in the cell matches one of the pop-up menu choices you define in `ColumnFormat`, then the `Data` is shown in the cell. If it does not match, then the cell defaults to display the first option from the choices you specify in `ColumnFormat`. Similarly, if `Data` is numeric or logical with the `ColumnFormat` as pop-up menu, if the `Data` value in the cell does not match any of the choices you specify in `ColumnFormat`, the cell defaults to display the first option in the pop-menu choice.

This table describes how `Data` values correspond with your `ColumnFormat` when the columns are editable.

| <b>ColumnFormat Selections</b> |      |         |
|--------------------------------|------|---------|
| numeric                        | char | logical |



# Uitable Properties

|                  |         |                                                                                                                                                  |                                                                                                                                                                                                                                                                                                                    |                                                                                                                                                  |
|------------------|---------|--------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Data Type</b> | numeric | Values match. MATLAB displays numbers as is.                                                                                                     | MATLAB converts the text string entered to a double. See <code>str2double</code> for more information. If string cannot be converted, <b>NaN</b> is displayed.                                                                                                                                                     | Does not work: warning is thrown.<br><hr/> <b>Note</b> If you have defined <code>CellEditCallback</code> , this warning will not be thrown <hr/> |
|                  | char    | MATLAB converts the entered number to a text string.                                                                                             | Values match. MATLAB displays the string as is.                                                                                                                                                                                                                                                                    | Does not work: warning is thrown.<br><hr/> <b>Note</b> If you have defined <code>CellEditCallback</code> , this warning will not be thrown <hr/> |
|                  | logical | Does not work: warning is thrown.<br><hr/> <b>Note</b> If you have defined <code>CellEditCallback</code> , this warning will not be thrown <hr/> | If text string entered is <code>true</code> or <code>false</code> , MATLAB converts string to the corresponding logical value and displays it. For all others, it Does not work: warning is thrown.<br><hr/> <b>Note</b> If you have defined <code>CellEditCallback</code> , this warning will not be thrown <hr/> | Values match. MATLAB displays logical value as a check box as is.                                                                                |

# Uitable Properties

---

If you get a mismatch error, you have the following options:

- Change the `ColumnFormat` or value of `Data` to match.
- Implement the `CellEditCallback` to handle custom data conversion.

## ColumnName

1-by-*n* cell array of strings | {'numbered'} | empty matrix ([])

*Column heading names.* Each element of the cell array is the name of a column. Multiline column names can be expressed as a string vector separated by vertical slash (|) characters, e.g., 'Standard|Deviation'

For sequentially numbered column headings starting with 1, specify `ColumnName` as 'numbered'. This is the default.

To remove the column headings, specify `ColumnName` as the empty matrix ([]).

The number of columns in the table is the larger of `ColumnName` and the number of columns in the `Data` property matrix or cell array.

## ColumnWidth

1-by-*n* cell array or 'auto'

*Column widths.* The width of each column in units of pixels. Column widths are always specified in pixels; they do not obey the `Units` property. Each column in the cell array corresponds to a column in the uitable. By default, the width of the column name, as specified in `ColumnName`, along with some other factors, is used to determine the width of a column. If `ColumnWidth` is a cell array and the width of a column is set to 'auto' or if **auto** is selected for that column in the Property Inspector GUI for columns, the column width defaults to a size determined by the table. The table decides the default size using a number of factors, including the `ColumnName` and the minimum column size.

To default all column widths in an existing table, use

```
set(uitable_handle, 'ColumnWidth', 'auto')
```

To default some column widths but not others, use a cell array containing a mixture of pixel values and 'auto'. For example,

```
set(uitable_handle, 'ColumnWidth', {64 'auto' 40 40 'auto' 72})
```

## CreateFcn

string or function handle

*Callback routine executed during object creation.* The specified function executes when MATLAB creates a `uitable` object. MATLAB sets all property values for the `uitable` before executing the `CreateFcn` callback so these values are available to the callback. Within the function, use `gcbo` to get the handle of the `uitable` being created.

Setting this property on an existing `uitable` object has no effect.

You can define a default `CreateFcn` callback for all new `uitables`. This default applies unless you override it by specifying a different `CreateFcn` callback when you call `uitable`. For example, the code

```
set(0, 'DefaultUitableCreateFcn', 'set(gcbo, ...
 'BackgroundColor', 'blue')')
```

creates a default `CreateFcn` callback that runs whenever you create a new `uitable`. It sets the default background color of all new `uitables`.

To override this default and create a `uitable` whose `BackgroundColor` is set to a different value, call `uitable` with code similar to

```
hpt = uitable(..., 'CreateFcn', 'set(gcbo, ...
 'BackgroundColor', 'white')')
```

# Uitable Properties

---

---

**Note** To override a default `CreateFcn` callback you must provide a new callback and not just provide different values for the specified properties. This is because the `CreateFcn` callback runs after the property values are set, and can override property values you have set explicitly in the `uitable` call. In the example above, if instead of redefining the `CreateFcn` property for this `uitable`, you had explicitly set `BackgroundColor` to `white`, the default `CreateFcn` callback would have set `BackgroundColor` back to the default, i.e., `blue`.

---

Do not call `copyobj` or `textwrap` (which calls `copyobj`) inside a `CreateFcn`. The act of copying the `uicontrol` object fires the `CreateFcn` repeatedly, which raises a series of error messages after exceeding the root object's `RecursionLimit` property.

See “Function Handle Callbacks” for information on how to use function handles to define a callback function.

## Data

matrix or cell array of numeric, logical, or character data

*Data content of `uitable`.* The matrix or cell array must be 2-dimensional. A cell array can mix data types.

Use `get` and `set` to modify `Data`. For example,

```
data = get(tablehandle, 'Data')
data(event.indices(1), event.indices(2)) = pi();
set(tablehandle, 'Data', data);
```

See `CellEditCallback` for information about the event data structure. See `ColumnFormat` for information about specifying the data display format.

The number of rows in the table is the larger of `RowName` and the number of rows in `Data`. The number of columns in the table is the larger of `ColumnName` and the number of columns in `Data`.

## DeleteFcn

string or function handle

*Delete uitable callback routine.* A callback routine that executes when you delete the `uitable` object (e.g., when you issue a `delete` command or `clear` the figure containing the `uitable`). MATLAB executes the routine before destroying the object's properties so these values are available to the callback routine.

The handle of the object whose `DeleteFcn` is being executed is accessible only through the root `CallbackObject` property, which you can query using `gcbo`.

See “Function Handle Callbacks” for information on how to use function handles to define a callback function.

## Enable

{on} | inactive | off

*Enable or disable the uitable.* This property determines how uitables respond to mouse button clicks, including which callback routines execute.

- `on` – The `uitable` is operational (the default).
- `inactive` – The `uitable` is not operational, but looks the same as when `Enable` is `on`.
- `off` – The `uitable` is not operational and its image is grayed out.

When you left-click on a `uitable` whose `Enable` property is `on`, MATLAB performs these actions in this order:

- 1 Sets the figure's `SelectionType` property.

# Uitable Properties

---

- 2 Executes the uitable's `CellSelectionCallback` routine (but only for table cells, not header cells). Row and column indices of the cells the user selects continuously update the `Indices` field in the `eventdata` passed to the callback.
- 3 Does not set the figure's `CurrentPoint` property and does not execute either the table's `ButtonDownFcn` or the figure's `WindowButtonDownFcn` callback.

When you left-click on a uitable whose `Enable` property is `off`, or when you right-click a uitable whose `Enable` property has any value, MATLAB performs these actions in this order:

- 1 Sets the figure's `SelectionType` property.
- 2 Sets the figure's `CurrentPoint` property.
- 3 Executes the figure's `WindowButtonDownFcn` callback.

## Extent

position rectangle (read only)

*Size of uitable rectangle.* A four-element vector of the form `[0,0,width,height]` that contains the calculated values of the largest extent of the table based on the current `Data`, `RowNames` and `ColumnNames` property values. Calculation depends on column and row widths, when they are available. The calculated extent can be larger than the figure.

The first two elements are always zero. `width` and `height` are the dimensions of the rectangle. All measurements are in units specified by the `Units` property.

When the uitable's `Units` property is set to `'Normalized'`, its `Extent` is measured relative to the figure, regardless of whether the table is contained in (parented to) a `uipanel` or not.

You can use this property to determine proper sizing for the uitable with respect to its content. Do this by setting the `width`

and height of the uitable `Position` property to the width and height of the `Extent` property. However, doing this can cause the table to extend beyond the right or top edge of the figure and/or its uipanel parent, if any, for tables with large extents.

## FontAngle

{normal} | italic | oblique

*Character slant of cell content.* MATLAB uses this property to select a font from those available on your particular system. Setting this property to `italic` or `oblique` selects a slanted version of the font, when it is available on your system.

## FontName

string

*Font family for cell content.* The name of the font in which to display cell content. To display and print properly, this must be a font that your system supports. The default font is system dependent.

To use a fixed-width font that looks good in any locale (and displays properly in Japan, where multibyte character sets are used), set `FontName` to the string `FixedWidth` (this string value is case sensitive):

```
set(uitable_handle, 'FontName', 'FixedWidth')
```

This parameter value eliminates the need to hard code the name of a fixed-width font, which may not display text properly on systems that do not use ASCII character encoding (such as in Japan). A properly written MATLAB application that needs to use a fixed-width font should set `FontName` to `FixedWidth` and rely on the root `FixedWidthFontName` property to be set correctly in the end user's environment.

End users can adapt a MATLAB application to different locales or personal environments by setting the root `FixedWidthFontName`

# Uitable Properties

---

property to the appropriate value for that locale from `startup.m`. Setting the root `FixedWidthFontName` property causes an immediate update of the display to use the new font.

## FontSize

size in FontUnits

*Font size for cell contents.* A number specifying the size of the font in which to display cell contents, in units determined by the `FontUnits` property. The default point size is system dependent. If `FontUnits` is set to `normalized`, `FontSize` is a number between 0 and 1.

## FontUnits

{points} | normalized | inches |  
centimeters | pixels

*Font size units for cell contents.* This property determines the units used by the `FontSize` property. Normalized units interpret `FontSize` as a fraction of the height of the uitable. When you resize the uitable, MATLAB modifies the screen `FontSize` accordingly. `pixels`, `inches`, `centimeters`, and `points` are absolute units (1 point =  $1/72$  inch).

## FontWeight

light | {normal} | demi | bold

*Weight of cell text characters.* MATLAB uses this property to select a font from those available on your particular system. Setting this property to `bold` causes MATLAB to use a bold version of the font, when it is available on your system.

## ForegroundColor

1-by-3 matrix of RGB triples or a color name

*Color of text in cells.* Determines the color of the text defined for cell contents. Text in all cells share the current color. Specify as a 1-by-3 matrix of RGB triples, such as `[0 0 .8]` or as a color name.



The default is a 1-by-3 matrix of platform-dependent colors. See `ColorSpec` for information about specifying RGB colors.

## `HandleVisibility`

`{on} | callback | off`

*Control access to object's handle.* This property determines when an object's handle is visible in its parent's list of children. When a handle is not visible in its parent's list of children, it is not returned by functions that obtain handles by searching the object hierarchy or querying handle properties. This includes `get`, `findobj`, `gca`, `gcf`, `gco`, `newplot`, `cla`, `clf`, and `close`. Neither is the handle visible in the parent figure's `CurrentObject` property. Handles that are hidden are still valid. If you know an object's handle, you can `set` and `get` its properties, and pass it to any function that operates on handles.

- Handles are always visible when `HandleVisibility` is `on`.
- Setting `HandleVisibility` to `callback` causes handles to be visible from within callback routines or functions invoked by callback routines, but not from within functions invoked from the command line. This provides a means to protect GUIs from command-line users, while allowing callback routines to have complete access to object handles.
- Setting `HandleVisibility` to `off` makes handles invisible at all times. This may be necessary when a callback routine invokes a function that might potentially damage the GUI (such as evaluating a user-typed string), and so temporarily hides its own handles during the execution of that function.

You can set the root `ShowHiddenHandles` property to `on` to make all handles visible, regardless of their `HandleVisibility` settings. This does not affect the values of the `HandleVisibility` properties.

## `HitTest`

`{on} | off`

# Uitable Properties

---

*Selectable by mouse click.* When `HitTest` is `off`, the `ButtonDownFcn` callback does not execute.

**Interruptible**  
{on} | off

*Callback routine interruption mode.* If a callback is executing and the user triggers an event (such as a mouse click) on an object for which a callback is defined, that callback attempts to interrupt the first callback. The MATLAB processes the callbacks according to these factors:

- The `Interruptible` property of the object whose callback is executing
- Whether the executing callback contains `drawnow`, `figure`, `getframe`, `pause`, or `waitfor` statements
- The `BusyAction` property of the object whose callback is waiting to execute

If the `Interruptible` property of the object whose callback is executing is `on` (the default), the callback can be interrupted. Whenever the callback calls one of the `drawnow`, `figure`, `getframe`, `pause`, or `waitfor` functions, the function processes any events in the event queue, including the waiting callback, before performing its defined task.

If the `Interruptible` property of the object whose callback is executing is `off`, the callback cannot be interrupted (except by certain callbacks; see the note below). The `BusyAction` property of the object whose callback is waiting to execute determines what happens to the callback.

---

**Note** If the interrupting callback is a DeleteFcn or CreateFcn callback or a figure's CloseRequest or ResizeFcn callback, it interrupts an executing callback regardless of the value of that object's Interruptible property. The interrupting callback starts execution at the next drawnow, figure, getframe, pause, or waitfor statement. A figure's WindowButtonDownFcn callback routine, or an object's ButtonDownFcn or Callback routine are processed according to the rules described above.

---

## KeyPressFcn

string or function handle

*Key press callback function.* A callback routine invoked by a key press when the callback's uitable object has focus. Focus is denoted by a border or a dotted border, respectively, in UNIX and Microsoft Windows. If no uitable has focus, the figure's key press callback function, if any, is invoked. KeyPressFcn can be a function handle, the name of an M-file, or any legal MATLAB expression.

If the specified value is the name of an M-file, the callback routine can query the figure's CurrentCharacter property to determine what particular key was pressed and thereby limit the callback execution to specific keys.

If the specified value is a function handle, the callback routine can retrieve information about the key that was pressed from its event data structure argument.

| Event Data Structure Field | Description                                           | Examples: |     |       |         |
|----------------------------|-------------------------------------------------------|-----------|-----|-------|---------|
|                            |                                                       | a         | =   | Shift | Shift/a |
| Character                  | Character interpretation of the key that was pressed. | 'a'       | '=' | ' '   | 'A'     |

# Uitable Properties

| Event Data Structure Field | Description                                                                         | Examples:  |            |           |           |
|----------------------------|-------------------------------------------------------------------------------------|------------|------------|-----------|-----------|
|                            |                                                                                     | a          | =          | Shift     | Shift/a   |
| Modifier                   | Current modifier, such as 'control', or an empty cell array if there is no modifier | {1x0 cell} | {1x0 cell} | {'shift'} | {'shift'} |
| Key                        | Name of the key that was pressed.                                                   | 'a'        | 'equal'    | 'shift'   | 'a'       |

The uitable `KeyPressFcn` callback executes for all keystrokes, including arrow keys or when a user edits cell content.

See “Function Handle Callbacks” for information on how to use function handles to define the callback function.

Parent  
handle

*Uitable parent.* The handle of the uitable’s parent object. You can move a uitable object to another figure, uipanel, or uibuttongroup by setting this property to the handle of the new parent.

Position  
position rectangle

*Size and location of uitable.* The rectangle defined by this property specifies the size and location of the table within the parent figure window, ui, or uibuttongroup. Specify `Position` as a 4–element vector:

```
[left bottom width height]
```

`left` and `bottom` are the distance from the lower-left corner of the parent object to the lower-left corner of the uitable object. `width` and `height` are the dimensions of the uitable rectangle. All measurements are in units specified by the `Units` property.

---

**Note** If you are specifying both `Units` and `Position` in the same call to `uitable`, specify `Units` first if you want `Position` to be interpreted using those units.

---

`RearrangeableColumn`  
`on` | `{off}`

*This object can be rearranged.* The `RearrangeableColumn` property provides a mechanism that you can use to reorder the columns in the table. All columns are rearrangeable when this property is turned on. MATLAB software sets the `RearrangeableColumn` property to `off` by default.

When this property is on, the user of a table can move any column of data (but not the row labels) at a time left or right to reorder it by clicking and dragging its header. Rearranging columns does not affect the ordering of columns in the table's `Data`, only the user's view of it.

`RowName`  
1-by-n cell array of strings | `'numbered'` | empty matrix (`[]`)

*Row heading names.* Each element of the cell array is the name of a row. Row names are restricted to one line of text.

For sequentially numbered row headings starting with 1, specify `RowName` as `'numbered'`. This is the default.

To remove the row headings, specify `RowName` as the empty matrix (`[]`).

The number of rows in the table is the larger of `RowName` and the number of rows in the `Data` property matrix or cell array.

`RowStriping`  
`{on}` | `off`

# Uitable Properties

---

*Color striping of table rows.* When `RowStriping` is on, the background of consecutive rows of the table display in the pair of colors that the `BackgroundColor` color matrix specifies. The first color matrix row applies to odd-numbered rows, and the second to even-numbered rows. If the `BackgroundColor` matrix has only one row, it is applied to all rows (that is, no striping occurs).

When `RowStriping` is off, the first color specified for `BackgroundColor` is applied to all rows.

`Selected`  
on | {off}

*Is object selected.* When this property is on, MATLAB displays selection handles if the `SelectionHighlight` property is also on. You can, for example, define the `ButtonDownFcn` to set this property, allowing users to select the object with the mouse.

`SelectionHighlight`  
{on} | off

*Object highlight when selected.* When the `Selected` property is on, MATLAB indicates the selected state by drawing four edge handles and four corner handles. When `SelectionHighlight` is off, MATLAB does not draw the handles.

`Tag`  
string (GUIDE sets this property)

*User-specified object label.* The `Tag` property provides a means to identify graphics objects with a user-specified label. This is particularly useful when constructing interactive graphics programs that would otherwise need to define object handles as global variables or pass them as arguments between callback routines. You can define `Tag` as any string.

`TooltipString`  
string

*Content of tooltip for object.* The `TooltipString` property specifies the text of the tooltip associated with the uitable. When the user moves the mouse pointer over the table and leaves it there, the tooltip is displayed.

## Type

string (read only)

*Class of graphics object.* For uitable objects, Type is always the string 'uitable'.

## UIContextMenu

handle

*Associate a context menu with uitable.* Assign this property the handle of a `uicontextmenu` object. MATLAB displays the context menu whenever you right-click over the uitable. Use the `uicontextmenu` function to create the context menu.

## Units

{pixels} | normalized | inches | centimeters | points | characters (GUIDE default: normalized)

*Units of measurement.* MATLAB uses these units to interpret the `Extent` and `Position` properties. All units are measured from the lower-left corner of the parent object.

- Normalized units map the lower-left corner of the parent object to (0,0) and the upper-right corner to (1.0,1.0).
- pixels, inches, centimeters, and points are absolute units (1 point = 1/72 inch).
- Character units are characters using the default system font; the width of one character is the width of the letter x, the height of one character is the distance between the baselines of two lines of text.

If you change the value of `Units`, it is good practice to return it to its default value after completing your computation so as not

# Uitable Properties

---

to affect other functions that assume `Units` is set to the default value.

`UserData`  
matrix

*User-specified data.* Any data you want to associate with the uitable object. MATLAB does not use this data, but you can access it using `set` and `get`.

`Visible`  
{on} | off

*Uitable visibility.* By default, all uitables are visible. When set to `off`, the uitable is not visible, but still exists and you can query and set its properties.

---

**Note** Setting `Visible` to `off` for uitables that are not displayed initially in the GUI, can result in faster startup time for the GUI.

---

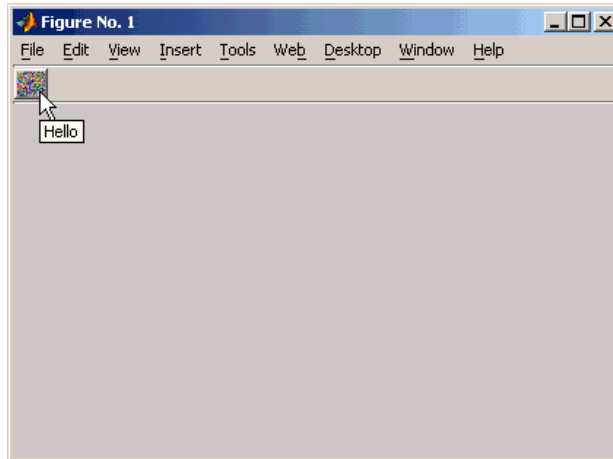


|                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
|--------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Purpose</b>     | Create toggle button on toolbar                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| <b>Syntax</b>      | <pre>htt = uitoggletool('PropertyName1',value1,'PropertyName2',<br/>    value2,...)<br/>htt = uitoggletool(ht,...)</pre>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| <b>Description</b> | <p>htt =<br/>uitoggletool('PropertyName1',value1,'PropertyName2',value2,...)<br/>creates a toggle button on the uitoolbar at the top of the current figure window, and returns a handle to it. <code>uitoggletool</code> assigns the specified property values, and assigns default values to the remaining properties. You can change the property values at a later time using the <code>set</code> function.</p> <p>Type <code>get(htt)</code> to see a list of <code>uitoggletool</code> object properties and their current values. Type <code>set(htt)</code> to see a list of <code>uitoggletool</code> object properties you can set and legal property values. See the <code>Uitoggletool Properties</code> reference page for more information.</p> <p><code>htt = uitoggletool(ht,...)</code> creates a button with <code>ht</code> as a parent. <code>ht</code> must be a <code>uitoolbar</code> handle.</p> |
| <b>Remarks</b>     | <p><code>uitoggletool</code> accepts property name/property value pairs, as well as structures and cell arrays of properties as input arguments.</p> <p>Toggle tools appear in figures whose <code>Window Style</code> is <code>normal</code> or <code>docked</code>. They do not appear in figures whose <code>WindowStyle</code> is <code>modal</code>. If the <code>WindowStyle</code> property of a figure containing a tool bar and its toggle tool children is changed to <code>modal</code>, the toggle tools still exist and are contained in the <code>Children</code> list of the tool bar, but are not displayed until the <code>WindowStyle</code> is changed to <code>normal</code> or <code>docked</code>.</p>                                                                                                                                                                                             |
| <b>Examples</b>    | <p>This example creates a <code>uitoolbar</code> object and places a <code>uitoggletool</code> object on it.</p> <pre>h = figure('ToolBar','none');<br/>ht = uitoolbar(h);<br/>a = rand(16,16,3);</pre>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |

# uitoggletool

---

```
htt = uitoggletool(ht,'CData',a,'TooltipString','Hello');
```



## See Also

[get](#), [set](#), [uicontrol](#), [uipushtool](#), [uitoolbar](#)

## Purpose

Describe toggle tool properties

## Modifying Properties

You can set and query graphics object properties in two ways:

- The Property Inspector is an interactive tool that enables you to see and change object property values. The Property inspector is available from GUIDE, or use the `inspect` function at the command line.
- The `set` and `get` functions enable you to set and query the values of properties.

You can set default Uitoggletool properties by typing:

```
set(h, 'DefaultUitoggletoolPropertyName', PropertyValue...)
```

Where `h` can be the root handle (0), a figure handle, a uitoolbar handle, or a uitoggletool handle. *PropertyName* is the name of the Uitoggletool property and *PropertyValue* is the value you specify as the default for that property.

For more information about changing the default value of a property see “Setting Default Property Values”.

## Properties

This section lists all properties useful to uitoggletool objects along with valid values and a descriptions of their use. Curly braces { } enclose default values.

| Property        | Purpose                                                 |
|-----------------|---------------------------------------------------------|
| BeingDeleted    | This object is being deleted.                           |
| BusyAction      | Callback routine interruption.                          |
| CData           | Truecolor image displayed on the toggle tool.           |
| ClickedCallback | Control action independent of the toggle tool position. |

# Uitoggletool Properties

---

| Property         | Purpose                                                     |
|------------------|-------------------------------------------------------------|
| CreateFcn        | Callback routine executed during object creation.           |
| DeleteFcn        | Callback routine executed during object deletion.           |
| Enable           | Enable or disable the uitoggletool.                         |
| HandleVisibility | Control access to object's handle.                          |
| HitTest          | Whether selectable by mouse click                           |
| Interruptible    | Callback routine interruption mode.                         |
| OffCallback      | Control action when toggle tool is set to the off position. |
| OnCallback       | Control action when toggle tool is set to the on position.  |
| Parent           | Handle of uitoggletool's parent toolbar.                    |
| Separator        | Separator line mode.                                        |
| State            | Uitoggletool state.                                         |
| Tag              | User-specified object label.                                |
| TooltipString    | Content of object's tooltip.                                |
| Type             | Object class.                                               |
| UIContextMenu    | Uicontextmenu object associated with the uitoggletool       |
| UserData         | User specified data.                                        |
| Visible          | Uitoggletool visibility.                                    |

BeingDeleted  
on | {off} (read only)

*This object is being deleted.* The **BeingDeleted** property provides a mechanism that you can use to determine if objects are

in the process of being deleted. MATLAB software sets the `BeingDeleted` property to on when the object's delete function callback is called (see the `DeleteFcn` property) It remains set to on while the delete function executes, after which the object no longer exists.

For example, some functions may not need to perform actions on objects that are being deleted, and therefore, can check the object's `BeingDeleted` property before acting.

## `BusyAction`

`cancel` | `{queue}`

*Callback routine interruption.* If a callback is executing and the user triggers an event (such as a mouse click) on an object for which a callback is defined, the callback associated with the new event uses the value of `BusyAction` to decide whether or not to attempt to interrupt the executing callback.

- If the value is `cancel`, the event is discarded and the second callback does not execute.
- If the value is `queue`, and the `Interruptible` property of the first callback is on, the second callback is added to the event queue and executes in its turn after the first callback finishes execution.

---

**Note** If the interrupting callback is a `DeleteFcn` or `CreateFcn` callback or a figure's `CloseRequest` or `ResizeFcn` callback, it interrupts an executing callback regardless of the value of that object's `Interruptible` property. See the `Interruptible` property for information about controlling a callback's interruptibility.

---

## `CData`

3-dimensional array

# Uitoggletool Properties

---

*Truecolor image displayed on control.* An  $n$ -by- $m$ -by-3 array of RGB values that defines a truecolor image displayed on either a push button or toggle button. Each value must be between 0.0 and 1.0. If your CData array is larger than 16 in the first or second dimension, it may be clipped or cause other undesirable effects. If the array is clipped, only the center 16-by-16 part of the array is used.

**ClickedCallback**  
string or function handle

*Control action independent of the toggle tool position.* A routine that executes after either the OnCallback routine or OffCallback routine runs to completion. The uitoggletool's Enable property must be set to on.

**CreateFcn**  
string or function handle

*Callback routine executed during object creation.* The specified function executes when MATLAB creates a uitoggletool object. MATLAB sets all property values for the uitoggletool before executing the CreateFcn callback so these values are available to the callback. Within the function, use gcbo to get the handle of the toggle tool being created.

Setting this property on an existing uitoggletool object has no effect.

You can define a default CreateFcn callback for all new uitoggletools. This default applies unless you override it by specifying a different CreateFcn callback when you call uitoggletool. For example, the statement,

```
set(0, 'DefaultUitoggletoolCreateFcn', ...
 'set(gcbo, ''Enable'', ''off'')')
```

creates a default `CreateFcn` callback that runs whenever you create a new toggle tool. It sets the toggle tool `Enable` property to `off`.

To override this default and create a toggle tool whose `Enable` property is set to `on`, you could call `uitoggletool` with code similar to

```
htt = uitoggletool(...,'CreateFcn',...
 'set(gcbo,'Enable','on'),'...',...)
```

---

**Note** To override a default `CreateFcn` callback you must provide a new callback and not just provide different values for the specified properties. This is because the `CreateFcn` callback runs after the property values are set, and can override property values you have set explicitly in the `uitoggletool` call. In the example above, if instead of redefining the `CreateFcn` property for this toggle tool, you had explicitly set `Enable` to `on`, the default `CreateFcn` callback would have set `CData` back to `off`.

---

Do not call `copyobj` or `textwrap` (which calls `copyobj`) inside a `CreateFcn`. The act of copying the `uicontrol` object fires the `CreateFcn` repeatedly, which raises a series of error messages after exceeding the root object's `RecursionLimit` property.

See [Function Handle Callbacks](#) for information on how to use function handles to define a callback function.

**DeleteFcn**  
string or function handle

*Callback routine executed during object deletion.* A callback routine that executes when you delete the `uitoggletool` object (e.g., when you call the `delete` function or cause the figure containing the `uitoggletool` to reset). MATLAB executes the routine before

# Uitoggletool Properties

---

destroying the object's properties so these values are available to the callback routine.

The handle of the object whose `DeleteFcn` is being executed is accessible only through the root `CallbackObject` property, which you can query using `gcbo`.

See [Function Handle Callbacks](#) for information on how to use function handles to define a callback function.

## Enable

{on} | off

*Enable or disable the uitoggletool.* This property controls how uitoggletools respond to mouse button clicks, including which callback routines execute.

- **on** – The uitoggletool is operational (the default).
- **off** – The uitoggletool is not operational and its image (set by the `Cdata` property) is grayed out.

When you left-click on a uitoggletool whose `Enable` property is `on`, MATLAB performs these actions in this order:

- 1** Sets the figure's `SelectionType` property.
- 2** Executes the toggle tool's `ClickedCallback` routine.
- 3** Does not set the figure's `CurrentPoint` property and does not execute the figure's `WindowButtonDownFcn` callback.

When you left-click on a uitoggletool whose `Enable` property is `off`, or when you right-click a uitoggletool whose `Enable` property has any value, MATLAB performs these actions in this order:

- 4** Sets the figure's `SelectionType` property.
- 5** Sets the figure's `CurrentPoint` property.
- 6** Executes the figure's `WindowButtonDownFcn` callback.



- 7 Does not execute the toggle tool's OnCallback, OffCallback, or ClickedCallback routines.

## HandleVisibility

{on} | callback | off

*Control access to object's handle.* This property determines when an object's handle is visible in its parent's list of children. When a handle is not visible in its parent's list of children, it is not returned by functions that obtain handles by searching the object hierarchy or querying handle properties. This includes `get`, `findobj`, `gca`, `gcf`, `gco`, `newplot`, `cla`, `clf`, and `close`. Neither is the handle visible in the parent figure's `CurrentObject` property. Handles that are hidden are still valid. If you know an object's handle, you can `set` and `get` its properties, and pass it to any function that operates on handles.

- Handles are always visible when `HandleVisibility` is `on`.
- Setting `HandleVisibility` to `callback` causes handles to be visible from within callback routines or functions invoked by callback routines, but not from within functions invoked from the command line. This provides a means to protect GUIs from command-line users, while allowing callback routines to have complete access to object handles.
- Setting `HandleVisibility` to `off` makes handles invisible at all times. This may be necessary when a callback routine invokes a function that might potentially damage the GUI (such as evaluating a user-typed string), and so temporarily hides its own handles during the execution of that function.

You can set the root `ShowHiddenHandles` property to `on` to make all handles visible, regardless of their `HandleVisibility` settings. This does not affect the values of the `HandleVisibility` properties.

## HitTest

{on} | off

# Uitoggletool Properties

---

*Selectable by mouse click.* This property has no effect on uitoggletool objects.

Interruptible  
{on} | off

*Callback routine interruption mode.* If a callback is executing and the user triggers an event (such as a mouse click) on an object for which a callback is defined, that callback attempts to interrupt the first callback. MATLAB processes the callbacks according to these factors:

- The Interruptible property of the object whose callback is executing
- Whether the executing callback contains drawnow, figure, getframe, pause, or waitfor statements
- The BusyAction property of the object whose callback is waiting to execute

If the Interruptible property of the object whose callback is executing is on (the default), the callback can be interrupted. Whenever the callback calls one of the drawnow, figure, getframe, pause, or waitfor functions, the function processes any events in the event queue, including the waiting callback, before performing its defined task.

If the Interruptible property of the object whose callback is executing is off, the callback cannot be interrupted (except by certain callbacks; see the note below).

---

**Note** If the interrupting callback is a `DeleteFcn` or `CreateFcn` callback or a figure's `CloseRequest` or `ResizeFcn` callback, it interrupts an executing callback regardless of the value of that object's `Interruptible` property. The interrupting callback starts execution at the next `drawnow`, `figure`, `getframe`, `pause`, or `waitfor` statement.

---

## OffCallback

string or function handle

*Control action.* A routine that executes if the `uitoggletool`'s `Enable` property is set to `on`, and either

- The toggle tool `State` is set to `off`.
- The toggle tool is set to the `off` position by pressing a mouse button while the pointer is on the toggle tool itself or in a 5-pixel wide border around it.

The `ClickedCallback` routine, if there is one, runs after the `OffCallback` routine runs to completion.

## OnCallback

string or function handle

*Control action.* A routine that executes if the `uitoggletool`'s `Enable` property is set to `on`, and either

- The toggle tool `State` is set to `on`.
- The toggle tool is set to the `on` position by pressing a mouse button while the pointer is on the toggle tool itself or in a 5-pixel wide border around it.

The `ClickedCallback` routine, if there is one, runs after the `OffCallback` routine runs to completion.

# Uitoggletool Properties

---

## Parent

handle

*Uitoggletool parent.* The handle of the uitoggletool's parent toolbar. You can move a uitoggletool object to another toolbar by setting this property to the handle of the new parent.

## Separator

on | {off}

*Separator line mode.* Setting this property to on draws a dividing line to left of the uitoggletool.

## State

on | {off}

*Uitoggletool state.* When the state is on, the toggle tool appears in the down, or pressed, position. When the state is off, it appears in the up position. Changing the state causes the appropriate OnCallback or OffCallback routine to run.

## Tag

string

*User-specified object identifier.* The Tag property provides a means to identify graphics objects with a user-specified label. You can define Tag as any string.

With the findobj function, you can locate an object with a given Tag property value. This saves you from defining object handles as global variables. For example, this function call returns the handles of all children (of the specified toolbars) that have the Tag value 'Bold'.

```
h = findobj(uitoolbarhandles, 'Tag', 'Bold')
```

## TooltipString

string

*Content of tooltip for object.* The `TooltipString` property specifies the text of the tooltip associated with the `uitoggletool`. When the user moves the mouse pointer over the control and leaves it there, the tooltip is displayed.

## Type

string (read-only)

Object class. This property identifies the kind of graphics object. For `uitoggletool` objects, `Type` is always the string `'uitoggletool'`.

## UIContextMenu

handle

*Associate a context menu with uicontrol.* This property has no effect on `uitoggletool` objects.

## UserData

array

*User specified data.* You can specify `UserData` as any array you want to associate with the `uitoggletool` object. The object does not use this data, but you can access it using the `set` and `get` functions.

## Visible

{on} | off

*Uitoggletool visibility.* By default, all `uitoggletools` are visible. When set to `off`, the `uitoggletool` is not visible, but still exists and you can query and set its properties.

# uitoolbar

---

**Purpose** Create toolbar on figure

**Syntax**

```
ht =
uitoolbar('PropertyName1',value1,'PropertyName2',value2,
 ...)
ht = uitoolbar(h,...)
```

**Description**

ht =  
uitoolbar('PropertyName1',value1,'PropertyName2',value2,...)  
creates an empty toolbar at the top of the current figure window, and returns a handle to it. `uitoolbar` assigns the specified property values, and assigns default values to the remaining properties. You can change the property values at a later time using the `set` function.

Type `get(ht)` to see a list of `uitoolbar` object properties and their current values. Type `set(ht)` to see a list of `uitoolbar` object properties that you can set and legal property values. See the `Uitoolbar Properties` reference page for more information.

`ht = uitoolbar(h,...)` creates a toolbar with `h` as a parent. `h` must be a figure handle.

**Remarks**

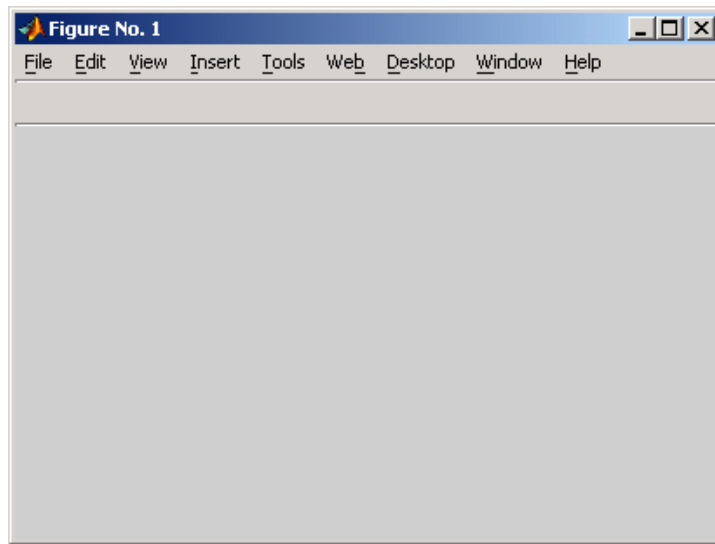
`uitoolbar` accepts property name/property value pairs, as well as structures and cell arrays of properties as input arguments.

Uitoolbars appear in figures whose `Window Style` is `normal` or `docked`. They do not appear in figures whose `WindowStyle` is `modal`. If the `WindowStyle` property of a figure containing a `uitoolbar` is changed to `modal`, the `uitoolbar` still exists and is contained in the `Children` list of the figure, but is not displayed until the `WindowStyle` is changed to `normal` or `docked`.

**Example**

This example creates a figure with no toolbar, then adds a toolbar to it.

```
h = figure('ToolBar','none')
ht = uitoolbar(h)
```



For more information on using the menus and toolbar in a MATLAB figure window, see the online MATLAB Graphics documentation.

## See Also

`set`, `get`, `uicontrol`, `uipushtool`, `uitoggletool`

# Uitoolbar Properties

---

## Purpose

Describe toolbar properties

## Modifying Properties

You can set and query graphics object properties in two ways:

- The Property Inspector is an interactive tool that enables you to see and change object property values. The Property inspector is available from GUIDE, or use the `inspect` function at the command line.
- The `set` and `get` functions enable you to set and query the values of properties.

You can set default Uitoolbar properties by typing:

```
set(h, 'DefaultUitoolbarPropertyName', PropertyValue...)
```

Where `h` can be the root handle (0), a figure handle, or a uitoolbar handle. *PropertyName* is the name of the Uitoolbar property and *PropertyValue* is the value you specify as the default for that property.

For more information about changing the default value of a property see Setting Default Property Values.

## Uitoolbar Properties

This section lists all properties useful to `uitoolbar` objects along with valid values and a descriptions of their use. Curly braces { } enclose default values.

| Property                  | Purpose                                           |
|---------------------------|---------------------------------------------------|
| <code>BeingDeleted</code> | This object is being deleted.                     |
| <code>BusyAction</code>   | Callback routine interruption.                    |
| <code>Children</code>     | Handles of uitoolbar's children.                  |
| <code>CreateFcn</code>    | Callback routine executed during object creation. |
| <code>DeleteFcn</code>    | Callback routine executed during object deletion. |



| Property         | Purpose                                            |
|------------------|----------------------------------------------------|
| HandleVisibility | Control access to object's handle.                 |
| HitTest          | Whether selectable by mouse click                  |
| Interruptible    | Callback routine interruption mode.                |
| Parent           | Handle of uitoolbar's parent.                      |
| Tag              | User-specified object identifier.                  |
| Type             | Object class.                                      |
| UIContextMenu    | Uicontextmenu object associated with the uitoolbar |
| UserData         | User specified data.                               |
| Visible          | Uitoolbar visibility.                              |

## BeingDeleted

on | {off} (read-only)

*This object is being deleted.* The `BeingDeleted` property provides a mechanism that you can use to determine if objects are in the process of being deleted. MATLAB software sets the `BeingDeleted` property to `on` when the object's delete function callback is called (see the `DeleteFcn` property) It remains set to `on` while the delete function executes, after which the object no longer exists.

For example, some functions may not need to perform actions on objects that are being deleted, and therefore, can check the object's `BeingDeleted` property before acting.

## BusyAction

cancel | {queue}

*Callback routine interruption.* If a callback is executing and the user triggers an event (such as a mouse click) on an object for which a callback is defined, the callback associated with the new

# Uitoolbar Properties

---

event uses the value of `BusyAction` to decide whether or not to attempt to interrupt the executing callback.

- If the value is `cancel`, the event is discarded and the second callback does not execute.
- If the value is `queue`, and the `Interruptible` property of the first callback is `on`, the second callback is added to the event queue and executes in its turn after the first callback finishes execution.

---

**Note** If the interrupting callback is a `DeleteFcn` or `CreateFcn` callback or a figure's `CloseRequest` or `ResizeFcn` callback, it interrupts an executing callback regardless of the value of that object's `Interruptible` property. See the `Interruptible` property for information about controlling a callback's interruptibility.

---

## Children

vector of handles

*Handles of tools on the toolbar.* A vector containing the handles of all children of the `uitoolbar` object, in the order in which they appear on the toolbar. The children objects of `uitoolbars` are `uipushtools` and `uitoggletools`. You can use this property to reorder the children.

## CreateFcn

string or function handle

*Callback routine executed during object creation.* The specified function executes when MATLAB creates a `uitoolbar` object. MATLAB sets all property values for the `uitoolbar` before executing the `CreateFcn` callback so these values are available to the callback. Within the function, use `gcb0` to get the handle of the toolbar being created.

Setting this property on an existing uitoolbar object has no effect.

You can define a default `CreateFcn` callback for all new uitoolbars. This default applies unless you override it by specifying a different `CreateFcn` callback when you call `uitoolbar`. For example, the statement,

```
set(0, 'DefaultUitoolbarCreateFcn', ...
 'set(gcbo, ''Visibility'', ''off'')')
```

creates a default `CreateFcn` callback that runs whenever you create a new toolbar. It sets the toolbar visibility to `off`.

To override this default and create a toolbar whose `Visibility` property is set to `on`, you could call `uitoolbar` with a call similar to

```
ht = uitoolbar(..., 'CreateFcn', ...
 'set(gcbo, ''Visibility'', ''on'')', ...)
```

---

**Note** To override a default `CreateFcn` callback you must provide a new callback and not just provide different values for the specified properties. This is because the `CreateFcn` callback runs after the property values are set, and can override property values you have set explicitly in the `uitoolbar` call. In the example above, if instead of redefining the `CreateFcn` property for this toolbar, you had explicitly set `Visibility` to `on`, the default `CreateFcn` callback would have set `Visibility` back to `off`.

---

Do not call `copyobj` or `textwrap` (which calls `copyobj`) inside a `CreateFcn`. The act of copying the uicontrol object fires the `CreateFcn` repeatedly, which raises a series of error messages after exceeding the root object's `RecursionLimit` property.

# Uitoolbar Properties

---

See [Function Handle Callbacks](#) for information on how to use function handles to define a callback function.

## DeleteFcn

string or function handle

*Callback routine executed during object deletion.* A callback function that executes when the uitoolbar object is deleted (e.g., when you call the `delete` function or cause the figure containing the uitoolbar to reset). MATLAB executes the routine before destroying the object's properties so these values are available to the callback routine.

Within the function, use `gcbo` to get the handle of the toolbar being deleted.

## HandleVisibility

{on} | callback | off

*Control access to object's handle.* This property determines when an object's handle is visible in its parent's list of children. When a handle is not visible in its parent's list of children, it is not returned by functions that obtain handles by searching the object hierarchy or querying handle properties. This includes `get`, `findobj`, `gca`, `gcf`, `gco`, `newplot`, `cla`, `clf`, and `close`. Neither is the handle visible in the parent figure's `CurrentObject` property. Handles that are hidden are still valid. If you know an object's handle, you can `set` and `get` its properties, and pass it to any function that operates on handles.

- Handles are always visible when `HandleVisibility` is `on`.
- Setting `HandleVisibility` to `callback` causes handles to be visible from within callback routines or functions invoked by callback routines, but not from within functions invoked from the command line. This provides a means to protect GUIs from command-line users, while allowing callback routines to have complete access to object handles.

- Setting `HandleVisibility` to `off` makes handles invisible at all times. This may be necessary when a callback routine invokes a function that might potentially damage the GUI (such as evaluating a user-typed string), and so temporarily hides its own handles during the execution of that function.

You can set the root `ShowHiddenHandles` property to `on` to make all handles visible, regardless of their `HandleVisibility` settings. This does not affect the values of the `HandleVisibility` properties.

## HitTest

`{on} | off`

*Selectable by mouse click.* This property has no effect on uitoolbar objects.

## Interruptible

`{on} | off`

*Callback routine interruption mode.* If a callback is executing and the user triggers an event (such as a mouse click) on an object for which a callback is defined, that callback attempts to interrupt the first callback. MATLAB processes the callbacks according to these factors:

- The `Interruptible` property of the object whose callback is executing
- Whether the executing callback contains `drawnow`, `figure`, `getframe`, `pause`, or `waitfor` statements
- The `BusyAction` property of the object whose callback is waiting to execute

If the `Interruptible` property of the object whose callback is executing is `on` (the default), the callback can be interrupted. Whenever the callback calls one of the `drawnow`, `figure`, `getframe`, `pause`, or `waitfor` functions, the function processes

# Uitoolbar Properties

---

any events in the event queue, including the waiting callback, before performing its defined task.

If the `Interruptible` property of the object whose callback is executing is `off`, the callback cannot be interrupted (except by certain callbacks; see the note below). The `BusyAction` property of the object whose callback is waiting to execute determines what happens to the callback.

---

**Note** If the interrupting callback is a `DeleteFcn` or `CreateFcn` callback or a figure's `CloseRequest` or `ResizeFcn` callback, it interrupts an executing callback regardless of the value of that object's `Interruptible` property. The interrupting callback starts execution at the next `drawnow`, `figure`, `getframe`, `pause`, or `waitfor` statement. A figure's `WindowButtonDownFcn` callback routine, or an object's `ButtonDownFcn` or `Callback` routine are processed according to the rules described above.

---

## Parent

handle

*Uitoolbar parent.* The handle of the uitoolbar's parent figure. You can move a uitoolbar object to another figure by setting this property to the handle of the new parent.

## Tag

string

*User-specified object identifier.* The `Tag` property provides a means to identify graphics objects with a user-specified label. You can define `Tag` as any string.

With the `findobj` function, you can locate an object with a given `Tag` property value. This saves you from defining object handles as global variables. For example, this function call returns the

handles of all children (of the specified figures) that have the Tag value 'FormatTb'.

```
h = findobj(figurehandles,'Tag','FormatTb')
```

## Type

string (read-only)

Object class. This property identifies the kind of graphics object. For uitoolbar objects, Type is always the string 'uitoolbar'.

## UIContextMenu

handle

*Associate a context menu with uicontrol.* This property has no effect on uitoolbar objects.

## UserData

array

*User specified data.* You can specify UserData as any array you want to associate with the uitoolbar object. The object does not use this data, but you can access it using the `set` and `get` functions.

## Visible

{on} | off

*Uitoolbar visibility.* By default, all uitoolbars are visible. When set to `off`, the uitoolbar is not visible, but still exists and you can query and set its properties.

# uiwait

---

**Purpose** Block execution and wait for resume

**Syntax** `uiwait`  
`uiwait(h)`  
`uiwait(h,timeout)`

**Description** `uiwait` blocks execution until `uiresume` is called or the current figure is deleted. This syntax is the same as `uiwait(gcf)`.

`uiwait(h)` blocks execution until `uiresume` is called or the figure `h` is deleted.

`uiwait(h,timeout)` blocks execution until `uiresume` is called, the figure `h` is deleted, or `timeout` seconds elapse.

**Remarks** The `uiwait` and `uiresume` functions block and resume MATLAB and Simulink program execution. `uiwait` also blocks the execution of Simulink models. The functions `pause` (with no argument) and `waitfor` also block execution in this manner. `uiwait` is a convenient way to use the `waitfor` command. You typically use it in conjunction with a dialog box. It provides a way to block the execution of the M-file that created the dialog, until the user responds to the dialog box. When used in conjunction with a modal dialog, `uiwait` can block the execution of the M-file *and* restrict user interaction to the dialog only.

**Example** This example creates a GUI with a **Continue** push button. The example calls `uiwait` to block MATLAB execution until `uiresume` is called. This happens when the user clicks the **Continue** push button because the push button's `Callback` callback, which responds to the click, calls `uiresume`.

```
f = figure;
h = uicontrol('Position',[20 20 200 40],'String','Continue',...
 'Callback','uiresume(gcf)');
disp('This will print immediately');
uiwait(gcf);
disp('This will print after you click Continue');
```



```
close(f);
```

gcbf is the handle of the figure that contains the object whose callback is executing.

“Using a Modal Dialog Box to Confirm an Operation” is a more complex example for a GUIDE GUI. See “Icon Editor” for an example for a programmatically created GUI.

**See Also**

dialog, figure, uicontrol, uimenu, uiresume, waitfor

# undocheckout

---

**Purpose** Undo previous checkout from source control system (UNIX platforms)

**GUI Alternatives** As an alternative to the `undocheckout` function, select **Source Control > Undo Checkout** in the **File** menu of the Editor, Simulink software, or Stateflow software, or in the context menu of the Current Directory browser. For more information, see “Undoing the Checkout on UNIX Platforms”.

**Syntax** `undocheckout('filename')`  
`undocheckout({'filename1','filename2', ..., 'filenamen'})`

**Description** `undocheckout('filename')` makes the file `filename` available for checkout, where `filename` does not reflect any of the changes you made after you last checked it out. Use the full path for `filename` and include the file extension.

`undocheckout({'filename1','filename2', ..., 'filenamen'})` makes `filename1` through `filenamen` available for checkout, where the files do not reflect any of the changes you made after you last checked them out. Use the full paths for the file names and include the file extensions.

**Examples** Typing

```
undocheckout({'/myserver/mymfiles/clock.m', ...
 '/myserver/mymfiles/calendar.m'})
```

undoes the checkouts of `/myserver/mymfiles/clock.m` and `/myserver/mymfiles/calendar.m` from the source control system.

**See Also** `checkin`, `checkout`

For Microsoft Windows platforms, use `verctrl`.

|                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|--------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Purpose</b>     | Convert Unicode characters to numeric bytes                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| <b>Syntax</b>      | <pre>bytes = unicode2native(unicodestr) bytes = unicode2native(unicodestr, encoding)</pre>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| <b>Description</b> | <p><code>bytes = unicode2native(unicodestr)</code> takes a char vector of Unicode characters, <code>unicodestr</code>, converts it to the MATLAB default character encoding scheme, and returns the bytes as a <code>uint8</code> vector, <code>bytes</code>. Output vector <code>bytes</code> has the same general array shape as the <code>unicodestr</code> input. You can save the output of <code>unicode2native</code> to a file using the <code>fwrite</code> function.</p> <p><code>bytes = unicode2native(unicodestr, encoding)</code> converts the Unicode characters to the character encoding scheme specified by the string <code>encoding</code>. <code>encoding</code> must be the empty string (<code>''</code>) or a name or alias for an encoding scheme. Some examples are <code>'UTF-8'</code>, <code>'latin1'</code>, <code>'US-ASCII'</code>, and <code>'Shift_JIS'</code>. For common names and aliases, see the Web site <a href="http://www.iana.org/assignments/character-sets">http://www.iana.org/assignments/character-sets</a>. If <code>encoding</code> is unspecified or is the empty string (<code>''</code>), the MATLAB default encoding scheme is used.</p> |
| <b>Examples</b>    | <p>This example begins with two strings containing Unicode characters. It assumes that string <code>str1</code> contains text in a Western European language and string <code>str2</code> contains Japanese text. The example writes both strings into the same file, using the ISO-8859-1 character encoding scheme for the first string and the Shift-JIS encoding scheme for the second string. The example uses <code>unicode2native</code> to convert the two strings to the appropriate encoding schemes.</p> <pre>fid = fopen('mixed.txt', 'w'); bytes1 = unicode2native(str1, 'ISO-8859-1'); fwrite(fid, bytes1, 'uint8'); bytes2 = unicode2native(str2, 'Shift_JIS'); fwrite(fid, bytes2, 'uint8'); fclose(fid);</pre>                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| <b>See Also</b>    | <code>native2unicode</code>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |

# union

---

**Purpose** Find set union of two vectors

**Syntax**

```
c = union(A, B)
c = union(A, B, 'rows')
[c, ia, ib] = union(...)
```

**Description** `c = union(A, B)` returns the combined values from A and B but with no repetitions. In set theoretic terms,  $c = A \cup B$ . Inputs A and B can be numeric or character vectors or cell arrays of strings. The resulting vector is sorted in ascending order.

`c = union(A, B, 'rows')` when A and B are matrices with the same number of columns returns the combined rows from A and B with no repetitions. MATLAB ignores the rows flag for all cell arrays.

`[c, ia, ib] = union(...)` also returns index vectors ia and ib such that  $c = a(ia) \cup b(ib)$ , or for row combinations,  $c = a(ia,:) \cup b(ib,:)$ . If a value appears in both a and b, union indexes its occurrence in b. If a value appears more than once in b or in a (but not in b), union indexes the last occurrence of the value.

**Remarks** Because NaN is considered to be not equal to itself, every occurrence of NaN in A or B is also included in the result c.

**Examples**

```
a = [-1 0 2 4 6];
b = [-1 0 1 3];
[c, ia, ib] = union(a, b);
c =
```

```
 -1 0 1 2 3 4 6
```

```
ia =
```

```
 3 4 5
```

```
ib =
```

1 2 3 4

**See Also**

`intersect`, `setdiff`, `setxor`, `unique`, `ismember`, `issorted`

# unique

---

**Purpose** Find unique elements of vector

**Syntax**

```
b = unique(A)
b = unique(A, 'rows')
[b, m, n] = unique(...)
[b, m, n] = unique(..., occurrence)
```

**Description** `b = unique(A)` returns the same values as in `A` but with no repetitions. `A` can be a numeric or character array or a cell array of strings. If `A` is a vector or an array, `b` is a vector of unique values from `A`. If `A` is a cell array of strings, `b` is a cell vector of unique strings from `A`. The resulting vector `b` is sorted in ascending order and its elements are of the same class as `A`.

`b = unique(A, 'rows')` returns the unique rows of `A`.

`[b, m, n] = unique(...)` also returns index vectors `m` and `n` such that `b = A(m)` and `A = b(n)`. Each element of `m` is the greatest subscript such that `b = A(m)`. For row combinations, `b = A(m,:)` and `A = b(n,:)`.

`[b, m, n] = unique(..., occurrence)`, where `occurrence` can be

- 'first', which returns the vector `m` to index the first occurrence of each unique value in `A`, or
- 'last', which returns the vector `m` to index the last occurrence.

If you do not specify `occurrence`, it defaults to 'last'.

You can specify 'rows' in the same command as 'first' or 'last'. The order of appearance in the argument list is not important.

## Examples

```
A = [1 1 5 6 2 3 3 9 8 6 2 4]
A =
 1 1 5 6 2 3 3 9 8 6 2 4
```

Get a sorted vector of unique elements of A. Also get indices of the first elements in A that make up vector b, and the first elements in b that make up vector A:

```
[b1, m1, n1] = unique(A, 'first')
b1 =
 1 2 3 4 5 6 8 9
m1 =
 1 5 6 12 3 4 9 8
n1 =
 1 1 5 6 2 3 3 8 7 6 2 4
```

Verify that  $b1 = A(m1)$  and  $A = b1(n1)$ :

```
all(b1 == A(m1)) && all(A == b1(n1))
ans =
 1
```

Get a sorted vector of unique elements of A. Also get indices of the last elements in A that make up vector b, and the last elements in b that make up vector A:

```
[b2, m2, n2] = unique(A, 'last')
b2 =
 1 2 3 4 5 6 8 9
m2 =
 2 11 7 12 3 10 9 8
n2 =
 1 1 5 6 2 3 3 8 7 6 2 4
```

Verify that  $b2 = A(m2)$  and  $A = b2(n2)$ :

```
all(b2 == A(m2)) && all(A == b2(n2))
ans =
 1
```

Because NaNs are not equal to each other, unique treats them as unique elements.

# unique

---

```
unique([1 1 NaN NaN])
ans =
 1 NaN NaN
```

## See Also

intersect, ismember, sort, issorted, setdiff, setxor, union



**Purpose**           Execute UNIX command and return result

**Syntax**           unix command  
                  status = unix('command')  
                  [status, result] = unix('command')  
                  [status,result] = unix('command','-echo')

## Description

`unix` command calls upon the UNIX<sup>28</sup> operating system to execute the given command.

`status = unix('command')` returns completion status to the `status` variable.

`[status, result] = unix('command')` returns the standard output to the `result` variable, in addition to completion status.

`[status,result] = unix('command', '-echo')` displays the results in the Command Window as it executes, and assigns the results to `w`.

---

**Note** The MATLAB software uses a shell program to execute the given command. It determines which shell program to use by checking environment variables on your system. MATLAB first checks the `MATLAB_SHELL` variable, and if either empty or not defined, then checks `SHELL`. If `SHELL` is also empty or not defined, MATLAB uses `/bin/sh`.

---

## Examples

List all users that are currently logged in.

```
[s,w] = unix('who');
```

MATLAB returns 0 (success) in `s` and a string containing the list of users in `w`.

In this example

```
[s,w] = unix('why')
s =
 1
w =
why: Command not found.
```

MATLAB returns a nonzero value in `s` to indicate failure, and returns an error message in `w` because `why` is not a UNIX command.

28. UNIX is a registered trademark of The Open Group in the United States and other countries.

**See Also**

dos, ! (exclamation point), perl, system

“Running External Programs” in the MATLAB Desktop Tools and Development Environment documentation

# unloadlibrary

---

**Purpose** Unload shared library from memory

**Syntax** `unloadlibrary('libname')`  
`unloadlibrary libname`

**Description** `unloadlibrary('libname')` unloads the shared library `libname` from memory. If you need to use functions in this library, you must reload the library using the `loadlibrary` function.

`unloadlibrary libname` is the command format for this function.

If you used an alias when initially loading the library, then you must use that alias for the `libname` argument.

**Examples** Load the MATLAB sample shared library, `shrlibsample`. Call one of its functions, and then unload the library:

```
addpath([matlabroot '\extern\examples\shrlib'])
loadlibrary shrlibsample shrlibsample.h
```

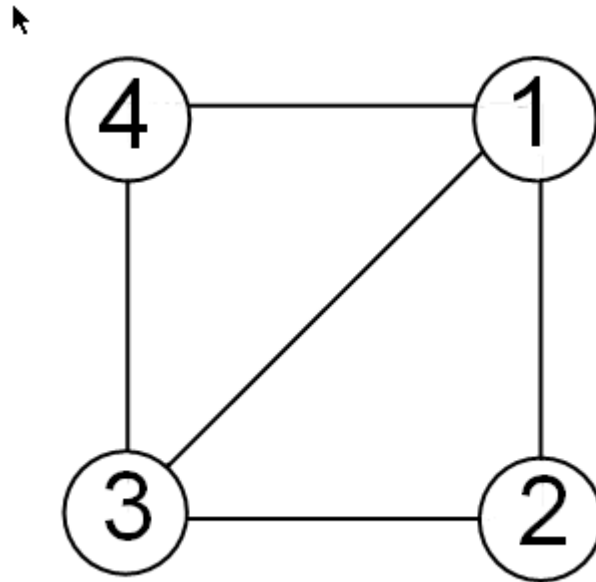
```
s.p1 = 476; s.p2 = -299; s.p3 = 1000;
calllib('shrlibsample', 'addStructFields', s)
ans =
 1177
```

```
unloadlibrary shrlibsample
```

**See Also** `loadlibrary`, `libisloaded`

---

|                    |                                                                                                                                                                                                                                                        |                                               |
|--------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------|
| <b>Purpose</b>     | Convert edge matrix to coordinate and Laplacian matrices                                                                                                                                                                                               |                                               |
| <b>Syntax</b>      | $[L,XY] = \text{UNMESH}(E)$                                                                                                                                                                                                                            |                                               |
| <b>Description</b> | $[L,XY] = \text{UNMESH}(E)$ returns the Laplacian matrix $L$ and mesh vertex coordinate matrix $XY$ for the $M$ -by-4 edge matrix $E$ . Each row of the edge matrix must contain the coordinates $[x1\ y1\ x2\ y2]$ of the edge endpoints.             |                                               |
| <b>Inputs</b>      | $E$                                                                                                                                                                                                                                                    | $M$ -by-4 edge matrix $E$ .                   |
| <b>Outputs</b>     | $L$                                                                                                                                                                                                                                                    | Laplacian matrix representation of the graph. |
|                    | $XY$                                                                                                                                                                                                                                                   | Mesh vertex coordinate matrix.                |
| <b>Examples</b>    | Take a simple example of a square with vertices at $(1,1)$ , $(1,-1)$ , $(-1,-1)$ , and $(-1,1)$ , where the connections between vertices are the four perpendicular edges of the square plus one diagonal connection between $(-1, -1)$ and $(1,1)$ . |                                               |



The edge matrix E for this graph is:

```
E=[1 1 1 -1; % edge from 1 to 2
1 -1 -1 -1; % edge from 2 to 3
-1 -1 -1 1; % edge from 3 to 4
-1 -1 1 1; % edge from 4 to 1
-1 1 1 1] % edge from 3 to 1
```

Use unmesh to create the output matrices,

```
[A,XY]=unmesh(E);
4 vertices:
4/4
```

The Laplacian matrix is defined as

$$L_{ij} = \begin{cases} \deg(v_i) & \text{if } i = j \\ -1 & \text{if } i \neq j \text{ and } v_i \text{ is adjacent to } v_j \\ 0 & \text{otherwise} \end{cases}$$

unmesh returns the Laplacian matrix L in sparse notation.

L

L =

|       |    |
|-------|----|
| (1,1) | 3  |
| (2,1) | -1 |
| (3,1) | -1 |
| (4,1) | -1 |
| (1,2) | -1 |
| (2,2) | 2  |
| (4,2) | -1 |
| (1,3) | -1 |
| (3,3) | 2  |
| (4,3) | -1 |
| (1,4) | -1 |
| (2,4) | -1 |
| (3,4) | -1 |

To see L in regular matrix notation, use the full command.

full(L)

ans =

|    |    |    |    |
|----|----|----|----|
| 3  | -1 | -1 | -1 |
| -1 | 2  | 0  | -1 |
| -1 | 0  | 2  | -1 |
| -1 | -1 | -1 | 3  |

The mesh coordinate matrix XY returns the coordinates of the corners of the square.

# unmesh

---

XY

XY =

|    |    |
|----|----|
| -1 | -1 |
| -1 | 1  |
| 1  | -1 |
| 1  | 1  |

## See Also

gplot  
treeplot



**Purpose** Piecewise polynomial details

**Syntax** `[breaks,coefs,l,k,d] = unmkpp(pp)`

**Description** `[breaks,coefs,l,k,d] = unmkpp(pp)` extracts, from the piecewise polynomial `pp`, its breaks `breaks`, coefficients `coefs`, number of pieces `l`, order `k`, and dimension `d` of its target. Create `pp` using `spline` or the spline utility `mkpp`.

**Examples** This example creates a description of the quadratic polynomial

$$\frac{-x^2}{4} + x$$

as a piecewise polynomial `pp`, then extracts the details of that description.

```
pp = mkpp([-8 -4],[-1/4 1 0]);
[breaks,coefs,l,k,d] = unmkpp(pp)
```

```
breaks =
 -8 -4
```

```
coefs =
 -0.2500 1.0000 0
```

```
l =
 1
```

```
k =
 3
```

```
d =
 1
```

**See Also** `mkpp`, `ppval`, `spline`

# unregisterallevents

---

**Purpose** Unregister all event handlers for COM object event at run-time

**Syntax** h.unregisterallevents  
unregisterallevents(h)

**Description** h.unregisterallevents unregisters all events that have previously been registered with COM object, h. After calling unregisterallevents, the object no longer responds to any events until you register them again using the registerevent function.  
unregisterallevents(h) is an alternate syntax.

**Remarks** COM functions are available on Microsoft Windows systems only.

**Examples** **mwsamp Control Example**

Create an mwsamp control, registering three events and their respective handler routines. Use the eventlisteners function to see the event handler used by each event:

```
f = figure ('position', [100 200 200 200]);
h = actxcontrol('mwsamp.mwsampctrl.2', ...
 [0 0 200 200], f, ...
 {'Click' 'myclick'; 'Db1Click' 'my2click'; ...
 'MouseDown' 'mymoused'});
h.eventlisteners
```

MATLAB displays:

```
ans =
 'click' 'myclick'
 'dblclick' 'my2click'
 'mousedown' 'mymoused'
```

Unregister all of these events at once with unregisterallevents. Now, calling eventlisteners returns an empty cell array, indicating that there are no longer any events registered with the control:

```
h.unregisterallevents;
h.eventlisteners
```

MATLAB displays:

```
ans =
 {}
```

To unregister specific events, use the `unregisterevent` function.

## Workbook Events Example

Create a Microsoft Excel Workbook object and register some events.

```
myApp = actxserver('Excel.Application');
wbs = myApp.Workbooks;
wb = wbs.Add;
wb.registerevent({'Activate' 'EvtActivateHndlr'; ...
 'Deactivate' 'EvtDeactivateHndlr'})
wb.eventlisteners
```

MATLAB shows the events registered to their corresponding event handlers.

```
ans =

 'Activate' 'EvtActivateHndlr'
 'Deactivate' 'EvtDeactivateHndlr'
```

Use `unregisterallevents` to clear the events.

```
wb.unregisterallevents
wb.eventlisteners
```

MATLAB displays an empty cell array, showing that no events are registered.

```
ans =
```

# unregisterallevents

---

```
{}
```

## **See Also**

events (COM), eventlisteners, registerevent, unregisterevent, isevent

## Purpose

Unregister event handler for COM object event at run-time

## Syntax

```
h.unregisterevent(event_handler)
unregisterevent(h, event_handler)
```

## Description

`h.unregisterevent(event_handler)` unregisters certain event handler routines with their corresponding events. Once you unregister an event, the object no longer responds to any further occurrences of the event.

`unregisterevent(h, event_handler)` is an alternate syntax.

You can unregister events at any time after a control has been created. The `event_handler` argument, which is a cell array, specifies both events and event handlers. For example:

```
h.unregisterevent({'event_name', @event_handler});
```

See “Writing Event Handlers” in the External Interfaces documentation.

You must specify events in the `event_handler` argument using the names of the events. Strings used in the `event_handler` argument are not case sensitive. Unlike `actxcontrol` and `registerevent`, `unregisterevent` does not accept numeric event identifiers.

## Remarks

COM functions are available on Microsoft Windows systems only.

## Examples

### Control Example

Create an `mwsamp` control and register all events with the same handler routine, `sampev`. Use `eventlisteners` to see the event handler used by each event. In this case, each event, when fired, calls `sampev.m`:

```
f = figure ('position', [100 200 200 200]);
h = actxcontrol('mwsamp.mwsampctrl.2', ...
 [0 0 200 200], f, ...
 'sampev');
h.eventlisteners
```

## unregisterevent

---

MATLAB displays:

```
ans =
 'Click' 'sampev'
 'DbClick' 'sampev'
 'MouseDown' 'sampev'
 'Event_Args' 'sampev'
```

Unregister just the `dblclick` event. Now, when you list the registered events using `eventlisteners`, `dblclick` is no longer registered and the control does not respond when you double-click the mouse over it:

```
h.unregisterevent({'dblclick' 'sampev'});
h.eventlisteners
```

MATLAB displays:

```
ans =
 'Click' 'sampev'
 'MouseDown' 'sampev'
 'Event_Args' 'sampev'
```

This time, register the `click` and `dblclick` events with a different event handler for `myclick` and `my2click`, respectively:

```
h.unregisterallevents;
h.registerevent({'click' 'myclick'; ...
 'dblclick' 'my2click'});
h.eventlisteners
```

MATLAB displays:

```
ans =
 'click' 'myclick'
 'dblclick' 'my2click'
```

You can unregister these same events by specifying event names and their handler routines in a cell array. `eventlisteners` now returns

an empty cell array, meaning no events are registered for the `mwsamp` control:

```
h.unregisterevent({'click' 'myclick'; ...
 'dblclick' 'my2click'});
h.eventlisteners
```

MATLAB displays:

```
ans =
 {}
```

## Workbook Events Example

Create a Microsoft Excel Workbook object:

```
myApp = actxserver('Excel.Application');
wbs = myApp.Workbooks;
wb = wbs.Add;
```

Register two events with the your event handler routines, `EvtActivateHndlr` and `EvtDeactivateHndlr`.

```
wb.registerevent({'Activate' 'EvtActivateHndlr'; ...
 'Deactivate' 'EvtDeactivateHndlr'})
wb.eventlisteners
```

MATLAB shows the events with the corresponding event handlers.

```
ans =

 'Activate' 'EvtActivateHndlr'
 'Deactivate' 'EvtDeactivateHndlr'
```

Next, unregister the `Deactivate` event handler.

```
wb.unregisterevent({'Deactivate' 'EvtDeactivateHndlr'})
wb.eventlisteners
```

# unregisterevent

---

MATLAB shows the remaining registered event (Activate) with its corresponding event handler.

```
ans =

 'Activate' 'EvtActivateHndlr'
```

## See Also

events (COM), eventlisteners, registerevent,  
unregisterallevents, isevent



**Purpose** Extract contents of tar file

**Syntax**

```
untar(tarfilename)
untar(tarfilename,outputdir)
untar(url, ...)
filenames = untar(...)
```

**Description** `untar(tarfilename)` extracts the archived contents of `tarfilename` into the current directory and sets the files' attributes. It overwrites any existing files with the same names as those in the archive if the existing files' attributes and ownerships permit it. For example, if you rerun `untar` on the same `tarfilename`, MATLAB software does not overwrite files with a read-only attribute; instead, `untar` displays a warning for such files. On Microsoft Windows platforms, the hidden, system, and archive attributes are not set.

`tarfilename` is a string specifying the name of the tar file. `tarfilename` is gunzipped to a temporary directory and deleted if its extension ends in `.tgz` or `.gz`. If an extension is omitted, `untar` searches for `tarfilename` appended with `.tgz`, `.tar.gz`, or `.tar`. `tarfilename` can include the directory name; otherwise, the file must be in the current directory or in a directory on the MATLAB path.

`untar(tarfilename,outputdir)` uncompresses the archive `tarfilename` into the directory `outputdir`. If `outputdir` does not exist, MATLAB creates it.

`untar(url, ...)` extracts the tar archive from an Internet URL. The URL must include the protocol type (for example, `'http://'` or `'ftp://'`). MATLAB downloads the URL to a temporary directory, and then deletes it.

`filenames = untar(...)` extracts the tar archive and returns the names of the extracted files in the string cell array `filenames`. If `outputdir` specifies a relative path, `filenames` contains the relative path. If `outputdir` specifies an absolute path, `filenames` contains the absolute path.

# untar

---

## Examples

### Using tar and untar to Copy Files

Copy all .m files in the current directory to the directory backup.

```
tar('mymfiles.tar.gz','*.m');
untar('mymfiles','backup');
```

### Using untar with URL

Run untar to list Cleve Moler's "Numerical Computing with MATLAB" examples to the output directory ncm.

```
url = 'http://www.mathworks.com/moler/ncm.tar.gz';
ncmFiles = untar(url,'ncm')
```

## See Also

gzip, gunzip, tar, unzip, zip

**Purpose** Correct phase angles to produce smoother phase plots

**Syntax**

```
Q = unwrap(P)
Q = unwrap(P,tol)
Q = unwrap(P,[],dim)
Q = unwrap(P,tol,dim)
```

**Description** `Q = unwrap(P)` corrects the radian phase angles in a vector `P` by adding multiples of  $\pm 2\pi$  when absolute jumps between consecutive elements of `P` are greater than or equal to the default jump tolerance of  $\pi$  radians. If `P` is a matrix, `unwrap` operates columnwise. If `P` is a multidimensional array, `unwrap` operates on the first nonsingleton dimension.

`Q = unwrap(P,tol)` uses a jump tolerance `tol` instead of the default value,  $\pi$ .

`Q = unwrap(P,[],dim)` unwraps along `dim` using the default tolerance.

`Q = unwrap(P,tol,dim)` uses a jump tolerance of `tol`.

---

**Note** A jump tolerance less than  $\pi$  has the same effect as a tolerance of  $\pi$ . For a tolerance less than  $\pi$ , if a jump is greater than the tolerance but less than  $\pi$ , adding  $\pm 2\pi$  would result in a jump larger than the existing one, so `unwrap` chooses the current point. If you want to eliminate jumps that are less than  $\pi$ , try using a finer grid in the domain.

---

## Examples

### Example 1

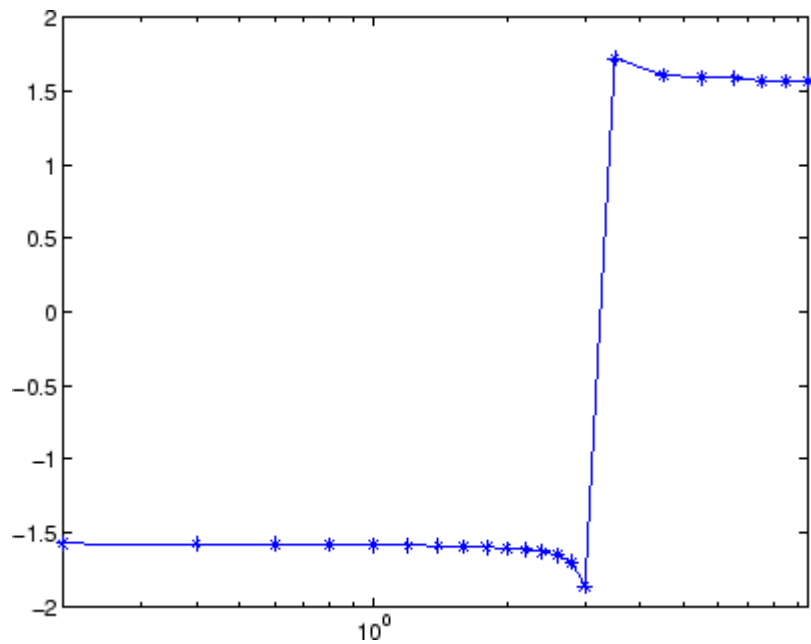
The following phase data comes from the frequency response of a third-order transfer function. The phase curve jumps 3.5873 radians between `w = 3.0` and `w = 3.5`, from -1.8621 to 1.7252.

```
w = [0:.2:3,3.5:1:10];
p = [0
 -1.5728
 -1.5747
 -1.5772
```

# unwrap

---

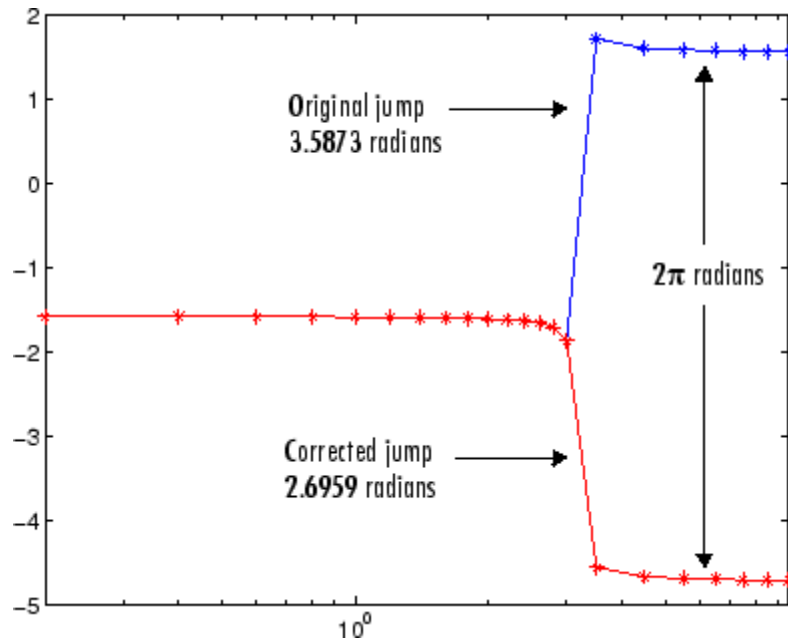
```
-1.5790
-1.5816
-1.5852
-1.5877
-1.5922
-1.5976
-1.6044
-1.6129
-1.6269
-1.6512
-1.6998
-1.8621
1.7252
1.6124
1.5930
1.5916
1.5708
1.5708
1.5708];
semilogx(w,p,'b*-'), hold
```



Using `unwrap` to correct the phase angle, the resulting jump is 2.6959, which is less than the default jump tolerance  $\pi$ . This figure plots the new curve over the original curve.

```
semilogx(w,unwrap(p),'r*-')
```

# unwrap



**Note** If you have the “Control System Toolbox”, you can create the data for this example with the following code.

```
h = freqresp(tf(1,[1 .1 10 0]));
p = angle(h(:));
```

## Example 2

Array P features smoothly increasing phase angles except for discontinuities at elements (3,1) and (1,2).

```
P = [0 7.0686 1.5708 2.3562
 0.1963 0.9817 1.7671 2.5525
 6.6759 1.1781 1.9635 2.7489
 0.5890 1.3744 2.1598 2.9452]
```

The function  $Q = \text{unwrap}(P)$  eliminates these discontinuities.

Q =

|        |        |        |        |
|--------|--------|--------|--------|
| 0      | 7.0686 | 1.5708 | 2.3562 |
| 0.1963 | 7.2649 | 1.7671 | 2.5525 |
| 0.3927 | 7.4613 | 1.9635 | 2.7489 |
| 0.5890 | 7.6576 | 2.1598 | 2.9452 |

**See Also**

abs, angle

# unzip

---

**Purpose** Extract contents of zip file

**Syntax**

```
unzip(zipfilename)
unzip(zipfilename,outputdir)
unzip(url, ...)
filenames = unzip(...)
```

**Description** `unzip(zipfilename)` extracts the archived contents of `zipfilename` into the current directory and sets the files' attributes, preserving the timestamps. It overwrites any existing files with the same names as those in the archive if the existing files' attributes and ownerships permit it. For example, files from rerunning `unzip` on the same zip filename do not overwrite any of those files that have a read-only attribute; instead, `unzip` issues a warning for such files.

`zipfilename` is a string specifying the name of the zip file. The `.zip` extension is appended to `zipfilename` if omitted. `zipfilename` can include the directory name; otherwise, the file must be in the current directory or in a directory on the MATLAB path.

`unzip(zipfilename,outputdir)` extracts the contents of `zipfilename` into the directory `outputdir`.

`unzip(url, ...)` extracts the zipped contents from an Internet URL. The URL must include the protocol type (for example, `http://`). The URL is downloaded to the temp directory and deleted.

`filenames = unzip(...)` extracts the zip archive and returns the names of the extracted files in the string cell array `filenames`. If `outputdir` specifies a relative path, `filenames` contains the relative path. If `outputdir` specifies an absolute path, `filenames` contains the absolute path.

`unzip` does not support password-protected or encrypted zip archives.

## Examples **Using zip and unzip to Copy Files**

Copy the demos HTML files to the directory archive:

```
% Zip the demos html files to demos.zip
```



```
zip('demos.zip','*.html',fullfile(matlabroot,'demos'))
% Unzip demos.zip to the 'directory' archive
unzip('demos','archive')
```

### Using unzip with URL

Run `unzip` to list Cleve Moler's "Numerical Computing with MATLAB" examples to the output directory `ncm`.

```
url = 'http://www.mathworks.com/moler/ncm.zip';
ncmFiles = unzip(url,'ncm')
```

### See Also

`fileattrib`, `gzip`, `gunzip`, `tar`, `untar`, `zip`

# upper

---

**Purpose** Convert string to uppercase

**Syntax** `t = upper('str')`  
`B = upper(A)`

**Description** `t = upper('str')` converts any lowercase characters in the string `str` to the corresponding uppercase characters and leaves all other characters unchanged.

`B = upper(A)` when `A` is a cell array of strings, returns a cell array the same size as `A` containing the result of applying `upper` to each string within `A`.

**Examples** `upper('attention!')` is ATTENTION!.

**Remarks** Character sets supported:

- PC: Windows Latin-1
- Other: ISO Latin-1 (ISO 8859-1)

**See Also** `lower`

**Purpose**

Read content at URL

**Syntax**

```
s = urlread('url')
s = urlread('url','method','params')
[s,status] = urlread(...)
```

**Description**

`s = urlread('url')` reads the content at a URL into the string `s`. If the server returns binary data, `s` will be unreadable.

`s = urlread('url','method','params')` reads the content at a URL into the string `s`, passing information to the server as part of the request where `method` can be `get` or `post`, and `params` is a cell array of parameter name/parameter value pairs.

`[s,status] = urlread(...)` catches any errors and returns the error code.

---

**Note** If you need to specify a proxy server to connect to the Internet, select **File -> Preferences -> Web** and enter your proxy information. Use this feature if you have a firewall.

---

**Examples****Download Content from Web Page**

Use `urlread` to download the contents of the Authors list at the MATLAB Central File Exchange:

```
urlstring = sprintf('%s%s', ...
 'http://www.mathworks.com/matlabcentral/', ...
 'fileexchange/authors');

s = urlread(urlstring);
```

**Download Content from File on FTP Server**

```
page = 'ftp://ftp.mathworks.com/pub/tech-support/docexamples/README
s=urlread(page);
```

s

MATLABdisplays:

The MathWorks FTP site has recently changed. If you are trying to access one of the following pages, please see the corresponding new link:

=====

OLD:

...

File updated: 15 November 2004

## Download Content from Local File

```
s = urlread('file:///c:/winnt/matlab.ini')
```

## See Also

urlwrite, web

tcpip if the Instrument Control Toolbox™ is installed

**Purpose**

Save contents of URL to file

**Syntax**

```
urlwrite('url','filename')
f = urlwrite('url','filename')
f = urlwrite('url','method','params')
[f,status] = urlwrite(...)
```

**Description**

`urlwrite('url','filename')` reads the contents of the specified URL, saving the contents to `filename`. If you do not specify the path for `filename`, the file is saved in the MATLAB current directory.

`f = urlwrite('url','filename')` reads the contents of the specified URL, saving the contents to `filename` and assigning `filename` to `f`.

`f = urlwrite('url','method','params')` saves the contents of the specified URL to `filename`, passing information to the server as part of the request where `method` can be `get` or `post`, and `params` is a cell array of parameter name/parameter value pairs.

`[f,status] = urlwrite(...)` catches any errors and returns the error code.

---

**Note** If you need to specify a proxy server to connect to the Internet, select **File -> Preferences -> Web** and enter your proxy information. Use this feature if you have a firewall.

---

**Examples**

Download the files submitted to the MATLAB Central File Exchange, saving the results to `samples.html` in the MATLAB current directory.

```
urlstring = sprintf('%s%s', ...
 'http://www.mathworks.com/matlabcentral/', ...
 'fileexchange/Category.jsp?type=category&id=1');

urlwrite(urlstring, 'samples.html');
```

View the file in the Help browser.

# urlwrite

---

```
open('samples.html')
```

## See Also

`urlread`

**Purpose** Determine whether Sun Java feature is supported in MATLAB software

**Syntax** `usejava(feature)`

**Description** `usejava(feature)` returns 1 if the specified feature is supported and 0 otherwise. Possible feature arguments are shown in the following table.

| Feature   | Description                                                   |
|-----------|---------------------------------------------------------------|
| 'awt'     | Abstract Window Toolkit components <sup>1</sup> are available |
| 'desktop' | The MATLAB interactive desktop is running                     |
| 'jvm'     | The Java Virtual Machine software (JVM) is running            |
| 'swing'   | Swing components <sup>2</sup> are available                   |

1. Java GUI components in the Abstract Window Toolkit
2. Java lightweight GUI components in the Java Foundation Classes

## Examples

The following conditional code ensures that the AWT's GUI components are available before the M-file attempts to display a Java Frame.

```
if usejava('awt')
 myFrame = java.awt.Frame;
else
 disp('Unable to open a Java Frame');
end
```

The next example is part of an M-file that includes Java code. It fails gracefully when run in a MATLAB session that does not have access to JVM software.

```
if ~usejava('jvm')
 error(['mfilename ' requires Java to run.']);
end
```

# usejava

---

## See Also

[javachk](#)



**Purpose** View or change user portion of search path

**Syntax**

```
userpath
userpath('newpath')
userpath('reset')
userpath('clear')
```

**Description** userpath returns a string specifying the user portion of the search path. The user portion of the search path is the first directory on the search path, above the directories supplied by The MathWorks. The default directory is My Documents/MATLAB on Microsoft Windows platforms, and Documents/MATLAB on Microsoft Windows Vista™ platforms.

On Apple Macintosh and UNIX<sup>29</sup> platforms, the default value is *userhome/Documents/MATLAB*. If you remove the *userpath* directory from the search path and save the changes to the path, it also clears the value of *userpath*. You can define the *userpath* directory to also be the MATLAB startup directory. On Windows platforms, *userpath* is the startup directory, unless the startup directory is otherwise specified, such as by the MATLAB shortcut properties **Start in** field. On UNIX and Macintosh platforms, the startup directory is *userpath* if the value of the environment variable `MATLAB_USE_USERPATH` is set to 1 prior to startup and if the startup directory is not otherwise specified, such as via a `startup.m` file. On Macintosh and UNIX platforms, you can automatically add additional subdirectories to the top of the search path upon startup by specifying the path for the subdirectories via the `MATLABPATH` environment variable.

`userpath('newpath')` sets the *userpath* value to *newpath*. The *newpath* directory appears at the top of the search path immediately and at startup in future sessions, and MATLAB removes the directory previously specified by *userpath* from the search path. *newpath* cannot be a relative path. `userpath('newpath')` does not work when the `-nojvm` startup option is used. Upon the next startup, *newpath*, can become the current directory, as described in the syntax for *userpath* with no arguments.

`userpath('reset')` sets the *userpath* value to the default for that platform, creating the `Documents/MATLAB` (or `My Documents/MATLAB`) directory if it does not exist. MATLAB immediately adds the default directory to the top of the search path, and also adds it to the path at startup in future sessions; it can become the startup directory as described for the *userpath* syntax with no arguments. MATLAB removes the directory previously specified by *userpath* from the search path. `userpath('reset')` does not work when the `-nojvm` startup option is used.

`userpath('clear')` clears the value for *userpath*. MATLAB removes the directory previously specified by *userpath* from the search path.

29. UNIX is a registered trademark of The Open Group in the United States and other countries.

This does not work when the `-nojvm` startup option is used. You can otherwise specify the startup directory—see “Startup Directory for the MATLAB Program”.

## Examples

- “Viewing userpath” on page 2-4063
- “Setting a New Value for userpath” on page 2-4064
- “Clearing the Value for userpath, and Specifying a New Startup Directory on Windows Platforms” on page 2-4065
- “Removing userpath from the Search Path; Resets the Startup Directory” on page 2-4066
- “Assigning userpath as the Startup Directory on a UNIX or Macintosh Platform” on page 2-4068
- “Adding Directories to the Search Path Upon Startup on a UNIX or Macintosh Platform” on page 2-4069

### Viewing userpath

This example assumes `userpath` is set to the default value on the Windows XP platform, `My Documents\MATLAB`. Start MATLAB and run

```
cd
```

MATLAB displays the current directory

```
H:\My Documents\MATLAB
```

where H is the drive at which `My Documents` is located for this example. This is the directory specified by `userpath`. To confirm, run

```
userpath
```

and MATLAB returns

```
H:\My Documents\MATLAB;
```

Run

# userpath

---

```
path
```

and MATLAB displays the search path; the userpath portion is at the top:

```
MATLABPATH

H:\My Documents\MATLAB
C:\Program Files\MATLAB\R2009a\toolbox\matlab\general
C:\Program Files\MATLAB\R2009a\toolbox\matlab\ops
```

## Setting a New Value for userpath

This example assumes userpath is set to the default value on the Windows XP platform, My Documents\MATLAB. To change the value from the default for userpath to C:\Research\_Project, run

```
userpath('C:\Research_Project')
```

To view the effect of the change on the search path, run

```
path
```

and MATLAB displays the search path, with the new value for userpath portion at the top:

```
MATLABPATH

C:\Research_Project
C:\Program Files\MATLAB\R2009a\toolbox\matlab\general
C:\Program Files\MATLAB\R2009a\toolbox\matlab\ops
...
```

Note that MATLAB automatically removed the previous value of userpath, H:\My Documents\MATLAB, from the search path when you assigned a new value to userpath. The next time you start MATLAB, the current directory will be C:\Research\_Project on Windows platforms.

## Clearing the Value for userpath, and Specifying a New Startup Directory on Windows Platforms

Assume userpath is set to the default value and you do not want any directories to be added to the search path upon startup. To confirm the default is currently set, run

```
userpath
```

and MATLAB returns

```
H:\My Documents\MATLAB
```

Note the userpath directory at the top of the search path by running

```
path
```

MATLAB returns

```
MATLABPATH
```

```
H:\My Documents\MATLAB
C:\Program Files\MATLAB\R2009a\toolbox\matlab\general
C:\Program Files\MATLAB\R2009a\toolbox\matlab\ops
...
```

To clear the value, run

```
userpath('clear')
```

To verify the result, run

```
userpath
```

MATLAB returns

```
ans =
 ''
```

Confirm the userpath directory was removed from the path by running:

# userpath

---

```
path
```

MATLAB returns

```
MATLABPATH
```

```
C:\Program Files\MATLAB\R2009a\toolbox\matlab\general
C:\Program Files\MATLAB\R2009a\toolbox\matlab\ops
...
```

After clearing the `userpath` value, unless you otherwise specify the startup directory, the startup directory will be the desktop on Windows platforms. There are a number of ways to specify the startup directory. For example, right-click the Windows shortcut icon for MATLAB and select **Properties** from the context menu. In the Properties dialog box **Shortcut** tab, enter the full path to the new startup directory in the **Start in** field, for example, `I:\my_matlab_files\my_mfiles`. The next time you start MATLAB, the current directory will be `I:\my_matlab_files\my_mfiles`, but that directory will *not* be on the search path. Note that you do not have to clear the `userpath` to specify a different startup directory; when you otherwise specify a startup directory, the `userpath` directory is added to the search path upon startup, but is not the startup directory.

## **Removing userpath from the Search Path; Resets the Startup Directory**

In this example, assume `userpath` is set to the default value and you remove the `userpath` directory from the search path, then save the changes. This has the same effect as clearing the value for `userpath`. To confirm the default is currently set, run

```
userpath
```

and MATLAB returns

```
H:\My Documents\MATLAB
```

Note the `userpath` directory at the top of the search path by running

path

MATLAB returns

MATLABPATH

```
H:\My Documents\MATLAB
C:\Program Files\MATLAB\R2009a\toolbox\matlab\general
C:\Program Files\MATLAB\R2009a\toolbox\matlab\ops
...
```

Remove H:\My Documents\MATLAB from the search path and confirm the result by running

```
rmpath('H:\My Documents\MATLAB')
path
```

MATLAB returns

MATLABPATH

```
C:\Program Files\MATLAB\R2009a\toolbox\matlab\general
C:\Program Files\MATLAB\R2009a\toolbox\matlab\ops
...
```

Running

userpath

at this point shows the value is still set

```
H:\My Documents\MATLAB
```

Save changes to the path by running

```
savepath
```

Now when you run

```
userpath
```

MATLAB returns

```
ans =
 ''
```

showing the value is now cleared. Removing the directory from the search path *and* saving the changes to the path has the same effect as clearing the value for `userpath`. At the next startup, the startup directory will *not* be `H:\My Documents\MATLAB`, and `H:\My Documents\MATLAB` will *not* be on the search path.

## Assigning `userpath` as the Startup Directory on a UNIX or Macintosh Platform

This example assumes `userpath` is set to the default value on a Macintosh platform and that you start MATLAB using a bash X11 shell, where `smith` is the home directory. Set the `MATLAB_USE_USERPATH` environment variable so that `userpath` will be used as the startup directory:

```
export MATLAB_USE_USERPATH=1
```

From that shell, start MATLAB. After MATLAB starts, verify its current directory by running

```
pwd
```

MATLAB returns

```
/Users/smith/Documents/MATLAB
```

That is the value defined for `userpath`, which you can confirm by running

```
userpath
```

MATLAB returns

```
/Users/smith/Documents/MATLAB
```



The `userpath` is at the top of the search path, which you can confirm by running

```
path
```

MATLAB returns

```
/Users/smith/Documents/MATLAB
/Users/smith/Applications/MATLAB/R2009a/toolbox/matlab/general
/Users/smith/Applications/MATLAB/R2009a/toolbox/matlab/ops
```

```
...
```

## Adding Directories to the Search Path Upon Startup on a UNIX or Macintosh Platform

This example assumes `userpath` is set to the default value on a UNIX platform with a `csh` shell, where `j` is the user's home directory.

To add additional directories to the search path upon startup, for example, `/home/j/Documents/MATLAB/mine` and `/home/j/Documents/MATLAB/mine/research`, run the following in an X11 terminal:

```
setenv MATLABPATH '/home/j/Documents/MATLAB/mine': '/home/j/Documents/MATLAB/mine/research'
```

Separate multiple directories using a `:` (colon).

MATLAB displays

```
MATLABPATH
```

```
home/j/Documents/MATLAB
home/j/Documents/MATLAB/mine
home/j/Documents/MATLAB/mine/research
home/j/Applications/MATLAB/R2009a/toolbox/matlab/general
home/j/Applications/MATLAB/R2009a/toolbox/matlab/ops
...
```

## See Also

`addpath`, `path`, `pathtool`, `rmpath`, `savepath`, `startup`,

“Startup and Shutdown” and “Search Path” in the MATLAB Desktop  
Tools and Development Environment documentation

## Purpose

Check validity of array

## Syntax

```
validateattributes(A, classes, attributes)
validateattributes(A, classes, attributes, position)
validateattributes(A, classes, attributes, funname)
validateattributes(A, classes, attributes, funname, varname)
validateattributes(A, classes, attributes, funname, varname,
 position)
```

## Description

`validateattributes(A, classes, attributes)` validates that array `A` belongs to at least one of the classes specified by the `classes` input and has all of the attributes specified by the `attributes` input. If the validation succeeds, the command completes without displaying any output and without throwing an error. If the validation does not succeed, MATLAB issues a formatted error message.

The `classes` input is a cell array of one or more strings, each string containing the name of a MATLAB class (i.e., one of the 15 MATLAB data types), the name of a MATLAB class, or the keyword `numeric`. (See the table [Class Values](#) on page 2-4072.)

The `attributes` input is a cell array of one or more strings, each string describing an array attribute. Size validation requires two inputs: the `'size'` keyword and the length of each dimension specified within square brackets (e.g., `{'size', [4,3,7]}`). Value range validation requires two inputs for each aspect of the range being validated (e.g., `{'>', 10, '<=', 65}`). (See the table [Attribute Values](#) on page 2-4073.)

`validateattributes(A, classes, attributes, position)` validates array `A` and, if the validation fails, displays an error message that includes the position of the failing variable in the function argument list. The `position` input must be a positive integer.

`validateattributes(A, classes, attributes, funname)` validates array `A` and, if the validation fails, displays an error message that includes the name of the function performing the validation (`funname`). The `funname` input must be a string enclosed in single quotation marks.

# validateattributes

---

`validateattributes(A, classes, attributes, funname, varname)` validates array A and, if the validation fails, displays an error message that includes the name of the function performing the validation (`funname`), and the name of the variable being validated (`varname`). The `funname` and `varname` inputs must be strings enclosed in single quotation marks.

`validateattributes(A, classes, attributes, funname, varname, position)` validates array A and, if the validation fails, displays an error message that includes the name of the function performing the validation (`funname`), the name of the variable being validated (`varname`), and the position of this variable in the function argument list (`position`). The `funname` and `varname` inputs must be strings enclosed in single quotation marks. The `position` input must be a positive integer.

## Class Values

| <b>classes Argument</b> | <b>Contents of Array A</b> |
|-------------------------|----------------------------|
| 'numeric'               | Any numeric value          |
| 'single'                | Single-precision number    |
| 'double'                | Double-precision number    |
| 'int8'                  | Signed 8-bit integer       |
| 'int16'                 | Signed 16-bit integer      |
| 'int32'                 | Signed 32-bit integer      |
| 'int64'                 | Signed 64-bit integer      |
| 'uint8'                 | Unsigned 8-bit integer     |
| 'uint16'                | Unsigned 16-bit integer    |
| 'uint32'                | Unsigned 32-bit integer    |
| 'uint64'                | Unsigned 64-bit integer    |
| 'logical'               | Logical true or false      |

## Class Values (Continued)

| classes Argument  | Contents of Array A        |
|-------------------|----------------------------|
| 'char'            | Character or string        |
| 'struct'          | MATLAB structure           |
| 'cell'            | Cell array                 |
| 'function_handle' | Scalar function handle     |
| <i>class name</i> | Object of any MATLAB class |

## Attribute Values

| attributes Argument | Description of array A                                                                     |
|---------------------|--------------------------------------------------------------------------------------------|
| '>', N              | Array in which all values are greater than N.                                              |
| '>=', N             | Array in which all values are greater than or equal to N.                                  |
| '<', N              | Array in which all values are less than N.                                                 |
| '<=', N             | Array in which all values are less than or equal to N.                                     |
| '2d'                | Array having dimensions M-by-N (includes scalars, vectors, 2-D matrices, and empty arrays) |
| 'column'            | Array having dimensions N-by-1                                                             |
| 'even'              | Numeric or logical array in which all elements are even (includes zero)                    |
| 'finite'            | Numeric array in which all elements are finite                                             |
| 'integer'           | Numeric array in which all elements are integer-valued                                     |
| 'nonempty'          | Array having no dimension equal to zero                                                    |
| 'nonnan'            | Numeric array in which there are no elements equal to NaN (Not a Number)                   |

# validateattributes

---

## Attribute Values (Continued)

| attributes Argument  | Description of array A                                                            |
|----------------------|-----------------------------------------------------------------------------------|
| 'nonnegative'        | Numeric array in which all elements are zero or greater than zero                 |
| 'nonsparse'          | Array that is not sparse                                                          |
| 'nonzero'            | Numeric or logical array in which all elements are less than or greater than zero |
| 'odd'                | Numeric or logical array in which all elements are odd integers                   |
| 'positive'           | Numeric or logical array in which all elements are greater than zero              |
| 'real'               | Numeric array in which all elements are real                                      |
| 'row'                | Array having dimensions 1-by-N                                                    |
| 'scalar'             | Array having dimensions 1-by-1                                                    |
| 'size',<br>[M,N,...] | Array having dimensions M-by-N-by- ....                                           |
| 'vector'             | Array having dimensions N-by-1 or 1-by-N (includes scalar arrays)                 |

Numeric properties, such as `positive` and `nonnan`, do not apply to strings. If you attempt to validate numeric properties on a string, `validateattributes` generates an error.

## Examples

### Example 1

In this example, the `empl_profile1` function compares the values passed in each argument to the specified classes and attributes and throws an error if they are not correct:

```
function empl_profile1(empl_id, empl_info, healthplan, ...
 vacation)
```

```
validateattributes(empl_id, {'numeric'}, ...
 {'integer', 'nonempty'});
validateattributes(empl_info, {'struct'}, {'vector'});
validateattributes(healthplan, {'cell', 'char'}, ...
 {'vector'});
validateattributes(vacation, {'numeric'}, ...
 {'nonnegative', 'scalar'});
```

Call the `empl_profile1` function, passing the expected argument types, and the example completes without error:

```
empl_id = 51723;
empl_info.name = 'John Miller';
empl_info.address = '128 Forsythe St.';
empl_info.town = 'Duluth'; empl_info.state='MN';

empl_profile1(empl_id, empl_info, 'HCP Medical Plus', 14.3)
```

If you accidentally pass the argument values out of their correct sequence, MATLAB throws an error in response to the first argument that is not a match:

```
empl_profile1(empl_id, empl_info, 14.3, 'HCP Medical Plus')

??? Error using ==> empl_profile1 at 6
Expected input to be one of these types:

 cell, char
```

Instead its type was double.

## Example 2

Write a new function `empl_profile2` that displays the function name, variable name, and position of the argument:

```
function empl_profile2(empl_id, empl_info, healthplan, ...
 vacation)
```

# validateattributes

---

```
validateattributes(empl_id, ...
 {'numeric'}, {'integer', 'nonempty'}, ...
 mfilename, 'Employee Identification', 1);

validateattributes(empl_info, ...
 {'struct'}, {'vector'}, ...
 mfilename, 'Employee Info', 2);

validateattributes(healthplan, ...
 {'cell', 'char'}, {'vector'}, ...
 mfilename, 'Health Plan', 3);

validateattributes(vacation, ...
 {'numeric'}, {'nonnegative', 'scalar'}, ...
 mfilename, 'Vacation Accrued', 4);
```

Call `empl_profile2` with the argument values out of sequence. MATLAB throws an error that includes the name of the function validating the attributes, the name of the variable that was in error, and its position in the input argument list:

```
??? Error using ==> empl_profile2
Expected input number 3, Health Plan, to be one of
these types:
```

```
 cell, char
```

Instead its type was double.

```
Error in ==> empl_profile2 at 12
validateattributes(healthplan, ...
```



## Example 3

Write a new function `empl_profile2` that checks the input parameters with `inputParser`. Use `validateattributes` as the validating function for the `inputParser` methods:

```
function empl_profile3(empl_id, varargin)
 p = inputParser;

 % Validate the input arguments.
 addRequired(p, 'empl_id', ...
 @(x)validateattributes(x, {'numeric'}, {'integer'}));
 addOptional(p, 'empl_info', '', ...
 @(x)validateattributes(x, {'struct'}, {'nonempty'}));
 addParamValue(p, 'health', 'HCP Medical Plus', ...
 @(x)validateattributes(x, {'cell', 'char'}, ...
 {'vector'}));
 addParamValue(p, 'vacation', [], ...
 @(x)validateattributes(x, {'numeric'}, ...
 {'nonnegative', 'scalar'}));
 parse(p, empl_id, varargin{:});
 p.Results
```

Call `empl_profile` using appropriate input arguments:

```
empl_info.name = 'John Miller';
empl_info.address = '128 Forsythe St.';
empl_info.town = 'Duluth'; empl_info.state='MN';

empl_profile(51723, empl_info, 'vacation', 14.3)

ans =
 empl_id: 51723
 empl_info: [1x1 struct]
 health: 'HCP Medical Plus'
 vacation: 14.3000
```

# validateattributes

---

Call `empl_profile` using a character string where a structure is expected:

```
empl_profile(51723, empl_info.name, 'vacation', 14.3)
```

```
??? Error using ==> empl_profile at 12
Argument 'empl_info' failed validation with error:
Expected input to be one of these types:
```

```
struct
```

Instead its type was char.

## Example 4

Validate the size of a 4-by-2-by-6 array:

```
x = rand(4,2,6);

validateattributes(x, {'numeric'}, {'size', [4,2,6]});
```

## Example 5

The next two commands validate that the input value `x` lies within the specified range:

```
x = uint8(50:10:200);

validateattributes(x, {'uint8'}, {'>=' , 50, '<=' , 200})

validateattributes(x, {'uint8'}, {'>=' , 50, '<' , 200})
??? Expected input to be an array with all of the values < 200.
```

## See Also

`validatestring`, `is*`, `isa`, `inputParser`

**Purpose** Check validity of text string

**Syntax**

```
validstr = validatestring(str, strarray)
validstr = validatestring(str, strarray, position)
validstr = validatestring(str, strarray, funname)
validstr = validatestring(str, strarray, funname, varname)
validstr = validatestring(str, strarray, funname, varname,
 position)
```

**Description** `validstr = validatestring(str, strarray)` checks the validity of text string `str`. If `str` matches one or more of the text strings in the cell array `strarray`, MATLAB returns the matching string in `validstr`. If `str` does not match any of the strings in `strarray`, MATLAB issues a formatted error message. MATLAB compares the strings without respect to letter case.

This table shows how `validatestring` determines what value to return. If multiple matches are found, `validatestring` returns the shortest matching string.

| Type of Match                                                     | Example – Match 'ball' with . . . | Return Value |
|-------------------------------------------------------------------|-----------------------------------|--------------|
| Exact match                                                       | ball, barn, bell                  | ball         |
| Partial match (leading characters)                                | balloon, barn                     | balloon      |
| Multiple partial matches where each string is a subset of another | ball, ballo, balloo, balloon      | ball         |
| Multiple partial matches where strings are unique                 | balloon, ballet                   | Error        |
| No match                                                          | barn, bell                        | Error        |

`validstr = validatestring(str, strarray, position)` checks the validity of text string `str` and, if the validation fails, displays an error message that includes the position of the failing variable in the function argument list. The `position` input must be a positive integer.

# validatestring

---

`validstr = validatestring(str, strarray, funname)` checks the validity of text string `str` and, if the validation fails, displays an error message that includes the name of the function performing the validation (`funname`). The `funname` input must be a string enclosed in single quotation marks.

`validstr = validatestring(str, strarray, funname, varname)` checks the validity of text string `str` and, if the validation fails, displays an error message that includes the name of the function performing the validation (`funname`) and the name of the variable being validated (`varname`). The `funname` and `varname` inputs must be strings enclosed in single quotation marks.

`validstr = validatestring(str, strarray, funname, varname, position)` checks the validity of text string `str` and, if the validation fails, displays an error message that includes the name of the function performing the validation (`funname`), the name of the variable being validated (`varname`), and the position of this variable in the function argument list (`position`). The `funname` and `varname` inputs must be strings enclosed in single quotation marks. The `position` input must be a positive integer.

## Examples

### Example 1

Use `validatestring` to find the word `won` in the cell array of strings:

```
validatestring('won', {'wind', 'won', 'when'})
ans =
 won
```

Replace the word `won` with `wonder` in the string array. Because the leading characters of the input string and `wonder` are the same, `validatestring` finds a partial match between the two words and returns the full word `wonder`:

```
validatestring('won', {'wind', 'wonder', 'when'})
ans =
 wonder
```

If there is more than one partial match, and each string in the array is a subset or superset of the others, `validatestring` returns the shortest matching string:

```
validatestring('wond', {'won', 'wonder', 'wonderful'})
ans =
 wonder
```

However, if each string in the array is not subset or superset of each other, MATLAB throws an error because there is no exact match and it is not clear which of the two partial matches should be returned:

```
validatestring('wond', {'won', 'wonder', 'wondrous'})
??? Error using ==> validatestring at 89
Function VALIDATESTRING expected its input argument to
 match one of these strings:

 won, wonder, wondrous
```

The input, 'wond', matched more than one valid string.

## Example 2

In this example, the `get_flight_numbers` function returns the flight numbers for routes between two cities: a point of origin and point of destination. The function uses `validatestring` to see if the origin and destination are among those covered by the airline. If not, an error message is displayed:

```
function get_flight_numbers(origin, destination)
% Only part of the airline's flight data is shown here.
 flights.chi2rio = [503, 196, 331, 373, 1475];
 flights.chi2par = [718, 9276, 172, 903, 7724 992, 1158];
 flights.chi2hon = [9193, 880, 471, 391];

 routes = {'Athens', 'Paris', 'Chicago', 'Sydney', ...
 'Cancun', 'London', 'Rio de Janeiro', 'Honolulu', ...
 'Rome', 'New York City'};
 orig = ''; dest = '';
```

# validatestring

---

```
% Does the airline cover these cities?
try
 orig = validatestring(origin, routes);
 dest = validatestring(destination, routes);
catch
 % If not covered, then display error message.
 if isempty(orig)
 fprintf(...
 'We have no flights with origin: %s.\n', ...
 origin)
 elseif isempty(dest)
 fprintf('%s%s%s.\n', 'We have no flights ', ...
 'with destination: ', destination)
 end
 return
end

% If covered, display the flights from 'orig' to 'dest'.
fprintf(...
 'Flights available from %s to %s are:\n', orig, dest)
reply = eval(...
 ['flights.' lower(orig(1:3)) '2' lower(dest(1:3))]);
fprintf(' Flight %d\n', reply)
```

Enter a point of origin that is not covered by this airline:

```
get_flight_numbers('San Diego', 'Rio de Janeiro')
ans =
We have no flights with origin: San Diego.
```

Enter a destination that is misspelled:

```
get_flight_numbers('Chicago', 'Reo de Janeiro')
ans =
We have no flights with destination: Reo de Janeiro.
```

Enter a route that is covered:

```
get_flight_numbers('Chicago', 'Rio de Janeiro')
ans =
Flights available from Chicago to Rio de Janeiro are:
 Flight 503
 Flight 196
 Flight 331
 Flight 373
 Flight 1475
```

### Example 3

Rewrite the try-catch block of Example 2 by adding funname, varname, and position arguments to the call to validatestring and replacing the return statement with rethrow:

```
% See if the cities entered are covered by this airline.
try
 orig = validatestring(...
 origin, routes, mfilename, 'Flight Origin', 1);
 dest = validatestring(...
 destination, routes, mfilename, ...
 'Flight Destination', 2);
catch e
 % If not covered, then display error message.
 if isempty(orig)
 fprintf(...
 'We have no flights with origin: %s.\n', ...
 origin)
 elseif isempty(dest)
 fprintf('%s%s%s.\n', 'We have no flights ', ...
 'with destination: ', destination)
 end
 rethrow(e);
end
```

In response to the rethrow command, MATLAB displays an error message that includes the function name `get_flight_numbers`, the

# validatestring

---

failing variable name `Flight Destination`, and its position in the argument list, 2:

```
get_flight_numbers('Chicago', 'Reo de Janeiro')
We have no flights with destination: Reo de Janeiro.
```

```
??? Error using ==> validatestring at 89
Function GET_FLIGHT_NUMBERS expected its input argument
number 2, Flight Destination, to match one of these
strings:
```

```
Athens, Paris, Chicago, Sydney, Cancun, London, Rio de
Janeiro, Honolulu, Rome
```

```
The input, 'Reo de Janeiro', did not match any of the valid
strings.
```

```
Error in ==> get_flight_numbers at 17
dest = validatestring(destination, routes, mfilename,
'destination', 2);
```

## See Also

`validateattributes`, `is*`, `isa`, `inputParser`



**Purpose** Return values of containers.Map object

**Syntax**  
`v = values(M)`  
`v = values(M, keys)`

**Description**  
`v = values(M)` returns in cell array `v` the values that correspond to all keys in Map object `M`.  
`v = values(M, keys)` returns in cell array `v`, those values in Map object `M` that correspond to the keys specified by the `keys` argument.  
Read more about Map Containers in the MATLAB Programming Fundamentals documentation.

**Examples** Create a Map object of four US states and their capital cities:

```
US_Capitals = containers.Map(...
 {'Georgia', 'Alaska', 'Vermont', 'Oregon'}, ...
 {'Atlanta', 'Juneau', 'Montpelier', 'Salem'})
```

Find the capital cities of all states contained in the map:

```
v = values(US_Capitals)
v =
 'Juneau' 'Atlanta' 'Salem' 'Montpelier'
```

Find the capital cities of selected states:

```
v = values(US_Capitals, {'Oregon', 'Alaska'})
v =
 'Salem' 'Juneau'
```

**See Also** `containers.Map`, `keys(Map)`, `size(Map)`, `length(Map)`, `isKey(Map)`, `remove(Map)`, `handle`

# vander

---

**Purpose** Vandermonde matrix

**Syntax** `A = vander(v)`

**Description** `A = vander(v)` returns the Vandermonde matrix whose columns are powers of the vector `v`, that is,  $A(i, j) = v(i)^{(n-j)}$ , where  $n = \text{length}(v)$ .

**Examples** `vander(1:.5:3)`

`ans =`

|         |         |        |        |        |
|---------|---------|--------|--------|--------|
| 1.0000  | 1.0000  | 1.0000 | 1.0000 | 1.0000 |
| 5.0625  | 3.3750  | 2.2500 | 1.5000 | 1.0000 |
| 16.0000 | 8.0000  | 4.0000 | 2.0000 | 1.0000 |
| 39.0625 | 15.6250 | 6.2500 | 2.5000 | 1.0000 |
| 81.0000 | 27.0000 | 9.0000 | 3.0000 | 1.0000 |

**See Also** `gallery`

**Purpose**

Variance

**Syntax**

```
V = var(X)
V = var(X,1)
V = var(X,w)
V = var(X,w,dim)
```

**Description**

`V = var(X)` returns the variance of `X` for vectors. For matrices, `var(X)` is a row vector containing the variance of each column of `X`. For `N`-dimensional arrays, `var` operates along the first nonsingleton dimension of `X`. The result `V` is an unbiased estimator of the variance of the population from which `X` is drawn, as long as `X` consists of independent, identically distributed samples.

`var` normalizes `V` by `N-1` if `N>1`, where `N` is the sample size. This is an unbiased estimator of the variance of the population from which `X` is drawn, as long as `X` consists of independent, identically distributed samples. For `N=1`, `V` is normalized by `N`.

`V = var(X,1)` normalizes by `N` and produces the second moment of the sample about its mean. `var(X,0)` is equivalent to `var(X)`.

`V = var(X,w)` computes the variance using the weight vector `w`. The length of `w` must equal the length of the dimension over which `var` operates, and its elements must be nonnegative. The elements of `w` must be positive. `var` normalizes `w` to sum of 1.

`V = var(X,w,dim)` takes the variance along the dimension `dim` of `X`. Pass in 0 for `w` to use the default normalization by `N-1`, or 1 to use `N`.

The variance is the square of the standard deviation (STD).

**See Also**

`corrcoef`, `cov`, `mean`, `median`, `std`

# var (timeseries)

---

**Purpose** Variance of timeseries data

**Syntax**  
`ts_var = var(ts)`  
`ts_var = var(ts, 'PropertyName1', PropertyValue1, ...)`

**Description** `ts_var = var(ts)` returns the variance of `ts.data`. When `ts.Data` is a vector, `ts_var` is the variance of `ts.Data` values. When `ts.Data` is a matrix, `ts_var` is a row vector containing the variance of each column of `ts.Data` (when `IsTimeFirst` is true and the first dimension of `ts` is aligned with time). For the N-dimensional `ts.Data` array, `var` always operates along the first nonsingleton dimension of `ts.Data`.

`ts_var = var(ts, 'PropertyName1', PropertyValue1, ...)` specifies the following optional input arguments:

- 'MissingData' property has two possible values, 'remove' (default) or 'interpolate', indicating how to treat missing data during the calculation.
- 'Quality' values are specified by an integer vector, indicating which quality codes represent missing samples (for vector data) or missing observations (for data arrays with two or more dimensions).
- 'Weighting' property has two possible values, 'none' (default) or 'time'.  
When you specify 'time', larger time values correspond to larger weights.

**Examples** The following example shows how to calculate the variance values of a multi-variate timeseries object.

**1** Load a 24-by-3 data array.

```
load count.dat
```

**2** Create a timeseries object with 24 time values.

```
count_ts = timeseries(count,[1:24], 'Name', 'CountPerSecond')
```

- 3** Calculate the variance of each data column for this `timeseries` object.

```
var(count_ts)
ans =
 1.0e+003 *
 0.6437 1.7144 4.6278
```

The variance is calculated independently for each data column in the `timeseries` object.

### See Also

```
iqr (timeseries), mean (timeseries), median (timeseries), std
(timeseries), timeseries
```

# varargin

---

**Purpose** Variable length input argument list

**Syntax** `function y = bar(varargin)`

**Description** `function y = bar(varargin)` accepts a variable number of arguments into function `bar.m`.

The `varargin` statement is used only inside a function M-file to contain optional input arguments passed to the function. The `varargin` argument must be declared as the last input argument to a function, collecting all the inputs from that point onwards. In the declaration, `varargin` must be lowercase.

## Examples

### Example 1

Write an M-file function that displays the expected and optional arguments you pass to it

```
function vartest(argA, argB, varargin)

optargin = size(varargin,2);
stdargin = nargin - optargin;

fprintf('Number of inputs = %d\n', nargin)

fprintf(' Inputs from individual arguments(%d):\n', ...
 stdargin)
if stdargin >= 1
 fprintf(' %d\n', argA)
end
if stdargin == 2
 fprintf(' %d\n', argB)
end

fprintf(' Inputs packaged in varargin(%d):\n', optargin)
for k= 1 : size(varargin,2)
 fprintf(' %d\n', varargin{k})
end
```

Call this function and observe that the MATLAB software extracts those arguments that are not individually-specified from the varargin cell array:

```
vartest(10,20,30,40,50,60,70)
Number of inputs = 7
 Inputs from individual arguments(2):
 10
 20
 Inputs packaged in varargin(5):
 30
 40
 50
 60
 70
```

## Example 2

The function

```
function myplot(x,varargin)
plot(x,varargin{:})
```

collects all the inputs starting with the second input into the variable varargin. myplot uses the comma-separated list syntax varargin{:} to pass the optional parameters to plot. The call

```
myplot(sin(0:.1:1),'color',[.5 .7 .3],'linestyle',':')
```

results in varargin being a 1-by-4 cell array containing the values 'color', [.5 .7 .3], 'linestyle', and ':'.

## See Also

varargout, nargin, nargout, nargchk, nargoutchk, inputname

# varargout

---

**Purpose** Variable length output argument list

**Syntax** `function varargout = foo(n)`

**Description** `function varargout = foo(n)` returns a variable number of arguments from function `foo.m`.

The `varargout` statement is used only inside a function M-file to contain the optional output arguments returned by the function. The `varargout` argument must be declared as the last output argument to a function, collecting all the outputs from that point onwards. In the declaration, `varargout` must be lowercase.

**Examples** The function

```
function [s,varargout] = mysize(x)
nout = max(nargout,1)-1;
s = size(x);
for k=1:nout, varargout(k) = {s(k)}; end
```

returns the size vector and, optionally, individual sizes. So

```
[s,rows,cols] = mysize(rand(4,5));
```

returns `s = [4 5]`, `rows = 4`, `cols = 5`.

**See Also** `varargin`, `nargin`, `nargout`, `nargchk`, `nargoutchk`, `inputname`



|                    |                                                                                                                                                                                                                                                                                                                                                                                                                          |
|--------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Purpose</b>     | Vectorize expression                                                                                                                                                                                                                                                                                                                                                                                                     |
| <b>Syntax</b>      | <code>vectorize(s)</code><br><code>vectorize(fun)</code>                                                                                                                                                                                                                                                                                                                                                                 |
| <b>Description</b> | <p><code>vectorize(s)</code> where <code>s</code> is a string expression, inserts a <code>.</code> before any <code>^</code>, <code>*</code> or <code>/</code> in <code>s</code>. The result is a character string.</p> <p><code>vectorize(fun)</code> when <code>fun</code> is an inline function object, vectorizes the formula for <code>fun</code>. The result is the vectorized version of the inline function.</p> |
| <b>See Also</b>    | <code>inline</code> , <code>cd</code> , <code>dbtype</code> , <code>delete</code> , <code>dir</code> , <code>partialpath</code> , <code>path</code> , <code>what</code> , <code>who</code>                                                                                                                                                                                                                               |

|                         |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|-------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Purpose</b>          | Version information for MathWorks products                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| <b>GUI Alternatives</b> | As an alternative to the <code>ver</code> function, select <b>Help &gt; About</b> in any tool that has a <b>Help</b> menu.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| <b>Syntax</b>           | <pre>ver ver product v = ver('product')</pre>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| <b>Description</b>      | <p><code>ver</code> displays a header containing the current MathWorks product family version number, license number, operating system, and version of Sun Microsystems JVM software for the MATLAB product. This is followed by the version numbers for MATLAB, Simulink, if installed, and all other installed MathWorks products.</p> <p><code>ver product</code> displays the MathWorks product family header information followed by the current version number for product. The name <code>product</code> corresponds to the directory name that holds the <code>Contents.m</code> file for that product. For example, <code>Contents.m</code> for the Control System Toolbox product resides in the <code>control</code> directory. You therefore use <code>ver control</code> to obtain the version of this toolbox.</p> <p><code>v = ver('product')</code> returns the version information to structure array, <code>v</code>, having fields <code>Name</code>, <code>Version</code>, <code>Release</code>, and <code>Date</code>.</p> |
| <b>Remarks</b>          | <p>To use <code>ver</code> with your own product, the first two lines of the <code>Contents.m</code> file for the product must be of the form</p> <pre>% Toolbox Description % Version xxx dd-mmm-yyyy</pre> <p>Do not include any spaces in the date and use a two-character day; that is, use <code>02-Sep-2008</code> instead of <code>2-Sep-2008</code>.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| <b>Examples</b>         | <p>Using R2009a, return version information for MathWorks products, and specifically the Control System Toolbox product by typing</p> <pre>ver control</pre>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |

## MATLAB returns

```

MATLAB Version 7.8.0.3012 (R2009a)
MATLAB License Number: [not shown]
Operating System: Microsoft Windows XP Version 5.1 (Build 2600: Service Pack 3)
Java VM Version: Java 1.6.0_04-b12 with Sun Microsystems Inc. Java HotSpot(TM) Client VM mixed m

Control System Toolbox Version 8.3 (R2009a)

```

Return version information for the Control System Toolbox product in a structure array, `v`.

```

v = ver('control')
v =

 Name: 'Control System Toolbox'
 Version: '8.3'
 Release: '(R2009a)'
 Date: '24-Jan-2009'

```

Display version information for MathWorks 'Real-Time' products:

```

v = ver;
for k=1:length(v)
 if strfind(v(k).Name, 'Real-Time')
 disp(sprintf('%s, Version %s', ...
 v(k).Name, v(k).Version))
 end
end

Real-Time Windows Target, Version 3.3
Real-Time Workshop, Version 7.3
Real-Time Workshop Embedded Coder, Version 5.3

```

## See Also

`computer`, `help`, `hostid`, `license`, `verlessthan`, `version`, `whatsnew`

**Help > Check for Updates** in the MATLAB desktop.

# verctrl

**Purpose** Source control actions (Windows platforms)

**GUI Alternatives** As an alternative to the `verctrl` function, use **Source Control** in the **File** menu of the Editor, the Simulink product, or the Stateflow product, or in the context menu of the Current Directory browser.

**Syntax**

```
verctrl('action',{'filename1','filename2',...},0)
result=verctrl('action',{'filename1','filename2',...},0)
verctrl('action','filename',0)
result=verctrl('isdiff','filename',0)
list = verctrl('all_systems')
```

**Description** `verctrl('action',{'filename1','filename2',...},0)` performs the source control operation specified by `'action'` for a single file or multiple files. Enter one file as a string; specify multiple files using a cell array of strings. Use the full paths for each filename and include the extensions. Specify `0` as the last argument. Complete the resulting dialog box to execute the operation; for details about the dialog boxes, see the topic “Source Control Interface on Microsoft Windows” in the MATLAB Desktop Tools and Development Environment documentation. Available values for `'action'` are as follows:

| <b>action Argument</b> | <b>Purpose</b>                                                                                                      |
|------------------------|---------------------------------------------------------------------------------------------------------------------|
| 'add'                  | Adds files to the source control system. Files can be open in the Editor or closed when added.                      |
| 'checkin'              | Checks files into the source control system, storing the changes and creating a new version.                        |
| 'checkout'             | Retrieves files for editing.                                                                                        |
| 'get'                  | Retrieves files for viewing and compiling, but not editing. When you open the files, they are labeled as read-only. |
| 'history'              | Displays the history of files.                                                                                      |

| <b>action Argument</b> | <b>Purpose</b>                                                                                                                                                               |
|------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 'remove'               | Removes files from the source control system. It does not delete the files from disk, but only from the source control system.                                               |
| 'runsc'                | Starts the source control system. The filename can be an empty string.                                                                                                       |
| 'uncheckout'           | Cancels a previous checkout operation and restores the contents of the selected files to the precheckout version. All changes made to the files since the checkout are lost. |

`result=verctrl('action',{'filename1','filename2',...},0)` performs the source control operation specified by '*action*' on a single file or multiple files. The action can be any one of: 'add', 'checkin', 'checkout', 'get', 'history', or 'undocheckout'. `result` is a logical 1 (true) when you complete the operation by clicking **OK** in the resulting dialog box, and is a logical 0 (false) when you abort the operation by clicking **Cancel** in the resulting dialog box.

`verctrl('action','filename',0)` performs the source control operation specified by '*action*' for a single file. Use the full pathname for '*filename*'. Specify 0 as the last argument. Complete any resulting dialog boxes to execute the operation. Available values for '*action*' are as follows:

| <b>action Argument</b> | <b>Purpose</b>                                                                                                      |
|------------------------|---------------------------------------------------------------------------------------------------------------------|
| 'showdiff'             | Displays the differences between a file and the latest checked in version of the file in the source control system. |
| 'properties'           | Displays the properties of a file.                                                                                  |

`result=verctrl('isdiff','filename',0)` compares `filename` with the latest checked in version of the file in the source control system. `result` is a logical 1 (true) when the files are different, and is a logical 0 (false) when the files are identical. Use the full path for '`filename`'. Specify 0 as the last argument.

`list = verctrl('all_systems')` displays in the Command Window a list of all source control systems installed on your computer.

## Examples

### Check In a File

Check in `D:\file1.ext` to the source control system.

```
result = verctrl('checkin','D:\file1.ext', 0)
```

This opens the **Check in file(s)** dialog box. Click **OK** to complete the check in. MATLAB displays `result = 1`, indicating the checkin was successful.

### Add Files to the Source Control System

Add `D:\file1.ext` and `D:\file2.ext` to the source control system.

```
verctrl('add',{'D:\file1.ext','D:\file2.ext'}, 0)
```

This opens the **Add to source control** dialog box. Click **OK** to complete the operation.

### Display the Properties of a File

Display the properties of `D:\file1.ext`.

```
verctrl('properties','D:\file1.ext', 0)
```

This opens the source control properties dialog box for your source control system. The function is complete when you close the properties dialog box.

## Show Differences for a File

To show the differences between the version of `file1.ext` that you just edited and saved, with the last version in source control, run

```
verctrl('showdiff','D:\file1.ext',0)
```

MATLAB displays differences dialog boxes and results specific to your source control system. After checking in the file, if you run this statement again, MATLAB displays

```
??? The file is identical to latest version under source control.
```

## List All Installed Source Control Systems

To view all of the source control systems installed on your computer, type

```
list = verctrl ('all_systems')
```

MATLAB displays all the source control systems currently installed on your computer. For example:

```
list =
'Microsoft Visual SourceSafe'
'ComponentSoftware RCS'
```

## See Also

`checkin`, `checkout`, `undocheckout`, `cmopts`

“Source Control Interface on Microsoft Windows” in MATLAB Desktop Tools and Development Environment documentation

# verLessThan

---

**Purpose** Compare toolbox version to specified version string

**Syntax** `verLessThan(toolbox, version)`

**Description** `verLessThan(toolbox, version)` returns logical 1 (true) if the version of the toolbox specified by the string `toolbox` is older than the version specified by the string `version`, and logical 0 (false) otherwise. Use this function when you want to write code that can run across multiple versions of the MATLAB software, when there are differences in the behavior of the code in the different versions.

The `toolbox` argument is a string enclosed within single quotation marks that contains the name of a MATLAB toolbox directory. The `version` argument is a string enclosed within single quotation marks that contains the version to compare against. This argument must be in the form `major[.minor[.revision]]`, such as 7, 7.1, or 7.0.1. If `toolbox` does not exist, MATLAB generates an error.

To specify `toolbox`, find the directory that holds the `Contents.m` file for the toolbox and use that directory name. To see a list of all toolbox directory names, enter the following statement in the MATLAB Command Window:

```
dir([matlabroot ' /toolbox'])
```

**Remarks** The `verLessThan` function is available with MATLAB Version 7.4 and subsequent versions. If you are running a version of MATLAB prior to 7.4, you can download the `verLessThan` M-file from the following MathWorks Technical Support solution. You must be running MATLAB Version 6.0 or higher to use this M-file:

<http://www.mathworks.com/support/solutions/data/1-38LI61.html?solution=1->

**Examples** These examples illustrate usage of the `verLessThan` function.

## **Example 1 – Checking For the Minimum Required Version**

```
if verLessThan('simulink', '4.0')
 error('Simulink 4.0 or higher is required.');
```



```
end
```

## Example 2 – Choosing Which Code to Run

```
if verLessThan('matlab', '7.0.1')
% -- Put code to run under MATLAB 7.0.0 and earlier here --
else
% -- Put code to run under MATLAB 7.0.1 and later here --
end
```

## Example 3 – Looking Up the Directory Name

Find the name of the Data Acquisition Toolbox directory:

```
dir([matlabroot '/toolbox/d*'])

 daq database des distcomp dotnetbuilder
 dastudio datafeed dials dml dspblks
```

Use the toolbox directory name, `daq`, to compare the Data Acquisition Toolbox software version that MATLAB is currently running against version number 3:

```
verLessThan('daq', '3')
ans =
 1
```

## See Also

`ver`, `version`, `license`, `ispc`, `isunix`, `ismac`, `dir`

# version

---

**Purpose** Version number for MATLAB

**GUI Alternatives** As an alternative to the `version` function, select **Help > About MATLAB** in the MATLAB desktop.

**Syntax**

```
version
v = version
version option
v = version('option')
```

**Description** `version` displays the MathWorks product family version.

`v = version` returns the MathWorks product family version number in string `v`.

`version option` displays the following additional information about the version. You can specify no more than one option in a `version` command.

| Option              | Description                                                 |
|---------------------|-------------------------------------------------------------|
| <b>-date</b>        | Release date                                                |
| <b>-description</b> | Release description. Mostly used for Service Pack releases. |
| <b>-java</b>        | Sun Microsystems JVM software version used by MATLAB        |
| <b>-release</b>     | Release number                                              |

`v = version('option')` returns in string `v` the information displayed in response to the syntax shown above. You can only specify no more than one option when using this syntax.

**Remarks** On Microsoft Windows and UNIX<sup>30</sup> platforms, MATLAB includes JVM software and uses that version. If you use the MATLAB interface to

30. UNIX is a registered trademark of The Open Group in the United States and other countries.

Sun Microsystems Java software and the Java classes you want to use require a different version of the JVM software than that provided with MATLAB, it is possible to run MATLAB with a different version of JVM software. For details, see “Using a Different Version of JVM Software”.

On the Apple Macintosh platform, MATLAB does not include JVM software, but uses JVM software provided with Mac OS X.

## Examples

```
d = version('-date')
d =
 January 24, 2009
```

Run the following command in MATLAB Version 7.8 (R2009a):

```
['Release R' version('-release')]

ans =
 Release R2009a
```

## See Also

computer, ver, verlessthan, whatsnew

**Help > Check for Updates** in the MATLAB desktop.

# vertcat

---

**Purpose** Concatenate arrays vertically

**Syntax** `C = vertcat(A1, A2, ...)`

**Description** `C = vertcat(A1, A2, ...)` vertically concatenates matrices A1, A2, and so on. All matrices in the argument list must have the same number of columns.

`vertcat` concatenates N-dimensional arrays along the first dimension. The remaining dimensions must match.

MATLAB calls `C = vertcat(A1, A2, ...)` for the syntax `C = [A1; A2; ...]` when any of A1, A2, etc. is an object.

**Examples** Create a 5-by-3 matrix, A, and a 3-by-3 matrix, B. Then vertically concatenate A and B.

```
A = magic(5); % Create 5-by-3 matrix, A
A(:, 4:5) = []
```

```
A =
 17 24 1
 23 5 7
 4 6 13
 10 12 19
 11 18 25
```

```
B = magic(3)*100 % Create 3-by-3 matrix, B
```

```
B =
 800 100 600
 300 500 700
 400 900 200
```

```
C = vertcat(A,B) % Vertically concatenate A and B
```

```
C =
```

```
 17 24 1
 23 5 7
 4 6 13
 10 12 19
 11 18 25
 800 100 600
 300 500 700
 400 900 200
```

**See Also**

horzcat, cat

## vertcat (timeseries)

---

**Purpose** Vertical concatenation of `timeseries` objects

**Syntax** `ts = vertcat(ts1,ts2,...)`

**Description** `ts = vertcat(ts1,ts2,...)` performs

```
ts = [ts1;ts2;...]
```

This operation appends `timeseries` objects. The time vectors must not overlap. The last time in `ts1` must be earlier than the first time in `ts2`. The data sample size of the `timeseries` objects must agree.

**See Also** `timeseries`

**Purpose** Vertical concatenation for tscollection objects

**Syntax** `tsc = vertcat(tsc1,tsc2,...)`

**Description** `tsc = vertcat(tsc1,tsc2,...)` performs  
`tsc = [tsc1;tsc2;...]`

This operation appends tscollection objects. The time vectors must not overlap. The last time in tsc1 must be earlier than the first time in tsc2. All tscollection objects to be concatenated must have the same timeseries members.

**See Also** horzcat (tscollection), tscollection

# TriRep.vertexAttachments

---

|                    |                                                                                                                                                                                                                                                                          |                                                                                                                                                                                                                                                                                   |
|--------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Purpose</b>     | Return simplices attached to specified vertices                                                                                                                                                                                                                          |                                                                                                                                                                                                                                                                                   |
| <b>Syntax</b>      | SI = vertexAttachments(TR, VI)                                                                                                                                                                                                                                           |                                                                                                                                                                                                                                                                                   |
| <b>Description</b> | SI = vertexAttachments(TR, VI) returns the vertex-to-simplex information for the specified vertices VI. In relation to 2-D triangulations, if the triangulation has a consistent orientation the triangles in each cell will be ordered consistently around each vertex. |                                                                                                                                                                                                                                                                                   |
| <b>Inputs</b>      | TR                                                                                                                                                                                                                                                                       | Triangulation representation                                                                                                                                                                                                                                                      |
|                    | VI                                                                                                                                                                                                                                                                       | VI is a column vector of indices into the array of points representing the vertex coordinates, TR.X. The simplices associated with vertex i are the i'th entry in the cell array. If VI is not specified the vertex-simplex information for the entire triangulation is returned. |
| <b>Outputs</b>     | SI                                                                                                                                                                                                                                                                       | Cell array of indices of the simplices attached to a vertex. A cell array is used to store the information because the number of simplices associated with each vertex can vary. The simplices associated with vertex i are in the i'th entry in the cell array SI.               |
| <b>Definitions</b> | A simplex is a triangle/tetrahedron or higher dimensional equivalent.                                                                                                                                                                                                    |                                                                                                                                                                                                                                                                                   |
| <b>Examples</b>    | <b>Example 1</b>                                                                                                                                                                                                                                                         |                                                                                                                                                                                                                                                                                   |
|                    | Load a 2-D triangulation and use TriRep to compute the vertex-to-triangle relations.                                                                                                                                                                                     |                                                                                                                                                                                                                                                                                   |
|                    | <pre>load trimesh2d</pre>                                                                                                                                                                                                                                                |                                                                                                                                                                                                                                                                                   |
|                    | Find the indices of the tetrahedra attached to the first vertex:                                                                                                                                                                                                         |                                                                                                                                                                                                                                                                                   |



```
Tv = vertexAttachments(trep, 1)
Tv{:}
```

## Example 2

Perform a direct query of a 2-D triangulation created using `DelaunayTri`.

```
x = rand(20,1);
y = rand(20,1);
dt = DelaunayTri(x,y);
```

Find the triangles attached to vertex 5:

```
t = vertexAttachments(dt,5);
```

Plot the triangulation:

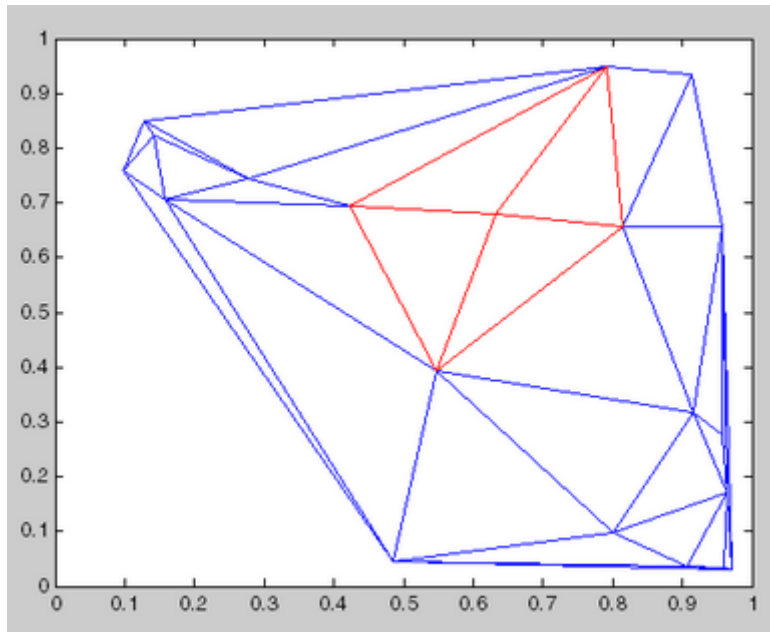
```
triplot(dt);
hold on;
```

Plot the triangles attached to vertex 5 (in red):

```
triplot(dt(t{:},:),x,y,'Color','r');
hold off;
```

# TriRep.vertexAttachments

---



**See Also**

`DeLaunayTri`

**Purpose**

Viewpoint specification

**Syntax**

```
view(az,e1)
view([x,y,z])
view(2)
view(3)
view(ax,...)
view(T)
[az,e1] = view
T = view
```

**Description**

The position of the viewer (the viewpoint) determines the orientation of the axes. You specify the viewpoint in terms of azimuth and elevation, or by a point in three-dimensional space.

`view(az,e1)` and `view([az,e1])` set the viewing angle for a three-dimensional plot. The azimuth, `az`, is the horizontal rotation about the  $z$ -axis as measured in degrees from the negative  $y$ -axis. Positive values indicate counterclockwise rotation of the viewpoint. `e1` is the vertical elevation of the viewpoint in degrees. Positive values of elevation correspond to moving above the object; negative values correspond to moving below the object.

`view([x,y,z])` sets the viewpoint to the Cartesian coordinates  $x$ ,  $y$ , and  $z$ . The magnitude of  $(x,y,z)$  is ignored.

`view(2)` sets the default two-dimensional view, `az = 0`, `e1 = 90`.

`view(3)` sets the default three-dimensional view, `az = 37.5`, `e1 = 30`.

`view(ax,...)` uses axes `ax` instead of the current axes.

`view(T)` sets the view according to the transformation matrix `T`, which is a 4-by-4 matrix such as a perspective transformation generated by `viewmtx`.

`[az,e1] = view` returns the current azimuth and elevation.

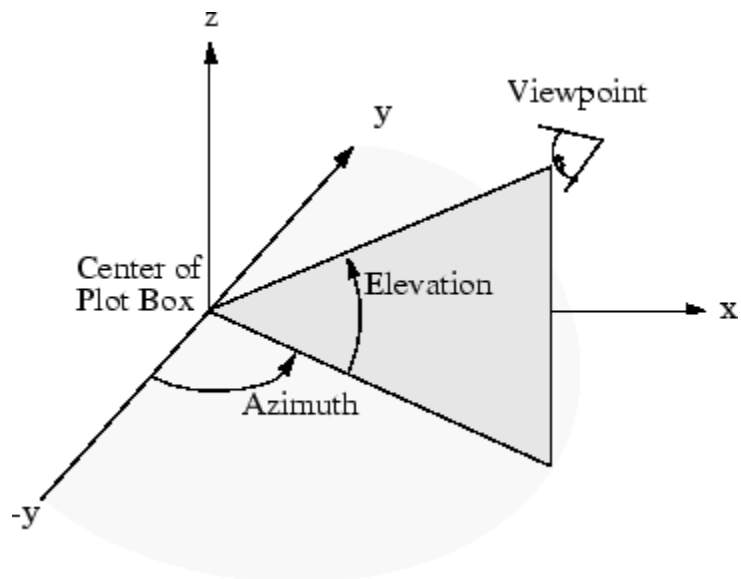
`T = view` returns the current 4-by-4 transformation matrix.

# view

## Remarks

Azimuth is a polar angle in the  $x$ - $y$  plane, with positive angles indicating counterclockwise rotation of the viewpoint. Elevation is the angle above (positive angle) or below (negative angle) the  $x$ - $y$  plane.

This diagram illustrates the coordinate system. The arrows indicate positive directions.



## Examples

View the object from directly overhead.

```
az = 0;
el = 90;
view(az, el);
```

Set the view along the  $y$ -axis, with the  $x$ -axis extending horizontally and the  $z$ -axis extending vertically in the figure.

```
view([0 0]);
```

Rotate the view about the  $z$ -axis by  $180^\circ$ .

```
az = 180;
el = 90;
view(az, el);
```

**See Also**

`viewmtx`, `hgtransform`, `rotate3d`

“Camera Viewpoint” on page 1-106 for related functions

Axes graphics object properties `CameraPosition`, `CameraTarget`, `CameraViewAngle`, `Projection`

Defining the View for more information on viewing concepts and techniques

Transforming Objects for information on moving and scaling objects in groups

# viewmtx

---

**Purpose** View transformation matrices

**Syntax**

```
viewmtx
T = viewmtx(az,e1)
T = viewmtx(az,e1,phi)
T = viewmtx(az,e1,phi,xc)
```

**Description** `viewmtx` computes a 4-by-4 orthographic or perspective transformation matrix that projects four-dimensional homogeneous vectors onto a two-dimensional view surface (e.g., your computer screen).

`T = viewmtx(az,e1)` returns an *orthographic* transformation matrix corresponding to azimuth `az` and elevation `e1`. `az` is the azimuth (i.e., horizontal rotation) of the viewpoint in degrees. `e1` is the elevation of the viewpoint in degrees. This returns the same matrix as the commands

```
view(az,e1)
T = view
```

but does not change the current view.

`T = viewmtx(az,e1,phi)` returns a *perspective* transformation matrix. `phi` is the perspective viewing angle in degrees. `phi` is the subtended view angle of the normalized plot cube (in degrees) and controls the amount of perspective distortion.

| Phi        | Description                |
|------------|----------------------------|
| 0 degrees  | Orthographic projection    |
| 10 degrees | Similar to telephoto lens  |
| 25 degrees | Similar to normal lens     |
| 60 degrees | Similar to wide-angle lens |

You can use the matrix returned to set the view transformation with `view(T)`. The 4-by-4 perspective transformation matrix transforms four-dimensional homogeneous vectors into unnormalized vectors of the

form  $(x,y,z,w)$ , where  $w$  is not equal to 1. The  $x$ - and  $y$ -components of the normalized vector  $(x/w, y/w, z/w, 1)$  are the desired two-dimensional components (see example below).

`T = viewmtx(az,el,phi,xc)` returns the perspective transformation matrix using `xc` as the target point within the normalized plot cube (i.e., the camera is looking at the point `xc`). `xc` is the target point that is the center of the view. You specify the point as a three-element vector, `xc = [xc,yc,zc]`, in the interval  $[0,1]$ . The default value is `xc = [0,0,0]`.

## Remarks

A four-dimensional homogenous vector is formed by appending a 1 to the corresponding three-dimensional vector. For example,  $[x, y, z, 1]$  is the four-dimensional vector corresponding to the three-dimensional point  $[x, y, z]$ .

## Examples

Determine the projected two-dimensional vector corresponding to the three-dimensional point  $(0.5,0.0,-3.0)$  using the default view direction. Note that the point is a column vector.

```
A = viewmtx(-37.5,30);
x4d = [.5 0 -3 1]';
x2d = A*x4d;
x2d = x2d(1:2)
x2d =
 0.3967
 -2.4459
```

Vectors that trace the edges of a unit cube are

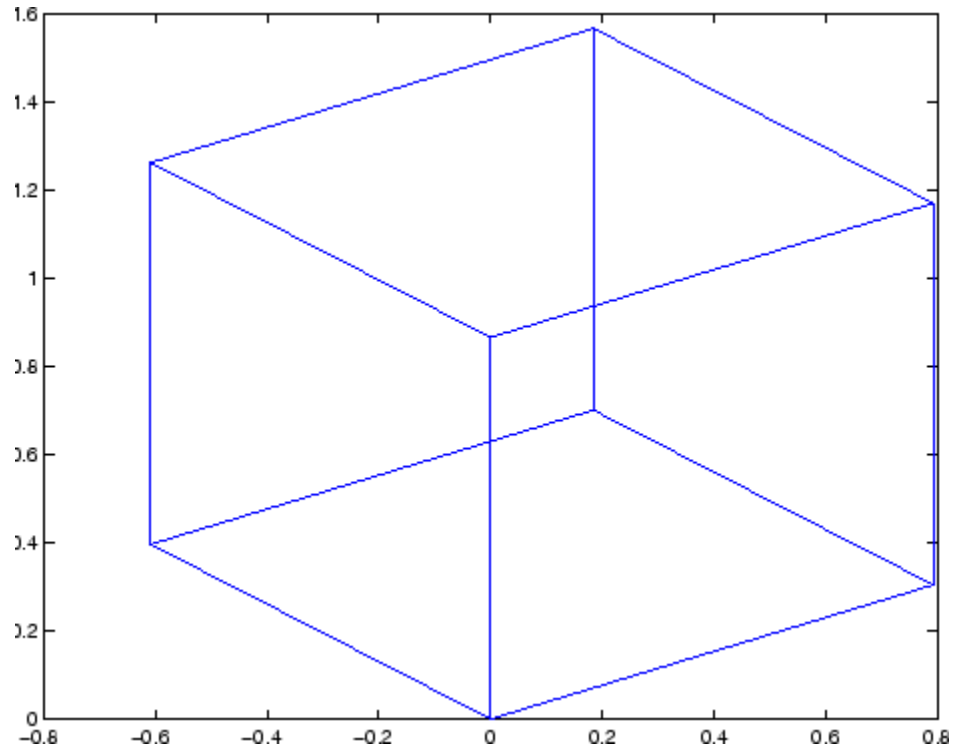
```
x = [0 1 1 0 0 0 1 1 0 0 1 1 1 1 0 0];
y = [0 0 1 1 0 0 0 1 1 0 0 0 1 1 1 1];
z = [0 0 0 0 0 1 1 1 1 1 1 1 0 0 1 1];
```

Transform the points in these vectors to the screen, then plot the object.

```
A = viewmtx(-37.5,30);
[m,n] = size(x);
x4d = [x(:),y(:),z(:),ones(m*n,1)]';
```

# viewmtx

```
x2d = A*x4d;
x2 = zeros(m,n); y2 = zeros(m,n);
x2(:) = x2d(1,:);
y2(:) = x2d(2,:);
plot(x2,y2)
```



Use a perspective transformation with a 25 degree viewing angle:

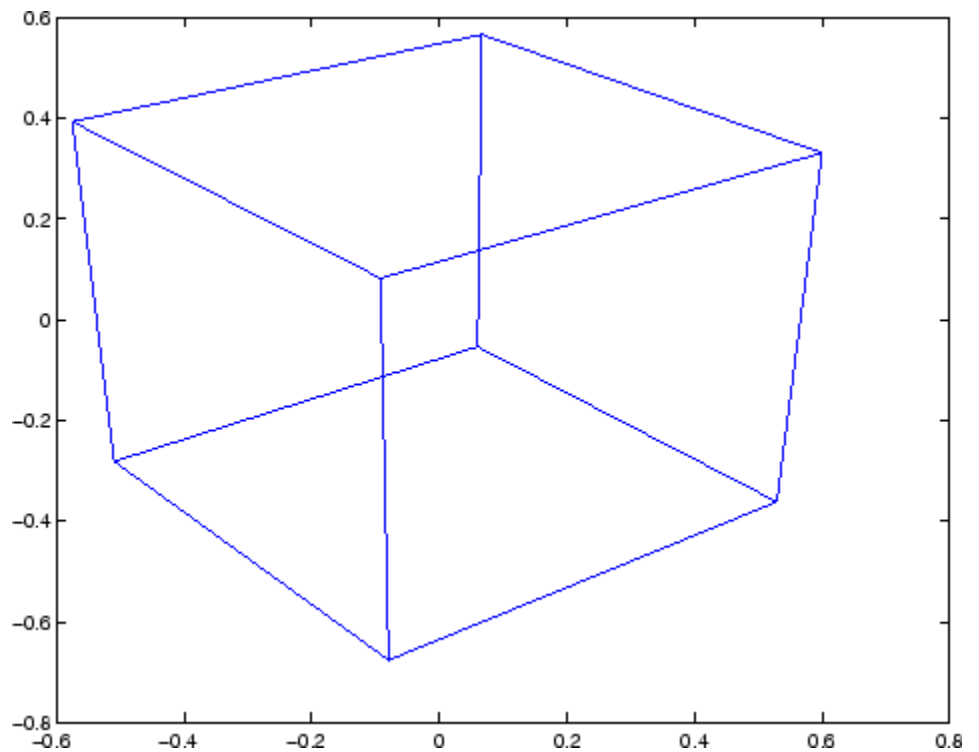
```
A = viewmtx(-37.5,30,25);
x4d = [.5 0 -3 1]';
x2d = A*x4d;
x2d = x2d(1:2)/x2d(4) % Normalize
x2d =
```



0.1777  
-1.8858

Transform the cube vectors to the screen and plot the object:

```
A = viewmtx(-37.5,30,25);
[m,n] = size(x);
x4d = [x(:),y(:),z(:),ones(m*n,1)]';
x2d = A*x4d;
x2 = zeros(m,n); y2 = zeros(m,n);
x2(:) = x2d(1,:)./x2d(4,:);
y2(:) = x2d(2,:)./x2d(4,:);
plot(x2,y2)
```



# viewmtx

---

## **See Also**

view, hgtransform

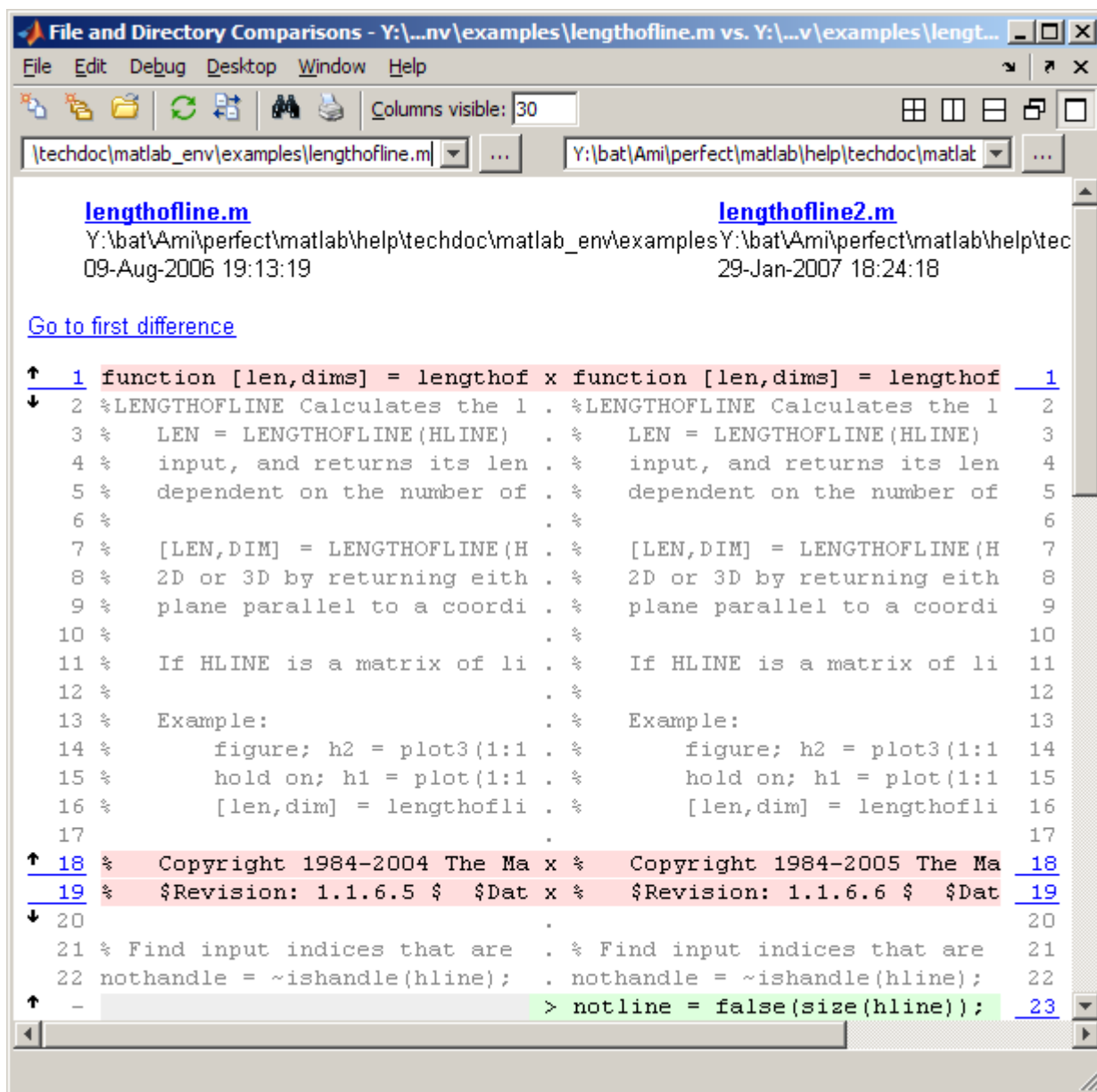
“Camera Viewpoint” on page 1-106 for related functions

Defining the View for more information on viewing concepts and techniques

---

|                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Purpose</b>         | Compare two text files, MAT-Files, or binary files                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| <b>GUI Alternative</b> | As an alternative to the <code>visdiff</code> function, select <b>Desktop &gt; File and Directory Comparisons</b> , and then in the File and Directory Comparisons tool select <b>File &gt; New File Comparison</b> .                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| <b>Syntax</b>          | <pre>visdiff('fname1', 'fname2') visdiff('fname1', 'fname2', showchars) S = visdiff('fname1', 'fname2')</pre>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| <b>Description</b>     | <p><code>visdiff('fname1', 'fname2')</code> opens the File and Directory Comparisons tool and presents the differences between the two files. The two files must be on the MATLAB path, or you must provide the full path for each file.</p> <p><code>visdiff('fname1', 'fname2', showchars)</code> opens the File and Directory Comparisons tool with the width of each column in the display set to <code>showchars</code> characters wide. MATLAB ignores the <code>showchars</code> option when you compare two binary files or two MAT-Files.</p> <p><code>S = visdiff('fname1', 'fname2')</code> creates an HTML report describing the differences between the two files and returns it in the string <code>S</code>.</p> |
| <b>Remarks</b>         | MATLAB supports displaying the differences in the File and Directory Comparisons tool only if Java software is installed. However, MATLAB supports assigning the HTML report to a string, even if the Java software is not installed.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| <b>Examples</b>        | <p><b>Compare Two Text Files in the Current Directory</b></p> <p>For this example, copy the sample files, <code>lengthofline.m</code> and <code>lengthofline2.m</code> to your current directory as described in “Comparing Files and Directories”, and then type:</p> <pre>visdiff('lengthofline.m', 'lengthofline2.m', 30)</pre>                                                                                                                                                                                                                                                                                                                                                                                              |

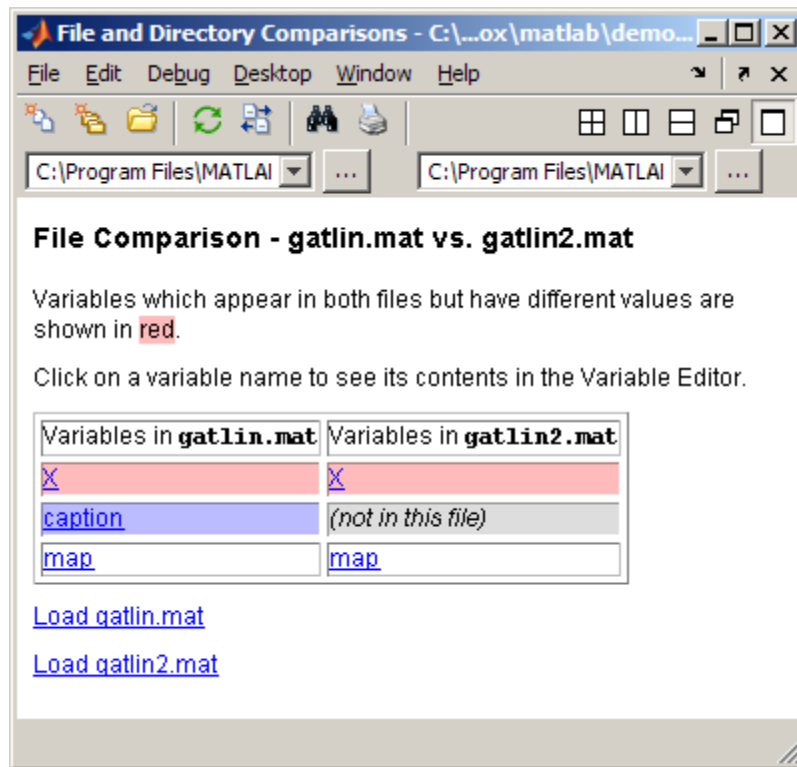
The File and Directory Comparisons tool opens and presents the differences between the two text files with the width of the left column set to 30.



## Compare Two MAT-Files Off the MATLAB Path

If you enter the following command, the File and Directory Comparisons tool opens and presents the differences between the two MAT-Files.

```
visdiff('C:\Program Files\MATLAB\R2009a\toolbox\matlab\demos\gatlin.mat', ...
 'C:\Program Files\MATLAB\R2009a\toolbox\matlab\demos\gatlin2.mat')
```



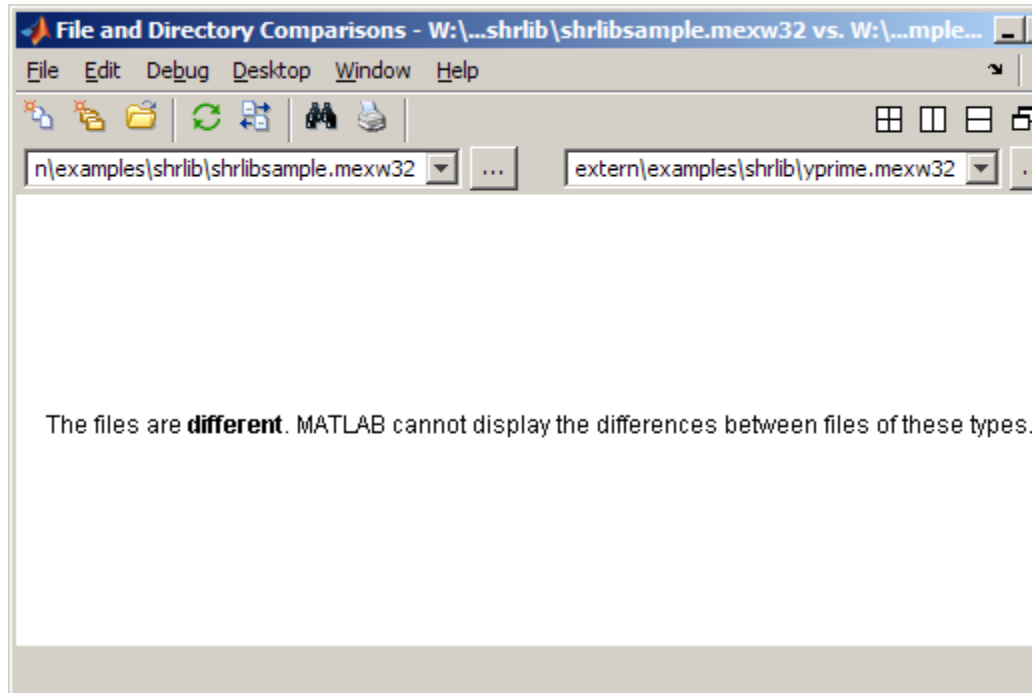
## Compare Two Binary Files on the MATLAB Path

Add the directory containing two MEX-files to the MATLAB path, and then compare the files, by issuing the following commands:

```
addpath([matlabroot '\extern\examples\shrlib'])
```

```
visdiff('shrlibsample.mexw32', 'yprime.mexw32')
```

The File and Directory Comparisons tool opens and indicates that the files are different, but does not provide details about the differences.



## See Also

“Comparing Files and Directories”

# volumebounds

---

**Purpose** Coordinate and color limits for volume data

**Syntax**

```
lims = volumebounds(X,Y,Z,V)
lims = volumebounds(X,Y,Z,U,V,W)
lims = volumebounds(V), lims = volumebounds(U,V,W)
```

**Description** `lims = volumebounds(X,Y,Z,V)` returns the x, y, z, and color limits of the current axes for scalar data. `lims` is returned as a vector:

```
[xmin xmax ymin ymax zmin zmax cmin cmax]
```

You can pass this vector to the `axis` command.

`lims = volumebounds(X,Y,Z,U,V,W)` returns the x, y, and z limits of the current axes for vector data. `lims` is returned as a vector:

```
[xmin xmax ymin ymax zmin zmax]
```

`lims = volumebounds(V)`, `lims = volumebounds(U,V,W)` assumes X, Y, and Z are determined by the expression

```
[X Y Z] = meshgrid(1:n,1:m,1:p)
```

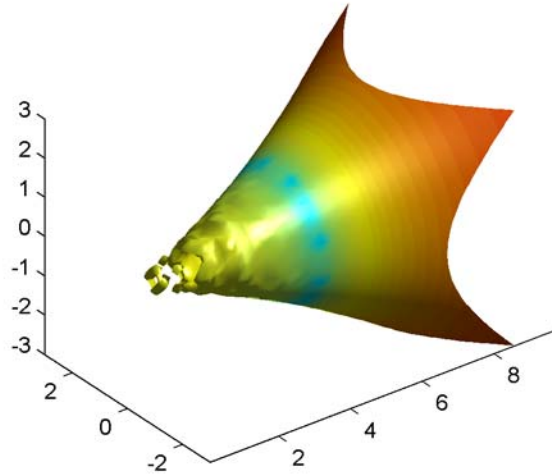
where `[m n p] = size(V)`.

## Examples

This example uses `volumebounds` to set the axis and color limits for an isosurface generated by the `flow` function.

```
[x y z v] = flow;
p = patch(isosurface(x,y,z,v,-3));
isonormals(x,y,z,v,p)
daspect([1 1 1])
isocolors(x,y,z,flipdim(v,2),p)
shading interp
axis(volumebounds(x,y,z,v))
view(3)
camlight
lighting phong
```





**See Also**

`isosurface`, `streamslice`

“Volume Visualization” on page 1-108 for related functions

# voronoi

---

**Purpose** Voronoi diagram

**Syntax**

```
voronoi(x,y)
voronoi(x,y,TRI)
voronoi(X,Y,options)
voronoi(AX,...)
voronoi(...,'LineStyleSpec')
h = voronoi(...)
[vx,vy] = voronoi(...)
```

**Definition** Consider a set of coplanar points  $P$ . For each point  $P_x$  in the set  $P$ , you can draw a boundary enclosing all the intermediate points lying closer to  $P_x$  than to other points in the set  $P$ . Such a boundary is called a *Voronoi polygon*, and the set of all Voronoi polygons for a given point set is called a *Voronoi diagram*.

**Description** `voronoi(x,y)` plots the bounded cells of the Voronoi diagram for the points `x,y`. Lines-to-infinity are approximated with an arbitrarily distant endpoint.

`voronoi(x,y,TRI)` uses the triangulation `TRI` instead of computing it via `delaunay`.

`voronoi(X,Y,options)` specifies a cell array of strings to be used as options in `Qhull` via `delaunay`.

If `options` is `[]`, the default `delaunay` options are used. If `options` is `{ '' }`, no options are used, not even the default.

`voronoi(AX,...)` plots into `AX` instead of `gca`.

`voronoi(...,'LineStyleSpec')` plots the diagram with color and line style specified.

`h = voronoi(...)` returns, in `h`, handles to the line objects created.

`[vx,vy] = voronoi(...)` returns the finite vertices of the Voronoi edges in `vx` and `vy` so that `plot(vx,vy,'-',x,y,'.')` creates the Voronoi diagram. The lines-to-infinity are the last columns of `vx` and

`vy`. To ensure the lines-to-infinity do not affect the settings of the axis limits, use the commands:

```
h = plot(VX,VY,'-',X,Y,'. ');
set(h(1:end-1),'xliminclude','off','yliminclude','off')
```

---

**Note** For the topology of the Voronoi diagram, i.e., the vertices for each Voronoi cell, use `voronoin`.

```
[v,c] = voronoin([x(:) y(:)])
```

---

## Visualization

Use one of these methods to plot a Voronoi diagram:

- If you provide no output argument, `voronoi` plots the diagram. See Example 1.
- To gain more control over color, line style, and other figure properties, use the syntax `[vx,vy] = voronoi(...)`. This syntax returns the vertices of the finite Voronoi edges, which you can then plot with the `plot` function. See Example 2.
- To fill the cells with color, use `voronoin` with `n = 2` to get the indices of each cell, and then use `patch` and other plot functions to generate the figure. Note that `patch` does not fill unbounded cells with color. See Example 3.

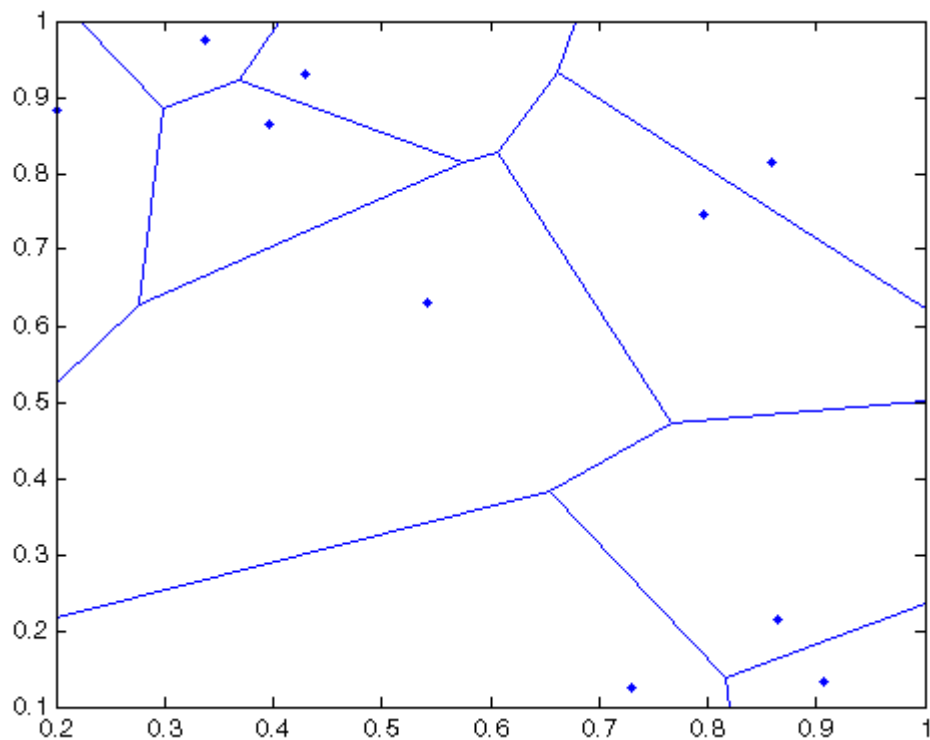
## Examples

### Example 1

This code uses the `voronoi` function to plot the Voronoi diagram for 10 randomly generated points.

```
rand('state',5);
x = rand(1,10); y = rand(1,10);
voronoi(x,y)
```

# voronoi



## Example 2

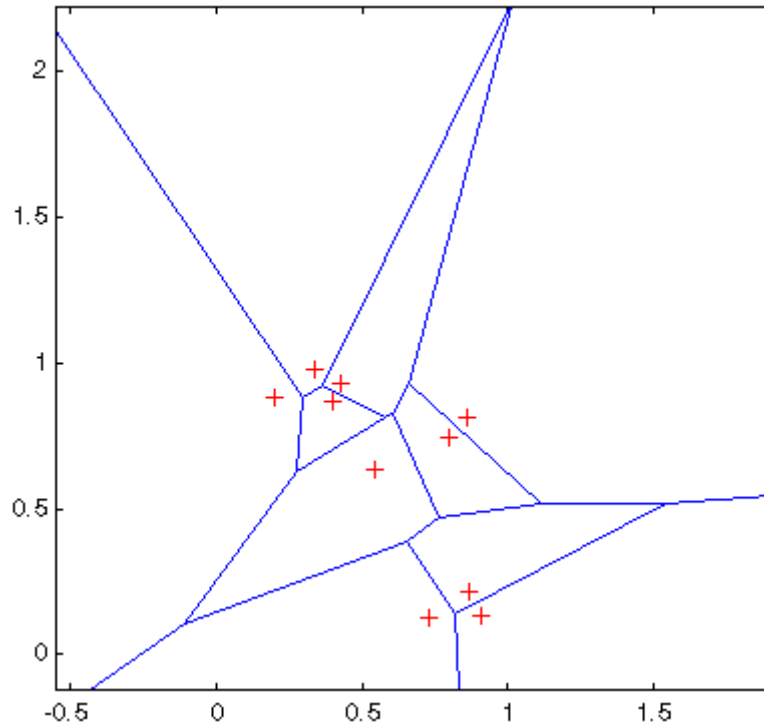
This code uses the vertices of the finite Voronoi edges to plot the Voronoi diagram for the same 10 points.

```
rand('state',5);
x = rand(1,10); y = rand(1,10);
[vx, vy] = voronoi(x,y);
plot(x,y,'r+',vx,vy,'b-'); axis equal
```

Note that you can add this code to get the figure shown in Example 1.

```
xlim([min(x) max(x)])
```

```
ylim([min(y) max(y)])
```



### Example 3

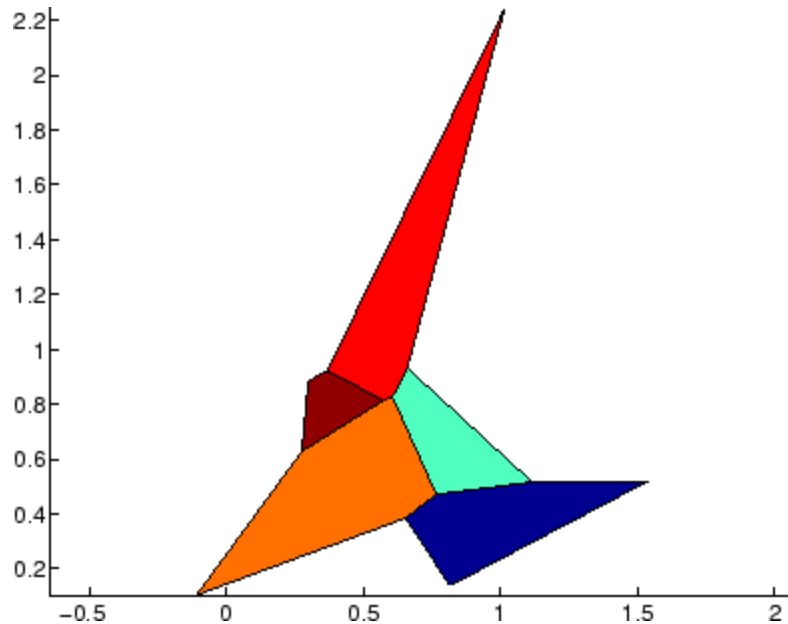
This code uses `voronoin` and `patch` to fill the bounded cells of the same Voronoi diagram with color.

```
rand('state',5);
x=rand(10,2);
[v,c]=voronoin(x);
for i = 1:length(c)
 if all(c{i}~=1) % If at least one of the indices is 1,
 % then it is an open region and we can't
 % patch that.
```

# voronoi

---

```
patch(v(c{i},1),v(c{i},2),i); % use color i.
end
end
axis equal
```



## Algorithm

If you supply no triangulation TRI, the voronoi function performs a Delaunay triangulation of the data that uses Qhull [1]. For information about Qhull, see <http://www.qhull.org/>. For copyright information, see <http://www.qhull.org/COPYING.txt>.

## See Also

convhull, delaunay, LineSpec, plot, voronoin

## Reference

[1] Barber, C. B., D.P. Dobkin, and H.T. Huhdanpaa, "The Quickhull Algorithm for Convex Hulls," *ACM Transactions on Mathematical Software*, Vol. 22, No. 4, Dec. 1996, p. 469-483.

**Purpose** Voronoi diagram

**Syntax** `[V, R] = voronoiDiagram(DT)`

**Description** `[V, R] = voronoiDiagram(DT)` returns the vertices  $V$  and regions  $R$  of the Voronoi diagram of the points  $DT.X$ . The region  $R\{i\}$  is a cell array of indices into  $V$  that represents the Voronoi vertices bounding the region. The Voronoi region associated with the  $i$ 'th point,  $DT.X(i)$  is  $R\{i\}$ . For 2-D, vertices in  $R\{i\}$  are listed in adjacent order, i.e. connecting them will generate a closed polygon (Voronoi diagram). For 3-D the vertices in  $R\{i\}$  are listed in ascending order.

The Voronoi regions associated with points that lie on the convex hull of  $DT.X$  are unbounded. Bounding edges of these regions radiate to infinity. The vertex at infinity is represented by the first vertex in  $V$ .

**Inputs**

|                 |                         |
|-----------------|-------------------------|
| <code>DT</code> | Delaunay triangulation. |
|-----------------|-------------------------|

**Outputs**

|                |                                                                                                                                                                                                                       |
|----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <code>V</code> | <code>numv-by-ndim</code> matrix representing the coordinates of the Voronoi vertices, where <code>numv</code> is the number of vertices and <code>ndim</code> is the dimension of the space where the points reside. |
| <code>R</code> | Vector cell array of <code>length(DR.X)</code> , representing the Voronoi cell associated with each point.                                                                                                            |

**Definitions** The *Voronoi diagram* of a discrete set of points  $X$  decomposes the space around each point  $X(i)$  into a region of influence  $R\{i\}$ . Locations within the region are closer to point  $i$  than any other point. The region of influence is called the Voronoi region. The collection of all the Voronoi regions is the Voronoi diagram.

# DelaunayTri.voronoiDiagram

---

The *convex hull* of a set of points  $X$  is the smallest convex polygon (or polyhedron in higher dimensions) containing all of the points of  $X$ .

## Examples

Compute the Voronoi Diagram of a set of points:

```
X = [0.5 0
 0 0.5
 -0.5 -0.5
 -0.2 -0.1
 -0.1 0.1
 0.1 -0.1
 0.1 0.1]
dt = DelaunayTri(X)
[V,R] = voronoiDiagram(dt)
```

## See Also

voronoi  
voronoin



**Purpose**

N-D Voronoi diagram

**Syntax**

[V,C] = voronoin(X)  
 [V,C] = voronoin(X,options)

**Description**

[V,C] = voronoin(X) returns Voronoi vertices V and the Voronoi cells C of the Voronoi diagram of X. V is a numv-by-n array of the numv Voronoi vertices in n-dimensional space, each row corresponds to a Voronoi vertex. C is a vector cell array where each element contains the indices into V of the vertices of the corresponding Voronoi cell. X is an m-by-n array, representing m n-dimensional points, where n > 1 and m >= n+1.

The first row of V is a point at infinity. If any index in a cell of the cell array is 1, then the corresponding Voronoi cell contains the first point in V, a point at infinity. This means the Voronoi cell is unbounded.

voronoin uses Qhull.

[V,C] = voronoin(X,options) specifies a cell array of strings options to be used in Qhull. The default options are

- { 'Qbb' } for 2- and 3-dimensional input
- { 'Qbb', 'Qx' } for 4 and higher-dimensional input

If options is [], the default options are used. If code is { '' }, no options are used, not even the default. For more information on Qhull and its options, see <http://www.qhull.org>.

**Visualization**

You can plot individual bounded cells of an n-dimensional Voronoi diagram. To do this, use convhulln to compute the vertices of the facets that make up the Voronoi cell. Then use patch and other plot functions to generate the figure.

**Examples**

**Example 1**

Let

x = [ 0.5    0

## voronoin

---

```
0 0.5
-0.5 -0.5
-0.2 -0.1
-0.1 0.1
0.1 -0.1
0.1 0.1]
```

then

```
[V,C] = voronoin(x)
```

V =

```
Inf Inf
0.3833 0.3833
0.7000 -1.6500
0.2875 0.0000
-0.0000 0.2875
-0.0000 -0.0000
-0.0500 -0.5250
-0.0500 -0.0500
-1.7500 0.7500
-1.4500 0.6500
```

C =

```
[1x4 double]
[1x5 double]
[1x4 double]
[1x4 double]
[1x4 double]
[1x5 double]
[1x4 double]
```

Use a for loop to see the contents of the cell array C.

```
for i=1:length(C), disp(C{i}), end
```

```
4 2 1 3
10 5 2 1 9
```

```

 9 1 3 7
 10 8 7 9
 10 5 6 8
 8 6 4 3 7
 6 4 2 5

```

In particular, the fifth Voronoi cell consists of 4 points:  $V(10, :)$ ,  $V(5, :)$ ,  $V(6, :)$ ,  $V(8, :)$ .

### Example 2

The following example illustrates the options input to voronoin. The commands

```

X = [-1 -1; 1 -1; 1 1; -1 1];
[V,C] = voronoin(X)

```

return an error message.

```

? qhull input error: can not scale last coordinate. Input is
cocircular
or cospherical. Use option 'Qz' to add a point at infinity.

```

The error message indicates that you should add the option 'Qz'. The following command passes the option 'Qz', along with the default 'Qbb', to voronoin.

```

[V,C] = voronoin(X,{'Qbb','Qz'})
V =

```

```

 Inf Inf
 0 0

```

C =

```

[1x2 double]
[1x2 double]
[1x2 double]

```

# voronoin

---

[1x2 double]

## Algorithm

voronoin is based on Qhull [1]. For information about Qhull, see <http://www.qhull.org/>. For copyright information, see <http://www.qhull.org/COPYING.txt>.

## See Also

convhull, convhulln, delaunay, delaunayn, voronoi

## Reference

[1] Barber, C. B., D.P. Dobkin, and H.T. Huhdanpaa, "The Quickhull Algorithm for Convex Hulls," *ACM Transactions on Mathematical Software*, Vol. 22, No. 4, Dec. 1996, p. 469-483.

**Purpose** Wait until timer stops running

**Syntax** `wait(obj)`

**Description** `wait(obj)` blocks the MATLAB command line and waits until the timer, represented by the timer object `obj`, stops running. When a timer stops running, the value of the timer object's `Running` property changes from `'on'` to `'off'`.

If `obj` is an array of timer objects, `wait` blocks the MATLAB command line until all the timers have stopped running.

If the timer is not running, `wait` returns immediately.

**See Also** `timer`, `start`, `stop`

# waitbar

---

**Purpose** Open or update a wait bar dialog box

**Syntax**

```
h = waitbar(x, 'message')
waitbar(x, 'message', 'CreateCancelBtn', 'button_callback')
waitbar(x, 'message', property_name, property_value, ...)
waitbar(x)
waitbar(x, h)
waitbar(x, h, 'updated message')
```

**Description** A wait bar is a figure that displays what percentage of a calculation is complete as the calculation proceeds by progressively filling a bar with red from left to right.

`h = waitbar(x, 'message')` displays a wait bar of fractional length `x`. The wait bar figure displays until the code that controls it closes it or the user clicks its Close Window button. Its (figure) handle is returned in `h`. The argument `x` must be between 0 and 1.

---

**Note** Wait bars are not modal figures (their `WindowStyle` is 'normal'). They often appear to be modal because the computational loops within which they are called prevent interaction with the Command Window until they terminate. For more information, see `WindowStyle` in the MATLAB Figure Properties documentation.

---

`waitbar(x, 'message', 'CreateCancelBtn', 'button_callback')` specifying `CreateCancelBtn` adds a **Cancel** button to the figure that executes the MATLAB commands specified in `button_callback` when the user clicks the **Cancel** button or the **Close Figure** button. `waitbar` sets both the **Cancel** button callback and the figure `CloseRequestFcn` to the string specified in `button_callback`.

`waitbar(x, 'message', property_name, property_value, ...)` optional arguments `property_name` and `property_value` enable you to set figure properties for the waitbar.

`waitbar(x)` subsequent calls to `waitbar(x)` extend the length of the bar to the new position `x`. Successive values of `x` normally increase. If they decrease, the wait bar runs in reverse.

`waitbar(x,h)` extends the length of the bar in the wait bar `h` to the new position `x`.

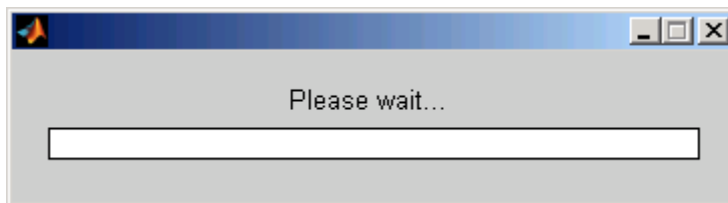
`waitbar(x,h,'updated message')` updates the message text in the waitbar figure, in addition to setting the fractional length to `x`.

## Examples

### Example 1 – Basic Wait Bar

Typically, you call `waitbar` repeatedly inside a `for` loop that performs a lengthy computation. For example:

```
h = waitbar(0,'Please wait...');
steps = 1000;
for step = 1:steps
 % computations take place here
 waitbar(step / steps)
end
close(h)
```



### Example 2 – Wait Bar with Dynamic Text and Cancel Button

Adding a **Cancel** button allows user to abort the computation. Clicking it sets a logical flag in the figure's application data (`appdata`). The function tests for that value within the main loop and exits the loop as soon as the flag has been set. The example iteratively approximates the value of  $\pi$ . At each step, the current value is encoded as a string and displayed in the wait bar's message field. When the function finishes,

it destroys the wait bar and returns the current estimate of  $\pi$  and the number of steps it ran.

Copy the following function to an M-file and save it as `approxpi.m`. Execute it as follows, allowing it to run for 10,000 iterations.

```
[estimated_pi steps] = approxpi(10000)
```

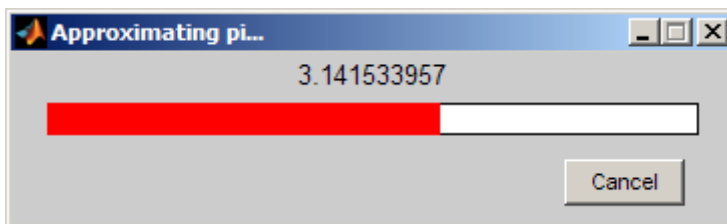
You can click **Cancel** or close the window to abort the computation and return the current estimate of  $\pi$ .

```
function [valueofpi step] = approxpi(steps)
% Converge on pi in steps iterations, displaying waitbar.
% User can click Cancel or close button to exit the loop.
% Ten thousand steps yields error of about 0.001 percent.

h = waitbar(0,'1','Name','Approximating pi...',...
 'CreateCancelBtn',...
 'setappdata(gcf,'canceling',1)');
setappdata(h,'canceling',0)
% Approximate as $\pi^2/8 = 1 + 1/9 + 1/25 + 1/49 + \dots$
pisqover8 = 1;
denom = 3;
valueofpi = sqrt(8 * pisqover8);
for step = 1:steps
 % Check for Cancel button press
 if getappdata(h,'canceling')
 break
 end
 % Report current estimate in the waitbar's message field
 waitbar(step/steps,h,sprintf('%12.9f',valueofpi))
 % Update the estimate
 pisqover8 = pisqover8 + 1 / (denom * denom);
 denom = denom + 2;
 valueofpi = sqrt(8 * pisqover8);
end
delete(h) % DELETE the waitbar; don't try to CLOSE it.
```



The function sets the figure Name property to describe what is being computed. In the for loop, calling waitbar sets the fractional progress indicator and displays intermediate results. the code `waitbar(i/steps,h,sprintf('%12.9f',valueofpi))` sets the wait bar's message variable to a string representation of the current estimate of  $\pi$ . Naturally, the extra computation involved makes iterations last longer than they need to, but such feedback can be helpful to users.



---

**Note** You should call `delete` to remove a wait bar when you give it a `CloseRequestFcn`, as in the preceding code; calling `close` does not close it, and makes its Cancel and Close Window buttons unresponsive. This happens because the figure's `CloseRequestFcn` recursively calls itself. In such a situation you must forcibly remove the wait bar, for example like this:

```
set(0,'ShowHiddenHandles','on')
delete(get(0,'Children'))
```

However, as issuing these commands will delete all open figures—not just the wait bar—it is best never to use `close` in a `CloseRequestFcn` to close a window.

---

## See Also

“Predefined Dialog Boxes” on page 1-110 for related functions  
`close`, `delete`, `dialog`, `msgbox`, `getappdata`, `setappdata`

# waitfor

---

**Purpose** Wait for condition before resuming execution

**Syntax**  
`waitfor(h)`  
`waitfor(h, 'PropertyName')`  
`waitfor(h, 'PropertyName', PropertyValue)`

**Description** The `waitfor` function blocks the caller's execution stream so that command-line expressions, callbacks, and statements in the blocked M-file do not execute until a specified condition is satisfied. It also blocks Simulink models from executing.

`waitfor(h)` returns when the graphics object identified by `h` is deleted or when a **Ctrl+C** is typed in the Command Window. If `h` does not exist, `waitfor` returns immediately without processing any events.

`waitfor(h, 'PropertyName')`, in addition to the conditions in the previous syntax, returns when the value of `'PropertyName'` for the graphics object `h` changes. If `'PropertyName'` is not a valid property for the object, `waitfor` returns immediately without processing any events.

`waitfor(h, 'PropertyName', PropertyValue)`, in addition to the conditions in the previous syntax, `waitfor` returns when the value of `'PropertyName'` for the graphics object `h` changes to `PropertyValue`. `waitfor` returns immediately without processing any events if `'PropertyName'` is set to `PropertyValue`.

**Remarks** While `waitfor` blocks an execution stream, other execution streams in the form of callbacks may execute as a result of various events (e.g., pressing a mouse button). The functions `pause` (with no argument) and `uiwait` also block execution of MATLAB and Simulink in this manner.

`waitfor` can block nested execution streams. For example, a callback invoked during a `waitfor` statement can itself invoke `waitfor`.

**See Also** `keyboard`, `pause`, `uiresume`, `uiwait`  
“User Interface Development” on page 1-111 for related functions

|                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|--------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Purpose</b>     | Wait for key press or mouse-button click                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| <b>Syntax</b>      | <code>k = waitforbuttonpress</code>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| <b>Description</b> | <p><code>k = waitforbuttonpress</code> blocks the caller's execution stream until the function detects that the user has clicked a mouse button or pressed a key while the figure window is active. The function returns</p> <ul style="list-style-type: none"><li>• 0 if it detects a mouse button click</li><li>• 1 if it detects a key press</li></ul> <p>Additional information about the event that causes execution to resume is available through the figure's <code>CurrentCharacter</code>, <code>SelectionType</code>, and <code>CurrentPoint</code> properties.</p> <p>If a <code>WindowButtonDownFcn</code> is defined for the figure, its callback is executed before <code>waitforbuttonpress</code> returns a value.</p> <p>You can interrupt <code>waitforbuttonpress</code> by typing <b>Ctrl+C</b>, but an error results unless the function is called from within a try-catch block. You also receive an error from <code>waitforbuttonpress</code> if you close the figure by clicking the <b>X</b> close box unless you call <code>waitforbuttonpress</code> within a try-catch block.</p> |
| <b>Example</b>     | <p>These statements display text in the Command Window when the user either clicks a mouse button or types a key in the figure window:</p> <pre>w = waitforbuttonpress; if w == 0     disp('Button click') else     disp('Key press') end</pre>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| <b>See Also</b>    | <code>dragrect</code> , <code>ginput</code> , <code>rbbox</code> , <code>waitfor</code><br>“User Interface Development” on page 1-111 for related functions                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |

# warndlg

---

**Purpose** Open warning dialog box

**Syntax**

```
h = warndlg
h = warndlg(warningstring)
h = warndlg(warningstring,dlgname)
h = warndlg(warningstring,dlgname,createmode)
```

**Description** `h = warndlg` displays a dialog box named Warning Dialog containing the string `This is the default warning string`. The `warndlg` function returns the handle of the dialog box in `h`. The warning dialog box disappears after the user clicks **OK**.

`h = warndlg(warningstring)` displays a dialog box with the title Warning Dialog containing the string specified by `warningstring`. The `warningstring` argument can be any valid string format – cell arrays are preferred.

To use multiple lines in your warning, define `warningstring` using either of the following:

- `sprintf` with newline characters separating the lines

```
warndlg(sprintf('Message line 1 \n Message line 2'))
```

- Cell arrays of strings

```
warndlg({'Message line 1';'Message line 2'})
```

`h = warndlg(warningstring,dlgname)` displays a dialog box with title `dlgname`.

`h = warndlg(warningstring,dlgname,createmode)` specifies whether the warning dialog box is modal or nonmodal. Optionally, it can also specify an interpreter for `warningstring` and `dlgname`. The `createmode` argument can be a string or a structure.

If `createmode` is a string, it must be one of the values shown in the following table.

---

| createmode Value    | Description                                                                                                                                                                                                                                                                                       |
|---------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| modal               | Replaces the warning dialog box having the specified <code>Title</code> , that was last created or clicked on, with a modal warning dialog box as specified. All other warning dialog boxes with the same title are deleted. The dialog box which is replaced can be either modal or nonmodal.    |
| non-modal (default) | Creates a new nonmodal warning dialog box with the specified parameters. Existing warning dialog boxes with the same title are not deleted.                                                                                                                                                       |
| replace             | Replaces the warning dialog box having the specified <code>Title</code> , that was last created or clicked on, with a nonmodal warning dialog box as specified. All other warning dialog boxes with the same title are deleted. The dialog box which is replaced can be either modal or nonmodal. |

---

**Note** A modal dialog box prevents the user from interacting with other windows before responding. To block MATLAB program execution as well, use the `uiwait` function.

If you open a dialog with `errordlg`, `msgbox`, or `warndlg` using `'CreateMode', 'modal'` and a non-modal dialog created with any of these functions is already present and *has the same name as the modal dialog*, the non-modal dialog closes when the modal one opens.

For more information about modal dialog boxes, see `WindowState` in the `Figure Properties`.

---

# warndlg

---

If `CreateMode` is a structure, it can have fields `WindowStyle` and `Interpreter`. `WindowStyle` must be one of the options shown in the table above. `Interpreter` is one of the strings `'tex'` or `'none'`. The default value for `Interpreter` is `'none'`.

## Examples

The statement

```
warndlg('Pressing OK will clear memory','!! Warning !!')
```

displays this dialog box:



## See Also

`dialog`, `errorDlg`, `helpDlg`, `inputDlg`, `listDlg`, `msgBox`, `questDlg`  
`figure`, `uiwait`, `uiresume`, `warning`

“Predefined Dialog Boxes” on page 1-110 for related functions

## Purpose

Warning message

## Syntax

```
warning('message')
warning('message', a1, a2,...)
warning('message_id', 'message')
warning('message_id', 'message', a1, a2, ..., an)
s = warning(state, 'message_id')
s = warning(state, mode)
```

## Description

`warning('message')` displays descriptive text message and sets the warning state that `lastwarn` returns. If `message` is an empty string (''), `warning` resets the warning state but does not display any text.

`warning('message', a1, a2,...)` displays a message string that contains formatting conversion characters, such as those used with the MATLAB `sprintf` function. Each conversion character in `message` is converted to one of the values `a1, a2, ...` in the argument list.

---

**Note** MATLAB converts special characters (like `\n` and `%d`) in the warning message string only when you specify more than one input argument with `warning`. See Example 4 below.

---

`warning('message_id', 'message')` attaches a unique identifier, or `message_id`, to the warning message. The identifier enables you to single out certain warnings during the execution of your program, controlling what happens when the warnings are encountered. See “Message Identifiers” and “Warning Control” in the MATLAB Programming Fundamentals documentation for more information on the `message_id` argument and how to use it.

`warning('message_id', 'message', a1, a2, ..., an)` includes formatting conversion characters in `message`, and the character translations in arguments `a1, a2, ..., an`.

`s = warning(state, 'message_id')` is a warning control statement that enables you to indicate how you want MATLAB to act on certain

# warning

---

warnings. The `state` argument can be `'on'`, `'off'`, or `'query'`. The `message_id` argument can be a message identifier string, `'all'`, or `'last'`. See “Warning Control Statements” in the MATLAB Programming Fundamentals documentation for more information.

Output `s` is a structure array that indicates the previous state of the selected warnings. The structure has the fields `identifier` and `state`. See “Output from Control Statements” in the MATLAB Programming Fundamentals documentation for more.

`s = warning(state, mode)` is a warning control statement that enables you to display an M-stack trace or display more information with each warning. The `state` argument can be `'on'`, `'off'`, or `'query'`. The `mode` argument can be `'backtrace'` or `'verbose'`. See “Backtrace and Verbose Modes” in the MATLAB Programming Fundamentals documentation for more information.

## Examples

### Example 1

Generate a warning that displays a simple string:

```
if ~ischar(p1)
 warning('Input must be a string')
end
```

### Example 2

Generate a warning string that is defined at run-time. The first argument defines a message identifier for this warning:

```
warning('MATLAB:paramAmbiguous', ...
 'Ambiguous parameter name, "%s".', param)
```

### Example 3

Using a message identifier, enable just the `actionNotTaken` warning from Simulink by first turning off all warnings and then setting just that warning to on:

```
warning off all
warning on Simulink:actionNotTaken
```



Use `query` to determine the current state of all warnings. It reports that you have set all warnings to `off` with the exception of `Simulink:actionNotTaken`:

```
warning query all
The default warning state is 'off'. Warnings not set to the default are

State Warning Identifier

on Simulink:actionNotTaken
```

#### Example 4

MATLAB converts special characters (like `\n` and `%d`) in the warning message string only when you specify more than one input argument with `warning`. In the single argument case shown below, `\n` is taken to mean `backslash-n`. It is not converted to a newline character:

```
warning('In this case, the newline \n is not converted.')
Warning: In this case, the newline \n is not converted.
```

But, when more than one argument is specified, MATLAB does convert special characters. This is true regardless of whether the additional argument supplies conversion values or is a message identifier:

```
warning('WarnTests:convertTest', ...
 'In this case, the newline \n is converted.')
Warning: In this case, the newline
is converted.
```

#### Example 5

Turn on one particular warning, saving the previous state of this one warning in `s`. Remember that this nonquery syntax performs an implicit query prior to setting the new state:

```
s = warning('on', 'Control:parameterNotSymmetric');
```

After doing some work that includes making changes to the state of some warnings, restore the original state of all warnings:

# warning

---

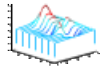
warning(s)


## **See Also**

lastwarn, warndlg, error, lasterror, errordlg, dbstop, disp,  
sprintf

**Purpose**

Waterfall plot

**GUI Alternatives**

To graph selected variables, use the Plot Selector  in the Workspace Browser, or use the Figure Palette Plot Catalog. Manipulate graphs in *plot edit* mode with the Property Editor. For details, see Plotting Tools — Interactive Plotting in the MATLAB Graphics documentation and Creating Graphics from the Workspace Browser in the MATLAB Desktop Tools documentation.

**Syntax**

```
waterfall(Z)
waterfall(X,Y,Z)
waterfall(...,C)
waterfall(axes_handles,...)
h = waterfall(...)
```

**Description**

The `waterfall` function draws a mesh similar to the `meshz` function, but it does not generate lines from the columns of the matrices. This produces a “waterfall” effect.

`waterfall(Z)` creates a waterfall plot using `x = 1:size(Z,1)` and `y = 1:size(Z,1)`. `Z` determines the color, so color is proportional to surface height.

`waterfall(X,Y,Z)` creates a waterfall plot using the values specified in `X`, `Y`, and `Z`. `Z` also determines the color, so color is proportional to the surface height. If `X` and `Y` are vectors, `X` corresponds to the columns of `Z`, and `Y` corresponds to the rows, where `length(x) = n`, `length(y) = m`, and `[m,n] = size(Z)`. `X` and `Y` are vectors or matrices that define the `x`- and `y`-coordinates of the plot. `Z` is a matrix that defines the `z`-coordinates of the plot (i.e., height above a plane). If `C` is omitted, color is proportional to `Z`.

`waterfall(...,C)` uses scaled color values to obtain colors from the current colormap. Color scaling is determined by the range of `C`, which

# waterfall

---

must be the same size as `Z`. MATLAB performs a linear transformation on `C` to obtain colors from the current colormap.

`waterfall(axes_handles, ...)` plots into the axes with handle `axes_handle` instead of the current axes (`gca`).

`h = waterfall(...)` returns the handle of the patch graphics object used to draw the plot.

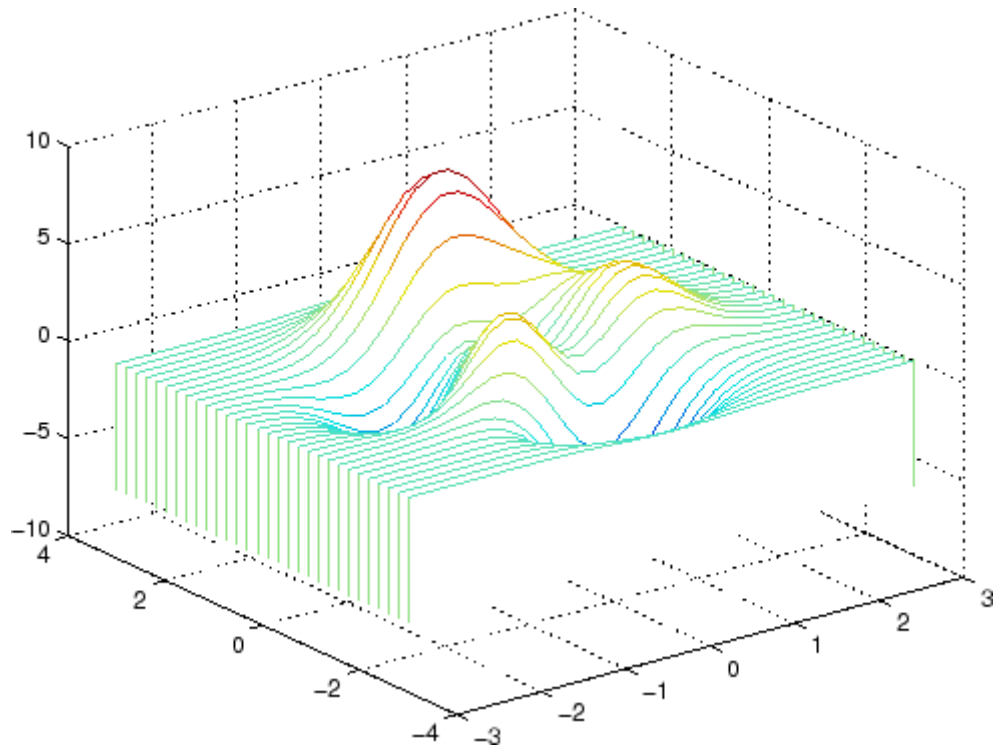
## Remarks

For column-oriented data analysis, use `waterfall(Z')` or `waterfall(X',Y',Z')`.

## Examples

Produce a waterfall plot of the peaks function.

```
[X,Y,Z] = peaks(30);
waterfall(X,Y,Z)
```



## Algorithm

The range of X, Y, and Z, or the current setting of the axes `Llim`, `YLim`, and `ZLim` properties, determines the range of the axes (also set by `axis`). The range of C, or the current setting of the axes `CLim` property, determines the color scaling (also set by `caxis`).

The `CData` property for the patch graphics objects specifies the color at every point along the edge of the patch, which determines the color of the lines.

The `waterfall` plot looks like a mesh surface; however, it is a patch graphics object. To create a surface plot similar to `waterfall`, use the `meshz` function and set the `MeshStyle` property of the surface to `'Row'`.

# waterfall

---

For a discussion of parametric surfaces and related color properties, see `surf`.

## **See Also**

`axes`, `axis`, `caxis`, `meshz`, `ribbon`, `surf`

Properties for patch graphics objects

**Purpose** Information about Microsoft WAVE (.wav) sound file

**Syntax** `[m d] = wavinfo(filename)`

**Description** `[m d] = wavinfo(filename)` returns information about the contents of the WAVE sound file specified by the string `filename`. Enclose the `filename` input in single quotes.

`m` is the string 'Sound (WAV) file', if `filename` is a WAVE file. Otherwise, it contains an empty string ('').

`d` is a string that reports the number of samples in the file and the number of channels of audio data. If `filename` is not a WAVE file, it contains the string 'Not a WAVE file'.

**See Also** `wavplay`, `wavread`, `wavrecord`, `wavwrite`

# wavplay

---

**Purpose** Play recorded sound on PC-based audio output device

**Syntax** `wavplay(y,Fs)`  
`wavplay(...,'mode')`

**Description** `wavplay(y,Fs)` plays the audio signal stored in the vector `y` on a PC-based audio output device. You specify the audio signal sampling rate with the integer `Fs` in samples per second. The default value for `Fs` is 11025 Hz (samples per second). `wavplay` supports only 1- or 2-channel (mono or stereo) audio signals.

`wavplay(...,'mode')` specifies how `wavplay` interacts with the command line, according to the string `'mode'`. The string `'mode'` can be

- `'async'`: You have immediate access to the command line as soon as the sound begins to play on the audio output device (a nonblocking device call).
- `'sync'` (default value): You don't have access to the command line until the sound has finished playing (a blocking device call).

The audio signal `y` can be one of four data types. The number of bits used to quantize and play back each sample depends on the data type.

## Data Types for wavplay

| Data Type                        | Quantization   |
|----------------------------------|----------------|
| Double-precision (default value) | 16 bits/sample |
| Single-precision                 | 16 bits/sample |
| 16-bit signed integer            | 16 bits/sample |
| 8-bit unsigned integer           | 8 bits/sample  |

**Remarks** You can play your signal in stereo if `y` is a two-column matrix.



**Examples**

The MAT-files `gong.mat` and `chirp.mat` both contain an audio signal `y` and a sampling frequency `Fs`. Load and play the gong and the chirp audio signals. Change the names of these signals in between load commands and play them sequentially using the 'sync' option for `wavplay`.

```
load chirp;
y1 = y; Fs1 = Fs;
load gong;
wavplay(y1,Fs1,'sync') % The chirp signal finishes before the
wavplay(y,Fs) % gong signal begins playing.
```

**See Also**

`wavfinfo`, `wavread`, `wavrecord`, `wavwrite`

# wavread

---

## Purpose

Read Microsoft WAVE (.wav) sound file

## Graphical Interface

As an alternative to `wavread`, use the Import Wizard. To activate the Import Wizard, select **Import Data** from the **File** menu.

## Syntax

```
y = wavread(filename)
[y, Fs, nbits] = wavread(filename)
[...] = wavread(filename, N)
[...] = wavread(filename, [N1 N2])
y = wavread(filename, fmt)
siz = wavread(filename, 'size')
[y, fs, nbits, opts] = wavread(...)
```

## Description

`y = wavread(filename)` loads a WAVE file specified by `filename`, returning the sampled data in `y`. The `filename` input is a string enclosed in single quotes. The `.wav` extension is appended if no extension is given.

`[y, Fs, nbits] = wavread(filename)` returns the sample rate (`Fs`) in Hertz and the number of bits per sample (`nbits`) used to encode the data in the file.

`[...] = wavread(filename, N)` returns only the first `N` samples from each channel in the file.

`[...] = wavread(filename, [N1 N2])` returns only samples `N1` through `N2` from each channel in the file.

`y = wavread(filename, fmt)` specifies the data type format of `y` used to represent samples read from the file. `fmt` can be either of the following values.

| Value    | Description                                                                                                                                        |
|----------|----------------------------------------------------------------------------------------------------------------------------------------------------|
| 'double' | y contains double-precision normalized samples. This is the default value, if <i>fmt</i> is omitted.                                               |
| 'native' | y contains samples in the native data type found in the file. Interpretation of <i>fmt</i> is case-insensitive, and partial matching is supported. |

`siz = wavread(filename, 'size')` returns the size of the audio data contained in `filename` in place of the actual audio data, returning the vector `siz = [samples channels]`.

`[y, fs, nbits, opts] = wavread(...)` returns a structure `opts` of additional information contained in the WAV file. The content of this structure differs from file to file. Typical structure fields include `opts.fmt` (audio format information) and `opts.info` (text which may describe title, author, etc.).

### Output Scaling

The range of values in `y` depends on the data format *fmt* specified. Some examples of output scaling based on typical bit-widths found in a WAV file are given below for both 'double' and 'native' formats.

### Native Formats

| Number of Bits | MATLAB Data Type         | Data Range                     |
|----------------|--------------------------|--------------------------------|
| 8              | uint8 (unsigned integer) | $0 \leq y \leq 255$            |
| 16             | int16 (signed integer)   | $-32768 \leq y \leq +32767$    |
| 24             | int32 (signed integer)   | $-2^{23} \leq y \leq 2^{23}-1$ |
| 32             | single (floating point)  | $-1.0 \leq y < +1.0$           |

# wavread

---

## Double Formats

| Number of Bits | MATLAB Data Type | Data Range                                                                                                                     |
|----------------|------------------|--------------------------------------------------------------------------------------------------------------------------------|
| N<32           | double           | -1.0 <= y < +1.0                                                                                                               |
| N=32           | double           | -1.0 <= y <= +1.0<br>Note: Values in y might exceed -1.0 or +1.0 for the case of N=32 bit data samples stored in the WAV file. |

wavread supports multi-channel data, with up to 32 bits per sample.

wavread supports Pulse-code Modulation (PCM) data format only.

## See Also

auread, auwrite, wavfinfo, wavplay, wavrecord, wavwrite

**Purpose** Record sound using PC-based audio input device

**Syntax**

```
y = wavrecord(n,Fs)
y = wavrecord(...,ch)
y = wavrecord(...,'dtype')
```

**Description** `y = wavrecord(n,Fs)` records `n` samples of an audio signal, sampled at a rate of `Fs` Hz (samples per second). The default value for `Fs` is 11025 Hz.

`y = wavrecord(...,ch)` uses `ch` number of input channels from the audio device. `ch` can be either 1 or 2, for mono or stereo, respectively. The default value for `ch` is 1.

`y = wavrecord(...,'dtype')` uses the data type specified by the string `'dtype'` to record the sound. The following table lists the string values for `'dtype'` along with the corresponding bits per sample and acceptable data range for `y`.

| <b>dtype</b> | <b>Bits/sample</b> | <b>y Data Range</b>         |
|--------------|--------------------|-----------------------------|
| 'double'     | 16                 | $-1.0 \leq y < +1.0$        |
| 'single'     | 16                 | $-1.0 \leq y < +1.0$        |
| 'int16'      | 16                 | $-32768 \leq y \leq +32767$ |
| 'uint8'      | 8                  | $0 \leq y \leq 255$         |

**Remarks** Standard sampling rates for PC-based audio hardware are 8000, 11025, 2250, and 44100 samples per second. Stereo signals are returned as two-column matrices. The first column of a stereo audio matrix corresponds to the left input channel, while the second column corresponds to the right input channel.

The `wavrecord` function is for use only with 32-bit Microsoft Windows operating systems. To record audio data from audio input devices on other platforms, use `audiorecorder`.

# wavrecord

---

## Examples

Record 5 seconds of 16-bit audio sampled at 11025 Hz. Play back the recorded sound using `wavplay`. Speak into your audio device (or produce your audio signal) while the `wavrecord` command runs.

```
Fs = 11025;
y = wavrecord(5*Fs,Fs,'int16');
wavplay(y,Fs);
```

## See Also

`audiorecorder`, `wavfinfo`, `wavplay`, `wavread`, `wavwrite`

**Purpose** Write Microsoft WAVE (.wav) sound file

**Syntax**

```
wavwrite(y,filename)
wavwrite(y,Fs,filename)
wavwrite(y,Fs,N,filename)
```

**Description** `wavwrite(y,filename)` writes the data stored in the variable `y` to a WAVE file called `filename`. The `filename` input is a string enclosed in single quotes. The data has a sample rate of 8000 Hz and is assumed to be 16-bit. Each column of the data represents a separate channel. Therefore, stereo data should be specified as a matrix with two columns.

`wavwrite(y,Fs,filename)` writes the data stored in the variable `y` to a WAVE file called `filename`. The data has a sample rate of `Fs` Hz and is assumed to be 16-bit.

`wavwrite(y,Fs,N,filename)` writes the data stored in the variable `y` to a WAVE file called `filename`. The data has a sample rate of `Fs` Hz and is `N`-bit, where `N` is 8, 16, 24, or 32.

### Input Data Ranges

The range of values in `y` depends on the number of bits specified by `N` and the data type of `y`. The following tables list the valid input ranges based on the value of `N` and the data type of `y`.

If `y` contains integer data:

| <b>N Bits</b> | <b>y Data Type</b> | <b>y Data Range</b>              | <b>Output Format</b> |
|---------------|--------------------|----------------------------------|----------------------|
| 8             | uint8              | $0 \leq y \leq 255$              | uint8                |
| 16            | int16              | $-32768 \leq y \leq +32767$      | int16                |
| 24            | int32              | $-2^{23} \leq y \leq 2^{23} - 1$ | int32                |

# wavwrite

---

If  $y$  contains floating-point data:

| <b>N Bits</b> | <b>y Data Type</b> | <b>y Data Range</b>     | <b>Output Format</b> |
|---------------|--------------------|-------------------------|----------------------|
| 8             | single or double   | $-1.0 \leq y < +1.0$    | uint8                |
| 16            | single or double   | $-1.0 \leq y < +1.0$    | int16                |
| 24            | single or double   | $-1.0 \leq y < +1.0$    | int32                |
| 32            | single or double   | $-1.0 \leq y \leq +1.0$ | single               |

For floating point data where  $N < 32$ , amplitude values are clipped to the range  $-1.0 \leq y < +1.0$ .

---

**Note** 8-, 16-, and 24-bit files are type 1 integer pulse code modulation (PCM). 32-bit files are written as type 3 normalized floating point.

---

## See Also

auwrite, wavfinfo, wavplay, wavread, wavrecord



**Purpose** Day of week

**Syntax**

```
[N, S] = weekday(D)
[N, S] = weekday(D, form)
[N, S] = weekday(D, locale)
[N, S] = weekday(D, form, locale)
```

**Description** [N, S] = weekday(D) returns the day of the week in numeric (N) and string (S) form for a given serial date number or date string D. Input argument D can represent more than one date in an array of serial date numbers or a cell array of date strings.

[N, S] = weekday(D, form) returns the day of the week in numeric (N) and string (S) form, where the content of S depends on the form argument. If form is **'long'**, then S contains the full name of the weekday (e.g., Tuesday). If form is **'short'**, then S contains an abbreviated name (e.g., Tues) from this table.

The days of the week are assigned these numbers and abbreviations.

| <b>N</b> | <b>S (short)</b> | <b>S (long)</b> |
|----------|------------------|-----------------|
| 1        | Sun              | Sunday          |
| 2        | Mon              | Monday          |
| 3        | Tue              | Tuesday         |
| 4        | Wed              | Wednesday       |
| 5        | Thu              | Thursday        |
| 6        | Fri              | Friday          |
| 7        | Sat              | Saturday        |

[N, S] = weekday(D, locale) returns the day of the week in numeric (N) and string (S) form, where the format of the output depends on the locale argument. If locale is **'local'**, then weekday uses local format for its output. If locale is **'en\_US'**, then weekday uses US English.

# weekday

---

`[N, S] = weekday(D, form, locale)` returns the day of the week using the formats described above for `form` and `locale`.

## Examples

Either

```
[n, s] = weekday(728647)
```

or

```
[n, s] = weekday('19-Dec-1994')
```

returns `n = 2` and `s = Mon`.

## See Also

`datenum`, `datevec`, `eomday`

**Purpose**

List MATLAB files in current directory

**Graphical Interface**

As an alternative to the `what` function, use the Current Directory browser.

**Syntax**

```

what
what dirname
what classname
what packagename
s = what('dirname')
```

**Description**

`what` lists the path for the current working directory, and all files and directories related to MATLAB found in the working directory. Files listed are M, MAT, MEX, MDL, and P-files. Directories listed are all class and package directories.

`what dirname` lists path, file, and directory information for directory *dirname*. If this directory is on the MATLAB search path, it is not necessary to enter the full path to *dirname*. The last one or two components of the path are sufficient.

`what classname` lists path, file, and directory information for method directory `@classname`. For example, `what cfit` lists the MATLAB files and directories in `toolbox/curvefit/curvefit/@cfit`.

`what packagename` lists path, file, and directory information for package directory `+packagename`. For example, `what commsrc` lists the MATLAB files and directories in `toolbox/comm/comm/+commsrc`.

`s = what('dirname')` returns the results in a structure array with the fields shown in the following table.

| Field | Description                  |
|-------|------------------------------|
| path  | Path to directory            |
| m     | Cell array of M-file names   |
| mat   | Cell array of MAT-file names |

| Field    | Description                       |
|----------|-----------------------------------|
| mex      | Cell array of MEX-file names      |
| mdl      | Cell array of MDL-file names      |
| p        | Cell array of P-file names        |
| classes  | Cell array of class directories   |
| packages | Cell array of package directories |

## Examples

### List MATLAB Files in a Directory

List the files in toolbox/matlab/audiovideo:

```
what audiovideo
```

```
M-files in directory matlabroot\toolbox\matlab\audiovideo
```

```
Contents avifinfo sound
audiodevinfo aviinfo soundsc
audioplayerreg aviread wavfinfo
audiorecorderreg lin2mu wavplay
audiouniquename mmcompinfo wavread
aufinfo mmfileinfo wavrecord
auread movie2avi wavwrite
auwrite mu2lin
avgate prefspanel
```

```
MAT-files in directory matlabroot\toolbox\matlab\audiovideo
```

```
chirp handel splat
gong laughter train
```

```
MEX-files in directory matlabroot\toolbox\matlab\audiovideo
```

```
winaudioplayer
winaudiorecorder
```

Classes in directory matlabroot\toolbox\matlab\audiovideo

```
audioplayer avifile
audiorecorder mmreader
```

### **Return File Names to Structure**

Obtain a structure array containing the MATLAB file names in toolbox/matlab/general:

```
s = what('general')
s =
 path: 'matlabroot:\toolbox\matlab\general'
 m: {89x1 cell}
 mat: {0x1 cell}
 mex: {2x1 cell}
 mdl: {0x1 cell}
 p: {'callgraphviz.p'}
 classes: {'char'}
 packages: {0x1 cell}
```

### **List M-Files in a Package**

Find the supporting M-files for one of the packages in the Communications Toolbox product:

```
p1 = what('comm');
p1.packages
ans =
 'commdevice'
 'crc'
 'commsrc'

p2 = what('commsrc');
p2.m
ans =
 'abstractJitter.m'
```

# what

---

```
'abstractPulse.m'
'combinedjitter.m'
'diracjitter.m'
'periodicjitter.m'
'randomjitter.m'
```

## See Also

`dir`, `exist`, `lookfor`, `mfilename`, `path`, `which`, `who`

“Managing Files and Working with the Current Directory”

**Purpose** Release Notes for MathWorks products

**Syntax** `whatsnew`

**Description** `whatsnew` displays the Release Notes in the Help browser, presenting information about new features, problems from previous releases that have been fixed in the current release, and compatibility issues, all organized by product.

**See Also** `help`, `version`

# which

---

## Purpose

Locate functions and files

## Graphical Interface

As an alternative to the `which` function, you can use the Current Directory browser to find files. You can find functions using the Function Browser in the Command Window or Editor.

## Syntax

```
which fun
which classname/fun
which private/fun
which classname/private/fun
which fun1 in fun2
which fun(a,b,c,...)
which file.ext
which fun -all
s = which('fun',...)
```

## Description

`which fun` displays the full pathname for the argument `fun`. If `fun` is a

- MATLAB function or Simulink model in an M, P, or MDL file on the MATLAB path, then `which` displays the full pathname for the corresponding file
- Workspace variable, then `which` displays a message identifying `fun` as a variable
- Method in a loaded Java class, then `which` displays the package, class, and method name for that method

If `fun` is an overloaded function or method, then `which fun` returns only the pathname of the first function or method found.

`which classname/fun` displays the full pathname for the M-file defining the `fun` method in MATLAB class, `classname`. For example, `which serial/fopen` displays the path for `fopen.m` in the MATLAB class directory, `@serial`.



`which private/fun` limits the search to private functions. For example, `which private/orthog` displays the path for `orthog.m` in the `/private` subdirectory of `toolbox/matlab/elmat`.

`which classname/private/fun` limits the search to private methods defined by the MATLAB class, `classname`. For example, `which dfilt/private/todtf` displays the path for `todtf.m` in the private directory of the `dfilt` class.

`which fun1 in fun2` displays the pathname to function `fun1` in the context of the M-file `fun2`. You can use this form to determine whether a subfunction is being called instead of a function on the path. For example, `which get in editpath` tells you which `get` function is called by `editpath.m`.

During debugging of `fun2`, using `which fun1` gives the same result.

`which fun(a,b,c,...)` displays the path to the specified function with the given input arguments. For example, `which feval(g)`, when `g=inline('sin(x)')`, indicates that `inline/feval.m` would be invoked. `which toLowerCase(s)`, when `s=java.lang.String('my Java string')`, indicates that the `toLowerCase` method in class `java.lang.String` would be invoked.

`which file.ext` displays the full pathname of the specified file if that file is in the current working directory or on the MATLAB path. To display the path for a file that has no file extension, type “`which file.`” (the period following the filename is required). Use `exist` to check for the existence of files anywhere else.

`which fun -all` displays the paths to all items on the MATLAB path with the name `fun`. You may use the `-all` qualifier with any of the above formats of the `which` function.

`s = which('fun',...)` returns the results of `which` in the string `s`. For workspace variables, `s` is the string `'variable'`. You may specify an output variable in any of the above formats of the `which` function.

If `-all` is used with this form, the output `s` is always a cell array of strings, even if only one string is returned.

# which

---

## Examples

The statement below indicates that `pinv` is in the `matfun` directory of MATLAB.

```
which pinv
matlabroot\toolbox\matlab\matfun\pinv.m
```

To find the `fopen` function used on MATLAB serial class objects

```
which serial/fopen
matlabroot\toolbox\matlab\iofun\@serial\fopen.m % serial method
```

To find the `setMonth` method used on objects of the Java `Date` class, the class must first be loaded into MATLAB. The class is loaded when you create an instance of the class:

```
myDate = java.util.Date;
which setMonth
```

MATLAB displays:

```
setMonth is a Java method % java.util.Date method
```

When you specify an output variable, `which` returns a cell array of strings to the variable. You must use the *function* form of `which`, enclosing all arguments in parentheses and single quotes:

```
s = which('private/stradd', '-all');
whos s
 Name Size Bytes Class
 s 3x1 562 cell array
Grand total is 146 elements using 562 bytes
```

## See Also

`dir`, `doc`, `exist`, `lookfor`, `mfilename`, `path`, `type`, `what`, `who`

|                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
|--------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Purpose</b>     | Repeatedly execute statements while condition is true                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| <b>Syntax</b>      | <code>while expression, statements, end</code>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| <b>Description</b> | <p><code>while expression, statements, end</code> repeatedly executes one or more MATLAB <i>statements</i> in a loop, continuing until <i>expression</i> no longer holds true or until MATLAB encounters a <code>break</code>, or <code>return</code> instruction, thus forcing an immediate exit of the loop. If MATLAB encounters a <code>continue</code> statement in the loop code, it immediately exits the current pass at the location of the <code>continue</code> statement, skipping any remaining code in that pass, and begins another pass at the start of the loop <i>statements</i>.</p> <p><i>expression</i> is a MATLAB expression that evaluates to a result of logical 1 (true) or logical 0 (false). <i>expression</i> can be scalar or an array. It must contain all real elements, and the statement <code>all(A(:))</code> must be equal to logical 1 for the expression to be true.</p> <p><i>expression</i> usually consists of variables or smaller expressions joined by relational operators (e.g., <code>count &lt; limit</code>) or logical functions (e.g., <code>isreal(A)</code>). Simple expressions can be combined by logical operators (<code>&amp;&amp;</code>, <code>  </code>, <code>~</code>) into compound expressions such as the following. MATLAB evaluates compound expressions from left to right, adhering to “Operator Precedence” rules.</p> <pre>(count &lt; limit) &amp;&amp; ((height - offset) &gt;= 0)</pre> <p><i>statements</i> is one or more MATLAB statements to be executed only while the <i>expression</i> is true or nonzero.</p> <p>The scope of a <code>while</code> statement is always terminated with a matching <code>end</code>.</p> <p>See “Program Control Statements” in the MATLAB Programming Fundamentals documentation for more information on controlling the flow of your program code.</p> |

## Remarks

### Nonscalar Expressions

If the evaluated expression yields a nonscalar value, then every element of this value must be true or nonzero for the entire expression to be considered true. For example, the statement `while (A < B)` is true only if each element of matrix A is less than its corresponding element in matrix B. See “Example 2 – Nonscalar Expression” on page 2-4177, below.

### Partial Evaluation of the Expression Argument

Within the context of an `if` or `while` expression, MATLAB does not necessarily evaluate all parts of a logical expression. In some cases it is possible, and often advantageous, to determine whether an expression is true or false through only partial evaluation.

For example, if A equals zero in statement 1 below, then the expression evaluates to false, regardless of the value of B. In this case, there is no need to evaluate B and MATLAB does not do so. In statement 2, if A is nonzero, then the expression is true, regardless of B. Again, MATLAB does not evaluate the latter part of the expression.

```
1) while (A && B) 2) while (A || B)
```

You can use this property to your advantage to cause MATLAB to evaluate a part of an expression only if a preceding part evaluates to the desired state. Here are some examples.

```
while (b ~= 0) && (a/b > 18.5)
 if exist('myfun.m') && (myfun(x) >= y)
 if iscell(A) && all(cellfun('isreal', A))
```

### Empty Arrays

In most cases, using `while` on an empty array returns false. There are some conditions however under which `while` evaluates as true on an empty array. Two examples of this are

```
A = [];
while all(A), do_something, end
while 1|A, do_something, end
```

## Short-Circuiting Behavior

When used in the context of a `while` or `if` expression, and only in this context, the element-wise `|` and `&` operators use short-circuiting in evaluating their expressions. That is, `A|B` and `A&B` ignore the second operand, `B`, if the first operand, `A`, is sufficient to determine the result.

See “Short-Circuiting in Elementwise Operators” for more information on this.

## Examples

### Example 1 – Simple while Statement

The variable `eps` is a tolerance used to determine such things as near singularity and rank. Its initial value is the *machine epsilon*, the distance from 1.0 to the next largest floating-point number on your machine. Its calculation demonstrates `while` loops.

```
eps = 1;
while (1+eps) > 1
 eps = eps/2;
end
eps = eps*2
```

This example is for the purposes of illustrating `while` loops only and should not be executed in your MATLAB session. Doing so will disable the `eps` function from working in that session.

### Example 2 – Nonscalar Expression

Given matrices `A` and `B`,

```
A = B =
 1 0 1 1
 2 3 3 4
```

| Expression            | Evaluates As | Because                                                    |
|-----------------------|--------------|------------------------------------------------------------|
| <code>A &lt; B</code> | false        | <code>A(1,1)</code> is not less than <code>B(1,1)</code> . |

# while

---

| Expression    | Evaluates As | Because                                                              |
|---------------|--------------|----------------------------------------------------------------------|
| $A < (B + 1)$ | true         | Every element of A is less than that same element of B with 1 added. |
| $A \& B$      | false        | $A(1,2)$ is false, and B is ignored due to short-circuiting.         |
| $B < 5$       | true         | Every element of B is less than 5.                                   |

## See Also

end, for, break, continue, return, all, any, if, switch

---

|                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
|--------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Purpose</b>     | Change axes background color                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| <b>Syntax</b>      | <pre>whitebg whitebg(fig) whitebg(ColorSpec) whitebg(fig, ColorSpec) whitebg(fig, ColorSpec) whitebg(fig)</pre>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| <b>Description</b> | <p><code>whitebg</code> complements the colors in the current figure.</p> <p><code>whitebg(fig)</code> complements colors in all figures specified in the vector <code>fig</code>.</p> <p><code>whitebg(ColorSpec)</code> and <code>whitebg(fig, ColorSpec)</code> change the color of the axes, which are children of the figure, to the color specified by <code>ColorSpec</code>. Without a figure specification, <code>whitebg</code> or <code>whitebg(ColorSpec)</code> affects the current figure and the root's default properties so subsequent plots and new figures use the new colors.</p> <p><code>whitebg(fig, ColorSpec)</code> sets the default axes background color of the figures in the vector <code>fig</code> to the color specified by <code>ColorSpec</code>. Other axes properties and the figure background color can change as well so that graphs maintain adequate contrast. <code>ColorSpec</code> can be a 1-by-3 RGB color or a color string such as 'white' or 'w'.</p> <p><code>whitebg(fig)</code> complements the colors of the objects in the specified figures. This syntax is typically used to toggle between black and white axes background colors, and is where <code>whitebg</code> gets its name. Include the root window handle (0) in <code>fig</code> to affect the default properties for new windows or for <code>clf reset</code>.</p> |
| <b>Remarks</b>     | <p><code>whitebg</code> works best in cases where all the axes in the figure have the same background color.</p> <p><code>whitebg</code> changes the colors of the figure's children, with the exception of shaded surfaces. This ensures that all objects are visible against the new background color. <code>whitebg</code> sets the default properties on the root such that all subsequent figures use the new background color.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |

# whitebg

---

## Examples

Set the background color to blue-gray.

```
whitebg([0 .5 .6])
```

Set the background color to blue.

```
whitebg('blue')
```

## See Also

ColorSpec, colordef

The figure graphics object property `InvertHardCopy`

“Color Operations” on page 1-105 for related functions



## Purpose

List variables in workspace

## Graphical Interface

As an alternative to whos, use the Workspace browser. Or use the Current Directory browser to view the contents of MAT-files without loading them.

## Syntax

```
who
whos
who(variable_list)
whos(variable_list)
who(variable_list, qualifiers)
whos(variable_list, qualifiers)
s = who(variable_list, qualifiers)
s = whos(variable_list, qualifiers)
who variable_list qualifiers
whos variable_list qualifiers
```

Each of these syntaxes applies to both who and whos:

## Description

who lists in alphabetical order all variables in the currently active workspace.

whos lists in alphabetical order all variables in the currently active workspace along with their sizes and types. It also reports the totals for sizes.

---

**Note** If who or whos is executed within a nested function, the MATLAB software lists the variables in the workspace of that function and in the workspaces of all functions containing that function. See the Remarks section, below.

---

who(variable\_list) and whos(variable\_list) list only those variables specified in variable\_list, where variable\_list is a comma-delimited list of quoted strings: 'var1', 'var2', ..., 'varN'. You can use the wildcard character \* to display variables that

# who, whos

---

match a pattern. For example, `who('A*')` finds all variables in the current workspace that start with A.

`who(variable_list, qualifiers)` and `whos(variable_list, qualifiers)` list those variables in `variable_list` that meet all qualifications specified in `qualifiers`. You can specify any or all of the following qualifiers, and in any order.

| Qualifier Syntax       | Description                                                                         | Example                                       |
|------------------------|-------------------------------------------------------------------------------------|-----------------------------------------------|
| 'global'               | List variables in the global workspace.                                             | <code>whos('global')</code>                   |
| '-file',<br>filename   | List variables in the specified MAT-file. Use the full path for filename.           | <code>whos('-file', 'mydata')</code>          |
| '-regexp',<br>exprlist | List variables that match any of the regular expressions in <code>exprlist</code> . | <code>whos('-regexp', '[AB].', '\w\d')</code> |

`s = who(variable_list, qualifiers)` returns cell array `s` containing the names of the variables specified in `variable_list` that meet the conditions specified in `qualifiers`.

`s = whos(variable_list, qualifiers)` returns structure `s` containing the following fields for the variables specified in `variable_list` that meet the conditions specified in `qualifiers`:

| Field Name | Description                                                                           |
|------------|---------------------------------------------------------------------------------------|
| name       | Name of the variable                                                                  |
| size       | Dimensions of the variable array                                                      |
| bytes      | Number of bytes allocated for the variable array                                      |
| class      | Class of the variable. Set to the string '(unassigned)' if the variable has no value. |

| Field Name | Description                                                                                                                                                                                                                                      |
|------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| global     | True if the variable is global; otherwise false                                                                                                                                                                                                  |
| sparse     | True if the variable is sparse; otherwise false                                                                                                                                                                                                  |
| complex    | True if the variable is complex; otherwise false                                                                                                                                                                                                 |
| nesting    | Structure having the following fields: <ul style="list-style-type: none"> <li>• <code>function</code> — Name of the nested or outer function that defines the variable</li> <li>• <code>level</code> — Nesting level of that function</li> </ul> |
| persistent | True if the variable is persistent; otherwise false                                                                                                                                                                                              |

`who variable_list` `qualifiers` and `whos variable_list` `qualifiers` are the unquoted forms of the syntax. Both `variable_list` and `qualifiers` are space-delimited lists of unquoted strings.

## Remarks

**Nested Functions.** When you use `who` or `whos` inside of a nested function, MATLAB returns or displays all variables in the workspace of that function, and in the workspaces of all functions in which that function is nested. This applies whether you include calls to `who` or `whos` in your M-file code or if you call `who` or `whos` from the MATLAB debugger.

If your code assigns the output of `whos` to a variable, MATLAB returns the information in a structure array containing the fields described above. If you do not assign the output to a variable, MATLAB displays the information at the Command Window, grouped according to workspace.

If your code assigns the output of `who` to a variable, MATLAB returns the variable names in a cell array of strings. If you do not assign the output, MATLAB displays the variable names at the Command Window, but not grouped according to workspace.

**Compressed Data.** Information returned by the command `whos -file` is independent of whether the data in that file is compressed or not. The byte counts returned by this command represent the number of bytes data occupies in the MATLAB workspace, and not in the file the data was saved to. See the function reference for `save` for more information on data compression.

**MATLAB Objects.** `whos -file filename` does not return the sizes of any MATLAB objects that are stored in file *filename*.

## Examples

### Example 1

Show variable names starting with the letter a:

```
who a*
```

Show variables stored in MAT-file `mydata.mat`:

```
who -file mydata
```

### Example 2

Return information on variables stored in file `mydata.mat` in structure array `s`:

```
s = whos('-file', 'mydata1')
s =
6x1 struct array with fields:
 name
 size
 bytes
 class
 global
 sparse
 complex
 nesting
 persistent
```

Display the name, size, and class of each of the variables returned by whos:

```
for k=1:length(s)
disp([' ' s(k).name ' ' mat2str(s(k).size) ' ' s(k).class])
end
A [1 1] double
spArray [5 5] double
strArray [2 5] cell
x [3 2 2] double
y [4 5] cell
```

### Example 3

Show variables that start with java and end with Array. Also show their dimensions and class name:

```
whos -file mydata2 -regexp \<java.*Array\>
Name Size Bytes Class

javaCharArray 3x1 24 java.lang.String[][][]
javaDb1Array 4x1 32 java.lang.Double[][]
javaIntArray 14x1 112 java.lang.Integer[][]
```

### Example 4

The function shown here uses variables with persistent, global, sparse, and complex attributes:

```
function show_attributes
persistent p;
global g;
o = 1; g = 2;
s = sparse(eye(5));
c = [4+5i 9-3i 7+6i];
whos
```

When the function is run, whos displays these attributes:

```
show_attributes
```

# who, whos

---

| Name | Size | Bytes | Class  | Attributes |
|------|------|-------|--------|------------|
| c    | 1x3  | 48    | double | complex    |
| g    | 1x1  | 8     | double | global     |
| p    | 1x1  | 8     | double | persistent |
| s    | 5x5  | 84    | double | sparse     |

## Example 5

Function `whos_demo` contains two nested functions. One of these functions calls `whos`; the other calls `who`:

```
function whos_demo
date_time = datestr(now);

[str pos] = textscan(date_time, '%s%s%s', ...
 1, 'delimiter', '- :');
get_date(str);

str = textscan(date_time(pos+1:end), '%s%s%s', ...
 1, 'delimiter', '- :');
get_time(str);

function get_date(d)
 day = d{1}; mon = d{2}; year = d{3};
 whos
end
function get_time(t)
 hour = t{1}; min = t{2}; sec = t{3};
 who
end
end
```

When nested function `get_date` calls `whos`, MATLAB displays information on the variables in all workspaces that are in scope at the time. This includes nested function `get_date` and also the function in which it is nested, `whos_demo`. The information is grouped by workspace:

```

whos_demo
 Name Size Bytes Class

---- get_date ----
 d 1x3 378 cell
 day 1x1 64 cell
 mon 1x1 66 cell
 year 1x1 68 cell

---- whos_demo ----
 ans 0x0 0 (unassigned)
 date_time 1x20 40 char
 pos 1x1 8 double
 str 1x3 378 cell

```

When nested function `get_time` calls `who`, MATLAB displays names of the variables in the workspaces that are in scope at the time. This includes nested function `get_time` and also the function in which it is nested, `whos_demo`. The information is not grouped by workspace in this case:

Your variables are:

```

hour min sec t ans date_time
pos str

```

## See Also

`assignin`, `clear`, `computer`, `dir`, `evalin`, `exist`, `inmem`, `load`, `save`, `what`, `workspace`

“MATLAB Workspace” in the Desktop Tools and Development Environment documentation

# wilkinson

---

**Purpose** Wilkinson's eigenvalue test matrix

**Syntax** `W = wilkinson(n)`

**Description** `W = wilkinson(n)` returns one of J. H. Wilkinson's eigenvalue test matrices. It is a symmetric, tridiagonal matrix with pairs of nearly, but not exactly, equal eigenvalues.

**Examples** `wilkinson(7)`

```
ans =

 3 1 0 0 0 0 0
 1 2 1 0 0 0 0
 0 1 1 1 0 0 0
 0 0 1 0 1 0 0
 0 0 0 1 1 1 0
 0 0 0 0 1 2 1
 0 0 0 0 0 1 3
```

The most frequently used case is `wilkinson(21)`. Its two largest eigenvalues are both about 10.746; they agree to 14, but not to 15, decimal places.

**See Also** `eig`, `gallery`, `pascal`



**Purpose** Open file in appropriate application (Windows)

**Syntax** `winopen(filename)`

**Description** `winopen(filename)` opens `filename` in the appropriate Microsoft Windows application. The `filename` input is a string enclosed in single quotes. The `winopen` function uses the appropriate Windows shell command, and performs the same action as if you double-click the file in the Windows Explorer program. If `filename` is not in the current directory, specify the absolute path for `filename`.

**Examples** Open the file `thesis.doc`, located in the current directory, in the Microsoft Word program:

```
winopen('thesis.doc')
```

Open `myresults.html` in your system Web browser:

```
winopen('D:/myfiles/myresults.html')
```

**See Also** `dos`, `open`, `web`

# winqueryreg

---

**Purpose** Item from Windows registry

**Syntax**

```
valnames = winqueryreg('name', 'rootkey', 'subkey')
value = winqueryreg('rootkey', 'subkey', 'valname')
value = winqueryreg('rootkey', 'subkey')
```

**Description** `valnames = winqueryreg('name', 'rootkey', 'subkey')` returns all value names in `rootkey\subkey` of Microsoft Windows operating system registry to a cell array of strings. The first argument is the literal quoted string, 'name'.

`value = winqueryreg('rootkey', 'subkey', 'valname')` returns the value for value name `valname` in `rootkey\subkey`.

If the value retrieved from the registry is a string, `winqueryreg` returns a string. If the value is a 32-bit integer, `winqueryreg` returns the value as an integer of the MATLAB software type `int32`.

`value = winqueryreg('rootkey', 'subkey')` returns a value in `rootkey\subkey` that has no value name property.

---

**Note** The literal **name** argument and the `rootkey` argument are case-sensitive. The `subkey` and `valname` arguments are not.

---

**Remarks** This function works only for the following registry value types:

- strings (REG\_SZ)
- expanded strings (REG\_EXPAND\_SZ)
- 32-bit integer (REG\_DWORD)

## Examples

### Example 1

Get the value of CLSID for the MATLAB sample Microsoft COM control `mwsampctrl.2`:

```
winqueryreg 'HKEY_CLASSES_ROOT' 'mwsamp.mwsampctrl.2\clsid'
```

```
ans =
 {5771A80A-2294-4CAC-A75B-157DCDDD3653}
```

## Example 2

Get a list in variable `mousechar` for registry subkey `Mouse`, which is under subkey `Control Panel`, which is under root key `HKEY_CURRENT_USER`.

```
mousechar = winqueryreg('name', 'HKEY_CURRENT_USER', ...
 'control panel\mouse');
```

For each name in the `mousechar` list, get its value from the registry and then display the name and its value:

```
for k=1:length(mousechar)
 setting = winqueryreg('HKEY_CURRENT_USER', ...
 'control panel\mouse', mousechar{k});
 str = sprintf('%s = %s', mousechar{k}, num2str(setting));
 disp(str)
end
```

```
ActiveWindowTracking = 0
DoubleClickHeight = 4
DoubleClickSpeed = 830
DoubleClickWidth = 4
MouseSpeed = 1
MouseThreshold1 = 6
MouseThreshold2 = 10
SnapToDefaultButton = 0
SwapMouseButtons = 0
```

# wk1finfo

---

**Purpose** Determine whether file contains 1-2-3 WK1 worksheet

**Syntax** `[extens, typ] = wk1finfo(filename)`

**Description** `[extens, typ] = wk1finfo(filename)` returns the string 'WK1' in `extens`, and ' 1-2-3 Spreadsheet' in `typ` if the file `filename` contains a readable worksheet. The `filename` input is a string enclosed in single quotes.

**Examples** This example returns information on spreadsheet file `matA.wk1`:

```
[extens, typ] = wk1finfo('matA.wk1')

extens =
 WK1
typ =
 123 Spreadsheet
```

**See Also** `wk1read`, `wk1write`, `csvread`, `csvwrite`

**Purpose** Read Lotus 1-2-3 WK1 spreadsheet file into matrix

**Syntax**

```
M = wk1read(filename)
M = wk1read(filename,r,c)
M = wk1read(filename,r,c,range)
```

**Description**

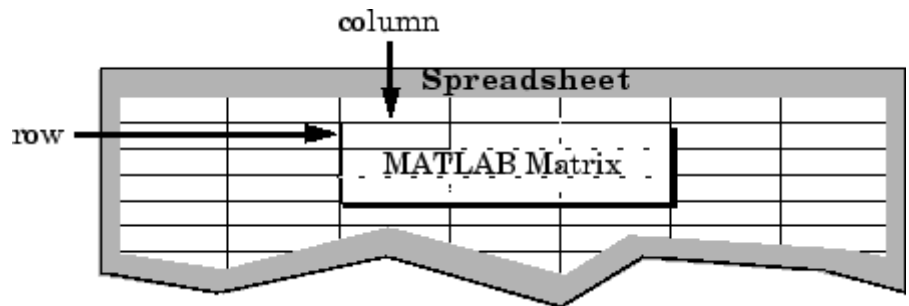
`M = wk1read(filename)` reads a Lotus1-2-3 WK1 spreadsheet file into the matrix `M`. The `filename` input is a string enclosed in single quotes.

`M = wk1read(filename,r,c)` starts reading at the row-column cell offset specified by `(r,c)`. `r` and `c` are zero based so that `r=0, c=0` specifies the first value in the file.

`M = wk1read(filename,r,c,range)` reads the range of values specified by the parameter `range`, where `range` can be

- A four-element vector specifying the cell range in the format

```
[upper_left_row upper_left_col lower_right_row lower_right_col]
```



- A cell range specified as a string, for example, 'A1...C5'
- A named range specified as a string, for example, 'Sales'

**Examples** Create a 8-by-8 matrix `A` and export it to Lotus spreadsheet `matA.wk1`:

```
A = [1:8; 11:18; 21:28; 31:38; 41:48; 51:58; 61:68; 71:78]
A =
```

# wk1read

---

```
 1 2 3 4 5 6 7 8
 11 12 13 14 15 16 17 18
 21 22 23 24 25 26 27 28
 31 32 33 34 35 36 37 38
 41 42 43 44 45 46 47 48
 51 52 53 54 55 56 57 58
 61 62 63 64 65 66 67 68
 71 72 73 74 75 76 77 78
```

```
wk1write('matA.wk1', A);
```

To read in a limited block of the spreadsheet data, specify the upper left row and column of the block using zero-based indexing:

```
M = wk1read('matA.wk1', 3, 2)
M =
 33 34 35 36 37 38
 43 44 45 46 47 48
 53 54 55 56 57 58
 63 64 65 66 67 68
 73 74 75 76 77 78
```

To select a more restricted block of data, you can specify both the upper left and lower right corners of the block you want imported. Read in a range of values from row 4, column 3 (defining the upper left corner) to row 6, column 6 (defining the lower right corner). Note that, unlike the second and third arguments, the range argument [4 3 6 6] is one-based:

```
M = wk1read('matA.wk1', 3, 2, [4 3 6 6])
M =
 33 34 35 36
 43 44 45 46
 53 54 55 56
```

## See Also

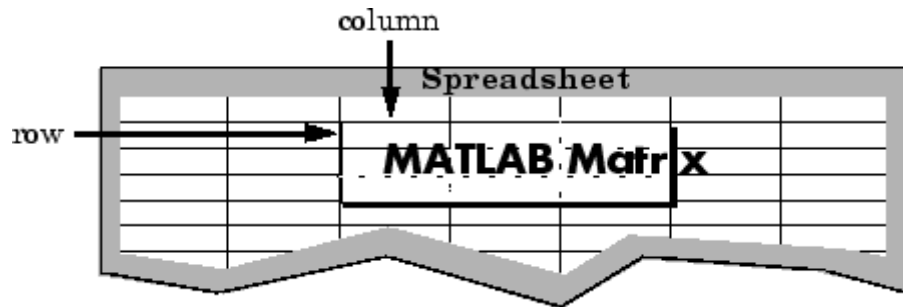
wk1write

**Purpose** Write matrix to Lotus 1-2-3 WK1 spreadsheet file

**Syntax**  
`wk1write(filename,M)`  
`wk1write(filename,M,r,c)`

**Description** `wk1write(filename,M)` writes the matrix `M` into a Lotus1-2-3 WK1 spreadsheet file named `filename`. The `filename` input is a string enclosed in single quotes.

`wk1write(filename,M,r,c)` writes the matrix starting at the spreadsheet location `(r,c)`. `r` and `c` are zero based so that `r=0, c=0` specifies the first cell in the spreadsheet.



**Examples** Write a 4-by-5 matrix `A` to spreadsheet file `matA.wk1`. Place the matrix with its upper left corner at row 2, column 3 using zero-based indexing:

```
A = [1:5; 11:15; 21:25; 31:35]
```

```
A =
```

```

 1 2 3 4 5
 11 12 13 14 15
 21 22 23 24 25
 31 32 33 34 35
```

```
wk1write('matA.wk1', A, 2, 3)
```

```
M = wk1read('matA.wk1')
```

```
M =
```

# wk1write

---

```
0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0
0 0 0 1 2 3 4 5
0 0 0 11 12 13 14 15
0 0 0 21 22 23 24 25
0 0 0 31 32 33 34 35
```

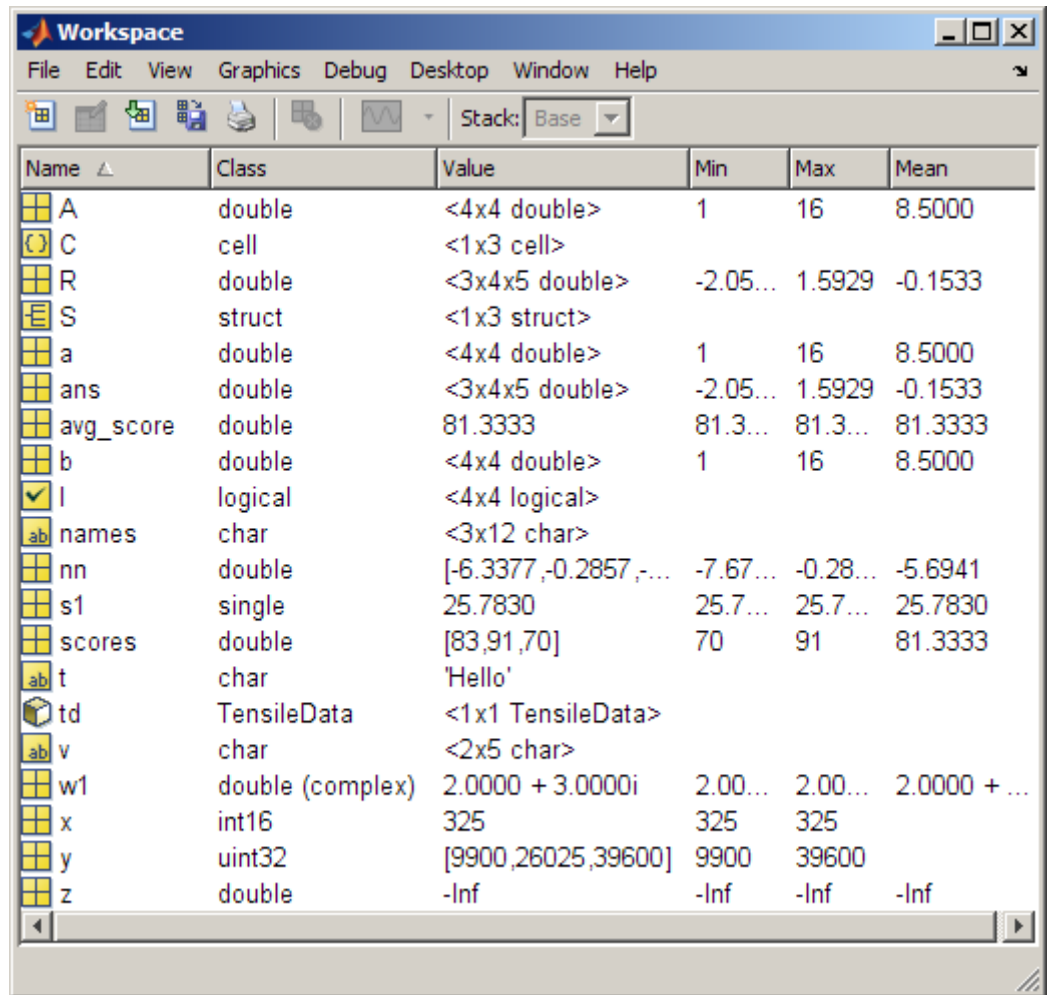
## See Also

`wk1read`, `d1mwrite`, `d1mread`, `csvwrite`, `csvread`



|                         |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|-------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Purpose</b>          | Open Workspace browser to manage workspace                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| <b>GUI Alternatives</b> | As an alternative to the <code>workspace</code> function, select <b>Desktop &gt; Workspace</b> in the MATLAB desktop.                                                                                                                                                                                                                                                                                                                                                                                                                           |
| <b>Syntax</b>           | <code>workspace</code>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| <b>Description</b>      | <p><code>workspace</code> displays the Workspace browser, a graphical user interface that allows you to view and manage the contents of the workspace in MATLAB. It provides a graphical representation of the <code>whos</code> display, and allows you to perform the equivalent of the <code>clear</code>, <code>load</code>, <code>open</code>, and <code>save</code> functions.</p> <p>The Workspace browser also displays and automatically updates statistical calculations for each variable, which you can choose to show or hide.</p> |

# workspace



You can edit a value directly in the Workspace browser for small numeric and character arrays. To see and edit a graphical representation of larger variables and for other classes, double-click the variable in the Workspace browser. The variable displays in the Variable Editor, where you can view the full contents and make changes.

**See Also**


openvar, who

“MATLAB Workspace”

# xlabel, ylabel, zlabel

---

**Purpose** Label  $x$ -,  $y$ -, and  $z$ -axis

**GUI Alternative** To control the presence and appearance of axis labels on a graph, use the Property Editor, one of the plotting tools . For details, see The Property Editor in the MATLAB Graphics documentation.

**Syntax**

```
xlabel('string')
xlabel(fname)
xlabel(..., 'PropertyName', PropertyValue, ...)
xlabel(axes_handle, ...)
h = xlabel(...)
```

```
ylabel(...)
ylabel(axes_handle, ...)
h = ylabel(...)
```

```
zlabel(...)
zlabel(axes_handle, ...)
h = zlabel(...)
```

**Description** Each axes graphics object can have one label for the  $x$ -,  $y$ -, and  $z$ -axis. The label appears beneath its respective axis in a two-dimensional plot and to the side or beneath the axis in a three-dimensional plot.

`xlabel('string')` labels the  $x$ -axis of the current axes.

`xlabel(fname)` evaluates the function `fname`, which must return a string, then displays the string beside the  $x$ -axis.

`xlabel(..., 'PropertyName', PropertyValue, ...)` specifies property name and property value pairs for the text graphics object created by `xlabel`.

`xlabel(axes_handle,...)`, `ylabel(axes_handle,...)`, and `zlabel(axes_handle,...)` plot into the axes with handle `axes_handle` instead of the current axes (`gca`).

`h = xlabel(...)`, `h = ylabel(...)`, and `h = zlabel(...)` return the handle to the text object used as the label.

`ylabel(...)` and `zlabel(...)` label the *y*-axis and *z*-axis, respectively, of the current axes.

## Remarks

Reissuing an `xlabel`, `ylabel`, or `zlabel` command causes the new label to replace the old label.

For three-dimensional graphics, MATLAB puts the label in the front or side, so that it is never hidden by the plot.

## Examples

Create a multiline label for the *x*-axis using a multiline cell array:

```
xlabel({'first line';'second line'})
```

Create a bold label for the *y*-axis that contains a single quote:

```
ylabel('George''s Popularity','fontsize',12,'fontweight','b')
```

## See Also

`strings`, `text`, `title`

“Annotating Plots” on page 1-94 for related functions

“Adding Axis Labels to Graphs” for more information about labeling axes


# xlim, ylim, zlim

---

## Purpose

Set or query axis limits

## GUI Alternative

To control the upper and lower axis limits on a graph, use the Property Editor, one of the plotting tools . For details, see The Property Editor in the MATLAB Graphics documentation.

## Syntax

```
xlim
xlim([xmin xmax])
xlim('mode')
xlim('auto')
xlim('manual')
xlim(axes_handle,...)
```

Note that the syntax for each of these three functions is the same; only the `xlim` function is used for simplicity. Each operates on the respective  $x$ -,  $y$ -, or  $z$ -axis.

## Description

`xlim` with no arguments returns the respective limits of the current axes.

`xlim([xmin xmax])` sets the axis limits in the current axes to the specified values.

`xlim('mode')` returns the current value of the axis limits mode, which can be either `auto` (the default) or `manual`.

`xlim('auto')` sets the axis limit mode to `auto`.

`xlim('manual')` sets the respective axis limit mode to `manual`.

`xlim(axes_handle,...)` performs the set or query on the axes identified by the first argument, `axes_handle`. When you do not specify an axes handle, these functions operate on the current axes.

## Remarks

`xlim`, `ylim`, and `zlim` set or query values of the axes object `XLim`, `YLim`, `ZLim`, and `XLimMode`, `YLimMode`, `ZLimMode` properties.

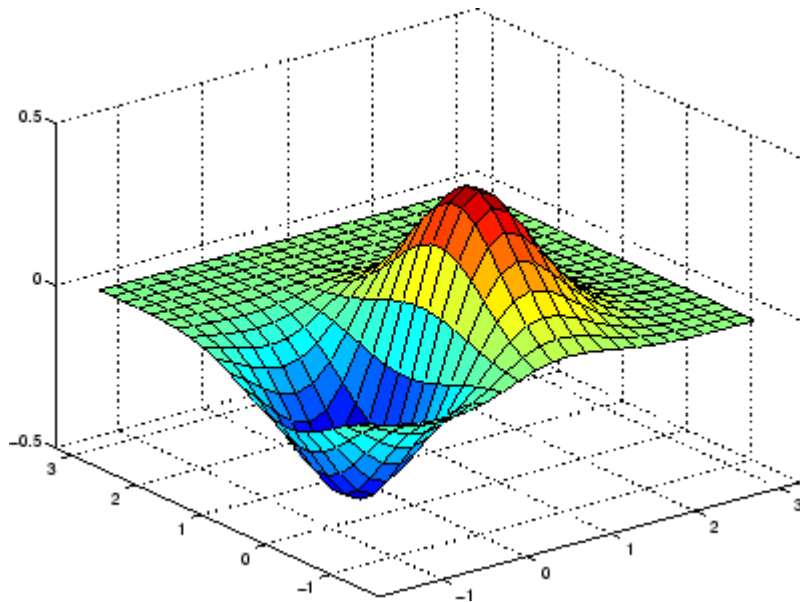
When the axis limit modes are `auto` (the default), MATLAB uses limits that span the range of the data being displayed and are round numbers.

Setting a value for any of the limits also sets the corresponding mode to manual. Note that high-level plotting functions like `plot` and `surf` reset both the modes and the limits. If you set the limits on an existing graph and want to maintain these limits while adding more graphs, use the `hold` command.

## Examples

This example illustrates how to set the  $x$ - and  $y$ -axis limits to match the actual range of the data, rather than the rounded values of  $[-2\ 3]$  for the  $x$ -axis and  $[-2\ 4]$  for the  $y$ -axis originally selected by MATLAB.

```
[x,y] = meshgrid([-1.75:.2:3.25]);
z = x.*exp(-x.^2-y.^2);
surf(x,y,z)
xlim([-1.75 3.25])
ylim([-1.75 3.25])
```



# xlim, ylim, zlim

---

## See Also

axis

The axes properties XLim, YLim, ZLim

“Aspect Ratio and Axis Limits” on page 1-107 for related functions

Understanding Axes Aspect Ratio for more information on how axis limits affect the axes



---

|                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
|--------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Purpose</b>     | Determine whether file contains a Microsoft Excel spreadsheet                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| <b>Syntax</b>      | <pre>typ = xlsinfo(filename) [typ, desc] = xlsinfo(filename) [typ, desc, fmt] = xlsinfo(filename) xlsinfo filename</pre>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| <b>Description</b> | <p><code>typ = xlsinfo(filename)</code> returns the string 'Microsoft Excel Spreadsheet' if the file specified by <code>filename</code> is an Excel file that can be read by the MATLAB <code>xlsread</code> function. Otherwise, <code>typ</code> is the empty string, (''). The <code>filename</code> input is a string enclosed in single quotation marks.</p> <p><code>[typ, desc] = xlsinfo(filename)</code> returns in <code>desc</code> a cell array of strings containing the names of each spreadsheet in the file. If a spreadsheet is unreadable, the cell in <code>desc</code> that represents that spreadsheet contains an error message.</p> <p><code>[typ, desc, fmt] = xlsinfo(filename)</code> returns in the <code>fmt</code> output a string containing the Excel-reported file format. On UNIX systems, or on Windows systems without Excel software installed, <code>xlsinfo</code> returns <code>fmt</code> as an empty string, ('').</p> <p><code>xlsinfo filename</code> is the command format for <code>xlsinfo</code>. It returns only the first output, <code>typ</code>, assigning it to the MATLAB default variable <code>ans</code>.</p> |
| <b>Remarks</b>     | If your system has Excel for Windows installed, <code>xlsinfo</code> uses the COM server to obtain information. This server is part of the typical installation of Excel for Windows. If the COM server is unavailable, <code>xlsinfo</code> returns a warning indicating that it cannot start an ActiveX server. To establish connectivity with the COM server, you might need to reinstall your Excel software.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| <b>Examples</b>    | Get information about an .xls file:<br><pre>[typ, desc, fmt] = xlsinfo('myaccount.xls')</pre>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |

# xlsfinfo

---

```
typ =
 Microsoft Excel Spreadsheet

desc =
 'Sheet1' 'Income' 'Expenses'

fmt =
 xlWorkbookNormal
```

Export the .xls file to comma-separated value (CSV) format. Use `xlsfinfo` to see the format of the exported file:

```
[typ, desc, fmt] = xlsfinfo('myaccount.csv');
fmt

fmt =
 xlCSV
```

Export the .xls file to HTML format. `xlsfinfo` returns the following format string:

```
[typ, desc, fmt] = xlsfinfo('myaccount.html');
fmt

fmt =
 xlHtml
```

Export the .xls file to XML format. `xlsfinfo` returns the following format string:

```
[typ, desc, fmt] = xlsfinfo('myaccount.xml');
fmt

fmt =
 xlXMLSpreadsheet
```

## See Also

`xlsread`, `xlswrite`

**Purpose**

Read Microsoft Excel spreadsheet file

**Syntax**

```
num = xlsread(filename)
num = xlsread(filename, -1)
num = xlsread(filename, sheet)
num = xlsread(filename, range)
num = xlsread(filename, sheet, range)
num = xlsread(filename, sheet, range, 'basic')
num = xlsread(filename, ..., functionhandle)
[num, txt]= xlsread(filename, ...)
[num, txt, raw] = xlsread(filename, ...)
[num, txt, raw, X] = xlsread(filename, ..., functionhandle)
xlsread filename sheet range basic
```

**Description**

`num = xlsread(filename)` returns numeric data in double array `num` from the first sheet in the Microsoft Excel spreadsheet file named `filename`. The `filename` argument is a string enclosed in single quotation marks.

`xlsread` ignores any *outer* rows or columns of the spreadsheet that contain no numeric data. If there are single or multiple nonnumeric rows at the top or bottom, or single or multiple nonnumeric columns to the left or right, `xlsread` does not include these rows or columns in the output. For example, `xlsread` ignores one or more header lines appearing at the top of a spreadsheet.

Any *inner* rows or columns in which some or all cells contain nonnumeric data are *not* ignored. Instead, `xlsread` assigns a value of NaN to the nonnumeric cells.

`num = xlsread(filename, -1)` opens the file `filename` in an Excel window, enabling you to interactively select the worksheet to read and the range of data on that worksheet to import.

To import an entire worksheet, first select the sheet in the Excel window, and then click the **OK** button in the Data Selection Dialog box. To import a certain range of data from the sheet, select the worksheet in the Excel window, drag and drop the mouse over the desired range, and then click **OK**. (See “COM Server Requirements” on page 2-4210 below.)

`num = xlsread(filename, sheet)` reads the specified worksheet, where `sheet` is either a positive, double scalar value or a quoted string containing the sheet name. To determine the names of the sheets in a spreadsheet file, use `xlsfinfo`.

`num = xlsread(filename, range)` reads data from a specific rectangular region of the default worksheet (`Sheet1`). (See “COM Server Requirements” on page 2-4210 below.)

Specify `range` using the syntax '`C1:C2`', where `C1` and `C2` are two opposing corners that define the region to be read. For example, '`D2:H4`' represents the 3-by-5 rectangular region between the two corners `D2` and `H4` on the worksheet. The range input is not case sensitive and uses Excel A1 reference style. For more information on this reference style, see Excel help.

---

**Note** If you specify only two inputs, `xlsread` must decide whether the second input refers to a `sheet` or a `range`. To specify a range (even a range of a single cell), include a colon character in the input string (e.g., '`D2:H4`'). If you do not include a colon character (e.g., '`sales`' or '`D2`'), `xlsread` interprets the second input as the name or index of a worksheet.

---

`num = xlsread(filename, sheet, range)` reads data from a specific rectangular region (`range`) of the worksheet specified by `sheet`. If you specify both `sheet` and `range`, `range` can refer to a named range that you defined in the Excel file. (For more information on named ranges, see the Excel help.) See the previous two syntax formats for further explanation of the `sheet` and `range` inputs. (Also, see “COM Server Requirements” on page 2-4210 below.)

`num = xlsread(filename, sheet, range, 'basic')` imports data from the spreadsheet in basic import mode. `xlsread` uses this mode on systems where Excel software is not installed. Import ability is limited. `xlsread` ignores the value for `range` and, consequently, imports the whole active range of a sheet. (You can set `range` to the empty string

(' ').) Also, in basic mode, `sheet` is case sensitive and must be a quoted string.

`num = xlsread(filename, ..., functionhandle)` calls the function associated with `functionhandle` just prior to obtaining spreadsheet values. This enables you to operate on the spreadsheet data (for example, convert it to a numeric type) before reading it in. (See “COM Server Requirements” on page 2-4210 below.)

You can write your own custom function and pass a handle to this function to `xlsread`. When `xlsread` executes, it reads from the spreadsheet, executes your function on the data read from the spreadsheet, and returns the final results to you. When `xlsread` calls your function, it passes a range interface from the Excel application to provide access to the data read from the spreadsheet. Your function must include this interface both as an input and output argument. Example 5 below shows how you might use this syntax.

For more information, see “Function Handles” in the MATLAB Programming Fundamentals documentation.

`[num, txt]= xlsread(filename, ...)` returns numeric data in array `num` and text data in cell array `txt`. All cells in `txt` that correspond to numeric data contain the empty string.

`[num, txt, raw] = xlsread(filename, ...)` returns numeric and text data in `num` and `txt`, and unprocessed cell content in cell array `raw`, which contains both numeric and text data. (See “COM Server Requirements” on page 2-4210 below.)

If the Excel file includes cells with undefined values (such as '#N/A'), `xlsread` returns these values as '#N/A' in the `txt` output, and as 'ActiveX VT\_ERROR:' in the `raw` output.

`[num, txt, raw, X] = xlsread(filename, ..., functionhandle)` calls the function associated with `functionhandle` just prior to reading from the spreadsheet file. This syntax returns one additional output `X` from the function mapped to by `functionhandle`. Example 6 below shows how you might use this syntax. (See “COM Server Requirements” on page 2-4210 below.)

`xlsread filename sheet range basic` is an example of the command format for `xlsread`, showing its usage with all input arguments specified. When using this format, you must specify `sheet` as a string, (for example, `Income` or `Sheet4`) and not a numeric index. If the sheet name contains space characters, then quotation marks are required around the string, (for example, `'Income 2002'`).

## Remarks

### COM Server Requirements

The typical installation of Excel for Windows includes the ability to start a COM server. With Excel for Windows installed, you can use `xlsread` to read any file format recognized by your version of Excel, including XLS, XLSX, XLSB, XLSM, and HTML-based formats.

If your system does not have Excel for Windows installed, or MATLAB cannot access the COM server, `xlsread` operates in basic mode. In this mode, `xlsread` only reads XLS files.

The following five syntax formats are supported only on computer systems able to start a COM server from a MATLAB session. They are not supported in basic mode.

```
num = xlsread(filename, -1)
num = xlsread(filename, 'range')
num = xlsread(filename, sheet, 'range')
num = xlsread(filename, ..., functionhandle)
[num, txt, raw, opt] = xlsread(filename, ..., functionhandle)
```

### Handling Excel Date Values

MATLAB functions import all formatted dates as strings. To import a numeric date, the date field in Excel must have a numeric format.

Both Excel and MATLAB applications represent numeric dates as a number of serial days elapsed from a specific reference date. However, Excel and MATLAB use different reference dates:

| Application | Reference Date  |
|-------------|-----------------|
| MATLAB      | January 0, 0000 |

| <b>Application</b>      | <b>Reference Date</b> |
|-------------------------|-----------------------|
| Excel for Windows       | January 1, 1900       |
| Excel for the Macintosh | January 2, 1904       |

Therefore, you must convert any numeric date that you import before you process it in MATLAB. For more information, see “Converting Dates” in the MATLAB Programming Fundamentals documentation.

Consider using the `functionhandle` parameter for this conversion, discussed in the Syntax Description and in Example 5 and Example 6.

## Examples

### Example 1 – Reading Numeric Data

The Microsoft Excel spreadsheet file `testdata1.xls` contains this data:

```
1 6
2 7
3 8
4 9
5 10
```

To read this data into MATLAB, use this command:

```
A = xlsread('testdata1.xls')
A =
 1 6
 2 7
 3 8
 4 9
 5 10
```

### Example 2 – Handling Text Data

The Microsoft Excel spreadsheet file `testdata2.xls` contains a mix of numeric and text data:

```
1 6
2 7
3 8
```

```
4 9
5 text
```

xlsread puts a NaN in place of the text data in the result:

```
A = xlsread('testdata2.xls')
A =
 1 6
 2 7
 3 8
 4 9
 5 NaN
```

### Example 3 – Selecting a Range of Data

To import only rows 4 and 5 from worksheet 1, specify the range as 'A4:B5':

```
A = xlsread('testdata2.xls', 1, 'A4:B5')

A =
 4 9
 5 NaN
```

### Example 4 – Handling Files with Row or Column Headers

A Microsoft Excel spreadsheet labeled Temperatures in file tempdata.xls contains two columns of numeric data with text headers for each column:

```
Time Temp
12 98
13 99
14 97
```

If you want to import only the numeric data, use xlsread with a single return argument. Specify the filename and sheet name as inputs.

xlsread ignores any leading row or column of text in the numeric result.

```
ndata = xlsread('tempdata.xls', 'Temperatures')
```



```
ndata =
 12 98
 13 99
 14 97
```

To import both the numeric data and the text data, specify two return values for `xlsread`:

```
[ndata, headertext] = xlsread('tempdata.xls', 'Temperatures')

ndata =
 12 98
 13 99
 14 97

headertext =
 'Time' 'Temp'
```

### Example 5 – Passing a Function Handle

This example calls `xlsread` twice, the first time as a simple read from a file, and the second time requesting that `xlsread` execute some user-defined modifications on the data prior to returning the results of the read. A user-written function, `setMinMax`, that you pass as a function handle in the call to `xlsread`, performs these modifications. When `xlsread` executes, it reads from the spreadsheet, executes the function on the data read from the spreadsheet, and returns the final results to you.

---

**Note** The function passed to `xlsread` operates on the copy of the data read from the spreadsheet. It does not modify data in the spreadsheet itself.

---

Read a 10-by-3 numeric array from Excel spreadsheet `testsheet.xls` with a simple `xlsread` statement that does not pass a function handle. The returned values range from -587 to +4,149:

```
arr = xlsread('testsheet.xls')
arr =
 1.0e+003 *
 1.0020 4.1490 0.2300
 1.0750 0.1220 -0.4550
 -0.0301 3.0560 0.2471
 0.4070 0.1420 -0.2472
 2.1160 -0.0557 -0.5870
 0.4040 2.9280 0.0265
 0.1723 3.4440 0.1112
 4.1180 0.1820 2.8630
 0.9000 0.0573 1.9750
 0.0163 0.2000 -0.0223
```

In preparation for the second part of this example, write a function `setMinMax` that restricts the values returned from the read to be in the range of 0 to 2000. You need to pass this function in the call to `xlsread`, which then executes the function on the data it has read before returning it to you.

When `xlsread` calls your function, it passes an Excel range interface to provide access to the data read from the spreadsheet. This is shown as `DataRange` in this example. Your function must include this interface both as an input and output argument. The output argument allows your function to pass modified data back to `xlsread`:

```
function [DataRange] = setMinMax(DataRange)
maxval = 2000; minval = 0;

for k = 1:DataRange.Count
 v = DataRange.Value{k};
 if v > maxval || v < minval
 if v > maxval
 DataRange.Value{k} = maxval;
```

```

 else
 DataRange.Value{k} = minval;
 end
 end
end
end

```

Now call `xlsread`, passing a function handle for the `setMinMax` function as the final argument. After this call, all values are between 0 and 2000:

```

arr = xlsread('testsheet.xls', '', '', '', @setMinMax)
arr =
 1.0e+003 *
 1.0020 2.0000 0.2300
 1.0750 0.1220 0
 0 2.0000 0.2471
 0.4070 0.1420 0
 2.0000 0 0
 0.4040 2.0000 0.0265
 0.1723 2.0000 0.1112
 2.0000 0.1820 2.0000
 0.9000 0.0573 1.9750
 0.0163 0.2000 0

```

### Example 6 – Passing a Function Handle with Additional Output

This example adds onto the previous one by returning an additional output from the call to `setMinMax`. Modify the function so that it not only limits the range of values returned, but also returns the indices of the altered elements. Return this information in a new output argument, `indices`:

```

function [DataRange, indices] = setMinMax(DataRange)
maxval = 2000; minval = 0;
indices = [];

for k = 1:DataRange.Count
 v = DataRange.Value{k};
 if v > maxval || v < minval

```

# xlsread

---

```
 if v > maxval
 DataRange.Value{k} = maxval;
 else
 DataRange.Value{k} = minval;
 end
 indices = [indices k];
 end
end
```

When you call `xlsread` this time, account for the three initial outputs, and add a fourth called `idx` to accept the indices returned from `setMinMax`:

```
[arr txt raw idx] = xlsread('testsheet.xls', ...
 '', '', '', @setMinMax);

idx
idx =
 3 5 8 11 13 15 16 17 22 24 25 28 30
arr
arr =
 1.0e+003 *
 1.0020 2.0000 0.2300
 1.0750 0.1220 0
 0 2.0000 0.2471
 0.4070 0.1420 0
 2.0000 0 0
 0.4040 2.0000 0.0265
 0.1723 2.0000 0.1112
 2.0000 0.1820 2.0000
 0.9000 0.0573 1.9750
 0.0163 0.2000 0
```

## See Also

`xlswrite`, `xlsfinfo`, `importdata`, `uiimport`, `textscan`,  
`function_handle`

**Purpose**

Write Microsoft Excel spreadsheet file

**Syntax**

```
xlswrite(filename, M)
xlswrite(filename, M, sheet)
xlswrite(filename, M, range)
xlswrite(filename, M, sheet, range)
status = xlswrite(filename, ...)
[status, message] = xlswrite(filename, ...)
xlswrite filename M sheet range
```

**Description**

`xlswrite(filename, M)` writes matrix `M` to the Excel file `filename`. The `filename` input is a string enclosed in single quotation marks, and should include the file extension. The matrix `M` is an `m`-by-`n` numeric or character array. `xlswrite` writes the matrix data to the first worksheet in the file, starting at cell `A1`.

The matrix `M` can also be an `m`-by-`n` cell array if each cell includes a single element (see Example 2). To write cell arrays containing more than one element in each cell, use low-level export functions.

If `filename` does not exist, `xlswrite` creates a new file. The file extension you provide as part of `filename` determines the Excel format that `xlswrite` uses for the new file. An extension of `.xls` creates a worksheet compatible with Excel 97-2003 software. Use extensions `.xlsx`, `.xlsb`, or `.xlsm` to create worksheets in Excel 2007 file formats. The maximum size of the matrix `M` depends on the associated Excel version. (For more information on Excel specifications and limits, see Excel help.)

`xlswrite(filename, M, sheet)` writes matrix `M` to the specified worksheet `sheet` in the file `filename`. The `sheet` argument can be either a positive, double scalar value representing the worksheet index, or a quoted string containing the sheet name. The `sheet` argument cannot contain a colon.

If `sheet` does not exist, `xlswrite` adds a new sheet at the end of the worksheet collection. If `sheet` is an index larger than the number of worksheets, `xlswrite` appends empty sheets until the number of

# xlswrite

---

worksheets in the workbook equals `sheet`. In either case, `xlswrite` generates a warning indicating that it has added a new worksheet.

`xlswrite(filename, M, range)` writes matrix `M` to a rectangular region specified by `range` in the first worksheet of the file `filename`.

Specify `range` using the syntax '`C1:C2`', where `C1` and `C2` are two opposing corners that define the region to write. For example, the range '`D2:H4`' represents the 3-by-5 rectangular region between the two corners `D2` and `H4` on the worksheet. The range input is not case sensitive and uses the Excel A1 reference style. (For more information on this reference style, see Excel help.) `xlswrite` does not recognize named ranges.

The size defined by `range` should fit the size of `M`. If `range` is larger than the size of `M`, Excel software fills the remainder of the region with `#N/A`. If `range` is smaller than the size of `M`, `xlswrite` writes only the submatrix that fits into `range` to the file specified by `filename`.

---

**Note** If you specify only three inputs, `xlswrite` must decide whether the third input refers to a `sheet` or a `range`. To specify a `range`, include a colon character in the input string (such as '`D2:H4`'). If you do not include a colon character (such as '`sales`' or '`D2`'), `xlswrite` interprets the third input as a value for `sheet`.

---

`xlswrite(filename, M, sheet, range)` writes matrix `M` to a rectangular region specified by `range` in worksheet `sheet` of the file `filename`. If you specify both `sheet` and `range`, the `range` can either fit the size of `M` or contain only the first cell (such as '`A2`'). See the previous two syntax formats for further explanation of the `sheet` and `range` inputs.

`status = xlswrite(filename, ...)` returns the completion status of the write operation in `status`. If the write completes successfully, `status` is equal to logical 1 (`true`). Otherwise, `status` is logical 0 (`false`). Unless you specify an output parameter, `xlswrite` does not display a status value in the Command Window.

`[status, message] = xlswrite(filename, ...)` returns any warning or error message generated by the write operation in the MATLAB structure `message`. The message structure has two fields:

- `message` — String containing the text of the warning or error message
- `identifier` — String containing the message identifier for the warning or error

`xlswrite filename M sheet range` is the command format for `xlswrite`, showing its usage with all input arguments specified. When using this format, you must specify `sheet` as a string (for example, `Income` or `Sheet4`). If the `sheet` name contains space characters, then you must place quotation marks around the string (for example, `'Income 2002'`).

## Remarks

Full functionality of `xlswrite` depends on the use of the Microsoft Excel COM server. The typical installation of Excel for Windows includes access to this server. If your system does not have Excel for Windows installed, or if the COM server is unavailable, `xlswrite`:

- Writes matrix `M` as a text file in comma-separated value (CSV) format.
- Ignores the `sheet` and `range` arguments.
- Generates an error if the input matrix `M` is a cell array.

If your system has Microsoft Office 2003 software installed, but you want to create a file in an Excel 2007 format, you must install the Office 2007 Compatibility Pack.

Both Excel and MATLAB applications represent numeric dates as a number of serial days elapsed from a specific reference date. However, Excel and MATLAB use different reference dates:

| <b>Application</b> | <b>Reference Date</b> |
|--------------------|-----------------------|
| MATLAB             | January 0, 0000       |

| <b>Application</b>      | <b>Reference Date</b> |
|-------------------------|-----------------------|
| Excel for Windows       | January 1, 1900       |
| Excel for the Macintosh | January 2, 1904       |

For more information, see “Converting Dates” in the MATLAB Programming Fundamentals documentation.

## Examples

### Example 1 – Writing Numeric Data to the Default Worksheet

Write a 7-element vector to Microsoft Excel file `testdata.xls`. By default, `xlswrite` writes the data to cells A1 through G1 in the first worksheet in the file:

```
xlswrite('testdata.xls', [12.7 5.02 -98 63.9 0 -.2 56])
```

### Example 2 – Writing Mixed Data to a Specific Worksheet

This example writes the following mixed text and numeric data to the file `tempdata.xls`:

```
d = {'Time', 'Temp'; 12 98; 13 99; 14 97};
```

Call `xlswrite`, specifying the worksheet labeled `Temperatures`, and the region within the worksheet to write the data to. `xlswrite` writes the 4-by-2 matrix to the rectangular region that starts at cell E1 in its upper left corner:

```
s = xlswrite('tempdata.xls', d, 'Temperatures', 'E1')
s =
 1
```

The output status `s` shows that the write operation succeeded. The data appears as shown here in the output file:

```
Time Temp
 12 98
 13 99
 14 97
```



### Example 3 – Appending a New Worksheet to the File

Now write the same data to a worksheet that doesn't yet exist in `tempdata.xls`. In this case, `xlswrite` appends a new sheet to the workbook, calling it by the name you supplied in the `sheets` input argument, `'NewTemp'`. `xlswrite` displays a warning indicating that it has added a new worksheet to the file:

```
xlswrite('tempdata.xls', d, 'NewTemp', 'E1')
Warning: Added specified worksheet.
```

If you don't want to see these warnings, you can turn them off with this command:

```
warning off MATLAB:xlswrite:AddSheet
```

Now try the write command again, this time creating another new worksheet, `NewTemp2`. Although the message does not appear this time, you can still retrieve it and its identifier from the second output argument, `msg`:

```
[stat msg] = xlswrite('tempdata.xls', d, 'NewTemp2', 'E1');

msg
msg =
 message: 'Added specified worksheet.'
 identifier: 'MATLAB:xlswrite:AddSheet'
```

### See Also

`xlsread`, `xlsfinfo`

# xmlread

---

**Purpose** Parse XML document and return Document Object Model node

**Syntax** DOMnode = xmlread(filename)

**Description** DOMnode = xmlread(filename) reads a URL or filename and returns a Document Object Model node representing the parsed document. The filename input is a string enclosed in single quotes. The node can be manipulated by using standard DOM functions.

A properly parsed document displays to the screen as

```
xDoc = xmlread(...)
xDoc =
 [#document: null]
```

**Remarks** Find out more about the Document Object Model at the World Wide Web Consortium (W3C®) Web site, <http://www.w3.org/DOM/>. For specific information on using Java DOM objects, visit the Sun Web site, <http://www.java.sun.com/xml/docs/api>.

## Examples **Example 1**

All XML files have a single root element. Some XML files declare a preferred schema file as an attribute of this element. Use the `getAttribute` method of the DOM node to get the name of the preferred schema file:

```
xDoc = xmlread(fullfile(matlabroot, ...
 'toolbox/matlab/general/info.xml'));

xRoot = xDoc.getDocumentElement;
schemaURL = ...
 char(xRoot.getAttribute('xsi:noNamespaceSchemaLocation'))

schemaURL =
 http://www.mathworks.com/namespace/info/v1/info.xsd
```

## Example 2

Each `info.xml` file on the MATLAB path contains several `listitem` elements with a `label` and `callback` element. This script finds the callback that corresponds to the label 'Plot Tools':

```
infoLabel = 'Plot Tools';
infoCbk = '';
itemFound = false;

xDoc = xmlread(fullfile(matlabroot, ...
 'toolbox/matlab/general/info.xml'));

% Find a deep list of all listitem elements.
allListItems = xDoc.getElementsByTagName('listitem');

% Note that the item list index is zero-based.
for k = 0:allListItems.getLength-1
 thisListItem = allListItems.item(k);
 childNode = thisListItem.getFirstChild;

 while ~isempty(childNode)
 %Filter out text, comments, and processing instructions.
 if childNode.getNodeType == childNode.ELEMENT_NODE
 % Assume that each element has a single
 % org.w3c.dom.Text child.
 childText = char(childNode.getFirstChild.getData);

 switch char(childNode.getTagname)
 case 'label';
 itemFound = strcmp(childText, infoLabel);
 case 'callback' ;
 infoCbk = childText;
 end
 end % End IF
 childNode = childNode.getNextSibling;
 end % End WHILE
```

```
 if itemFound
 break;
 else
 infoCbk = '';
 end
 end % End FOR

 disp(sprintf('Item "%s" has a callback of "%s".', ...
 infoLabel, infoCbk))
```

### Example 3

This function parses an XML file using methods of the DOM node returned by `xmlread`, and stores the data it reads in the `Name`, `Attributes`, `Data`, and `Children` fields of a MATLAB structure:

```
function theStruct = parseXML(filename)
% PARSEXML Convert XML file to a MATLAB structure.
try
 tree = xmlread(filename);
catch
 error('Failed to read XML file %s.',filename);
end

% Recurse over child nodes. This could run into problems
% with very deeply nested trees.
try
 theStruct = parseChildNodes(tree);
catch
 error('Unable to parse XML file %s.',filename);
end

% ----- Subfunction PARSECHILDNODES -----
function children = parseChildNodes(theNode)
% Recurse over node children.
children = [];
if theNode.hasChildNodes
```

```

 childNodes = theNode.getChildNodes;
 numChildNodes = childNodes.getLength;
 allocCell = cell(1, numChildNodes);

 children = struct(
 'Name', allocCell, 'Attributes', allocCell, ...
 'Data', allocCell, 'Children', allocCell);

 for count = 1:numChildNodes
 theChild = childNodes.item(count-1);
 children(count) = makeStructFromNode(theChild);
 end
 end

% ----- Subfunction MAKESTRUCTFROMNODE -----
function nodeStruct = makeStructFromNode(theNode)
% Create structure of node info.

nodeStruct = struct(
 'Name', char(theNode.getNodeName), ...
 'Attributes', parseAttributes(theNode), ...
 'Data', '', ...
 'Children', parseChildNodes(theNode));

if any(strcmp(methods(theNode), 'getData'))
 nodeStruct.Data = char(theNode.getData);
else
 nodeStruct.Data = '';
end

% ----- Subfunction PARSEATTRIBUTES -----
function attributes = parseAttributes(theNode)
% Create attributes structure.

attributes = [];
if theNode.hasAttributes
 theAttributes = theNode.getAttributes;

```

# xmlread

---

```
numAttributes = theAttributes.getLength();
allocCell = cell(1, numAttributes);
attributes = struct('Name', allocCell, 'Value', ...
 allocCell);

for count = 1:numAttributes
 attrib = theAttributes.item(count-1);
 attributes(count).Name = char(attrib.getName);
 attributes(count).Value = char(attrib.getValue);
end
end
```

## See Also

xmlwrite, xslt

|                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
|--------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Purpose</b>     | Serialize XML Document Object Model node                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| <b>Syntax</b>      | <pre>xmlwrite(filename, DOMnode) str = xmlwrite(DOMnode)</pre>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| <b>Description</b> | <p><code>xmlwrite(filename, DOMnode)</code> serializes the Document Object Model node <code>DOMnode</code> to the file specified by <code>filename</code>. The <code>filename</code> input is a string enclosed in single quotes.</p> <p><code>str = xmlwrite(DOMnode)</code> serializes the Document Object Model node <code>DOMnode</code> and returns the node tree as a string, <code>s</code>.</p>                                                                                                                                                   |
| <b>Remarks</b>     | Find out more about the Document Object Model at the World Wide Web Consortium (W3C) Web site, <a href="http://www.w3.org/DOM/">http://www.w3.org/DOM/</a> .                                                                                                                                                                                                                                                                                                                                                                                              |
| <b>Example</b>     | <pre>% Create a sample XML document. docNode = com.mathworks.xml.XMLUtils.createDocument...     ('root_element') docRootNode = docNode.getDocumentElement; for i=1:20     thisElement = docNode.createElement('child_node');     thisElement.appendChild...         (docNode.createTextNode(sprintf('%i',i)));     docRootNode.appendChild(thisElement); end docNode.appendChild(docNode.createComment('this is a comment'));  % Save the sample XML document. xmlFileName = [tempname, '.xml']; xmlwrite(xmlFileName, docNode); edit(xmlFileName);</pre> |
| <b>See Also</b>    | <code>xmlread</code> , <code>xslt</code>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |

# xor

---

**Purpose** Logical exclusive-OR

**Syntax** `C = xor(A, B)`

**Description** `C = xor(A, B)` performs an exclusive OR operation on the corresponding elements of arrays A and B. The resulting element `C(i, j, ...)` is logical true (1) if `A(i, j, ...)` or `B(i, j, ...)`, but not both, is nonzero.

| <b>A</b> | <b>B</b> | <b>C</b> |
|----------|----------|----------|
| Zero     | Zero     | 0        |
| Zero     | Nonzero  | 1        |
| Nonzero  | Zero     | 1        |
| Nonzero  | Nonzero  | 0        |

## Examples

Given `A = [0 0 pi eps]` and `B = [0 -2.4 0 1]`, then

```
C = xor(A,B)
C =
 0 1 1 0
```

To see where either A or B has a nonzero element and the other matrix does not,

```
spy(xor(A,B))
```

## See Also

`all`, `any`, `find`, Elementwise Logical Operators, Short-Circuit Logical Operators



---

|                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
|--------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Purpose</b>     | Transform XML document using XSLT engine                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| <b>Syntax</b>      | <pre>result = xslt(source, style, dest) [result,style] = xslt(...) xslt(...,'-web')</pre>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| <b>Description</b> | <p><code>result = xslt(source, style, dest)</code> transforms an XML document using a stylesheet and returns the resulting document's URL. The function uses these inputs, the first of which is required:</p> <ul style="list-style-type: none"><li>• <code>source</code> is the filename or URL of the source XML file. <code>source</code> can also specify a DOM node.</li><li>• <code>style</code> is the filename or URL of an XSL stylesheet.</li><li>• <code>dest</code> is the filename or URL of the desired output document. If <code>dest</code> is absent or empty, the function uses a temporary filename. If <code>dest</code> is <code>'-tostring'</code>, the function returns the output document as a MATLAB string.</li></ul> <p><code>[result,style] = xslt(...)</code> returns a processed stylesheet appropriate for passing to subsequent XSLT calls as <code>style</code>. This prevents costly repeated processing of the stylesheet.</p> <p><code>xslt(...,'-web')</code> displays the resulting document in the Help Browser.</p> |
| <b>Remarks</b>     | Find out more about XSL stylesheets and how to write them at the World Wide Web Consortium (W3C) web site, <a href="http://www.w3.org/Style/XSL/">http://www.w3.org/Style/XSL/</a> .                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| <b>Example</b>     | <p>This example converts the file <code>info.xml</code> using the stylesheet <code>info.xsl</code>, writing the output to the file <code>info.html</code>. It launches the resulting HTML file in the Help Browser. MATLAB has several <code>info.xml</code> files that are used by the <b>Start</b> menu.</p> <pre>xslt info.xml info.xsl info.html -web</pre>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |

# xslt

---

## **See Also**

`xmlread`, `xmlwrite`

**Purpose**

Create array of all zeros

**Syntax**

```
B = zeros(n)
B = zeros(m,n)
B = zeros([m n])
B = zeros(m,n,p,...)
B = zeros([m n p ...])
B = zeros(size(A))
zeros(m, n,...,classname)
zeros([m,n,...],classname)
```

**Description**

`B = zeros(n)` returns an  $n$ -by- $n$  matrix of zeros. An error message appears if  $n$  is not a scalar.

`B = zeros(m,n)` or `B = zeros([m n])` returns an  $m$ -by- $n$  matrix of zeros.

`B = zeros(m,n,p,...)` or `B = zeros([m n p ...])` returns an  $m$ -by- $n$ -by- $p$ -by-... array of zeros.

---

**Note** The size inputs  $m$ ,  $n$ ,  $p$ , ... should be nonnegative integers. Negative integers are treated as 0.

---

`B = zeros(size(A))` returns an array the same size as  $A$  consisting of all zeros.

`zeros(m, n,...,classname)` or `zeros([m,n,...],classname)` is an  $m$ -by- $n$ -by-... array of zeros of data type `classname`. `classname` is a string specifying the data type of the output. `classname` can have the following values: 'double', 'single', 'int8', 'uint8', 'int16', 'uint16', 'int32', 'uint32', 'int64', or 'uint64'.

**Example**

```
x = zeros(2,3,'int8');
```

**Remarks**

The MATLAB language does not have a dimension statement; MATLAB automatically allocates storage for matrices. Nevertheless, for large

## zeros

---

matrices, MATLAB programs may execute faster if the `zeros` function is used to set aside storage for a matrix whose elements are to be generated one at a time, or a row or column at a time. For example

```
x = zeros(1,n);
for i = 1:n, x(i) = i; end
```

### See Also

`eye`, `ones`, `rand`, `randn`, `complex`

**Purpose**

Compress files into zip file

**Syntax**

```
zip(zipfile,files)
zip(zipfile,files,rootdir)
entrynames = zip(...)
```

**Description**

`zip(zipfile,files)` creates a zip file with the name `zipfile` from the list of files and directories specified in `files`. Relative paths are stored in the zip file, but absolute paths are not. Directories recursively include all of their content.

`zipfile` is a string specifying the name of the zip file. If `zipfile` has no extension, MATLAB appends the `.zip` extension.

`files` is a string or cell array of strings containing the list of files or directories included in `zipfile`. Individual files that are on the MATLAB path can be specified as partial path names. Otherwise an individual file can be specified relative to the current directory or with an absolute path.

Directories must be specified relative to the current directory or with absolute paths. On UNIX<sup>31</sup> systems, directories can also start with `~/` or `~username/`, which expands to the current user's home directory or the specified user's home directory, respectively. The wildcard character `*` can be used when specifying files or directories, except when relying on the MATLAB path to resolve a file name or partial path name.

`zip(zipfile,files,rootdir)` allows the path for `files` to be specified relative to `rootdir` rather than the current directory.

`entrynames = zip(...)` returns a string cell array of the names of the files contained in `zipfile`. If `files` contains a relative path, `entrynames` also contains the relative path.

## Examples

### Zip a File

Create a zip file of the file `guide.viewlet`, which is in the MATLAB demos directory. It saves the zip file in `d:/mymfiles/viewlet.zip`.

```
file = fullfile(matlabroot,'demos','guide.viewlet');
zip('d:/mymfiles/viewlet.zip',file)
```

Run `zip` for the files `guide.viewlet` and `import.viewlet` and save the zip file in `viewlets.zip`. The source files and zipped file are in the current directory.

```
zip('viewlets.zip',{'guide.viewlet','import.viewlet'})
```

### Zip Selected Files

Run `zip` for all `.m` and `.mat` files in the current directory to the file `backup.zip`:

```
zip('backup',{'*.m','*.mat'});
```

31. UNIX is a registered trademark of The Open Group in the United States and other countries.

### Zip a Directory

Run `zip` for the directory `D:/mymfiles` and its contents to the zip file `mymfiles` in the directory one level up from the current directory.

```
zip('../mymfiles','D:/mymfiles')
```

### Zip Between Directories

Run `zip` for the files `thesis.doc` and `defense.ppt`, which are located in `d:/PhD`, to the zip file `thesis.zip` in the current directory.

```
zip('thesis.zip',{'thesis.doc','defense.ppt'},'d:/PhD')
```

### See Also

`gzip`, `gunzip`, `tar`, `untar`, `unzip`

# zoom

---

**Purpose** Turn zooming on or off or magnify by factor

**GUI Alternatives** Use the **Zoom** tools on the figure toolbar to zoom in or zoom out on a plot, or select **Zoom In** or **Zoom Out** from the figure's **Tools** menu. For details, see “Enlarging the View” in the MATLAB Graphics documentation.

**Syntax**

```
zoom on
zoom off
zoom out
zoom reset
zoom
zoom xon
zoom yon
zoom(factor)
zoom(fig, option)
h = zoom(figure_handle)
```

**Description** `zoom on` turns on interactive zooming. When interactive zooming is enabled in a figure, pressing a mouse button while your cursor is within an axes zooms into the point or out from the point beneath the mouse. Zooming changes the axes limits. When using zoom mode, you

- Zoom in by positioning the mouse cursor where you want the center of the plot to be and either
  - Press the mouse button or
  - Rotate the mouse scroll wheel away from you (upward).
- Zoom out by positioning the mouse cursor where you want the center of the plot to be and either
  - Simultaneously press **Shift** and the mouse button, or
  - Rotate the mouse scroll wheel toward you (downward).

Each mouse click or scroll wheel click zooms in or out by a factor of 2.



Clicking and dragging over an axes when zooming in is enabled draws a rubberband box. When you release the mouse button, the axes zoom in to the region enclosed by the rubberband box.

Double-clicking over an axes returns the axes to its initial zoom setting in both zoom-in and zoom-out modes.

`zoom off` turns interactive zooming off.

`zoom out` returns the plot to its initial zoom setting.

`zoom reset` remembers the current zoom setting as the initial zoom setting. Later calls to `zoom out`, or double-clicks when interactive zoom mode is enabled, will return to this zoom level.

`zoom` toggles the interactive zoom status between off and on (restoring the most recently used zoom tool).

`zoom xon` and `zoom yon` set `zoom on` for the *x*- and *y*-axis, respectively.

`zoom(factor)` zooms in or out by the specified zoom factor, without affecting the interactive zoom mode. Values greater than 1 zoom in by that amount, while numbers greater than 0 and less than 1 zoom out by  $1/\text{factor}$ .

`zoom(fig, option)` Any of the preceding options can be specified on a figure other than the current figure using this syntax.

`h = zoom(figure_handle)` returns a *zoom mode object* for the figure `figure_handle` for you to customize the mode's behavior.

## Using Zoom Mode Objects

Access the following properties of zoom mode objects via `get` and modify some of them using `set`.

- *Enable* 'on' | 'off' — Specifies whether this figure mode is currently enabled on the figure
- *FigureHandle* <handle> — The associated figure handle, a read-only property that cannot be set

- *Motion* 'horizontal' | 'vertical' | 'both' — The type of zooming enabled for the figure
- *Direction* 'in' | 'out' — The direction of the zoom operation
- *RightClickAction* 'InverseZoom' | 'PostContextMenu' — The behavior of a right-click action

A value of 'InverseZoom' causes a right-click to zoom out. A value of 'PostContextMenu' displays a context menu. This setting persists between MATLAB sessions.

- *UIContextMenu* <handle> — Specifies a custom context menu to be displayed during a right-click action

This property is ignored if the *RightClickAction* property has been set to 'on'.

## Zoom Mode Callbacks

You can program the following callbacks for zoom mode operations.

- *ButtonDownFilter* <function\_handle> — Function to intercept *ButtonDown* events

The application can inhibit the zoom operation under circumstances the programmer defines, depending on what the callback returns. The input function handle should reference a function with two implicit arguments (similar to Handle Graphics object callbacks), as follows:

```
function [res] = myfunction(obj,event_obj)
% obj handle to the object that has been clicked on
% event_obj struct for event data (empty in this release)
% res [output] a logical flag to determine whether the zoom
% operation should take place or the 'ButtonDownFcn'
% property of the object should take precedence
```

- *ActionPreCallback* <function\_handle> — Function to execute before zooming

Set this callback if you want to execute code when a zoom operation starts. The input function handle should reference a function with two implicit arguments (similar to Handle Graphics object callbacks), as follows:

```
function myfunction(obj,event_obj)
% obj handle to the figure that has been clicked on.
% event_obj object containing struct of event data
```

The event data has the following field.

|      |                                             |
|------|---------------------------------------------|
| Axes | The handle of the axes that is being zoomed |
|------|---------------------------------------------|

- **ActionPostCallback** <function\_handle> — Function to execute after zooming

Set this callback if you want to execute code when a zoom operation finishes. The input function handle should reference a function with two implicit arguments (similar to Handle Graphics object callbacks), as follows:

```
function myfunction(obj,event_obj)
% obj handle to the figure that has been clicked on
% event_obj object containing struct of event data (same as the
% event data of the 'ActionPreCallback' callback)
```

## Zoom Mode Utility Functions

The following functions in zoom mode query and set certain of its properties.

- **flags = isAllowAxesZoom(h,axes)** — Function querying permission to zoom axes

Calling the function `isAllowAxesZoom` on the zoom object, `h`, with a vector of axes handles, `axes`, as input returns a logical array of the

same dimension as the axes handle vector, which indicates whether a zoom operation is permitted on the axes objects.

- `setAllowAxesZoom(h, axes, flag)` — Function to set permission to zoom axes

Calling the function `setAllowAxesZoom` on the zoom object, `h`, with a vector of axes handles, `axes`, and a logical scalar, `flag`, either allows or disallows a zoom operation on the axes objects.

- `info = getAxesZoomMotion(h, axes)` — Function to get style of zoom operations

Calling the function `getAxesZoomMotion` on the zoom object, `H`, with a vector of axes handles, `axes`, as input returns a character cell array of the same dimension as the axes handle vector, which indicates the type of zoom operation for each axes. Possible values for the type of operation are 'horizontal', 'vertical', or 'both'.

- `setAxesZoomMotion(h, axes, style)` — Function to set style of zoom operations

Calling the function `setAxesZoomMotion` on the zoom object, `h`, with a vector of axes handles, `axes`, and a character array, `style`, sets the style of zooming on each axes.

## Examples

### Example 1 — Entering Zoom Mode

Plot a graph and turn on Zoom mode:

```
plot(1:10);
zoom on
% zoom in on the plot
```

### Example 2 — Constrained Zoom

Create zoom mode object and constrain to  $x$ -axis zooming:

```
plot(1:10);
h = zoom;
set(h, 'Motion', 'horizontal', 'Enable', 'on');
```

```
% zoom in on the plot in the horizontal direction.
```

### Example 3 – Constrained Zoom in Subplots

Create four axes as subplots and set zoom style differently for each by setting a different property for each axes handle:

```
ax1 = subplot(2,2,1);
plot(1:10);
h = zoom;
ax2 = subplot(2,2,2);
plot(rand(3));
setAllowAxesZoom(h,ax2,false);
ax3 = subplot(2,2,3);
plot(peaks);
setAxesZoomMotion(h,ax3,'horizontal');
ax4 = subplot(2,2,4);
contour(peaks);
setAxesZoomMotion(h,ax4,'vertical');
% Zoom in on the plots.
```

### Example 4 – Coding a ButtonDown Callback

Create a `ButtonDown` callback for zoom mode objects to trigger. Copy the following code to a new M-file, execute it, and observe zooming behavior:

```
function demo
% Allow a line to have its own 'ButtonDownFcn' callback.
hLine = plot(rand(1,10));
set(hLine,'ButtonDownFcn','disp(''This executes'')');
set(hLine,'Tag','DoNotIgnore');
h = zoom;
set(h,'ButtonDownFilter',@mycallback);
set(h,'Enable','on');
% mouse click on the line
%
```

```
function [flag] = mycallback(obj,event_obj)
% If the tag of the object is 'DoNotIgnore', then return true.
objTag = get(obj,'Tag');
if strcmpi(objTag,'DoNotIgnore')
 flag = true;
else
 flag = false;
end
```

### Example 5 – Coding Pre- and Post-Callback Behavior

Create callbacks for pre- and post-buttonDown events for zoom mode objects to trigger. Copy the following code to a new M-file, execute it, and observe zoom behavior:

```
function demo
% Listen to zoom events
plot(1:10);
h = zoom;
set(h,'ActionPreCallback',@myprecallback);
set(h,'ActionPostCallback',@mypostcallback);
set(h,'Enable','on');
%
function myprecallback(obj,evd)
disp('A zoom is about to occur.');
```

```
%
function mypostcallback(obj,evd)
newLim = get(evd.Axes,'XLim');
msgbox(sprintf('The new X-Limits are [%.2f %.2f].',newLim));
```

### Example 6 – Creating a Context Menu for Zoom Mode

Coding a context menu that lets the user to switch to Pan mode by right-clicking:

```
figure;plot(magic(10))
hCMZ = uicontextmenu;
```

```
hZMenu = uimenu('Parent',hCMZ,'Label','Switch to pan','Callback','p
hZoom = zoom(gcf);
set(hZoom,'UIContextMenu',hCMZ);
zoom('on')
```

You cannot add items to the built-in zoom context menu, but you can replace it with your own.

## Remarks

zoom changes the axes limits by a factor of 2 (in or out) each time you press the mouse button while the cursor is within an axes. You can also click and drag the mouse to define a zoom area, or double-click to return to the initial zoom level.

You can create a zoom mode object once and use it to customize the behavior of different axes, as Example 3 illustrates. You can also change its callback functions on the fly.

---

**Note Do not change figure callbacks within an interactive mode.** While a mode is active (when panning, zooming, etc.), you will receive a warning if you attempt to change any of the figure's callbacks and the operation will not succeed. The one exception to this rule is the figure `WindowButtonMotionFcn` callback, which can be changed from within a mode. Therefore, if you are creating a GUI that updates a figure's callbacks, the GUI should some keep track of which interactive mode is active, if any, before attempting to do this.

---

When you assign different zoom behaviors to different subplot axes via a mode object and then link them using the `linkaxes` function, the behavior of the axes you manipulate with the mouse carries over to the linked axes, regardless of the behavior you previously set for the other axes.

## See Also

`linkaxes`, `pan`, `rotate3d`

“Object Manipulation” on page 1-107 for related functions





## Symbols and Numerics

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