MATLAB 7
Function Reference: Volume 2 (F-O)

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508-647-7000 (Phone)

508-647-7001 (Fax)

The MathWorks, Inc.
3 Apple Hill Drive
Natick, MA 01760-2098

For contact information about worldwide offices, see the MathWorks Web site.

MATLAB Function Reference

Revision History

December 1996	First printing	For MATLAB 5.0 (Release 8)
June 1997	Online only	Revised for MATLAB 5.1 (Release 9)
October 1997	Online only	Revised for MATLAB 5.2 (Release 10)
January 1999	Online only	Revised for MATLAB 5.3 (Release 11)
June 1999	Second printing	For MATLAB 5.3 (Release 11)
June 2001	Online only	Revised for MATLAB 6.1 (Release 12.1)
July 2002	Online only	Revised for 6.5 (Release 13)
June 2004	Online only	Revised for 7.0 (Release 14)
September 2006	Online only	Revised for 7.3 (Release 2006b)

Contents

1 Functions — By Category

2 Functions — Alphabetical List

Index

Functions — By Category

Desktop Tools and Development Environment

Startup and Shutdown

exit	Terminate MATLAB (same as `quit`)
finish	MATLAB termination M-file
matlab (UNIX)	Start MATLAB (UNIX systems)
matlab (Windows)	Start MATLAB (Windows systems)
matlabrc	MATLAB startup M-file for single-user systems or system administrators
prefdir	Directory containing preferences, history, and layout files
preferences	Open Preferences dialog box for MATLAB and related products

quit	Terminate MATLAB
startup	MATLAB startup M-file for user-defined options

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
docopt	Web browser for UNIX platforms
docsearch	Open Help browser **Search** pane and search for specified term
echodemo	Run M-file demo step-by-step in Command Window
help	Help for MATLAB 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
web	Open Web site or file in Web browser or Help browser
whatsnew	Release Notes for MathWorks products

Workspace, Search Path, and File Operations

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 class
openvar	Open workspace variable in Array Editor or other tool for graphical editing
pack	Consolidate workspace memory
uiimport	Open Import Wizard to import data
which	Locate functions and files
workspace	Open Workspace browser to manage workspace

Search Path

addpath	Add directories to MATLAB search path
genpath	Generate path string
partialpath	Partial pathname description

path	View or change MATLAB directory search path
path2rc	Save current MATLAB search path to `pathdef.m` file
pathdef	Directories in MATLAB search path
pathsep	Path separator for current platform
pathtool	Open Set Path dialog box to view and change MATLAB path
restoredefaultpath	Restore default MATLAB search path
rmpath	Remove directories from MATLAB search path
savepath	Save current MATLAB search path to `pathdef.m` file

File Operations

See also “File I/O” on page 1-75 functions.

cd	Change working directory
copyfile	Copy file or directory
delete	Remove files or graphics objects
dir	Directory listing
exist	Check existence of variable, function, directory, or Java class
fileattrib	Set or get attributes of file or directory
filebrowser	Current Directory browser
isdir	Determine whether input is a directory
lookfor	Search for keyword in all help entries

ls	Directory contents on UNIX system
matlabroot	Root directory of MATLAB installation
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
web	Open Web site or file in Web browser or Help browser
what	List MATLAB files in current directory
which	Locate functions and files

Programming Tools

Edit and Debug M-Files (p. 1-9)	Edit and debug M-files
Improve Performance and Tune M-Files (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

Edit and Debug M-Files

clipboard	Copy and paste strings to and from system clipboard
datatipinfo	Produce short description of input variable
dbclear	Clear breakpoints
dbcont	Resume execution
dbdown	Change local workspace context when 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	Change local workspace context
debug	List M-file debugging functions
edit	Edit or create M-file
keyboard	Input from keyboard

Improve Performance and Tune M-Files

memory	Help for memory limitations
mlint	Check M-files for possible problems
mlintrpt	Run `mlint` 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)
checkout	Check files out of source control system (UNIX)
cmopts	Name of source control system
customverctrl	Allow custom source control system (UNIX)
undocheckout	Undo previous checkout from source control system (UNIX)
verctrl	Source control actions (Windows)

Publishing

grabcode	MATLAB code from M-files published to HTML
notebook	Open M-book in Microsoft Word (Windows)
publish	Publish M-file containing cells, saving output to file of specified type

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 is running
dos	Execute DOS command and return result
getenv	Environment variable
hostid	MATLAB server host identification number
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 Microsoft Windows registry

MATLAB Version and License

ismac	Determine whether running Macintosh OS X versions of MATLAB
ispc	Determine whether PC (Windows) version of MATLAB
isstudent	Determine whether Student Version of MATLAB
isunix	Determine whether UNIX version of MATLAB
javachk	Generate error message based on Java feature support
license	Return license number or perform licensing task
prefdir	Directory containing preferences, history, and layout files
usejava	Determine whether Java feature is supported in MATLAB
ver	Version information for MathWorks products
verLessThan	Compare toolbox version to specified version string
version	Version number for MATLAB

Mathematics

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. 1-17)	Create, sort, rotate, permute, reshape, and shift array contents
Specialized Matrices (p. 1-18)	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)

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

Elementary Matrices and Arrays

blkdiag	Construct block diagonal matrix from input arguments
diag	Diagonal matrices and diagonals of matrix
eye	Identity matrix
freqspace	Frequency spacing for frequency response
ind2sub	Subscripts from linear index
linspace	Generate linearly spaced vectors
logspace	Generate logarithmically spaced vectors
meshgrid	Generate X and Y arrays for 3-D plots
ndgrid	Generate arrays for N-D functions and interpolation
ones	Create array of all ones
rand	Uniformly distributed pseudorandom numbers
randn	Normally distributed random numbers
sub2ind	Single index from subscripts
zeros	Create array of all zeros

Array Operations

See “Linear Algebra” on page 1-19 and “Elementary Math” on page 1-23 for other array operations.

accumarray	Construct array with accumulation
arrayfun	Apply function to each element of array
bsxfun	Applies 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. 1-19)	Compute norm, rank, determinant, condition number, etc.
Linear Equations (p. 1-20)	Solve linear systems, least squares, LU factorization, Cholesky factorization, etc.
Eigenvalues and Singular Values (p. 1-21)	Eigenvalues, eigenvectors, Schur decomposition, Hessenburg matrices, etc.
Matrix Logarithms and Exponentials (p. 1-22)	Matrix logarithms, exponentials, square root
Factorization (p. 1-22)	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	Find eigenvalues and eigenvectors
eigs	Find largest eigenvalues and eigenvectors of sparse 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
sqrtm	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. 1-25)	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 (e.g., Prime Factors) (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 ofo 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	Determine whether 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 infinity
fix	Round toward zero
floor	Round toward minus infinity
idivide	Integer division with rounding option
mod	Modulus after division
rem	Remainder after division
round	Round to nearest integer

Discrete Math (e.g., Prime Factors)

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

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
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

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
tetramesh	Tetrahedron mesh plot
trimesh	Triangular mesh plot
triplot	2-D triangular plot
trisurf	Triangular surface plot
tsearch	Search for enclosing Delaunay triangle
tsearchn	N-D closest simplex search

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 (IVP) (p. 1-32)	Solve stiff and nonstiff differential equations, define the problem, set solver options, evaluate solution
Delay Differential Equations (p. 1-33)	Solve delay differential equations with constant and general delays, set solver options, evaluate solution
Boundary Value Problems (p. 1-33)	Solve boundary value problems for ordinary differential equations, set solver options, evaluate solution

Partial Differential Equations (p. 1-34)	Solve initial-boundary value problems for parabolic-elliptic PDEs, evaluate solution
Optimization (p. 1-34)	Find minimum of single and multivariable functions, solve nonnegative least-squares constraint problem
Numerical Integration (Quadrature) (p. 1-34)	Evaluate Simpson, Lobatto, and vectorized quadratures, evaluate double and triple integrals

Ordinary Differential Equations (IVP)

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
bvpget	Extract properties from options structure created with `bvpset`
bvpinit	Form initial guess for `bvp4c`
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 `pdepe`

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
quad	Numerically evaluate integral, adaptive Simpson 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
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
legendre	Associated Legendre functions
psi	Psi (polygamma) function

Sparse Matrices

Elementary Sparse Matrices (p. 1-36)	Create random and nonrandom sparse matrices
Full to Sparse Conversion (p. 1-36)	Convert full matrix to sparse, sparse matrix to full

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

Working with Sparse Matrices

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	Find largest eigenvalues and eigenvectors of sparse 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
cgs	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
symmlq	Symmetric LQ method

Tree Operations

etree	Elimination tree
etreeplot	Plot elimination tree
gplot	Plot nodes and links representing adjacency matrix
symbfact	Symbolic factorization analysis
treelayout	Lay out tree or forest
treeplot	Plot picture of tree

Math Constants

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

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

Data Analysis

Basic Operations

cumprod	Cumulative product
cumsum	Cumulative sum
prod	Product of array elements
sort	Sort array elements in ascending or descending order
sortrows	Sort rows in ascending order
sum	Sum of array elements

Descriptive Statistics

corrcoef	Correlation coefficients
cov	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

General Purpose

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

timeseries	Create `timeseries` object
tsdata.event	Construct event object for `timeseries` object
tsprops	Help on `timeseries` object properties
tstool	Open Time Series Tools GUI

Data Manipulation

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

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

Event Data

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

Descriptive Statistics

iqr (timeseries)	Interquartile range of `timeseries` data
max (timeseries)	Maximum value of `timeseries` data
mean (timeseries)	Mean value of `timeseries` data
median (timeseries)	Median value of `timeseries` data

min (timeseries)	Minimum value of `timeseries` data
std (timeseries)	Standard deviation of `timeseries` data
sum (timeseries)	Sum of `timeseries` data
var (timeseries)	Variance of `timeseries` data

Time Series Collections

General Purpose (p. 1-47)	Query and set `tscollection` object properties, plot `tscollection` objects
Data Manipulation (p. 1-48)	Add or delete data, manipulate `tscollection` objects

General Purpose

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

Data Manipulation

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

Programming and Data Types

Data Types

Cell Arrays (p. 1-53)	Data of varying types and sizes stored in cells of array
Function Handles (p. 1-54)	Invoke a function indirectly via handle
MATLAB Classes and Objects (p. 1-55)	MATLAB object-oriented class system
Java Classes and Objects (p. 1-55)	Access Java classes through MATLAB interface
Data Type Identification (p. 1-57)	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
isinf	Array elements that are infinite
isnan	Array elements that are NaN
isnumeric	Determine whether input is numeric array
isreal	Determine whether input is real array
isscalar	Determine whether input is scalar
isvector	Determine whether input is vector
permute	Rearrange dimensions of N-D array
realmax	Largest positive floating-point number
realmin	Smallest positive floating-point number
reshape	Reshape array
squeeze	Remove singleton dimensions
zeros	Create array of all zeros

Characters and Strings

See “String Functions” on page 1-62 for all string-related functions.

cellstr	Create cell array of strings from character array
char	Convert to character array (string)
eval	Execute string containing MATLAB expression
findstr	Find string within another, longer string

isstr	Determine whether input is character array
regexp, regexpi	Match regular expression
sprintf	Write formatted data to string
sscanf	Read formatted data from string
strcat	Concatenate strings horizontally
strcmp, strcmpi	Compare strings
strings	MATLAB 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

MATLAB Classes and Objects

class	Create object or return class of object
fieldnames	Field names of structure, or public fields of object
inferiorto	Establish inferior class relationship
isa	Determine whether input is object of given class
isobject	Determine whether input is MATLAB OOPs object
loadobj	User-defined extension of `load` function for user objects
methods	Information on class methods
methodsview	Information on class methods in separate window
saveobj	User-defined extension of `save` function for user objects
subsasgn	Subscripted assignment for objects
subsindex	Subscripted indexing for objects
subsref	Subscripted reference for objects
substruct	Create structure argument for `subsasgn` or `subsref`
superiorto	Establish superior class relationship

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 class
fieldnames	Field names of structure, or public fields of object
im2java	Convert image to Java image
import	Add package or class to current Java import list
inmem	Names of M-files, MEX-files, Java classes in memory
isa	Determine whether input is object of given class
isjava	Determine whether input is Java object
javaaddpath	Add entries to dynamic Java class path
javaArray	Construct Java array
javachk	Generate error message based on Java feature support
javaclasspath	Set and get dynamic Java class path
javaMethod	Invoke Java method
javaObject	Construct Java object
javarmpath	Remove entries from dynamic Java class path
methods	Information on class methods
methodsview	Information on class methods in separate window
usejava	Determine whether Java feature is supported in MATLAB
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 Java object
islogical	Determine whether input is logical array
isnumeric	Determine whether input is numeric array
isobject	Determine whether input is MATLAB OOPs object
isreal	Determine whether input is real array
isstr	Determine whether input is character array
isstruct	Determine whether input is structure array
who, whos	List variables in workspace

Data Type Conversion

Numeric

cast	Cast variable to different data type
double	Convert to double precision
int8, int16, int32, int64	Convert to signed integer
single	Convert to single precision
typecast	Convert data types without changing underlying data
uint8, uint16, uint32, uint64	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. 1-60)	Plus, minus, power, left and right divide, transpose, etc.
Relational Operators (p. 1-61)	Equal to, greater than, less than or equal to, etc.
Logical Operators (p. 1-61)	Element-wise and short circuit and, or, not
Special Characters (p. 1-62)	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 Functions” on page 1-66 for functions like `xor`, `all`, `any`, etc.

<table>
<tr><td>&&</td><td>Logical AND</td></tr>
<tr><td>||</td><td>Logical OR</td></tr>
<tr><td>&</td><td>Logical AND for arrays</td></tr>
<tr><td>|</td><td>Logical OR for arrays</td></tr>
<tr><td>~</td><td>Logical NOT</td></tr>
</table>

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

String Functions

Description of Strings in MATLAB (p. 1-63)	Basics of string handling in MATLAB
String Creation (p. 1-63)	Create strings, cell arrays of strings, concatenate strings together
String Identification (p. 1-63)	Identify characteristics of strings

Description of Strings in MATLAB

strings	MATLAB string handling

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

class	Create object or return class of object
isa	Determine whether input is object of given class
iscellstr	Determine whether input is cell array of strings
ischar	Determine whether item is character array

isletter	Array elements that are alphabetic letters
isscalar	Determine whether input is scalar
isspace	Array elements that are space characters
isstrprop	Determine whether string is of specified category
isvector	Determine whether input is vector

String Manipulation

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

bitand	Bitwise AND
bitcmp	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 Functions

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 1-60 for logical operators.

Relational Functions

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 1-60 for relational operators.

Set Functions

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 Functions

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-File Functions and Scripts (p. 1-68)	Declare functions, handle arguments, identify dependencies, etc.
Evaluation of Expressions and Functions (p. 1-70)	Evaluate expression in string, apply function to array, run script file, etc.
Timer Functions (p. 1-71)	Schedule execution of MATLAB commands
Variables and Functions in Memory (p. 1-71)	List files in memory, clear M-files in memory, assign to variable in nondefault workspace, refresh caches
Control Flow (p. 1-72)	if-then-else, for loops, switch-case, try-catch
Error Handling (p. 1-73)	Generate warnings and errors, test for and catch errors, retrieve most recent error message
MEX Programming (p. 1-74)	Compile MEX function from C or Fortran code, list MEX-files in memory, debug MEX-files

M-File Functions 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
depdir	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 preparsed pseudocode 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 of Expressions and Functions

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
evalin	Execute MATLAB expression in specified workspace
feval	Evaluate function
iskeyword	Determine whether input is MATLAB keyword
isvarname	Determine whether input is valid variable name
pause	Halt execution temporarily
run	Run script that is not on current path
script	Script M-file description
structfun	Apply function to each field of scalar structure

symvar	Determine symbolic variables in expression
tic, toc	Measure performance using stopwatch timer

Timer Functions

delete (timer)	Remove timer object from memory
disp (timer)	Information about timer object
get (timer)	Timer object properties
isvalid (timer)	Determine whether timer object is valid
set (timer)	Configure or display timer object properties
start	Start timer(s) running
startat	Start timer(s) running at specified time
stop	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, Java classes in memory
isglobal	Determine whether input is global variable
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 `for` or `while` loop
case	Execute block of code if condition is `true`
catch	Specify how to respond to error in `try` statement
continue	Pass control to next iteration of `for` or `while` loop
else	Execute statements if condition is false

elseif	Execute statements if additional condition is true
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 true
otherwise	Default part of switch statement
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

assert	Generate error when condition is violated
catch	Specify how to respond to error in `try` statement
error	Display message and abort function
ferror	Query MATLAB about errors in file input or output
intwarning	Control state of integer warnings
lasterr	Last error message
lasterror	Last error message and related information

lastwarn	Last warning message
rethrow	Reissue error
try	Attempt to execute block of code, and catch errors
warning	Warning message

MEX Programming

dbmex	Enable MEX-file debugging
inmem	Names of M-files, MEX-files, Java classes in memory
mex	Compile MEX-function from C or Fortran source code
mexext	MEX-filename extension

File I/O

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

Opening, Loading, Saving Files

daqread	Read Data Acquisition Toolbox (.daq) file
filehandle	Construct file handle object
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 about errors in file input or output

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

Text Files

csvread	Read comma-separated value file
csvwrite	Write comma-separated value file
dlmread	Read ASCII-delimited file of numeric data into matrix
dlmwrite	Write matrix to ASCII-delimited file
textread	Read data from text file; write to multiple outputs
textscan	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 Functions (p. 1-78)	Read and write Microsoft Excel spreadsheet
Lotus 1-2-3 Functions (p. 1-78)	Read and write Lotus WK1 spreadsheet

Microsoft Excel Functions

xlsfinfo	Determine whether file contains Microsoft Excel (`.xls`) spreadsheet
xlsread	Read Microsoft Excel spreadsheet file (`.xls`)
xlswrite	Write Microsoft Excel spreadsheet file (`.xls`)

Lotus 1-2-3 Functions

wk1finfo	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 (CDF)

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

Flexible Image Transport System

fitsinfo	Information about FITS file
fitsread	Read data from FITS file

Hierarchical Data Format (HDF)

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
hdfinfo	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

General (p. 1-81)	Create audio player object, obtain information about multimedia files, convert to/from audio signal
SPARCstation-Specific Sound Functions (p. 1-81)	Access NeXT/SUN (`.au`) sound files

Microsoft WAVE Sound Functions (p. 1-81)	Access Microsoft WAVE (`.wav`) sound files
Audio/Video Interleaved (AVI) Functions (p. 1-82)	Access Audio/Video interleaved (`.avi`) sound files

General

audioplayer	Create audio player object
audiorecorder	Create audio recorder object
beep	Produce beep sound
lin2mu	Convert linear audio signal to mu-law
mmfileinfo	Information about multimedia file
mu2lin	Convert mu-law audio signal to linear
sound	Convert vector into sound
soundsc	Scale data and play as sound

SPARCstation-Specific Sound Functions

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

Microsoft WAVE Sound Functions

wavfinfo	Information about Microsoft WAVE (`.wav`) sound file
wavplay	Play recorded sound on PC-based audio output device

wavread	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 (AVI) Functions

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. 1-83)	Send e-mail, read from given URL, extract from tar or zip file, compress and decompress files
FTP Functions (p. 1-83)	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 Functions

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

box	Axes border
errorbar	Plot error bars along curve
hold	Retain current graph in figure
LineSpec	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. 1-87)	1-D, 2-D, and 3-D graphs and charts
Contour Plots (p. 1-88)	Unfilled and filled contours in 2-D and 3-D
Direction and Velocity Plots (p. 1-88)	Comet, compass, feather and quiver plots
Discrete Data Plots (p. 1-88)	Stair, step, and stem plots
Function Plots (p. 1-88)	Easy-to-use plotting utilities for graphing functions
Histograms (p. 1-89)	Plots for showing distributions of data
Polygons and Surfaces (p. 1-89)	Functions to generate and plot surface patches in two or more dimensions
Scatter/Bubble Plots (p. 1-90)	Plots of point distributions
Animation (p. 1-90)	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

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

Direction and Velocity Plots

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

Discrete Data Plots

stairs	Stairstep graph
stem	Plot discrete sequence data
stem3	Plot 3-D discrete sequence data

Function Plots

ezcontour	Easy-to-use contour plotter
ezcontourf	Easy-to-use filled contour plotter
ezmesh	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
ezsurfc	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	Convert movie frame to indexed image
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	Convert movie frame to indexed image
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

frameedit	Edit print frames for Simulink and Stateflow block diagrams
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

Finding and Identifying Graphics Objects

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 object properties
ishandle	Is object handle valid
propedit	Open Property Editor
set	Set object properties

Object Creation Functions

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 object properties
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	Complete pending drawing events
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

Operating on Object Properties

get	Query 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 object properties

3-D Visualization

Surface and Mesh Plots

Creating Surfaces and Meshes

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
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

Colormaps

contrast	Grayscale colormap for contrast enhancement

View Control

Controlling the Camera Viewpoint (p. 1-98)	Orbiting, dollying, pointing, rotating camera positions and setting fields of view
Setting the Aspect Ratio and Axis Limits (p. 1-99)	Specifying what portions of axes to view and how to scale them
Object Manipulation (p. 1-99)	Panning, rotating, and zooming views
Selecting Region of Interest (p. 1-100)	Interactively identifying rectangular regions

Controlling the 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

Setting the 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

Selecting 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 `light` 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 the 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

Creating Graphical User Interfaces

Predefined Dialog Boxes

dialog	Create and display 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 a directory

uigetfile	Open standard dialog box for retrieving files
uigetpref	Open dialog box for retrieving preferences
uiopen	Open file selection dialog box with appropriate file filters
uiputfile	Open standard dialog box for saving files
uisave	Open standard dialog box for saving workspace variables
uisetcolor	Open standard dialog box for setting object's `ColorSpec`
uisetfont	Open standard dialog box for setting object's font characteristics
waitbar	Open waitbar
warndlg	Open warning dialog box

Deploying User Interfaces

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

Developing User Interfaces

addpref	Add preference
getappdata	Value of application-defined data
getpref	Preference

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

User Interface Objects

menu	Generate menu of choices for user input
uibuttongroup	Create container object to exclusively manage radio buttons and toggle buttons
uicontextmenu	Create context menu
uicontrol	Create user interface control object

uimenu	Create menus on figure windows
uipanel	Create panel container object
uipushtool	Create push button on toolbar
uitoggletool	Create toggle button on toolbar
uitoolbar	Create toolbar on figure

Finding Objects from Callbacks

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

GUI Utility Functions

align	Align user interface controls (uicontrols) and axes
getpixelposition	Get component position in pixels
listfonts	List available system fonts
selectmoveresize	Select, move, resize, or copy axes and uicontrol graphics objects
setpixelposition	Set component position in pixels
textwrap	Wrapped string matrix for given uicontrol
uistack	Reorder visual stacking order of objects

Controlling Program Execution

uiresume, uiwait	Control program execution

External Interfaces

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

Dynamic Link Libraries

calllib	Call function in external library
libfunctions	Information on functions in external library
libfunctionsview	Create window displaying information on functions in external library
libisloaded	Determine whether external library is loaded
libpointer	Create pointer object for use with external libraries

libstruct	Construct structure as defined in external library
loadlibrary	Load external library into MATLAB
unloadlibrary	Unload external 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 Java import list
inspect	Open Property Inspector
isa	Determine whether input is object of given class
isjava	Determine whether input is Java object
ismethod	Determine whether input is object method
isprop	Determine whether input is object property
javaaddpath	Add entries to dynamic Java class path
javaArray	Construct Java array
javachk	Generate error message based on Java feature support
javaclasspath	Set and get dynamic Java class path
javaMethod	Invoke Java method
javaObject	Construct Java object

javarmpath	Remove entries from dynamic Java class path
methods	Information on class methods
methodsview	Information on class methods in separate window
usejava	Determine whether Java feature is supported in MATLAB

Component Object Model and ActiveX

actxcontrol	Create ActiveX control in figure window
actxcontrollist	List all currently installed ActiveX controls
actxcontrolselect	Open GUI to create ActiveX control
actxGetRunningServer	Get handle to running instance of Automation server
actxserver	Create COM server
addproperty	Add custom property to object
class	Create object or return class of object
delete (COM)	Remove COM control or server
deleteproperty	Remove custom property from object
enableservice	Enable, disable, or report status of Automation server; enable DDE server
eventlisteners	List of events attached to listeners
events	List of events control can trigger
Execute	Execute MATLAB command in server
Feval (COM)	Evaluate MATLAB function in 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 server
GetFullMatrix	Get matrix from server
GetVariable	Get data from variable in server workspace
GetWorkspaceData	Get data from server workspace
inspect	Open Property Inspector
interfaces	List custom interfaces to COM server
invoke	Invoke method on object or interface, or display methods
isa	Determine whether input is object of given class
iscom	Is input COM object
isevent	Is input event
isinterface	Is input COM interface
ismethod	Determine whether input is object method
isprop	Determine whether input is object property
load (COM)	Initialize control object from file
MaximizeCommandWindow	Open server window on Windows desktop
methods	Information on class methods
methodsview	Information on class methods in separate window
MinimizeCommandWindow	Minimize size of server window

move	Move or resize control in parent window
propedit (COM)	Open built-in property page for control
PutCharArray	Store character array in server
PutFullMatrix	Store matrix in server
PutWorkspaceData	Store data in server workspace
Quit (COM)	Terminate MATLAB server
registerevent	Register event handler with control's event
release	Release interface
save (COM)	Serialize control object to file
send	Return list of events control can trigger
set (COM)	Set object or interface property to specified value
unregisterallevents	Unregister all events for control
unregisterevent	Unregister event handler with control's event

Dynamic Data Exchange

ddeadv	Set up advisory link
ddeexec	Send string for execution
ddeinit	Initiate Dynamic Data Exchange (DDE) conversation
ddepoke	Send data to application
ddereq	Request data from application

ddeterm	Terminate Dynamic Data Exchange (DDE) conversation
ddeunadv	Release advisory link

Web Services

callSoapService	Send SOAP message off to endpoint
createClassFromWsdl	Create MATLAB object based on WSDL file
createSoapMessage	Create SOAP message to send to server
parseSoapResponse	Convert response string from SOAP server into MATLAB data types

Serial Port Devices

clear (serial)	Remove serial port object from MATLAB workspace
delete (serial)	Remove serial port object from memory
disp (serial)	Serial port object summary information
fclose (serial)	Disconnect serial port object from device
fgetl (serial)	Read line of text from device and discard terminator
fgets (serial)	Read line of text from device and include terminator
fopen (serial)	Connect serial port object to device
fprintf (serial)	Write text to device
fread (serial)	Read binary data from device

fscanf (serial)	Read data from device, and format as text
fwrite (serial)	Write binary data to device
get (serial)	Serial port object properties
instrcallback	Event information when event occurs
instrfind	Read serial port objects from memory to MATLAB workspace
instrfindall	Find visible and hidden serial port objects
isvalid (serial)	Determine whether serial port objects are valid
length (serial)	Length of serial port object array
load (serial)	Load serial port objects and variables into MATLAB workspace
readasync	Read data asynchronously from device
record	Record data and event information to file
save (serial)	Save serial port objects and variables to MAT-file
serial	Create serial port object
serialbreak	Send break to device connected to serial port
set (serial)	Configure or display serial port object properties
size (serial)	Size of serial port object array
stopasync	Stop asynchronous read and write operations

2

Functions — 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
addevent
addframe
addOptional (inputParser)
addParamValue (inputParser)

bitand
bitcmp
bitget
bitmax
bitor
bitset
bitshift
bitxor
blanks
blkdiag
box
break
brighten
builddocsearchdb
builtin
bsxfun
bvp4c
bvpget
bvpinit
bvpset
bvpxtend
calendar
calllib
callSoapService
camdolly
cameratoolbar
camlight
camlookat
camorbit
campan
campos
camproj
camroll
camtarget
camup
camva
camzoom

cart2pol
cart2sph
case
cast
cat
catch
caxis
cd
cd (ftp)
cdf2rdf
cdfepoch
cdfinfo
cdfread
cdfwrite
ceil
cell
cell2mat
cell2struct
celldisp
cellfun
cellplot
cellstr
cgs
char
checkin
checkout
chol
cholinc
cholupdate
circshift
cla
clabel
class
clc
clear
clear (serial)
clf

clipboard
clock
close
close (avifile)
close (ftp)
closereq
cmopts
colamd
colmmd
colorbar
colordef
colormap
colormapeditor
ColorSpec
colperm
comet
comet3
commandhistory
commandwindow
compan
compass
complex
computer
cond
condeig
condest
coneplot
conj
continue
contour
contour3
contourc
contourf
Contourgroup Properties
contourslice
contrast
conv

conv2
convhull
convhulln
convn
copyfile
copyobj
corrcoef
cos
cosd
cosh
cot
cotd
coth
cov
cplxpair
cputime
createClassFromWsdl
createCopy (inputParser)
createSoapMessage
cross
csc
cscd
csch
csvread
csvwrite
ctranspose (timeseries)
cumprod
cumsum
cumtrapz
curl
customverctrl
cylinder
daqread
daspect
datacursormode
datatipinfo
date

datenum
datestr
datetick
datevec
dbclear
dbcont
dbdown
dblquad
dbmex
dbquit
dbstack
dbstatus
dbstep
dbstop
dbtype
dbup
dde23
ddeadv
ddeexec
ddeget
ddeinit
ddepoke
ddereq
ddesd
ddeset
ddeterm
ddeunadv
deal
deblank
debug
dec2base
dec2bin
dec2hex
decic
deconv
del2
delaunay

delaunay3
delaunayn
delete
delete (COM)
delete (ftp)
delete (serial)
delete (timer)
deleteproperty
delevent
delsample
delsamplefromcollection
demo
depdir
depfun
det
detrend
detrend (timeseries)
deval
diag
dialog
diary
diff
diffuse
dir
dir (ftp)
disp
disp (serial)
disp (timer)
display
divergence
dlmread
dlmwrite
dmperm
doc
docopt
docsearch
dos

exit
exp
expint
expm
expm1
export2wsdlg
eye
ezcontour
ezcontourf
ezmesh
ezmeshc
ezplot
ezplot3
ezpolar
ezsurf
ezsurfc
factor
factorial
false
fclose
fclose (serial)
feather
feof
ferror
feval
Feval (COM)
fft
fft2
fftn
fftshift
fftw
fgetl
fgetl (serial)
fgets
fgets (serial)
fieldnames
figure

Figure Properties
figurepalette
fileattrib
filebrowser
File Formats
filemarker
fileparts
filehandle
filesep
fill
fill3
filter
filter (timeseries)
filter2
find
findall
findfigs
findobj
findstr
finish
fitsinfo
fitsread
fix
flipdim
fliplr
flipud
floor
flops
flow
fminbnd
fminsearch
fopen
fopen (serial)
for
format
fplot
fprintf

fprintf (serial)
frame2im
frameedit
fread
fread (serial)
freqspace
frewind
fscanf
fscanf (serial)
fseek
ftell
ftp
full
fullfile
func2str
function
function_handle (@)
functions
funm
fwrite
fwrite (serial)
fzero
gallery
gamma, gammainc, gammaln
gca
gcbf
gcbo
gcd
gcf
gco
ge
genpath
genvarname
get
get (COM)
get (serial)
get (timer)

get (timeseries)
get (tscollection)
getabstime (timeseries)
getabstime (tscollection)
getappdata
GetCharArray
getdatasamplesize
getenv
getfield
getframe
GetFullMatrix
getinterpmethod
getpixelposition
getpref
getqualitydesc
getsampleusingtime (timeseries)
getsampleusingtime (tscollection)
gettimeseriesnames
gettsafteratevent
gettsafterevent
gettsatevent
gettsbeforeatevent
gettsbeforeevent
gettsbetweenevents
GetVariable
GetWorkspaceData
ginput
global
gmres
gplot
grabcode
gradient
graymon
grid
griddata
griddata3
griddatan

gsvd
gt
gtext
guidata
guide
guihandles
gunzip
gzip
hadamard
hankel
hdf
hdf5
hdf5info
hdf5read
hdf5write
hdfinfo
hdfread
hdftool
help
helpbrowser
helpdesk
helpdlg
helpwin
hess
hex2dec
hex2num
hgexport
hggroup
Hggroup Properties
hgload
hgsave
hgtransform
Hgtransform Properties
hidden
hilb
hist
histc

inputdlg
inputname
inputParser
inspect
instrcallback
instrfind
instrfindall
int2str
int8, int16, int32, int64
interfaces
interp1
interp1q
interp2
interp3
interpft
interpn
interpstreamspeed
intersect
intmax
intmin
intwarning
inv
invhilb
invoke
ipermute
iqr (timeseries)
is*
isa
isappdata
iscell
iscellstr
ischar
iscom
isdir
isempty
isempty (timeseries)
isempty (tscollection)

isequal
isequalwithequalnans
isevent
isfield
isfinite
isfloat
isglobal
ishandle
ishold
isinf
isinteger
isinterface
isjava
iskeyword
isletter
islogical
ismac
ismember
ismethod
isnan
isnumeric
isobject
isocaps
isocolors
isonormals
isosurface
ispc
ispref
isprime
isprop
isreal
isscalar
issorted
isspace
issparse
isstr
isstrprop

isstruct
isstudent
isunix
isvalid (serial)
isvalid (timer)
isvarname
isvector
j
javaaddpath
javaArray
javachk
javaclasspath
javaMethod
javaObject
javarmpath
keyboard
kron
lasterr
lasterror
lastwarn
lcm
ldl
ldivide, rdivide
le
legend
legendre
length
length (serial)
length (timeseries)
length (tscollection)
libfunctions
libfunctionsview
libisloaded
libpointer
libstruct
license
light

makehgtform
mat2cell
mat2str
material
matlabcolon (matlab:)
matlabrc
matlabroot
matlab (UNIX)
matlab (Windows)
max
max (timeseries)
MaximizeCommandWindow
mean
mean (timeseries)
median
median (timeseries)
disp (memmapfile)
get (memmapfile)
memmapfile
memory
menu
mesh, meshc, meshz
meshgrid
methods
methodsview
mex
mexext
mfilename
mget
min
min (timeseries)
MinimizeCommandWindow
minres
mislocked
mkdir
mkdir (ftp)
mkpp

not
notebook
now
nthroot
null
num2cell
num2hex
num2str
numel
nzmax
ode15i
ode23, ode45, ode113, ode15s, ode23s, ode23t, ode23tb
odefile
odeget
odeset
odextend
ones
open
openfig
opengl
openvar
optimget
optimset
or
ordeig
orderfields
ordqz
ordschur
orient
orth
otherwise
pack
pagesetupdlg
pan
pareto
parse (inputParser)
parseSoapResponse

polar
poly
polyarea
polyder
polyeig
polyfit
polyint
polyval
polyvalm
pow2
power
ppval
prefdir
preferences
primes
print, printopt
printdlg
printpreview
prod
profile
profsave
propedit
propedit (COM)
propertyeditor
psi
publish
PutCharArray
PutFullMatrix
PutWorkspaceData
pwd
qmr
qr
qrdelete
qrinsert
qrupdate
quad
quadl

shrinkfaces
sign
sin
sind
single
sinh
size
size (serial)
size (timeseries)
size (tscollection)
slice
smooth3
sort
sortrows
sound
soundsc
spalloc
sparse
spaugment
spconvert
spdiags
specular
speye
spfun
sph2cart
sphere
spinmap
spline
spones
spparms
sprand
sprandn
sprandsym
sprank
sprintf
spy
sqrt

strtrim
struct
struct2cell
structfun
strvcat
sub2ind
subplot
subsasgn
subsindex
subspace
subsref
substruct
subvolume
sum
sum (timeseries)
superiorto
support
surf, surfc
surf2patch
surface
Surface Properties
Surfaceplot Properties
surfl
surfnorm
svd
svds
swapbytes
switch
symamd
symbfact
symmlq
symmmd
symrcm
symvar
synchronize
syntax
system

tsearch
tsearchn
tsprops
tstool
type
typecast
uibuttongroup
Uibuttongroup Properties
uicontextmenu
Uicontextmenu Properties
uicontrol
Uicontrol Properties
uigetdir
uigetfile
uigetpref
uiimport
uimenu
Uimenu Properties
uint8, uint16, uint32, uint64
uiopen
uipanel
Uipanel Properties
uipushtool
Uipushtool Properties
uiputfile
uiresume, uiwait
uisave
uisetcolor
uisetfont
uisetpref
uistack
uitoggletool
Uitoggletool Properties
uitoolbar
Uitoolbar Properties
undocheckout
unicode2native

union
unique
unix
unloadlibrary
unmkpp
unregisterallevents
unregisterevent
untar
unwrap
unzip
upper
urlread
urlwrite
usejava
vander
var
var (timeseries)
varargin
varargout
vectorize
ver
verctrl
verLessThan
version
vertcat
vertcat (timeseries)
vertcat (tscollection)
view
viewmtx
volumebounds
voronoi
voronoin
wait
waitbar
waitfor
waitforbuttonpress
warndlg

warning
waterfall
wavfinfo
wavplay
wavread
wavrecord
wavwrite
web
weekday
what
whatsnew
which
while
whitebg
who, whos
wilkinson
winopen
winqueryreg
wk1finfo
wk1read
wk1write
workspace
xlabel, ylabel, zlabel
xlim, ylim, zlim
xlsfinfo
xlsread
xlswrite
xmlread
xmlwrite
xor
xslt
zeros
zip
zoom

factor

Purpose Prime factors

Syntax

```
f = factor(n)
```

Description `f = factor(n)` returns a row vector containing the prime factors of `n`.

Examples

```
f = factor(123)
f =
     3    41
```

See Also `isprime`, `primes`

Purpose Factorial function

Syntax `factorial(N)`

Description `factorial(N)`, for scalar `N`, is the product of all the integers from `1` to `N`, i.e. `prod(1:n)`. When `N` is an `N`-dimensional array, `factorial(N)` is the factorial for each element of `N`.

Since double precision numbers only have about 15 digits, the answer is only accurate for `n <= 21`. For larger `n`, the answer will have the right magnitude, and is accurate for the first 15 digits.

See Also `prod`

false

Purpose

Logical 0 (false)

Syntax

```
false
false(n)
false(m, n)
false(m, n, p, ...)
false(size(A))
```

Description

`false` is shorthand for `logical(0)`.

`false(n)` is an `n`-by-`n` matrix of logical zeros.

`false(m, n)` or `false([m, n])` is an `m`-by-`n` matrix of logical zeros.

`false(m, n, p, ...)` or `false([m n p ...])` is an `m`-by-`n`-by-`p`-by-`...` array of logical zeros.

Note The size inputs `m`, `n`, `p`, `...` should be nonnegative integers. Negative integers are treated as 0.

`false(size(A))` is an array of logical zeros that is the same size as array `A`.

Remarks

`false(n)` is much faster and more memory efficient than `logical(zeros(n))`.

See Also

`true`, `logical`

Purpose

Close one or more open files

Syntax

```
status = fclose(fid)
status = fclose('all')
```

Description

`status = fclose(fid)` closes the specified file if it is open, returning `0` if successful and `-1` if unsuccessful. Argument `fid` is a file identifier associated with an open file. (See `fopen` for a complete description of `fid`).

If `fid` does not represent an open file, or if it is equal to 0, 1, or 2, then `fclose` throws an error.

`status = fclose('all')` closes all open files (except standard input, output, and error), returning `0` if successful and `-1` if unsuccessful.

See Also

`ferror`, `fopen`, `fprintf`, `fread`, `frewind`, `fscanf`, `fseek`, `ftell`, `fwrite`

fclose (serial)

Purpose

Disconnect serial port object from device

Syntax

```
fclose(obj)
```

Arguments

`obj`	A serial port object or an array of serial port objects.

Description

`fclose(obj)` disconnects `obj` from the device.

Remarks

If `obj` was successfully disconnected, then the `Status` property is configured to `closed` and the `RecordStatus` property is configured to `off`. You can reconnect `obj` to the device using the `fopen` function.

An error is returned if you issue `fclose` while data is being written asynchronously. In this case, you should abort the write operation with the `stopasync` function, or wait for the write operation to complete.

If you use the `help` command to display help for `fclose`, then you need to supply the pathname shown below.

```
help serial/fclose
```

Example

This example creates the serial port object `s`, connects `s` to the device, writes and reads text data, and then disconnects `s` from the device using `fclose`.

```
s = serial('COM1');
fopen(s)
fprintf(s, '*IDN?')
idn = fscanf(s);
fclose(s)
```

At this point, the device is available to be connected to a serial port object. If you no longer need `s`, you should remove from memory with the `delete` function, and remove it from the workspace with the `clear` command.

See Also

Functions

clear, delete, fopen, stopasync

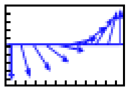
Properties

RecordStatus, Status

feather

Purpose

Plot velocity vectors



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

```
feather(U,V)
feather(Z)
feather(...,LineSpec)
feather(axes_handle,...)
h = feather(...)
```

Description

A feather plot displays vectors emanating from equally spaced points along a horizontal axis. You express the vector components relative to the origin of the respective vector.

`feather(U,V)` displays the vectors specified by `U` and `V`, where `U` contains the *x* components as relative coordinates, and `V` contains the *y* components as relative coordinates.

`feather(Z)` displays the vectors specified by the complex numbers in `Z`. This is equivalent to `feather(real(Z),imag(Z))`.

`feather(...,LineSpec)` draws a feather plot using the line type, marker symbol, and color specified by `LineSpec`.

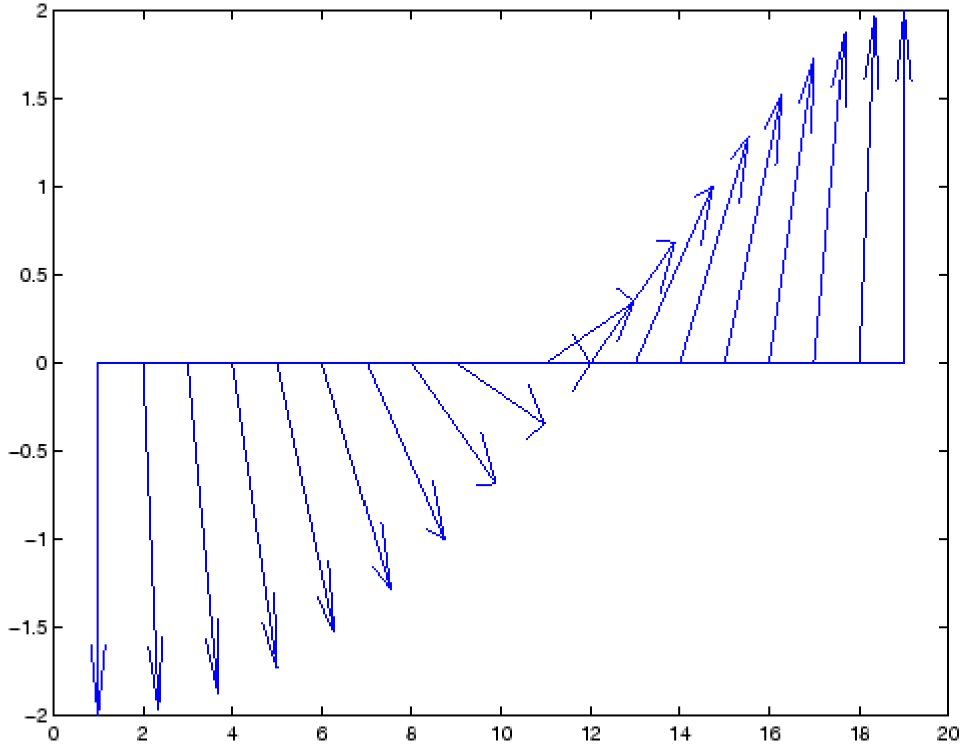
`feather(axes_handle,...)` plots into the axes with the handle `axes_handle` instead of into the current axes (`gca`).

`h = feather(...)` returns the handles to line objects in `h`.

Examples

Create a feather plot showing the direction of theta.

```
theta = (-90:10:90)*pi/180;
r = 2*ones(size(theta));
[u,v] = pol2cart(theta,r);
feather(u,v);
```



See Also

compass, LineSpec, rose

"Direction and Velocity Plots" on page 1-88 for related functions

Purpose

Test for end-of-file

Syntax

```
eofstat = feof(fid)
```

Description

`eofstat = feof(fid)` returns `1` if the end-of-file indicator for the file `fid` has been set and `0` otherwise. (See `fopen` for a complete description of `fid`.)

The end-of-file indicator is set when there is no more input from the file.

See Also

`fopen`

Purpose

Query MATLAB about errors in file input or output

Syntax

```
message = ferror(fid)
message = ferror(fid, 'clear')
[message,errnum] = ferror(...)
```

Description

`message = ferror(fid)` returns the error string `message`. Argument `fid` is a file identifier associated with an open file (see `fopen` for a complete description of `fid`).

`message = ferror(fid, 'clear')` clears the error indicator for the specified file.

`[message,errnum] = ferror(...)` returns the error status number `errnum` of the most recent file I/O operation associated with the specified file.

If the most recent I/O operation performed on the specified file was successful, the value of `message` is empty and `ferror` returns an `errnum` value of `0`.

A nonzero `errnum` indicates that an error occurred in the most recent file I/O operation. The value of `message` is a string that can contain information about the nature of the error. If the message is not helpful, consult the C run-time library manual for your host operating system for further details.

See Also

`fclose`, `fopen`, `fprintf`, `fread`, `fscanf`, `fseek`, `ftell`, `fwrite`

Purpose Evaluate function

Syntax

```
[y1, y2, ...] = feval(fhandle, x1, ..., xn)
[y1, y2, ...] = feval(function, x1, ..., xn)
```

Description `[y1, y2, ...]  = feval(fhandle, x1, ..., xn)` evaluates the function handle, `fhandle`, using arguments `x1` through `xn`. If the function handle is bound to more than one built-in or M-file, (that is, it represents a set of overloaded functions), then the data type of the arguments `x1` through `xn` determines which function is dispatched to.

Note It is not necessary to use `feval` to call a function by means of a function handle. This is explained in "Calling a Function Using Its Handle" in the MATLAB Programming documentation.

`[y1, y2, ...]  = feval(function, x1, ..., xn)`. If `function` is a quoted string containing the name of a function (usually defined by an M-file), then `feval(function, x1, ..., xn)` evaluates that function at the given arguments. The `function` parameter must be a simple function name; it cannot contain path information.

Remarks The following two statements are equivalent.

```
[V,D] = eig(A)
[V,D] = feval(@eig, A)
```

Examples The following example passes a function handle, `fhandle`, in a call to `fminbnd`. The `fhandle` argument is a handle to the `humps` function.

```
fhandle = @humps;
x = fminbnd(fhandle, 0.3, 1);
```

The `fminbnd` function uses `feval` to evaluate the function handle that was passed in.

```
function [xf, fval, exitflag, output] = ...
    fminbnd(funfcn, ax, bx, options, varargin)
            .
            .
            .
fx = feval(funfcn, x, varargin{:});
```

See Also assignin, function_handle, functions, builtin, eval, evalin

Feval (COM)

Purpose

Evaluate MATLAB function in server

Syntax

MATLAB Client

```
result = h.Feval('functionname', numout, arg1, arg2, ...)
result = Feval(h, 'functionname', numout, arg1, arg2, ...)
result = invoke(h, 'Feval', 'functionname', numout, ...
arg1, arg2, ...)
```

Method Signatures

```
HRESULT Feval([in] BSTR functionname, [in] long nargout,
[out] VARIANT* result, [in, optional] VARIANT arg1, arg2, ...)
```

Visual Basic Client

```
Feval(String functionname, long numout,
arg1, arg2, ...) As Object
```

Description

`Feval` executes the MATLAB function specified by the string `functionname` in the Automation server attached to handle `h`.

Indicate the number of outputs to be returned by the function in a 1-by-1 `double` array, `numout`. The server returns output from the function in the cell array, `result`.

You can specify as many as 32 input arguments to be passed to the function. These arguments follow `numout` in the `Feval` argument list. There are four ways to pass an argument to the function being evaluated.

Passing Mechanism	Description
Pass the value itself	To pass any numeric or string value, specify the value in the `Feval` argument list: `a = h.Feval('sin', 1, -pi:0.01:pi);`

Passing Mechanism	Description

Pass a client variable	To pass an argument that is assigned to a variable in the client, specify the variable name alone:
	`x = -pi:0.01:pi;`
	`a = h.Feval('sin', 1, x);`

Reference a server variable	To reference a variable that is defined in the server, specify the variable name followed by an equals (=) sign:
	`h.PutWorkspaceData('x', 'base', -pi:0.01:pi);`
	`a = h.Feval('sin', 1, 'x=');`
	Note that the server variable is not reassigned.

Remarks

If you want output from `Feval` to be displayed at the client window, you must assign a returned value.

Server function names, like `Feval`, are case sensitive when using the first two syntaxes shown in the Syntax section.

There is no difference in the operation of the three syntaxes shown above for the MATLAB client.

Examples

Passing Arguments — MATLAB Client

This section contains a number of examples showing how to use `Feval` to execute MATLAB commands on a MATLAB Automation server.

- Concatenate two strings in the server by passing the input strings in a call to `strcat` through `Feval` (`strcat` deletes trailing spaces; use leading spaces):

```
a = h.Feval('strcat', 1, 'hello', ' world')
a =
    'hello world'
```

- Perform the same concatenation, passing a string and a local variable `clistr` that contains the second string:

```
clistr = ' world';
a = h.Feval('strcat', 1, 'hello', clistr)
a =
    'hello world'
```

- This next example is different in that the variable `srvstr` is defined in the server, not the client. Putting an equals sign after a variable name (e.g., `srvstr=`) indicates that it a server variable, and that MATLAB should not expect the variable to be defined on the client:

```
% Define the variable srvstr on the server.
h.PutCharArray('srvstr', 'base', ' world')

% Pass the name of the server variable using 'name=' syntax
a = h.Feval('strcat', 1, 'hello', 'srvstr=')
a =
    'hello world'
```

Visual Basic.net Client

Here are the same examples shown above, but written for a Visual Basic.net client. These examples return the same strings as shown above.

- Pass the two strings to the MATLAB function `strcat` on the server:

```
Dim Matlab As Object
Dim out As Object
Matlab = CreateObject("matlab.application")
out = Matlab.Feval("strcat", 1, "hello", " world")
```

- Define `clistr` locally and pass this variable:

```
Dim clistr As String
clistr = " world"
out = Matlab.Feval("strcat", 1, "hello", clistr)
```

- Pass the name of a variable defined on the server:

```
Matlab.PutCharArray("srvstr", "base", " world")
out = Matlab.Feval("strcat", 1, "hello", "srvstr=")
```

Feval Return Values — MATLAB Client. `Feval` returns data from the evaluated function in a cell array. The cell array has one row for every return value. You can control how many values are returned using the second input argument to `Feval`, as shown in this example.

The second argument in the following example specifies that `Feval` return three outputs from the `fileparts` function. As is the case here, you can request fewer than the maximum number of return values for a function (`fileparts` can return up to four):

```
a = h.Feval('fileparts', 3, 'd:\work\ConsoleApp.cpp')
a =
    'd:\work'
    'ConsoleApp'
    '.cpp'
```

Convert the returned values from the cell array a to char arrays:

```
a{:}
ans =
d:\work

ans =
ConsoleApp

ans =
.cpp
```

Feval Return Values — Visual Basic.net Client

Here is the same example, but coded in Visual Basic. Define the argument returned by `Feval` as an `Object`.

```
Dim Matlab As Object
Dim out As Object
```

```
Matlab = CreateObject("matlab.application")
out = Matlab.Feval("fileparts", 3, "d:\work\ConsoleApp.cpp")
```

See Also

Execute, PutFullMatrix, GetFullMatrix, PutCharArray, GetCharArray

Purpose

Discrete Fourier transform

Syntax

```
Y = fft(X)
Y = fft(X,n)
Y = fft(X,[],dim)
Y = fft(X,n,dim)
```

Definition

The functions `X = fft(x)` and `x = ifft(X)` implement the transform and inverse transform pair given for vectors of length N by:

$$X(k) = \sum_{j=1}^{N} x(j)\omega_N^{(j-1)(k-1)}$$

$$x(j) = (1/N)\sum_{k=1}^{N} X(k)\omega_N^{-(j-1)(k-1)}$$

where

$$\omega_N = e^{(-2\pi i)/N}$$

is an Nth root of unity.

Description

`Y = fft(X)` returns the discrete Fourier transform (DFT) of vector `X`, computed with a fast Fourier transform (FFT) algorithm.

If `X` is a matrix, `fft` returns the Fourier transform of each column of the matrix.

If `X` is a multidimensional array, `fft` operates on the first nonsingleton dimension.

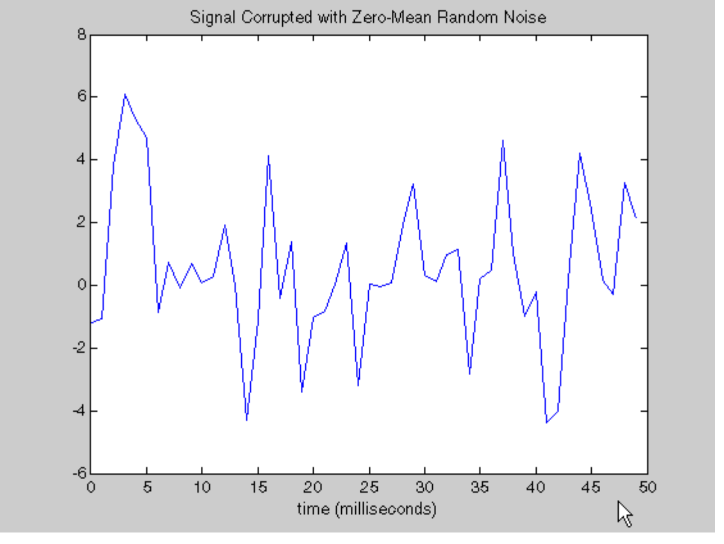
`Y = fft(X,n)` returns the `n`-point DFT. If the length of `X` is less than `n`, `X` is padded with trailing zeros to length `n`. If the length of `X` is greater than `n`, the sequence `X` is truncated. When `X` is a matrix, the length of the columns are adjusted in the same manner.

Y = fft(X,[],dim) and Y = fft(X,n,dim) applies the FFT operation across the dimension dim.

Examples

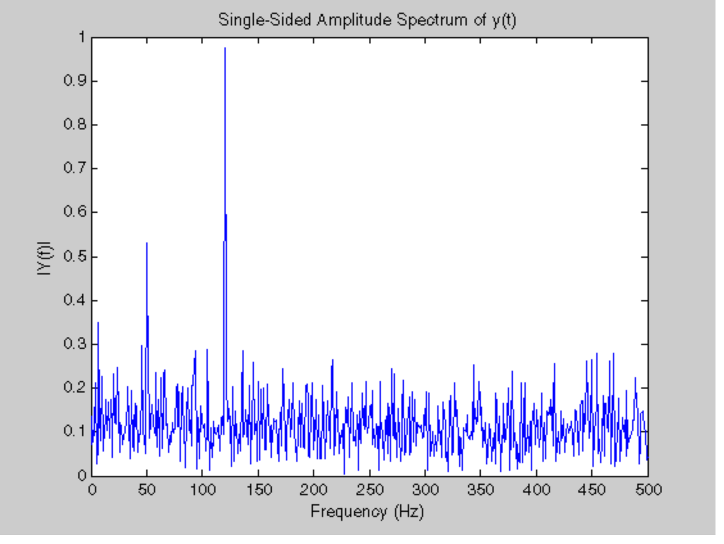
A common use of Fourier transforms is to find the frequency components of a signal buried in a noisy time domain signal. Consider data sampled at 1000 Hz. Form a signal containing a 50 Hz sinusoid of amplitude 0.7 and 120 Hz sinusoid of amplitude 1 and corrupt it with some zero-mean random noise:

```
Fs = 1000;                    % Sampling frequency
T = 1/Fs;                     % Sample time
L = 1000;                     % Length of signal
t = (0:L-1)*T;                % Time vector
% Sum of a 50 Hz sinusoid and a 120 Hz sinusoid
x = 0.7*sin(2*pi*50*t) + sin(2*pi*120*t);
y = x + 2*randn(size(t));     % Sinusoids plus noise
plot(Fs*t(1:50),y(1:50))
title('Signal Corrupted with Zero-Mean Random Noise')
xlabel('time (milliseconds)')
```



It is difficult to identify the frequency components by looking at the original signal. Converting to the frequency domain, the discrete Fourier transform of the noisy signal y is found by taking the fast Fourier transform (FFT):

```
NFFT = 2^nextpow2(L); % Next power of 2 from length of y
Y = fft(y,NFFT)/L;
f = Fs/2*linspace(0,1,NFFT/2);

% Plot single-sided amplitude spectrum.
plot(f,2*abs(Y(1:NFFT/2)))
title('Single-Sided Amplitude Spectrum of y(t)')
xlabel('Frequency (Hz)')
ylabel('|Y(f)|')
```



The main reason the amplitudes are not exactly at 0.7 and 1 is because of the noise. Several executions of this code (including recomputation of y) will produce different approximations to 0.7 and 1. The other reason is that you have a finite length signal. Increasing L from 1000 to

10000 in the example above will produce much better approximations on average.

Algorithm

The FFT functions (`fft`, `fft2`, `fftn`, `ifft`, `ifft2`, `ifftn`) are based on a library called FFTW [3],[4]. To compute an N-point DFT when N is composite (that is, when $N = N_1 N_2$), the FFTW library decomposes the problem using the Cooley-Tukey algorithm [1], which first computes N_1 transforms of size N_2, and then computes N_2 transforms of size N_1. The decomposition is applied recursively to both the N_1- and N_2-point DFTs until the problem can be solved using one of several machine-generated fixed-size "codelets." The codelets in turn use several algorithms in combination, including a variation of Cooley-Tukey [5], a prime factor algorithm [6], and a split-radix algorithm [2]. The particular factorization of N is chosen heuristically.

When N is a prime number, the FFTW library first decomposes an N-point problem into three ($N - 1$)-point problems using Rader's algorithm [7]. It then uses the Cooley-Tukey decomposition described above to compute the ($N - 1$)-point DFTs.

For most N, real-input DFTs require roughly half the computation time of complex-input DFTs. However, when N has large prime factors, there is little or no speed difference.

The execution time for `fft` depends on the length of the transform. It is fastest for powers of two. It is almost as fast for lengths that have only small prime factors. It is typically several times slower for lengths that are prime or which have large prime factors.

Note You might be able to increase the speed of `fft` using the utility function `fftw`, which controls how MATLAB optimizes the algorithm used to compute an FFT of a particular size and dimension.

Data Type Support

`fft` supports inputs of data types `double` and `single`. If you call `fft` with the syntax `y = fft(X, ...)`, the output `y` has the same data type as the input `X`.

See Also

`fft2`, `fftn`, `fftw`, `fftshift`, `ifft`

`dftmtx`, `filter`, and `freqz` in the Signal Processing Toolbox

References

[1] Cooley, J. W. and J. W. Tukey, "An Algorithm for the Machine Computation of the Complex Fourier Series,"*Mathematics of Computation*, Vol. 19, April 1965, pp. 297-301.

[2] Duhamel, P. and M. Vetterli, "Fast Fourier Transforms: A Tutorial Review and a State of the Art," *Signal Processing*, Vol. 19, April 1990, pp. 259-299.

[3] FFTW (`http://www.fftw.org`)

[4] Frigo, M. and S. G. Johnson, "FFTW: An Adaptive Software Architecture for the FFT,"*Proceedings of the International Conference on Acoustics, Speech, and Signal Processing*, Vol. 3, 1998, pp. 1381-1384.

[5] Oppenheim, A. V. and R. W. Schafer, *Discrete-Time Signal Processing*, Prentice-Hall, 1989, p. 611.

[6] Oppenheim, A. V. and R. W. Schafer, *Discrete-Time Signal Processing*, Prentice-Hall, 1989, p. 619.

[7] Rader, C. M., "Discrete Fourier Transforms when the Number of Data Samples Is Prime," *Proceedings of the IEEE*, Vol. 56, June 1968, pp. 1107-1108.

Purpose

2-D discrete Fourier transform

Syntax

```
Y = fft2(X)
Y = fft2(X,m,n)
```

Description

`Y = fft2(X)` returns the two-dimensional discrete Fourier transform (DFT) of `X`, computed with a fast Fourier transform (FFT) algorithm. The result `Y` is the same size as `X`.

`Y = fft2(X,m,n)` truncates `X`, or pads `X` with zeros to create an `m`-by-`n` array before doing the transform. The result is `m`-by-`n`.

Algorithm

`fft2(X)` can be simply computed as

```
fft(fft(X).').'
```

This computes the one-dimensional DFT of each column `X`, then of each row of the result. The execution time for `fft` depends on the length of the transform. It is fastest for powers of two. It is almost as fast for lengths that have only small prime factors. It is typically several times slower for lengths that are prime or which have large prime factors.

Note You might be able to increase the speed of `fft2` using the utility function `fftw`, which controls how MATLAB optimizes the algorithm used to compute an FFT of a particular size and dimension.

Data Type Support

`fft2` supports inputs of data types `double` and `single`. If you call `fft2` with the syntax `y = fft2(X, ...)`, the output `y` has the same data type as the input `X`.

See Also

`fft`, `fftn`, `fftw`, `fftshift`, `ifft2`

Purpose

N-D discrete Fourier transform

Syntax

```
Y = fftn(X)
Y = fftn(X,siz)
```

Description

`Y = fftn(X)` returns the discrete Fourier transform (DFT) of `X`, computed with a multidimensional fast Fourier transform (FFT) algorithm. The result `Y` is the same size as `X`.

`Y = fftn(X,siz)` pads `X` with zeros, or truncates `X`, to create a multidimensional array of size `siz` before performing the transform. The size of the result `Y` is `siz`.

Algorithm

`fftn(X)` is equivalent to

```
Y = X;
for p = 1:length(size(X))
    Y = fft(Y,[],p);
end
```

This computes in-place the one-dimensional fast Fourier transform along each dimension of `X`. The execution time for `fft` depends on the length of the transform. It is fastest for powers of two. It is almost as fast for lengths that have only small prime factors. It is typically several times slower for lengths that are prime or which have large prime factors.

Note You might be able to increase the speed of `fftn` using the utility function `fftw`, which controls how MATLAB optimizes the algorithm used to compute an FFT of a particular size and dimension.

Data Type Support

`fftn` supports inputs of data types `double` and `single`. If you call `fftn` with the syntax `y = fftn(X, ...)`, the output `y` has the same data type as the input `X`.

See Also

fft, fft2, fftn, fftw, ifftn

Purpose

Shift zero-frequency component to center of spectrum

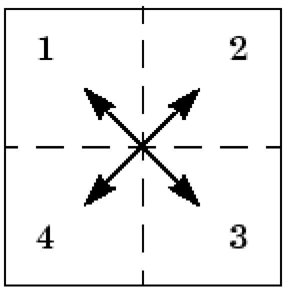
Syntax

```
Y = fftshift(X)
Y = fftshift(X,dim)
```

Description

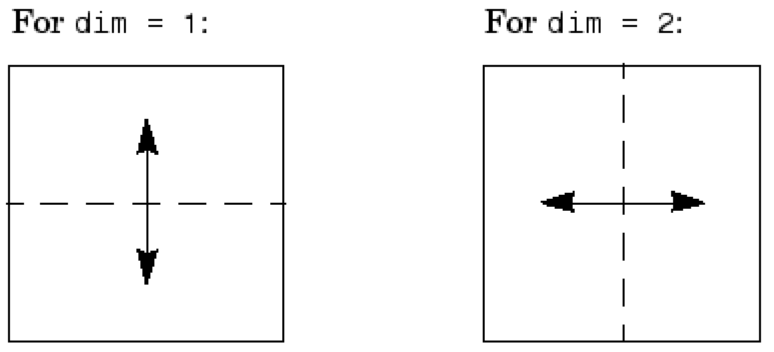
`Y = fftshift(X)` rearranges the outputs of `fft`, `fft2`, and `fftn` by moving the zero-frequency component to the center of the array. It is useful for visualizing a Fourier transform with the zero-frequency component in the middle of the spectrum.

For vectors, `fftshift(X)` swaps the left and right halves of `X`. For matrices, `fftshift(X)` swaps the first quadrant with the third and the second quadrant with the fourth.



For higher-dimensional arrays, `fftshift(X)` swaps “half-spaces” of `X` along each dimension.

`Y = fftshift(X,dim)` applies the `fftshift` operation along the dimension `dim`.



Note `ifftshift` will undo the results of `fftshift`. If the matrix `X` contains an odd number of elements, `ifftshift(fftshift(X))` must be done to obtain the original `X`. Simply performing `fftshift(X)` twice will not produce `X`.

Examples

For any matrix `X`

```
Y = fft2(X)
```

has `Y(1,1) = sum(sum(X))`; the zero-frequency component of the signal is in the upper-left corner of the two-dimensional FFT. For

```
Z = fftshift(Y)
```

this zero-frequency component is near the center of the matrix.

See Also

`circshift`, `fft`, `fft2`, `fftn`, `ifftshift`

Purpose

Interface to FFTW library run-time algorithm tuning control

Syntax

```
fftw('planner', method)
method = fftw('planner')
str = fftw('dwisdom')
str = fftw('swisdom')
fftw('dwisdom', str)
fftw('swisdom', str)
```

Description

`fftw` enables you to optimize the speed of the MATLAB FFT functions `fft`, `ifft`, `fft2`, `ifft2`, `fftn`, and `ifftn`. You can use `fftw` to set options for a tuning algorithm that experimentally determines the fastest algorithm for computing an FFT of a particular size and dimension at run time. MATLAB records the optimal algorithm in an internal data base and uses it to compute FFTs of the same size throughout the current session. The tuning algorithm is part of the FFTW library that MATLAB uses to compute FFTs.

`fftw('planner', method)` sets the method by which the tuning algorithm searches for a good FFT algorithm when the dimension of the FFT is not a power of 2. You can specify `method` to be one of the following. The default method is `estimate`:

- `'estimate'`
- `'measure'`
- `'patient'`
- `'exhaustive'`
- `'hybrid'`

When you call `fftw('planner', method)`, the next time you call one of the FFT functions, such as `fft`, the tuning algorithm uses the specified method to optimize the FFT computation. Because the tuning involves trying different algorithms, the first time you call an FFT function, it might run more slowly than if you did not call `fftw`. However, subsequent calls to any of the FFT functions, for a problem of the same size, often run more quickly than they would without using `fftw`.

Note The FFT functions only use the optimal FFT algorithm during the current MATLAB session. "Reusing Optimal FFT Algorithms" on page 2-1086 explains how to reuse the optimal algorithm in a future MATLAB session.

If you set the method to `'estimate'`, the FFTW library does not use run-time tuning to select the algorithms. The resulting algorithms might not be optimal.

If you set the method to `'measure'`, the FFTW library experiments with many different algorithms to compute an FFT of a given size and chooses the fastest. Setting the method to `'patient'` or `'exhaustive'` has a similar result, but the library experiments with even more algorithms so that the tuning takes longer the first time you call an FFT function. However, subsequent calls to FFT functions are faster than with `'measure'`.

If you set `'planner'` to `'hybrid'`, MATLAB

- Sets method to `'measure'` method for FFT dimensions 8192 or smaller.
- Sets method to `'estimate'` for FFT dimensions greater than 8192.

`method = fftw('planner')` returns the current planner method.

`str = fftw('dwisdom')` returns the information in the FFTW library's internal double-precision database as a string. The string can be saved and then later reused in a subsequent MATLAB session using the next syntax.

`str = fftw('swisdom')` returns the information in the FFTW library's internal single-precision database as a string.

`fftw('dwisdom', str)` loads `fftw` wisdom represented by the string `str` into the FFTW library's internal double-precision wisdom database. `fftw('dwisdom','')` or `fftw('dwisdom',[])` clears the internal wisdom database.

`fftw('swisdom', str)` loads `fftw` wisdom represented by the string `str` into the FFTW library's internal single-precision wisdom database. `fftw('swisdom','')` or `fftw('swisdom',[])` clears the internal wisdom database.

Note on large powers of 2 For FFT dimensions that are powers of 2, between 2^{14} and 2^{22}, MATLAB uses special preloaded information in its internal database to optimize the FFT computation. No tuning is performed when the dimension of the FTT is a power of 2, unless you clear the database using the command `fftw('wisdom', [])`.

For more information about the FFTW library, see `http://www.fftw.org`.

Example

Comparison of Speed for Different Planner Methods

The following example illustrates the run times for different settings of `planner`. The example first creates some data and applies `fft` to it using the default method, `estimate`.

```
t=0:.001:5;
x = sin(2*pi*50*t)+sin(2*pi*120*t);
y = x + 2*randn(size(t));

tic; Y = fft(y,1458); toc
Elapsed time is 0.000400 seconds.
```

If you execute the commands

```
tic; Y = fft(y,1458); toc
```

a second time, MATLAB reports the elapsed time as essentially 0. To measure the elapsed time more accurately, you can execute the command `Y = fft(y,1458)` 1000 times in a loop.

```
tic; for k=1:1000
Y = fft(y,1458);
end; toc
Elapsed time is 0.098355 seconds.
```

This tells you that it takes approximately 1/1000 of a second to execute `fft(y, 1458)` a single time.

For comparison, set `planner` to `patient`. Since this `planner` explores possible algorithms more thoroughly than `hybrid`, the first time you run `fft`, it takes longer to compute the results.

```
fftw('planner','patient')
tic;Y = fft(y,1458);toc
Elapsed time is 0.000387 seconds.
```

However, the next time you call `fft`, it runs approximately 10 times faster than it when you use the method `'measure'`.

```
tic;for k=1:1000
Y=fft(y,1458);
end;toc
Elapsed time is 0.097793 seconds.
```

Reusing Optimal FFT Algorithms

In order to use the optimized FFT algorithm in a future MATLAB session, first save the “wisdom” using the command

```
str = fftw('wisdom')
```

You can save `str` for a future session using the command

```
save str
```

The next time you open MATLAB, load `str` using the command

```
load str
```

and then reload the “wisdom” into the FFTW database using the command

```
fftw('wisdom', str)
```

See Also

`fft`, `fft2`, `fftn`, `ifft`, `ifft2`, `ifftn`, `fftshift`.

fgetl

Purpose

Read line from file, discarding newline character

Syntax

```
tline = fgetl(fid)
```

Description

`tline = fgetl(fid)` returns the next line of the file associated with the file identifier `fid`. If `fgetl` encounters the end-of-file indicator, it returns `-1`. (See `fopen` for a complete description of `fid`.) `fgetl` is intended for use with files that contain newline characters.

MATLAB reads characters using the encoding scheme associated with the file. See `fopen` for more information.

The returned string `tline` does not include the line terminator(s) with the text line. To obtain the line terminators, use `fgets`.

Examples

The example reads every line of the M-file `fgetl.m`.

```
fid=fopen('fgetl.m');
while 1
    tline = fgetl(fid);
    if ~ischar(tline),   break,   end
    disp(tline)
end
fclose(fid);
```

See Also

`fgets`

Purpose

Read line of text from device and discard terminator

Syntax

```
tline = fgetl(obj)
[tline,count] = fgetl(obj)
[tline,count,msg] = fgetl(obj)
```

Arguments

`obj`	A serial port object.
`tline`	Text read from the instrument, excluding the terminator.
`count`	The number of values read, including the terminator.
`msg`	A message indicating if the read operation was unsuccessful.

Description

`tline = fgetl(obj)` reads one line of text from the device connected to `obj`, and returns the data to `tline`. The returned data does not include the terminator with the text line. To include the terminator, use `fgets`.

`[tline,count] = fgetl(obj)` returns the number of values read to `count`.

`[tline,count,msg] = fgetl(obj)` returns a warning message to `msg` if the read operation was unsuccessful.

Remarks

Before you can read text from 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 to perform a read operation while `obj` is not connected to the device.

If `msg` is not included as an output argument and the read operation was not successful, then a warning message is returned to the command line.

The `ValuesReceived` property value is increased by the number of values read – including the terminator – each time `fgetl` is issued.

If you use the `help` command to display help for `fgetl`, then you need to supply the pathname shown below.

```
help serial/fgetl
```

Rules for Completing a Read Operation with fgetl

A read operation with `fgetl` blocks access to the MATLAB command line until:

- The terminator specified by the `Terminator` property is reached.
- The time specified by the `Timeout` property passes.
- The input buffer is filled.

Example

Create the serial port object `s`, connect `s` to a Tektronix TDS 210 oscilloscope, and write the `RS232?` command with the `fprintf` function. `RS232?` instructs the scope to return serial port communications settings.

```
s = serial('COM1');
fopen(s)
fprintf(s,'RS232?')
```

Because the default value for the `ReadAsyncMode` property is `continuous`, data is automatically returned to the input buffer.

```
s.BytesAvailable
ans =
    17
```

Use `fgetl` to read the data returned from the previous write operation, and discard the terminator.

```
settings = fgetl(s)
settings =
9600;0;0;NONE;LF
length(settings)
ans =
    16
```

Disconnect s from the scope, and remove s from memory and the workspace.

```
fclose(s)
delete(s)
clear s
```

See Also

Functions

fgets, fopen

Properties

BytesAvailable, InputBufferSize, ReadAsyncMode, Status, Terminator, Timeout, ValuesReceived

Purpose

Read line from file, keeping newline character

Syntax

```
tline = fgets(fid)
tline = fgets(fid, nchar)
```

Description

`tline = fgets(fid)` returns the next line of the file associated with file identifier `fid`. If `fgets` encounters the end-of-file indicator, it returns `-1`. (See `fopen` for a complete description of `fid`.) `fgets` is intended for use with files that contain newline characters.

MATLAB reads characters using the encoding scheme associated with the file. See `fopen` for more information.

The returned string `tline` includes the line terminators associated with the text line. To obtain the string without the line terminators, use `fgetl`.

`tline = fgets(fid, nchar)` returns at most `nchar` characters of the next line. No additional characters are read after the line terminators or an end-of-file.

See Also

`fgetl`

Purpose

Read line of text from device and include terminator

Syntax

```
tline = fgets(obj)
[tline,count] = fgets(obj)
[tline,count,msg] = fgets(obj)
```

Arguments

`obj`	A serial port object.
`tline`	Text read from the instrument, including the terminator.
`count`	The number of bytes read, including the terminator.
`msg`	A message indicating if the read operation was unsuccessful.

Description

`tline = fgets(obj)` reads one line of text from the device connected to `obj`, and returns the data to `tline`. The returned data includes the terminator with the text line. To exclude the terminator, use `fgetl`.

`[tline,count] = fgets(obj)` returns the number of values read to `count`.

`[tline,count,msg] = fgets(obj)` returns a warning message to `msg` if the read operation was unsuccessful.

Remarks

Before you can read text from 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 to perform a read operation while `obj` is not connected to the device.

If `msg` is not included as an output argument and the read operation was not successful, then a warning message is returned to the command line.

The `ValuesReceived` property value is increased by the number of values read – including the terminator – each time `fgets` is issued.

If you use the `help` command to display help for `fgets`, then you need to supply the pathname shown below.

```
help serial/fgets
```

Rules for Completing a Read Operation with fgets

A read operation with `fgets` blocks access to the MATLAB command line until:

- The terminator specified by the `Terminator` property is reached.
- The time specified by the `Timeout` property passes.
- The input buffer is filled.

Example

Create the serial port object `s`, connect `s` to a Tektronix TDS 210 oscilloscope, and write the `RS232?` command with the `fprintf` function. `RS232?` instructs the scope to return serial port communications settings.

```
s = serial('COM1');
fopen(s)
fprintf(s,'RS232?')
```

Because the default value for the `ReadAsyncMode` property is `continuous`, data is automatically returned to the input buffer.

```
s.BytesAvailable
ans =
    17
```

Use `fgets` to read the data returned from the previous write operation, and include the terminator.

```
settings = fgets(s)
settings =
9600;0;0;NONE;LF
length(settings)
ans =
    17
```

Disconnect s from the scope, and remove s from memory and the workspace.

```
fclose(s)
delete(s)
clear s
```

See Also

Functions

fgetl, fopen

Properties

BytesAvailable, BytesAvailableFcn, InputBufferSize, Status, Terminator, Timeout, ValuesReceived

fieldnames

Purpose Field names of structure, or public fields of object

Syntax

```
names = fieldnames(s)
names = fieldnames(obj)
names = fieldnames(obj, '-full')
```

Description

`names = fieldnames(s)` returns a cell array of strings containing the structure field names associated with the structure `s`.

`names = fieldnames(obj)` returns a cell array of strings containing the names of the public data fields associated with `obj`, which is a MATLAB, COM, or Java object.

`names = fieldnames(obj, '-full')` returns a cell array of strings containing the name, type, attributes, and inheritance of each field associated with `obj`, which is a MATLAB, COM, or Java object.

Examples

Given the structure

```
mystr(1,1).name = 'alice';
mystr(1,1).ID = 0;
mystr(2,1).name = 'gertrude';
mystr(2,1).ID = 1
```

the command `n = fieldnames(mystr)` yields

```
n =
    'name'
    'ID'
```

In another example, if `f` is an object of Java class `java.awt.Frame`, the command `fieldnames(f)` lists the properties of `f`.

```
f = java.awt.Frame;

fieldnames(f)
ans =
    'WIDTH'
```

```
'HEIGHT'
'PROPERTIES'
'SOMEBITS'
'FRAMEBITS'
'ALLBITS'
    .
    .
```

See Also

`setfield`, `getfield`, `isfield`, `orderfields`, `rmfield`, "Using Dynamic Field Names"

figure

Purpose

Create figure graphics object

Syntax

```
figure
figure('PropertyName',propertyvalue,...)
figure(h)
h = figure(...)
```

Description

`figure` creates figure graphics objects. Figure objects are the individual windows on the screen in which MATLAB displays graphical output.

`figure` creates a new figure object using default property values.

`figure('`*`PropertyName`*`',propertyvalue,...)` creates a new figure object using the values of the properties specified. MATLAB uses default values for any properties that you do not explicitly define as arguments.

`figure(h)` does one of two things, depending on whether or not a figure with handle `h` exists. If `h` is the handle to an existing figure, `figure(h)` makes the figure identified by `h` the current figure, makes it visible, and raises it above all other figures on the screen. The current figure is the target for graphics output. If `h` is not the handle to an existing figure, but is an integer, `figure(h)` creates a figure and assigns it the handle `h`. `figure(h)` where `h` is not the handle to a figure, and is not an integer, is an error.

`h = figure(...)` returns the handle to the figure object.

Remarks

To create a figure object, MATLAB creates a new window whose characteristics are controlled by default figure properties (both factory installed and user defined) and properties specified as arguments. See the properties section for a description of these 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).

Use `set` to modify the properties of an existing figure or `get` to query the current values of figure properties.

The gcf command returns the handle to the current figure and is useful as an argument to the set and get commands.

Figures can be docked in the desktop. The Dockable property determines whether you can dock the figure.

Making a Figure Current

The current figure is the target for graphics output. There are two ways to make a figure h the current figure.

- Make the figure h current, visible, and displayed on top of other figures:

  ```
  figure(h)
  ```

- Make the figure h current, but do not change its visibility or stacking with respect to other figures:

  ```
  set(0,'CurrentFigure',h)
  ```

Examples

Specifying Figure Size and Screen Location

To create a figure window that is one quarter the size of your screen and is positioned in the upper left corner, use the root object's ScreenSize property to determine the size. ScreenSize is a four-element vector: [left, bottom, width, height]:

```
scrsz = get(0,'ScreenSize');
figure('Position',[1 scrsz(4)/2 scrsz(3)/2 scrsz(4)/2])
```

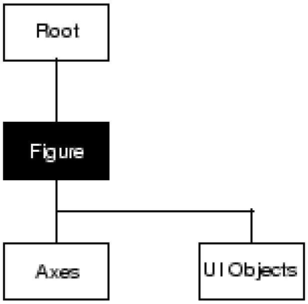
Specifying the Figure Window Title

You can add your own title to a figure by setting the Name property and you can turn off the figure number with the NumberTitle property:

```
figure('Name','Simulation Plot Window','NumberTitle','off')
```

See the Properties section for a description of all figure properties.

Object Hierarchy



Setting Default Properties

You can set default figure properties only on the root level.

```
set(0,'DefaultFigureProperty',PropertyValue...)
```

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

See Also

`axes`, `uicontrol`, `uimenu`, `close`, `clf`, `gcf`, `rootobject`

"Object Creation Functions" on page 1-93 for related functions

`Figure Properties` descriptions of all figure properties

See "Figure Properties" in the MATLAB Graphics User Guide for more information on figures.

Purpose

Figure 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”.

Figure Property Descriptions

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

`Alphamap`
: m-by-1 matrix of alpha values

  Figure alphamap. This property is an m-by-1 array of non-NaN alpha values. MATLAB accesses alpha values by their row number. For example, an index of 1 specifies the first alpha value, an index of 2 specifies the second alpha value, and so on. Alphamaps can be any length. The default alphamap contains 64 values that progress linearly from 0 to 1.

  Alphamaps affect the rendering of surface, image, and patch objects, but do not affect other graphics objects.

`BackingStore`
: `{on} | off`

  Offscreen pixel buffer. When `BackingStore` is `on`, MATLAB stores a copy of the figure window in an offscreen pixel buffer. When obscured parts of the figure window are exposed, MATLAB copies the window contents from this buffer rather than regenerating the objects on the screen. This increases the speed with which the screen is redrawn.

While refreshing the screen quickly is generally desirable, the buffers required do consume system memory. If memory limitations occur, you can set `BackingStore` to `off` to disable this feature and release the memory used by the buffers. If your computer does not support backing store, setting the `BackingStore` property results in a warning message, but has no other effect.

Setting `BackingStore` to `off` can increase the speed of animations because it eliminates the need to draw into both an off-screen buffer and the figure window.

Note that when the `Renderer` is set to `opengl`, MATLAB sets `BackingStore` to `off`.

`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 function interruption. The `BusyAction` property enables you to control how MATLAB handles events that potentially interrupt executing callback functions. If there is a callback function executing, callback functions 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 function.
- `queue` — Queue the event that attempted to execute a second callback function until the current callback finishes.

`ButtonDownFcn`

functional 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 in the figure window, but not over a child object (i.e., uicontrol, uipanel, axes, or axes child). Define the `ButtonDownFcn` as a function handle. The function must define at least two input arguments (handle of figure associated with the mouse button press and an empty event structure)

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

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

Using the ButtonDownFcn

This example, creates a figure and defines a function handle callback for the `ButtonDownFcn` property. When the user **Ctrl-**clicks the figure, the callback creates a new figure having the same callback.

Click to view in editor — This link opens the MATLAB editor with the following example.

Click to run example — **Ctrl-**click the figure to create a new figure.

```
fh_cb = @newfig; % Create function handle for newfig function
figure('ButtonDownFcn',fh_cb);

function newfig(src,evnt)
   if strcmp(get(src,'SelectionType'),'alt')
      figure('ButtonDownFcn',fh_cb)
   else
      disp('Use control-click to create a new figure')
   end
end
```

`Children`

vector of handles

Children of the figure. A vector containing the handles of all axes, user-interface objects displayed within the figure. You can change the order of the handles and thereby change the stacking of the objects on the display.

When an object's `HandleVisibility` property is set to `off`, it is not listed in its parent's `Children` property. See `HandleVisibility` for more information.

`Clipping`

`{on} | off`

This property has no effect on figures.

`CloseRequestFcn`

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

Function executed on figure close. This property defines a function that MATLAB executes whenever you issue the `close` command (either a `close(figure_handle)` or a `close all`), when you close a figure window from the computer's window manager menu, or when you quit MATLAB.

The `CloseRequestFcn` provides a mechanism to intervene in the closing of a figure. It allows you to, for example, display a dialog box to ask a user to confirm or cancel the close operation or to prevent users from closing a figure that contains a GUI.

The basic mechanism is

- A user issues the `close` command from the command line, by closing the window from the computer's window manager menu, or by quitting MATLAB.
- The close operation executes the function defined by the figure `CloseRequestFcn`. The default function is named `closereq` and is predefined as

```
if isempty(gcbf)
   if length(dbstack) == 1
      warning('MATLAB:closereq', ...
         'Calling closereq from the command line is now obso
   end
   close force
else
   delete(gcbf);
end
```

These statements unconditionally delete the current figure, destroying the window. `closereq` takes advantage of the fact that the `close` command makes all figures specified as arguments the current figure before calling the respective close request function.

Note that `closereq` honors the user's `ShowHiddenHandles` setting during figure deletion. This means that hidden figures are not deleted.

Redefining the CloseRequestFcn

Define the `CloseRequestFcn` as a function handle. For example,

```
set(gcf,'CloseRequestFcn',@my_closefcn)
```

Where `@my_closefcn` is a function handle referencing function `my_closefcn`.

Unless the close request function calls `delete` or `close`, MATLAB never closes the figure. (Note that you can always call `delete(`*`figure_handle`*`)` from the command line if you have created a window with a nondestructive close request function.)

A useful application of the close request function is to display a question dialog box asking the user to confirm the close operation. The following function illustrates how to do this.

Click to view in editor — This link opens the MATLAB editor with the following example.

Click to run example — **Ctrl-**click the figure to create a new figure.

```
function my_closereq(src,evnt)
% User-defined close request function
% to display a question dialog box
   selection = questdlg('Close This Figure?',...
      'Close Request Function',...
      'Yes','No','Yes');
   switch selection,
      case 'Yes',
         delete(gcf)
      case 'No'
      return
```

```
      end
   end
```

Now create a figure using the your`CloseRequestFcn`:

```
figure('CloseRequestFcn',@my_closereq)
```

To make this function your default close request function, set a default value on the root level.

```
set(0,'DefaultFigureCloseRequestFcn',@my_closereq)
```

MATLAB then uses this setting for the `CloseRequestFcn` of all subsequently created figures.

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

`Color`
`ColorSpec`

Background color. This property controls the figure window background color. You can specify a color using a three-element vector of RGB values or one of the MATLAB predefined names. See `ColorSpec` for more information.

`Colormap`
m-by-3 matrix of RGB values

Figure colormap. This property is an m-by-3 array of red, green, and blue (RGB) intensity values that define m individual colors. MATLAB accesses colors by their row number. For example, an index of 1 specifies the first RGB triplet, an index of 2 specifies the second RGB triplet, and so on.

Number of Colors Allowed

Colormaps can be any length (up to 256 only on MS-Windows), but must be three columns wide. The default figure colormap contains 64 predefined colors.

Objects That Use Colormaps

Colormaps affect the rendering of `surface`, image, and `patch` objects, but generally do not affect other graphics objects. See `colormap` and `ColorSpec` for more information.

`CreateFcn`

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

Callback function executed during figure creation. This property defines a callback function that executes when MATLAB creates a figure object. You must define this property as a default value on the root level. For example, the statement

```
set(0,'DefaultFigureCreateFcn',@fig_create)
```

defines a default value on the root level that causes all figures created to execute the setup function `fig_create`, which is defined below:

```
function fig_create(src,evnt)
set(src,'Color',[.2 .1 .5],...
   'IntegerHandle','off',...
   'MenuBar','none',...
   'ToolBar','none')
end
```

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

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

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

CurrentAxes
handle of current axes

Target axes in this figure. MATLAB sets this property to the handle of the figure's current axes (i.e., the handle returned by the gca command when this figure is the current figure). In all figures for which axes children exist, there is always a current axes. The current axes does not have to be the topmost axes, and setting an axes to be the CurrentAxes does not restack it above all other axes.

You can make an axes current using the axes and set commands. For example, axes(*axes_handle*) and set(gcf,'CurrentAxes',*axes_handle*) both make the axes identified by the handle *axes_handle* the current axes. In addition, axes(*axes_handle*) restacks the axes above all other axes in the figure.

If a figure contains no axes, get(gcf,'CurrentAxes') returns the empty matrix. Note that the gca function actually creates an axes if one does not exist.

CurrentCharacter
single character

Last key pressed. MATLAB sets this property to the last key pressed in the figure window. CurrentCharacter is useful for obtaining user input.

CurrentMenu
(Obsolete)

This property produces a warning message when queried. It has been superseded by the root CallbackObject property.

`CurrentObject`
object handle

Handle of current object. MATLAB sets this property to the handle of the last object clicked on by the mouse. This object is the front-most object in the view. You can use this property to determine which object a user has selected. The function `gco` provides a convenient way to retrieve the `CurrentObject` of the `CurrentFigure`.

Note that the `HitTest` property controls whether an object can become the `CurrentObject`.

Hidden Handle Objects

Clicking on an object whose `HandleVisibility` property is set to `off` (such as axis labels and title) causes the `CurrentObject` property to be set to empty `[]`. To avoid returning an empty value when users click on hidden objects, set the hidden object's `HitTest` property to `off`.

Mouse Over

Note that cursor motion over objects does not update the `CurrentObject`; you must click on objects to update this property. See the `CurrentPoint` property for related information.

`CurrentPoint`
two-element vector: [*x*-coordinate, *y*-coordinate]

Location of last button click in this figure. MATLAB sets this property to the location of the pointer at the time of the most recent mouse button press. MATLAB updates this property whenever you press the mouse button while the pointer is in the figure window.

Note that if you select a point in the figure and then use the values returned by the `CurrentPoint` property to plot that point, there can be differences in the position due to round off errors.

CurrentPoint and Cursor Motion

In addition to the behavior described above, MATLAB updates `CurrentPoint` before executing callback routines defined for the figure `WindowButtonMotionFcn` and `WindowButtonUpFcn` properties. This enables you to query `CurrentPoint` from these callback routines. It behaves like this:

- If there is no callback routine defined for the `WindowButtonMotionFcn` or the `WindowButtonUpFcn`, then MATLAB updates the `CurrentPoint` only when the mouse button is pressed down within the figure window.
- If there is a callback routine defined for the `WindowButtonMotionFcn`, then MATLAB updates the `CurrentPoint` just before executing the callback. Note that the `WindowButtonMotionFcn` executes only within the figure window unless the mouse button is pressed down within the window and then held down while the pointer is moved around the screen. In this case, the routine executes (and the `CurrentPoint` is updated) anywhere on the screen until the mouse button is released.
- If there is a callback routine defined for the `WindowButtonUpFcn`, MATLAB updates the `CurrentPoint` just before executing the callback. Note that the `WindowButtonUpFcn` executes only while the pointer is within the figure window unless the mouse button is pressed down initially within the window. In this case, releasing the button anywhere on the screen triggers callback execution, which is preceded by an update of the `CurrentPoint`.

The figure `CurrentPoint` is updated only when certain events occur, as previously described. In some situations, (such as when the `WindowButtonMotionFcn` takes a long time to execute and the pointer is moved very rapidly) the `CurrentPoint` may not reflect the actual location of the pointer, but rather the location at the time when the `WindowButtonMotionFcn` began execution.

The `CurrentPoint` is measured from the lower left corner of the figure window, in units determined by the `Units` property.

The root `PointerLocation` property contains the location of the pointer updated synchronously with pointer movement. However, the location is measured with respect to the screen, not a figure window.

See `uicontrol` for information on how this property is set when you click a uicontrol object.

`DeleteFcn`

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

Delete figure callback function. A callback function that executes when the figure object is deleted (e.g., when you issue a `delete` or a `close` command). MATLAB executes the function before destroying the object's properties so these values are available to the callback routine.

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

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

See also the figure `CloseRequestFcn` property

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

`Dithermap`

Obsolete

This property is not useful with TrueColor displays and will be removed in a future release.

`DithermapMode`

Obsolete

This property is not useful with TrueColor displays and will be removed in a future release.

`DockControls`

{on} | off

Displays controls used to dock figure. This property determines whether the figure enables the **Desktop** menu item and the dock figure button in the titlebar that allow you to dock the figure into the MATLAB desktop.

By default, the figure docking controls are visible. If you set this property to `off`, the **Desktop** menu item that enables you to dock the figure is disabled and the figure dock button is not displayed.

See also the `WindowStyle` property for more information on docking figure.

`DoubleBuffer`

{on} | off

Flash-free rendering for simple animations. Double buffering is the process of drawing to an off-screen pixel buffer and then blitting the buffer contents to the screen once the drawing is complete. Double buffering generally produces flash-free rendering for simple animations (such as those involving lines, as opposed to objects containing large numbers of polygons). Use double buffering with the animated objects' `EraseMode` property set to `normal`. Use the `set` command to disable double buffering.

```
set(figure_handle,'DoubleBuffer','off')
```

Double buffering works only when the figure `Renderer` property is set to `painters`.

`FileName`
String

GUI FIG-filename. GUIDE stores the name of the FIG-file used to save the GUI layout in this property.

`FixedColors`
m-by-3 matrix of RGB values (read only)

Noncolormap colors. Fixed colors define all colors appearing in a figure window that are not obtained from the figure colormap. These colors include axis lines and labels, the colors of `line`, `text`, `uicontrol`, and `uimenu` objects, and any colors that you explicitly define, for example, with a statement like

```
set(gcf,'Color',[0.3,0.7,0.9])
```

Fixed color definitions reside in the system color table and do not appear in the figure colormap. For this reason, fixed colors can limit the number of simultaneously displayed colors if the number of fixed colors plus the number of entries in the figure colormap exceed your system's maximum number of colors.

(See the root `ScreenDepth` property for information on determining the total number of colors supported on your system. See the `MinColorMap` and `ShareColors` properties for information on how MATLAB shares colors between applications.)

`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`.

Callback Visibility

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.

Visibility Off

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.

Visibility and Handles Returned by Other Functions

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.

Making All Handles Visible

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).

Validity of Hidden Handles

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 figure 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 figure. If `HitTest` is `off`, clicking the figure sets the `CurrentObject` to the empty matrix.

`IntegerHandle`
: `{on} | off`

Figure handle mode. Figure object handles are integers by default. When creating a new figure, MATLAB uses the lowest integer that is not used by an existing figure. If you delete a figure, its integer handle can be reused.

If you set this property to `off`, MATLAB assigns nonreusable real-number handles (e.g., 67.0001221) instead of integers. This feature is designed for dialog boxes where removing the handle from integer values reduces the likelihood of inadvertently drawing into the dialog box.

`Interruptible`
: `{on} | off`

Callback routine interruption mode. The `Interruptible` property controls whether a figure callback routine can be interrupted by callback routines invoked subsequently. Only callback routines defined for the `ButtonDownFcn`, `KeyPressFcn`, `KeyReleaseFcn`, `WindowButtonDownFcn`, `WindowButtonMotionFcn`, and `WindowButtonUpFcn` 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.

`InvertHardcopy`
`{on} | off`

Change hardcopy to black objects on white background. This property affects only printed output. Printing a figure having a background color (`Color` property) that is not white results in poor contrast between graphics objects and the figure background and also consumes a lot of printer toner.

When `InvertHardCopy` is `on`, MATLAB eliminates this effect by changing the color of the figure and axes to white and the axis lines, tick marks, axis labels, etc., to black. `lines`, `text`, and the edges of `patches` and`surfaces` might be changed, depending on the `print` command options specified.

If you set `InvertHardCopy` to `off`, the printed output matches the colors displayed on the screen.

See `print` for more information on printing MATLAB figures.

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

Key press callback function. A callback function invoked by a key press that occurs while the figure window has focus. Define the `KeyPressFcn` as a function handle. The function must define at least two input arguments (handle of figure associated with key release and an event structure)

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

When there is no callback specified for this property (which is the default state), MATLAB passes any key presses to the command window. However, when you define a callback for this property, the figure retains focus with each key press and executes the specified callback with each key press.

KeyPressFcn Event Structure

When the callback is a function handle, MATLAB passes a structure to the callback function that contains the following fields.

Field	Contents
`Character`	The character displayed as a result of the key(s) pressed.
`Modifier`	This field is a cell array that contains the names of one or more modifier keys that the user pressed (i.e., **control**, **alt**, **shift**). On Macintosh computers, MATLAB can also return **command**
`Key`	The key pressed (lower case label on key)

Some key combinations do not define a value for the `Character` field.

Using the KeyPressFcn

This example, creates a figure and defines a function handle callback for the `KeyPressFcn` property. When the "e" key is pressed, the callback exports the figure as an EPS file. When **Ctrl-t** is pressed, the callback exports the figure as a TIFF file.

```
function figure_keypress
   figure('KeyPressFcn',@printfig);

   function printfig(src,evnt)
      if evnt.Character == 'e'
         print ('-deps',['-f' num2str(src)])
      elseif length(evnt.Modifier) == 1 & strcmp(evnt.Modifier{:},'control') & evnt.Key ==
         print ('-dtiff','-r200',['-f' num2str(src)])
   end
end
```

`KeyReleaseFcn`

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

Key release callback function. A callback function invoked by a key release that occurs while the figure window has focus. Define the `KeyReleaseFcn` as a function handle. The function must define at least two input arguments (handle of figure associated with key release and an event structure)

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

KeyReleaseFcn Event Structure

When the callback is a function handle, MATLAB passes a structure as the second argument to the callback function that contains the following fields.

Field	Contents
Character	The character displayed as a result of the key(s) released.
Modifier	This field is a cell array that contains the names of one or more modifier keys that the user releases (i.e., **control**, **alt**, **shift**, or empty if no modifier keys were released). On Macintosh computers, MATLAB can also return **command**
Key	The lower case label on key that was released.

Some key combinations do not define a value for the Character field.

Properties Affected by the KeyReleaseFcn

When a callback is defined for the KeyReleaseFcn property, MATLAB updates the CurrentCharacter, CurrentKey, and CurrentModifier figure properties just before executing the callback.

Multiple Key Presses Events and a Single Key Release Event

Consider a figure having callbacks defined for both the KeyPressFcn and KeyReleaseFcn. In the case where a user presses multiple keys, one after another, MATLAB generates repeated KeyPressFcn events only for the last key pressed.

For example, suppose you press and hold down the **a** key, then press and hold down the **s** key. MATLAB generates repeated KeyPressFcn events for the **a** key until the **s** key is pressed, at which point MATLAB generates repeated KeyPressFcn events for the **s** key. If the **s** key is then released, a KeyReleaseFcn event is generated for the **s** key, but no new KeyPressFcn events are generated for the **a** key. When you then release the **a** key, the KeyReleaseFcn again executes.

The KeyReleaseFcn behavior is such that its callback is executed every time a key is released while the figure is in focus, regardless of what KeyPressFcns are generated.

Modifier Keys

When the user presses and releases a key and a modifier key, the modifier key is returned in the event structure Modifier field. If a modifier key is the only key pressed and released, it is not returned in the event structure of the KeyReleaseFcn, but is returned in the event structure of the KeyPressFcn.

Explore the Results

Click to view in editor — This link opens the MATLAB editor with the following example.

Click to run example — Press and release various key combinations while the figure has focus to see the data returned in the event structure.

The following code, creates a figure and defines a function handle callback for the KeyReleaseFcn property. The callback simply displays the values returned by the event structure and enables you to explore the KeyReleaseFcn behavior when you release various key combinations.

```
function key_releaseFcn
   figure('KeyReleaseFcn',@cb)

   function cb(src,evnt)
      if ~isempty(evnt.Modifier)
         for ii = 1:length(evnt.Modifier)
            out = sprintf('Character: %c\nModifier: %s\nKey: %s\n',evnt.Character,evnt.Mod
```

```
            disp(out)
         end
      else
         out = sprintf('Character: %c\nModifier: %s\nKey: %s\n',evnt.Character,'No modifier ke
         disp(out)
      end
   end
end
```

`MenuBar`
`none | {figure}`

Enable-disable figure menu bar. This property enables you to display or hide the menu bar that MATLAB places at the top of a figure window. The default (`figure`) is to display the menu bar.

This property affects only built-in menus. Menus defined with the `uimenu` command are not affected by this property.

If you start MATLAB with the `nojvm` option, figures do not display the menu bar because most items require Java figures.

`MinColormap`
scalar (default = 64)

Minimum number of color table entries used. This property specifies the minimum number of system color table entries used by MATLAB to store the colormap defined for the figure (see the `ColorMap` property). In certain situations, you may need to increase this value to ensure proper use of colors.

For example, suppose you are running color-intensive applications in addition to MATLAB and have defined a large figure colormap (e.g., 150 to 200 colors). MATLAB may select colors that are close but not exact from the existing colors in the system color table because there are not enough slots available to define all the colors you specified.

To ensure that MATLAB uses exactly the colors you define in the figure colormap, set `MinColorMap` equal to the length of the colormap.

```
set(gcf,'MinColormap',length(get(gcf,'ColorMap')))
```

Note that the larger the value of `MinColorMap`, the greater the likelihood that other windows (including other MATLAB figure windows) will be displayed in false colors.

`Name`
string

Figure window title. This property specifies the title displayed in the figure window. By default, `Name` is empty and the figure title is displayed as `Figure 1`, `Figure 2`, and so on. When you set this parameter to a string, the figure title becomes `Figure 1: <string>`. See the `NumberTitle` property.

`NextPlot`
`new | {add} | replace | replacechildren`

How to add next plot. `NextPlot` determines which figure MATLAB uses to display graphics output. If the value of the current figure is

- `new` — Create a new figure to display graphics (unless an existing parent is specified in the graphing function as a property/value pair).
- `add` — Use the current figure to display graphics (the default).
- `replace` — Reset all figure properties except `Position` to their defaults and delete all figure children before displaying graphics (equivalent to `clf reset`).
- `replacechildren` — Remove all child objects, but do not reset figure properties (equivalent to `clf`).

The `newplot` function provides an easy way to handle the `NextPlot` property. Also see the `NextPlot` axes property and "Controlling Graphics Output" for more information.

`NumberTitle`
`{on} | off` (GUIDE default `off`)

Figure window title number. This property determines whether the string `Figure No.  N` (where `N` is the figure number) is prefixed to the figure window title. See the `Name` property.

`PaperOrientation`
`{portrait} | landscape`

Horizontal or vertical paper orientation. This property determines how printed figures are oriented on the page. `portrait` orients the longest page dimension vertically; `landscape` orients the longest page dimension horizontally. See the `orient` command for more detail.

`PaperPosition`
four-element rect vector

Location on printed page. A rectangle that determines the location of the figure on the printed page. Specify this rectangle with a vector of the form

```
rect = [left, bottom, width, height]
```

where `left` specifies the distance from the left side of the paper to the left side of the rectangle and `bottom` specifies the distance from the bottom of the page to the bottom of the rectangle. Together these distances define the lower left corner of the rectangle. `width` and `height` define the dimensions of the rectangle. The `PaperUnits` property specifies the units used to define this rectangle.

`PaperPositionMode`
`auto | {manual}`

WYSIWYG printing of figure. In manual mode, MATLAB honors the value specified by the PaperPosition property. In auto mode, MATLAB prints the figure the same size as it appears on the computer screen, centered on the page.

See the Pixels per Inch Solution for information on specifying a pixels per inch resolution setting for MATLAB figures. Doing so might be necessary to obtain a printed figure that is the same size as it is on screen.

PaperSize
[width height]

Paper size. This property contains the size of the current PaperType, measured in PaperUnits. See PaperType to select standard paper sizes.

PaperType
Select a value from the following table.

Selection of standard paper size. This property sets the PaperSize to one of the following standard sizes.

Property Value	Size (Width x Height)
usletter (default)	8.5-by-11 inches
uslegal	11-by-14 inches
tabloid	11-by-17 inches
A0	841-by-1189mm
A1	594-by-841mm
A2	420-by-594mm
A3	297-by-420mm
A4	210-by-297mm
A5	148-by-210mm

Property Value	Size (Width x Height)
B0	1029-by-1456mm
B1	728-by-1028mm
B2	514-by-728mm
B3	364-by-514mm
B4	257-by-364mm
B5	182-by-257mm
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

Note that you may need to change the `PaperPosition` property in order to position the printed figure on the new paper size. One solution is to use `normalized` `PaperUnits`, which enables MATLAB to automatically size the figure to occupy the same relative amount of the printed page, regardless of the paper size.

`PaperUnits`

`normalized | {inches} | centimeters | points`

Hardcopy measurement units. This property specifies the units used to define the `PaperPosition` and `PaperSize` properties.

All units are measured from the lower left corner of the page. `normalized` units map the lower left corner of the page 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).

If you change the value of `PaperUnits`, it is good practice to return it to its default value after completing your computation so as not to affect other functions that assume `PaperUnits` is set to the default value.

`Parent`
handle

Handle of figure's parent. The parent of a figure object is the root object. The handle to the root is always 0.

`Pointer`

```
crosshair | {arrow} | watch | topl |
topr | botl | botr | circle | cross |
fleur | left | right | top | bottom |
fullcrosshair | ibeam | custom
```

Pointer symbol selection. This property determines the symbol used to indicate the pointer (cursor) position in the figure window. Setting `Pointer` to `custom` allows you to define your own pointer symbol. See the `PointerShapeCData` property and "Specifying the Figure Pointer" for more information.

`PointerShapeCData`
16-by-16 matrix

User-defined pointer. This property defines the pointer that is used when you set the `Pointer` property to `custom`. It is a 16-by-16 element matrix defining the 16-by-16 pixel pointer using the following values:

- `1` — Color pixel black.
- `2` — Color pixel white.

- NaN — Make pixel transparent (underlying screen shows through).

Element (1,1) of the PointerShapeCData matrix corresponds to the upper left corner of the pointer. Setting the Pointer property to one of the predefined pointer symbols does not change the value of the PointerShapeCData. Computer systems supporting 32-by-32 pixel pointers fill only one quarter of the available pixmap.

PointerShapeHotSpot
two-element vector

Pointer active area. A two-element vector specifying the row and column indices in the PointerShapeCData matrix defining the pixel indicating the pointer location. The location is contained in the CurrentPoint property and the root object's PointerLocation property. The default value is element (1,1), which is the upper left corner.

Position
four-element vector

Figure position. This property specifies the size and location on the screen of the figure window. Specify the position rectangle with a four-element vector of the form:

```
rect = [left, bottom, width, height]
```

where left and bottom define the distance from the lower left corner of the screen to the lower left corner of the figure window. width and height define the dimensions of the window. See the Units property for information on the units used in this specification. The left and bottom elements can be negative on systems that have more than one monitor.

Position of Docked Figures

If the figure is docked in the MATLAB desktop, then the `Position` property is specified with respect to the figure group container instead of the screen.

Moving and Resizing Figures

You can use the `get` function to obtain this property and determine the position of the figure and you can use the `set` function to resize and move the figure to a new location. You cannot set the figure `Position` when it is docked.

Note that on MS-Windows systems, figure windows cannot be less than 104 pixels wide, regardless of the value of the `Position` property.

`Renderer`

`painters | zbuffer | OpenGL`

Rendering method used for screen and printing This property enables you to select the method used to render MATLAB graphics. The choices are

- `painters` — The original rendering method used by MATLAB is faster when the figure contains only simple or small graphics objects.
- `zbuffer` — MATLAB draws graphics objects faster and more accurately because objects are colored on a per-pixel basis and MATLAB renders only those pixels that are visible in the scene (thus eliminating front-to-back sorting errors). Note that this method can consume a lot of system memory if MATLAB is displaying a complex scene.
- `OpenGL` — OpenGL is a renderer that is available on many computer systems. This renderer is generally faster than painters or zbuffer and in some cases enables MATLAB to access graphics hardware that is available on some systems. Note that when the `Renderer` is set to `opengl`, MATLAB sets `BackingStore` to `off`.

Hardware vs. Software OpenGL Implementations

There are two kinds of OpenGL implementations — hardware and software.

The hardware implementation makes use of special graphics hardware to increase performance and is therefore significantly faster than the software version. Many computers have this special hardware available as an option or may come with this hardware right out of the box.

Software implementations of OpenGL are much like the ZBuffer renderer that is available on MATLAB Version 5.0 and later; however, OpenGL generally provides superior performance to ZBuffer.

OpenGL Availability

OpenGL is available on all computers that run MATLAB. MATLAB automatically finds hardware accelerated versions of OpenGl if such versions are available. If the hardware accelerated version is not available, then MATLAB uses the software version.

The following software versions are available:

- On UNIX systems, MATLAB uses the software version of OpenGL that is included in the MATLAB distribution.
- On MS-Windows, OpenGL is available as part of the operating system. If you experience problems with OpenGL, contact your graphics driver vendor to obtain the latest qualified version of OpenGL.

MATLAB issues a warning if it cannot find a usable OpenGL library.

Selecting Hardware Accelerated or Software OpenGL

MATLAB enables you to switch between hardware accelerated and software OpenGL. However, MS-Windows and Unix systems behave differently:

- On MS-Windows systems, you can toggle between software and hardware versions any time during the MATLAB session.
- On UNIX systems, you must set the OpenGL version before MATLAB initializes OpenGL. Therefore, you cannot issue the `opengl info` command or create graphs before you call `opengl software`. To re-enable hardware accelerated OpenGL, you must restart MATLAB.

If you do not want to use hardware OpenGL, but do want to use object transparency, you can issue the following command.

```
opengl software
```

This command forces MATLAB to use software OpenGL. Software OpenGL is useful if your hardware accelerated version of OpenGL does not function correctly and you want to use image, patch, or surface transparency, which requires the OpenGL renderer. To reenable hardware OpenGL, use the command

```
opengl hardware
```

on MS-Windows systems or restart MATLAB on UNIX systems.

By default, MATLAB uses hardware accelerated OpenGL.

See the `opengl` reference page for additional information

Determining What Version You Are Using

To determine the version and vendor of the OpenGL library that MATLAB is using on your system, type the following command at the MATLAB prompt:

```
opengl info
```

The returned information contains a line that indicates if MATLAB is using software (`Software = true`) or hardware accelerated (`Software = false`) OpenGL.

This command also returns a string of extensions to the OpenGL specification that are available with the particular library MATLAB is using. This information is helpful to The MathWorks, so please include this information if you need to report bugs.

Note that issuing the `opengl info` command causes MATLAB to initialize OpenGL.

OpenGL vs. Other MATLAB Renderers

There are some differences between drawings created with OpenGL and those created with the other renderers. The OpenGL specific differences include

- OpenGL does not do colormap interpolation. If you create a surface or patch using indexed color and interpolated face or edge coloring, OpenGL interpolates the colors through the RGB color cube instead of through the colormap.
- OpenGL does not support the `phong` value for the `FaceLighting` and `EdgeLighting` properties of `surfaces` and `patches`.
- OpenGL does not support logarithmic-scale axes.
- OpenGL and Zbuffer renderers display objects sorted in front to back order, as seen on the monitor, and lines always draw in front of faces when at the same location on the plane of the monitor. Painters sorts by child order (order specified).

If You Are Having Problems

Consult the OpenGL Technical Note if you are having problems using OpenGL. This technical note contains a wealth of information on MATLAB renderers.

`RendererMode`

`{auto} | manual`

Automatic or user selection of renderer. This property enables you to specify whether MATLAB should choose the `Renderer` based on the contents of the figure window, or whether the `Renderer` should remain unchanged.

When the `RendererMode` property is set to `auto`, MATLAB selects the rendering method for printing as well as for screen display based on the size and complexity of the graphics objects in the figure.

For printing, MATLAB switches to `zbuffer` at a greater scene complexity than for screen rendering because printing from a Z-buffered figure can be considerably slower than one using the `painters` rendering method, and can result in large PostScript files. However, the output does always match what is on the screen. The same holds true for OpenGL: the output is the same as that produced by the ZBuffer renderer — a bitmap with a resolution determined by the `print` command's `-r` option.

Criteria for Autoselection of OpenGL Renderer

When the `RendererMode` property is set to `auto`, MATLAB uses the following criteria to determine whether to select the OpenGL renderer:

If the `opengl` autoselection mode is `autoselect`, MATLAB selects OpenGL if

- The host computer has OpenGL installed and is in True Color mode (OpenGL does not fully support 8-bit color mode).
- The figure contains no logarithmic axes (logarithmic axes are not supported in OpenGL).
- MATLAB would select `zbuffer` based on figure contents.

- Patch objects' faces have no more than three vertices (some OpenGL implementations of patch tessellation are unstable).
- The figure contains less than 10 uicontrols (OpenGL clipping around uicontrols is slow).
- No line objects use markers (drawing markers is slow).
- Phong lighting is not specified (OpenGL does not support Phong lighting; if you specify Phong lighting, MATLAB uses the ZBuffer renderer).

  Or

- Figure objects use transparency (OpenGL is the only MATLAB renderer that supports transparency).

When the `RendererMode` property is set to `manual`, MATLAB does not change the `Renderer`, regardless of changes to the figure contents.

`Resize`
`{on} | off`

Window resize mode. This property determines if you can resize the figure window with the mouse. `on` means you can resize the window, `off` means you cannot. When `Resize` is `off`, the figure window does not display any resizing controls (such as boxes at the corners), to indicate that it cannot be resized.

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

Window resize callback function. MATLAB executes the specified callback function whenever you resize the figure window and also when the figure is created. You can query the figure's `Position` property to determine the new size and position of the figure. 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 "Figure Resize Functions" for an example of how to implement a resize function for a GUI.

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

`Selected`
`on | off`

Is object selected? This property indicates whether the figure is selected. You can, for example, define the `ButtonDownFcn` to set this property, allowing users to select the object with the mouse.

`SelectionHighlight`
`{on} | off`

figures do not indicate selection.

`SelectionType`
`{normal} | extend | alt | open`

Mouse selection type. MATLAB maintains this property to provide information about the last mouse button press that occurred within the figure window. This information indicates the type of selection made. Selection types are actions that are generally associated with particular responses from the user interface software (e.g., single-clicking a graphics object places it in move or resize mode; double-clicking a filename opens it, etc.).

The physical action required to make these selections varies on different platforms. However, all selection types exist on all platforms.

Selection Type	MS-Windows	X-Windows
`Normal`	Click left mouse button.	Click left mouse button.

Selection Type	MS-Windows	X-Windows
Extend	**Shift** - click left mouse button or click both left and right mouse buttons.	**Shift** - click left mouse button or click middle mouse button.
Alternate	**Control** - click left mouse button or click right mouse button.	**Control** - click left mouse button or click right mouse button.
Open	Double-click any mouse button.	Double-click any mouse button.

Note that the ListBox style of uicontrols sets the figure SelectionType property to normal to indicate a single mouse click or to open to indicate a double mouse click. See uicontrol for information on how this property is set when you click a uicontrol object.

ShareColors

{on} | off Obsolete

Share slots in system color table with like colors. This property is obsolete because MATLAB now requires true color systems.

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 want to direct all graphics output from an M-file to a particular figure, regardless of user actions that may have changed the current figure. To do this, identify the figure with a `Tag`.

```
figure('Tag','Plotting Figure')
```

Then make that figure the current figure before drawing by searching for the `Tag` with `findobj`.

```
figure(findobj('Tag','Plotting Figure'))
```

`Toolbar`

`none | {auto} | figure`

Control display of figure toolbar. The `Toolbar` property enables you to control whether MATLAB displays the default figure toolbar on figures. There are three possible values:

- `none` — do not display the figure toolbar
- `auto` — display the figure toolbar, but remove it if a uicontrol is added to the figure
- `figure` — display the figure toolbar

Note that this property affects only the figure toolbar; other toolbars (e.g., the Camera Toolbar or Plot Edit Toolbar) are not affected. Selecting **Figure Toolbar** from the figure **View** menu sets this property to `figure`.

If you start MATLAB with the `nojvm` option, figures do not display the toolbar because most tool require Java figures.

`Type`

`string (read only)`

Object class. This property identifies the kind of graphics object. For figures, `Type` is always the string `'figure'`.

`UIContextMenu`
handle of a uicontextmenu object

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

`Units`

`{pixels} | normalized | inches |`
`centimeters | points | characters`

Units 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 window.

- `normalized` units map the lower left corner of the figure window 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).
- The size of a `pixel` depends on screen resolution.
- `characters` units are defined by characters from 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.

This property affects the `CurrentPoint` and `Position` properties. 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.

When specifying the units as property/value pairs during object creation, you must set the `Units` property before specifying the properties that you want to use these units.

`UserData`
matrix

User-specified data. You can specify `UserData` as any matrix you want to associate with the figure object. The object does not use this data, but you can access it using the `set` and `get` commands.

`Visible`
`{on} | off`

Object visibility. The `Visible` property determines whether an object is displayed on the screen. If the `Visible` property of a figure is `off`, the entire figure window is invisible.

A note about using the window button properties
Your window button callback functions might need to update the display by calling `drawnow` or `pause`, which causes MATLAB to process all events in the queue. Processing the event queue can cause your window button callback functions to be reentered. For example, a `drawnow` in the `WindowButtonDownFcn` might result in the `WindowButtonDownFcn` being called again before the first call has finished. You should design your code to handle reentrancy and you should not depend on global variables that might change state during reentrance.

You can use the `Interruptible` and `BusyAction` figure properties to control how events interact.

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

Button press callback function. Use this property to define a callback that MATLAB executes whenever you press a mouse button while the pointer is in the figure window. See the `WindowButtonMotionFcn` property for an example.

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

`WindowButtonMotionFcn`

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

Mouse motion callback function. Use this property to define a callback that MATLAB executes whenever you move the pointer within the figure window. Define the `WindowButtonMotionFcn` as a function handle. The function must define at least two input arguments (handle of figure associated with key release and an event structure).

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

Example using all window button properties

Click to view in editor — This example enables you to use mouse motion to draw lines. It uses all three window button functions.

Click to run example — Click the left mouse button in the axes and move the cursor, left-click to define the line end point, right-click to end drawing mode.

Note On some computer systems, the `WindowButtonMotionFcn` is executed when a figure is created even though there has been no mouse motion within the figure.

`WindowButtonUpFcn`

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

Button release callback function. Use this property to define a callback that MATLAB executes whenever you release a mouse button. Define the WindowButtonUpFcn as a function handle. The function must define at least two input arguments (handle of figure associated with key release and an event structure)

The button up event is associated with the figure window in which the preceding button down event occurred. Therefore, the pointer need not be in the figure window when you release the button to generate the button up event.

If the callback routines defined by WindowButtonDownFcn or WindowButtonMotionFcn contain drawnow commands or call other functions that contain drawnow commands and the Interruptible property is set to off, the WindowButtonUpFcn might not be called. You can prevent this problem by setting Interruptible to on.

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

WindowScrollWheelFcn
string, functional handle, or cell array containing function handle and additional arguments

Respond to mouse scroll wheel. Use this property to define a callback that MATLAB executes when the mouse wheel is scrolled while the figure has focus. MATLAB executes the callback with each single mouse wheel click.

Note that it is possible for another object to capture the event from MATLAB. For example, if the figure contains Java or ActiveX control objects that are listening for mouse scroll wheel events, then these objects can consume the events and prevent the WindowScrollWheelFcn from executing.

There is no default callback defined for this property.

WindowScrollWheelFcn Event Structure

When the callback is a function handle, MATLAB passes a structure to the callback function that contains the following fields.

Field	Contents
`VerticalScrollCount`	A positive or negative integer that indicates the number of scroll wheel clicks. Positive values indicate clicks of the wheel scrolled in the down direction. Negative values indicate clicks of the wheel scrolled in the up direction.
`VerticalScrollAmount`	The current system setting for the number of lines that are scrolled for each click of the scroll wheel. If the mouse property setting for scrolling is set to `One screen at a time`, VerticalScrollAmount returns a value of 1.

Effects On Other Properties

- `CurrentObject` property — mouse scrolling does not update this figure property
- `CurrentPoint` property — if there is no callback defined for the `WindowScrollWheelFcn` property, then MATLAB does not update the `CurrentPoint` property as the scroll wheel is turned. However, if there is a callback defined for the `WindowScrollWheelFcn` property, then MATLAB updates the `CurrentPoint` property just before executing the callback. This enables you to determine the point at which the mouse scrolling occurred.
- `HitTest` property — the `WindowScrollWheelFcn` callback executes regardless of the setting of the figure `HitTest` property.
- `SelectionType` property — the `WindowScrollWheelFcn` callback has no effect on this property.

Values Returned by VerticalScrollCount

When a user moves the mouse scroll wheel by one click, MATLAB increments the count by +/- 1, depending on the direction of the scroll (scroll down being positive). When MATLAB calls the `WindowScrollWheelFcn` callback, the counter is reset. In most cases, this means that the absolute value of the returned value is 1. However, if the `WindowScrollWheelFcn` callback takes a long enough time to return and/or the user spins the scroll wheel very fast, then the returned value can have an absolute value greater than one.

The actual value returned by `VerticalScrollCount` is the algebraic sum of all scroll wheel clicks that occurred since last processed. This enables your callback to respond correctly to the user's action.

Example

Click to view in editor — This example creates a graph of a function and enables you to use the mouse scroll wheel to change the range over which a mathematical function is evaluated and update the graph to reflect the new limits as you turn the scroll wheel.

Click to run example — Mouse over the figure and scroll your mouse wheel.

Related Information

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

`WindowStyle`

`{normal} | modal | docked`

Normal, modal, or dockable window behavior. When `WindowStyle` is set to `modal`:

- The figure window traps all keyboard and mouse events over all MATLAB windows as long as they are visible.
- Windows belonging to applications other than MATLAB are unaffected.
- Modal figures remain stacked above all normal figures and the MATLAB command window.
- When multiple modal windows exist, the most recently created window keeps focus and stays above all other windows until it becomes invisible, or is returned to `WindowStyle normal` , or is deleted. At that time, focus reverts to the window that last had focus.

Use modal figures to create dialog boxes that force the user to respond without being able to interact with other windows. Typing **Control C** while the figure has focus causes all figures with `WindowStyle modal` to revert to `WindowStyle normal` , allowing you to type at the command line.

Invisible Modal Figures

Figures with `WindowStyle modal` and `Visible off` do not behave modally until they are made visible, so it is acceptable to hide a `modal` window instead of destroying it when you want to reuse it.

Changing Modes

You can change the `WindowStyle` of a figure at any time, including when the figure is visible and contains children. However, on some systems this may cause the figure to flash or disappear and reappear, depending on the windowing system's implementation of normal and modal windows. For best visual results, you should set `WindowStyle` at creation time or when the figure is invisible.

Window Decorations on Modal Figures

Modal figures do not display `uimenu` children, built-in menus, or toolbars but it is not an error to create uimenus in a modal figure or to change `WindowStyle` to `modal` on a figure with uimenu children. The uimenu objects exist and their handles are retained by the figure. If you reset the figure's `WindowStyle` to `normal`, the uimenus are displayed.

Docked WindowStyle

When `WindowStyle` is set to `docked`, the figure is docked in the desktop or a document window. When you issue the following command,

```
set(figure_handle,'WindowStyle','docked')
```

MATLAB docks the figure identified by *`figure_handle`* and sets the `DockControls` property to `on`, if it was `off`.

Note that if `WindowStyle` is `docked`, you cannot set the `DockControls` property to `off`.

The value of the `WindowStyle` property is not changed by calling `reset` on a figure.

`WVisual`
identifier string (MS Windows only)

Specify pixel format for figure. MATLAB automatically selects a pixel format for figures based on your current display settings, the graphics hardware available on your system, and the graphical content of the figure.

Usually, MATLAB chooses the best pixel format to use in any given situation. However, in cases where graphics objects are not rendered correctly, you might be able select a different pixel format and improve results. See for more information.

Querying Available Pixel Formats on Window Systems

You can determine what pixel formats are available on your system for use with MATLAB using the following statement:

```
set(gcf,'WVisual')
```

MATLAB returns a list of the currently available pixel formats for the current figure. For example, the following are the first three entries from a typical list.

01 (RGB 16 bits(05 06 05 00) zdepth 24, Hardware Accelerated, Opengl, GDI, Window)

02 (RGB 16 bits(05 06 05 00) zdepth 24, Hardware Accelerated, Opengl, Double Buffered, Window)

03 (RGB 16 bits(05 06 05 00) zdepth 24, Hardware Accelerated, Opengl, Double Buffered, Window)

Use the number at the beginning of the string to specify which pixel format to use. For example,

```
set(gcf,'WVisual','02')
```

specifies the second pixel format in the list above. Note that pixel formats might differ on your system.

Understanding the WVisual String

The string returned by querying the `WVisual` property provide information on the pixel format. For example,

- `RGB 16 bits(05 06 05 00)` – indicates true color with 16-bit resolution (5 bits for red, 6 bits for green, 5 bits for blue, and 0 for alpha (transparency). MATLAB requires true color.
- `zdepth 24` – indicates 24-bit resolution for sorting object's front to back position on the screen. Selecting pixel formats with higher (24 or 32) zdepth might solve sorting problems.
- `Hardware Accelerated` – some graphics functions may be performed by hardware for increased speed. If there are incompatibilities between your particular graphic hardware and MATLAB, select a pixel format in which the term `Generic` appears instead of `Hardware Accelerated`.
- `Opengl` – supports OpenGL. See for more information.
- `GDI` – supports for Windows 2-D graphics interface.
- `Double Buffered` – support for double buffering with the OpenGL renderer. Note that the figure `DoubleBuffer` property applies only to the painters renderer.
- `Bitmap` – support for rendering into a bitmap (as opposed to drawing in the window)
- `Window` – support for rendering into a window

Pixel Formats and OpenGL

If you are experiencing problems using hardware OpenGL on your system, you can try using generic OpenGL, which is implemented in software. To do this, first instruct MATLAB to use the software version of OpenGL with the following statement.

```
opengl software
```

Then allow MATLAB to select best pixel format to use.

See the `Renderer` property for more information on how MATLAB uses OpenGL.

`WVisualMode`
`auto` | `manual` (MS Windows only)

Auto or manual selection of pixel format. `VisualMode` can take on two values — `auto` (the default) and `manual`. In `auto` mode, MATLAB selects the best pixel format to use based on your computer system and the graphical content of the figure. In `manual` mode, MATLAB does not change the visual from the one currently in use. Setting the `WVisual` property sets this property to `manual`.

`XDisplay`
display identifier (UNIX only)

Contains the display used for MATLAB. You can query this property to determine the name of the display that MATLAB is using. For example, if MATLAB is running on a system called `mycomputer`, querying `XDisplay` returns a string of the following form:

```
get(gcf,'XDisplay')
ans
mycomputer:0.0
```

Setting XDisplay on Motif

If your computer uses Motif-based figures, you can specify the display MATLAB uses for a figure by setting the value of the figure's `XDisplay` property. For example, to display the current figure on a system called `fred`, use the command

```
set(gcf,'XDisplay','fred:0.0')
```

`XVisual`
visual identifier (UNIX only)

Select visual used by MATLAB. You can select the visual used by MATLAB by setting the `XVisual` property to the desired visual ID. This can be useful if you want to test your application on an 8-bit or grayscale visual. To see what visuals are available on your system, use the UNIX `xdpyinfo` command. From MATLAB, type

```
!xdpyinfo
```

The information returned contains a line specifying the visual ID. For example,

```
visual id:    0x23
```

To use this visual with the current figure, set the `XVisual` property to the ID.

```
set(gcf,'XVisual','0x23')
```

To see which of the available visuals MATLAB can use, call `set` on the `XVisual` property:

```
set(gcf,'XVisual')
```

The following typical output shows the visual being used (in curly brackets) and other possible visuals. Note that MATLAB requires a TrueColor visual.

```
{ 0x23 (TrueColor, depth 24, RGB mask 0xff0000 0xff00 0x00ff) }
  0x24 (TrueColor, depth 24, RGB mask 0xff0000 0xff00 0x00ff)
```

```
0x25 (TrueColor, depth 24, RGB mask 0xff0000 0xff00 0x00ff)
0x26 (TrueColor, depth 24, RGB mask 0xff0000 0xff00 0x00ff)
0x27 (TrueColor, depth 24, RGB mask 0xff0000 0xff00 0x00ff)
0x28 (TrueColor, depth 24, RGB mask 0xff0000 0xff00 0x00ff)
0x29 (TrueColor, depth 24, RGB mask 0xff0000 0xff00 0x00ff)
0x2a (TrueColor, depth 24, RGB mask 0xff0000 0xff00 0x00ff)
```

You can also use the `glxinfo` Unix command to see what visuals are available for use with the OpenGL renderer. From MATLAB, type

```
!glxinfo
```

After providing information about the implementation of OpenGL on your system, `glxinfo` returns a table of visuals. The partial listing below shows typical output.

```
visual  x  bf lv rg d st colorbuffer ax dp st accumbuffer  ms  cav
 id dep cl sp sz l  ci b ro  r  g  b  a bf th cl  r  g  b  a ns b eat
----------------------------------------------------------------
-
0x23 24 tc  0 24  0 r  y  .  8  8  8  8  0  0  0  0  0  0  0  0 0 None
0x24 24 tc  0 24  0 r  .  .  8  8  8  8  0  0  0  0  0  0  0  0 0 None
0x25 24 tc  0 24  0 r  y  .  8  8  8  8  0 24  8  0  0  0  0  0 0 None
0x26 24 tc  0 24  0 r  .  .  8  8  8  8  0 24  8  0  0  0  0  0 0 None
0x27 24 tc  0 24  0 r  y  .  8  8  8  8  0  0  0 16 16 16  0  0 0 Slow
```

The third column is the class of visual. `tc` means a true color visual. Note that some visuals may be labeled `Slow` under the caveat column. Such visuals should be avoided.

To determine which visual MATLAB will use by default with the OpenGL renderer, use the MATLAB `opengl info` command. The returned entry for the visual might look like the following.

```
Visual = 0x23 (TrueColor, depth 24, RGB mask 0xff0000 0xff00 0x00ff)
```

Experimenting with a different TrueColor visual may improve certain rendering problems.

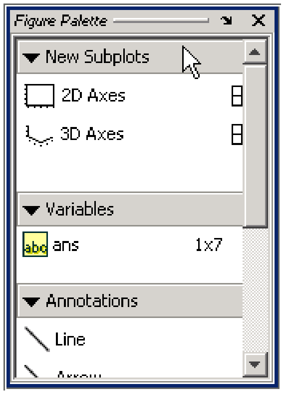
`XVisualMode`

`auto | manual`

Auto or manual selection of visual. `VisualMode` can take on two values — `auto` (the default) and `manual`. In `auto` mode, MATLAB selects the best visual to use based on the number of colors, availability of the OpenGL extension, etc. In `manual` mode, MATLAB does not change the visual from the one currently in use. Setting the `XVisual` property sets this property to `manual`.

Purpose

Show or hide figure palette



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 **Figure Palette** tool from the figure's **View** menu. For details, see "The Figure Palette" in the MATLAB Graphics documentation.

Syntax

```
figurepalette('show')
figurepalette('hide')
figurepalette('toggle')
figurepalette(figure_handle,...)
```

Description

`figurepalette('show')` displays the palette on the current figure.

`figurepalette('hide')` hides the palette on the current figure.

`figurepalette('toggle')` or `figurepalette` toggles the visibility of the palette on the current figure.

`figurepalette(figure_handle,...)` shows or hides the palette on the figure specified by `figure_handle`.

See Also `plottools`, `plotbrowser`, `propertyeditor`

Purpose

Set or get attributes of file or directory

Syntax

```
fileattrib
fileattrib('name')
fileattrib('name','attrib')
fileattrib('name','attrib','users')
fileattrib('name','attrib','users','s')
[status,message,messageid] =  fileattrib('name','attrib',
   'users','s')
```

Description

The `fileattrib` function is like the DOS `attrib` command or the UNIX `chmod` command.

`fileattrib` displays the attributes for the current directory. Values are as follows.

Value	Description
`0`	Attribute is off
`1`	Attribute is set (on)
`NaN`	Attribute does not apply

`fileattrib('name')` displays the attributes for `name`, where `name` is the absolute or relative pathname for a directory or file. Use the wildcard `*` at the end of `name` to view attributes for all matching files.

`fileattrib('name','attrib')` sets the attribute for `name`, where `name` is the absolute or relative pathname for a directory or file. Specify the `+` qualifier before the attribute to set it, and specify the `-` qualifier before the attribute to clear it. Use the wildcard `*` at the end of `name` to set attributes for all matching files. Values for *`attrib`* are as follows.

Value for attrib	Description
a	Archive (Windows only)
h	Hidden file (Windows only)
s	System file (Windows only)
w	Write access (Windows and UNIX)
x	Executable (UNIX only)

For example, `fileattrib('myfile.m','+w')` makes `myfile.m` a writable file.

`fileattrib('name','`*`attrib`*`','`*`users`*`')` sets the attribute for `name`, where `name` is the absolute or relative pathname for a directory or file, and defines which users are affected by *`attrib`*, where *`users`* is applicable only for UNIX systems. For more information about these attributes, see UNIX reference information for `chmod`. The default value for *`users`* is `u`. Values for *`users`* are

Value for users	Description
a	All users
g	Group of users
o	All other users
u	Current user

`fileattrib('name','`*`attrib`*`','`*`users`*`','`**`s`**`')` sets the attribute for `name`, where `name` is the absolute or relative pathname for a file or a directory and its contents, and defines which users are affected by *`attrib`*. Here the **`s`** specifies that *`attrib`* be applied to all contents of `name`, where `name` is a directory.

`[status,message,messageid] =`
`fileattrib('name','`*`attrib`*`','`*`users`*`','`**`s`**`')` sets
the attribute for `name`, 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. If `attrib`, *`users`*, and **`s`** are not specified, and `status` is `1`, `message` is a structure containing the file attributes and `messageid` is blank. If `status` is `0`, `messageid` contains the error. If you use a wildcard `*` at the end of `name`, `mess` will be a structure.

Examples

Get Attributes of File

To view the attributes of `myfile.m`, type

```
fileattrib('myfile.m')
```

MATLAB returns

```
          Name: 'd:/work/myfile.m'
       archive: 0
        system: 0
        hidden: 0
     directory: 0
      UserRead: 1
     UserWrite: 0
   UserExecute: 1
     GroupRead: NaN
    GroupWrite: NaN
  GroupExecute: NaN
     OtherRead: NaN
    OtherWrite: NaN
  OtherExecute: NaN
```

`UserWrite` is `0`, meaning `myfile.m` is read only. The `Group` and `Other` values are `NaN` because they do not apply to the current operating system, Windows.

Set File Attribute

To make `myfile.m` become writable, type

```
fileattrib('myfile.m','+w')
```

Running `fileattrib('myfile.m')` now shows `UserWrite` to be `1`.

Set Attributes for Specified Users

To make the directory `d:/work/results` be a read-only directory for all users, type

```
fileattrib('d:/work/results','-w','a')
```

The `-` preceding the write attribute, `w`, specifies that write status is removed.

Set Multiple Attributes for Directory and Its Contents

To make the directory `d:/work/results` and all its contents be read only and be hidden, on Windows, type

```
fileattrib('d:/work/results','+h-w','','s')
```

Because *users* is not applicable on Windows systems, its value is empty. Here, `s` applies the attribute to the contents of the specified directory.

Return Status and Structure of Attributes

To return the attributes for the directory `results` to a structure, type

```
[stat,mess]=fileattrib('results')
```

MATLAB returns

```
stat =
     1

mess =
           Name: 'd:\work\results'
        archive: 0
         system: 0
         hidden: 0
      directory: 1
       UserRead: 1
      UserWrite: 1
    UserExecute: 1
```

```
          GroupRead: NaN
         GroupWrite: NaN
       GroupExecute: NaN
          OtherRead: NaN
         OtherWrite: NaN
       OtherExecute: NaN
```

The operation was successful as indicated by the status, `stat`, being `1`. The structure `mess` contains the file attributes. Access the attribute values in the structure. For example, typing

```
mess.Name
```

returns the path for `results`

```
ans =
d:\work\results
```

Return Attributes with Wildcard for Name

Return the attributes for all files in the current directory whose names begin with `new`.

```
[stat,mess]=fileattrib('new*')
```

MATLAB returns

```
stat =
     1

mess =
1x3 struct array with fields:
    Name
    archive
    system
    hidden
    directory
    UserRead
    UserWrite
```

```
    UserExecute
    GroupRead
    GroupWrite
    GroupExecute
    OtherRead
    OtherWrite
    OtherExecute
```

The results indicate there are three matching files. To view the filenames, type

```
mess.Name
```

MATLAB returns

```
ans =
d:\work\results\newname.m

ans =
d:\work\results\newone.m

ans =
d:\work\results\newtest.m
```

To view just the first filename, type

```
mess(1).Name

ans =
d:\work\results\newname.m
```

See Also

`copyfile`, `cd`, `dir`, `filebrowser`, `fileparts`, `ls`, `mfilename`, `mkdir`, `movefile`, `rmdir`

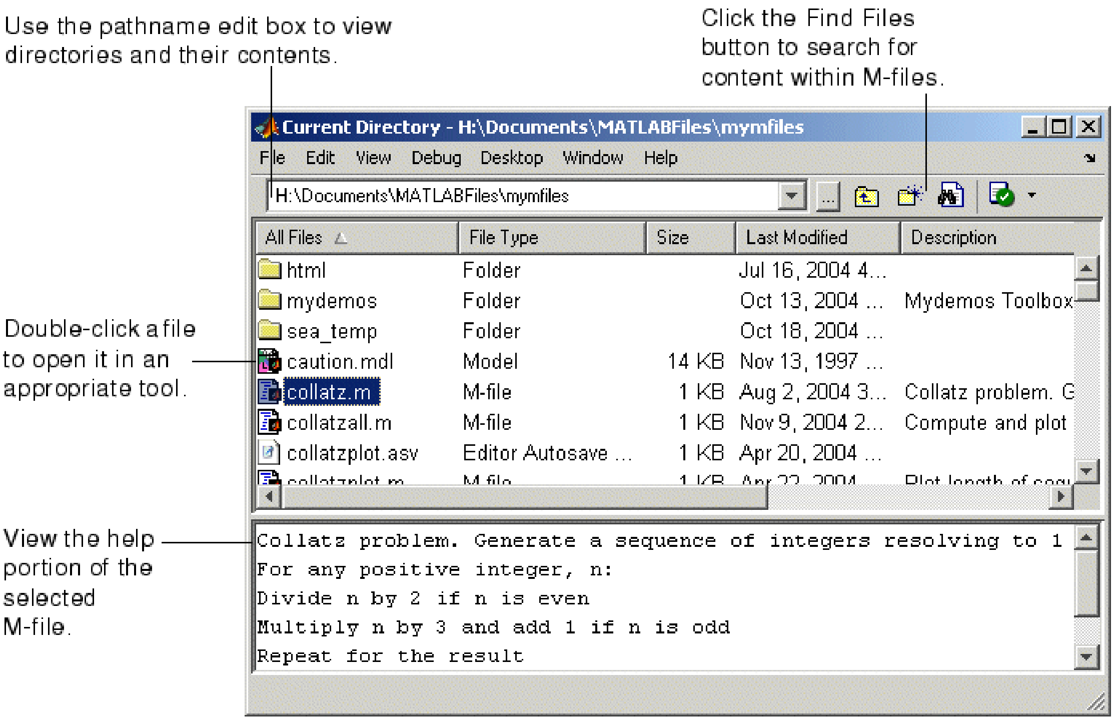
Purpose Current Directory browser

GUI Alternatives As an alternative to the `filebrowser` function, select **Desktop > Current Directory** in the MATLAB desktop.

Syntax

```
filebrowser
```

Description `filebrowser` displays the “Current Directory Browser”.



See Also `cd`, `copyfile`, `fileattrib`, `ls`, `mkdir`, `movefile`, `pwd`, `rmdir`

File Formats

Purpose Readable file formats

Description This table shows the file formats that MATLAB is capable of reading.

File Format	Extension	File Content	Read Command	Returns
Text	MAT	Saved MATLAB workspace	`load`	Variables in the file
	CSV	Comma-separated numbers	`csvread`	Double array
	DLM	Delimited text	`dlmread`	Double array
	TAB	Tab-separated text	`dlmread`	Double array
Scientific Data	CDF	Data in Common Data Format	`cdfread`	Cell array of CDF records
	FITS	Flexible Image Transport System data	`fitsread`	Primary or extension table data
	HDF4	Data in Hierarchical Data Format, version 4	`hdfread`	HDF or HDF-EOS data set
	HDF5	Data in Hierarchical Data Format, version 5	`hdf5read`	HDF5 data set
Spreadsheet	XLS	Excel worksheet	`xlsread`	Double or cell array
	WK1	Lotus 123 worksheet	`wk1read`	Double or cell array

File Format	Extension	File Content	Read Command	Returns
Image	TIFF	TIFF image	`imread`	True color, grayscale, or indexed image(s)
	PNG	PNG image	`imread`	True color, grayscale, or indexed image
	HDF4	HDF4 image	`imread`	True color, grayscale, or indexed image(s)
	BMP	BMP image	`imread`	True color or indexed image
	JPEG	JPEG image	`imread`	True color or grayscale image
	GIF	GIF image	`imread`	Indexed image
	PCX	PCX image	`imread`	Indexed image
	XWD	XWD image	`imread`	Indexed image
	CUR	Cursor image	`imread`	Indexed image
	ICO	Icon image	`imread`	Indexed image
Audio file	AU	NeXT/SUN sound	`auread`	Sound data and sample rate
	WAV	Microsoft WAVE sound	`wavread`	Sound data and sample rate
Movie	AVI	Audio/video	`aviread`	MATLAB movie

See Also

`fscanf`, `fread`, `textread`, `importdata`

filemarker

Purpose Character to separate file name and internal function name

Syntax

```
M = filemarker
```

Description `M = filemarker` returns the character that separates a file and a within-file function name.

Examples On Windows, for example, `filemarker` returns the '>' character:

```
filemarker
ans =
   >
```

You can use the following command on any platform to get the help text for subfunction `pdeodes` defined in M-file `pdepe.m`:

```
helptext = help(['pdepe' filemarker 'pdeodes'])

helptext =
 PDEODES  Assemble the difference equations and
    evaluate the time derivative for the ODE system.
```

See Also `filesep`

Purpose

Parts of file name and path

Syntax

```
[pathstr, name, ext, versn] = fileparts(filename)
```

Description

`[pathstr, name, ext, versn] = fileparts(filename)` returns the path, filename, extension, and version for the specified file. `filename` is a string enclosed in single quotes. The returned `ext` field contains a dot (`.`) before the file extension.

The `fileparts` function is platform dependent.

You can reconstruct the file from the parts using

```
fullfile(pathstr,[name ext versn])
```

Examples

This example returns the parts of `file` to `path`, `name`, `ext`, and `ver`.

```
file = '\home\user4\matlab\classpath.txt';

[pathstr, name, ext, versn] = fileparts(file)

pathstr =
\home\user4\matlab

name =
classpath

ext =
.txt

versn =
     ''
```

See Also

`fullfile`

filehandle

Purpose Construct file handle object

Syntax `output = filehandle(arglist)`

Description `output = filehandle(arglist)` this file is a place-holder for now.

Example

See Also `dialog`, `errordlg`, `helpdlg`, `listdlg`, `msgbox`, `questdlg`, `warndlg`

`figure`, `uiwait`, `uiresume`

"Predefined Dialog Boxes" on page 1-103 for related functions

Purpose Directory separator for current platform

Syntax

```
f = filesep
```

Description `f = filesep` returns the platform-specific file separator character. The file separator is the character that separates individual directory names in a path string.

Examples On the PC,

```
iofun_dir = ['toolbox' filesep 'matlab' filesep 'iofun']

iofun_dir =

toolbox\matlab\iofun
```

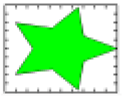
On a UNIX system,

```
iodir = ['toolbox' filesep 'matlab' filesep 'iofun']

iodir =

toolbox/matlab/iofun
```

See Also `fullfile`, `fileparts`, `pathsep`

Purpose

Filled 2-D polygons



Syntax

```
fill(X,Y,C)
fill(X,Y,ColorSpec)
fill(X1,Y1,C1,X2,Y2,C2,...)
fill(...,'PropertyName',PropertyValue)
h = fill(...)
```

Description

The `fill` function creates colored polygons.

`fill(X,Y,C)` creates filled polygons from the data in `X` and `Y` with vertex color specified by `C`. `C` is a vector or matrix used as an index into the colormap. If `C` is a row vector, `length(C)` must equal `size(X,2)` and `size(Y,2)`; if `C` is a column vector, `length(C)` must equal `size(X,1)` and `size(Y,1)`. If necessary, `fill` closes the polygon by connecting the last vertex to the first.

`fill(X,Y,`*`ColorSpec`*`)` fills two-dimensional polygons specified by `X` and `Y` with the color specified by `ColorSpec`.

`fill(X1,Y1,C1,X2,Y2,C2,...)` specifies multiple two-dimensional filled areas.

`fill(...,'`*`PropertyName`*`',PropertyValue)` allows you to specify property names and values for a patch graphics object.

`h = fill(...)` returns a vector of handles to patch graphics objects, one handle per patch object.

Remarks

If `X` or `Y` is a matrix, and the other is a column vector with the same number of elements as rows in the matrix, `fill` replicates the column vector argument to produce a matrix of the required size. `fill` forms a vertex from corresponding elements in `X` and `Y` and creates one polygon from the data in each column.

The type of color shading depends on how you specify color in the argument list. If you specify color using ColorSpec, fill generates flat-shaded polygons by setting the patch object's FaceColor property to the corresponding RGB triple.

If you specify color using C, fill scales the elements of C by the values specified by the axes property CLim. After scaling C, C indexes the current colormap.

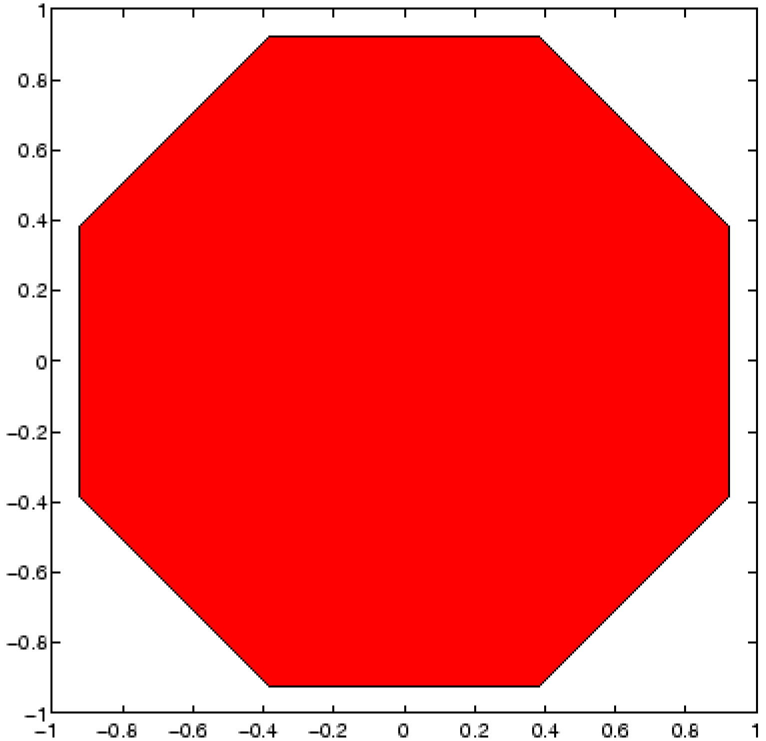
If C is a row vector, fill generates flat-shaded polygons where each element determines the color of the polygon defined by the respective column of the X and Y matrices. Each patch object's FaceColor property is set to 'flat'. Each row element becomes the CData property value for the nth patch object, where *n* is the corresponding column in X or Y.

If C is a column vector or a matrix, fill uses a linear interpolation of the vertex colors to generate polygons with interpolated colors. It sets the patch graphics object FaceColor property to 'interp' and the elements in one column become the CData property value for the respective patch object. If C is a column vector, fill replicates the column vector to produce the required sized matrix.

Examples

Create a red octagon.

```
t = (1/16:1/8:1)'*2*pi;
x = sin(t);
y = cos(t);
fill(x,y,'r')
axis square
```



See Also

`axis`, `caxis`, `colormap`, `ColorSpec`, `fill3`, `patch`

"Polygons and Surfaces" on page 1-89 for related functions

Purpose

Filled 3-D polygons

Syntax

```
fill3(X,Y,Z,C)
fill3(X,Y,Z,ColorSpec)
fill3(X1,Y1,Z1,C1,X2,Y2,Z2,C2,...)
fill3(...,'PropertyName',PropertyValue)
h = fill3(...)
```

Description

The `fill3` function creates flat-shaded and Gouraud-shaded polygons.

`fill3(X,Y,Z,C)` fills three-dimensional polygons. `X`, `Y`, and `Z` triplets specify the polygon vertices. If `X`, `Y`, or `Z` is a matrix, `fill3` creates *n* polygons, where *n* is the number of columns in the matrix. `fill3` closes the polygons by connecting the last vertex to the first when necessary.

`C` specifies color, where `C` is a vector or matrix of indices into the current colormap. If `C` is a row vector, `length(C)` must equal `size(X,2)` and `size(Y,2)`; if `C` is a column vector, `length(C)` must equal `size(X,1)` and `size(Y,1)`.

`fill3(X,Y,Z,`*`ColorSpec`*`)` fills three-dimensional polygons defined by `X`, `Y`, and `Z` with color specified by `ColorSpec`.

`fill3(X1,Y1,Z1,C1,X2,Y2,Z2,C2,...)` specifies multiple filled three-dimensional areas.

`fill3(...,'`*`PropertyName`*`',PropertyValue)` allows you to set values for specific patch properties.

`h = fill3(...)` returns a vector of handles to patch graphics objects, one handle per patch.

Algorithm

If `X`, `Y`, and `Z` are matrices of the same size, `fill3` forms a vertex from the corresponding elements of `X`, `Y`, and `Z` (all from the same matrix location), and creates one polygon from the data in each column.

If X, Y, or Z is a matrix, fill3 replicates any column vector argument to produce matrices of the required size.

If you specify color using ColorSpec, fill3 generates flat-shaded polygons and sets the patch object FaceColor property to an RGB triple.

If you specify color using C, fill3 scales the elements of C by the axes property CLim, which specifies the color axis scaling parameters, before indexing the current colormap.

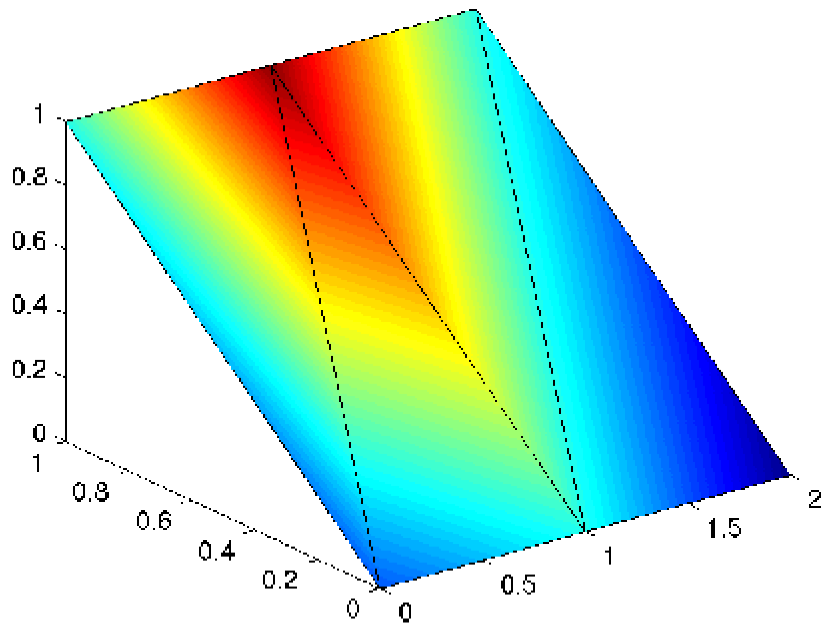
If C is a row vector, fill3 generates flat-shaded polygons and sets the FaceColor property of the patch objects to 'flat'. Each element becomes the CData property value for the respective patch object.

If C is a column vector or a matrix, fill3 generates polygons with interpolated colors and sets the patch object FaceColor property to 'interp'. fill3 uses a linear interpolation of the vertex colormap indices when generating polygons with interpolated colors. The elements in one column become the CData property value for the respective patch object. If C is a column vector, fill3 replicates the column vector to produce the required sized matrix.

Examples

Create four triangles with interpolated colors.

```
X = [0 1 1 2;1 1 2 2;0 0 1 1];
Y = [1 1 1 1;1 0 1 0;0 0 0 0];
Z = [1 1 1 1;1 0 1 0;0 0 0 0];
C = [0.5000 1.0000 1.0000 0.5000;
     1.0000 0.5000 0.5000 0.1667;
     0.3330 0.3330 0.5000 0.5000];
fill3(X,Y,Z,C)
```



See Also

`axis`, `caxis`, `colormap`, `ColorSpec`, `fill`, `patch`

"Polygons and Surfaces" on page 1-89 for related functions

Purpose

1-D digital filter

Syntax

```
y = filter(b,a,X)
[y,zf] = filter(b,a,X)
[y,zf] = filter(b,a,X,zi)
y = filter(b,a,X,zi,dim)
[...] = filter(b,a,X,[],dim)
```

Description

The `filter` function filters a data sequence using a digital filter which works for both real and complex inputs. The filter is a *direct form II transposed* implementation of the standard difference equation (see "Algorithm").

`y = filter(b,a,X)` filters the data in vector `X` with the filter described by numerator coefficient vector `b` and denominator coefficient vector `a`. If `a(1)` is not equal to `1`, `filter` normalizes the filter coefficients by `a(1)`. If `a(1)` equals `0`, `filter` returns an error.

If `X` is a matrix, `filter` operates on the columns of `X`. If `X` is a multidimensional array, `filter` operates on the first nonsingleton dimension.

`[y,zf] = filter(b,a,X)` returns the final conditions, `zf`, of the filter delays. If `X` is a row or column vector, output `zf` is a column vector of `max(length(a),length(b))-1`. If `X` is a matrix, `zf` is an array of such vectors, one for each column of `X`, and similarly for multidimensional arrays.

`[y,zf] = filter(b,a,X,zi)` accepts initial conditions, `zi`, and returns the final conditions, `zf`, of the filter delays. Input `zi` is a vector of length `max(length(a),length(b))-1`, or an array with the leading dimension of size `max(length(a),length(b))-1` and with remaining dimensions matching those of `X`.

`y = filter(b,a,X,zi,dim)` and `[...]  = filter(b,a,X,[],dim)` operate across the dimension `dim`.

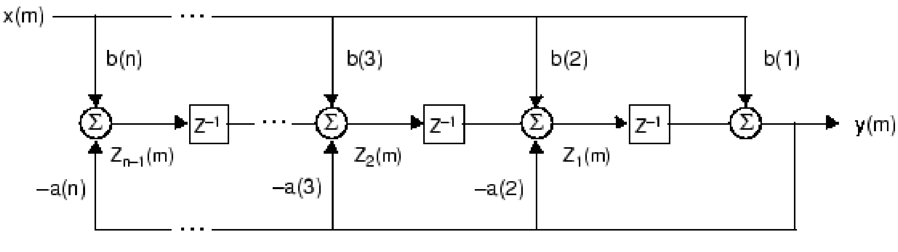
Example

You can use `filter` to find a running average without using a `for` loop. This example finds the running average of a 16-element vector, using a window size of 5.

```
data = [1:0.2:4]';
windowSize = 5;
filter(ones(1,windowSize)/windowSize,1,data)

ans =
    0.2000
    0.4400
    0.7200
    1.0400
    1.4000
    1.6000
    1.8000
    2.0000
    2.2000
    2.4000
    2.6000
    2.8000
    3.0000
    3.2000
    3.4000
    3.6000
```

Algorithm

The `filter` function is implemented as a direct form II transposed structure,



or

```
y(n) = b(1)*x(n) + b(2)*x(n-1) + ... + b(nb+1)*x(n-nb)
                 - a(2)*y(n-1) - ... - a(na+1)*y(n-na)
```

where `n-1` is the filter order, which handles both FIR and IIR filters [1], `na` is the feedback filter order, and `nb` is the feedforward filter order.

The operation of `filter` at sample m is given by the time domain difference equations

$$
\begin{aligned}
y(m) &= b(1)x(m) + z_1(m-1) \\
z_1(m) &= b(2)x(m) + z_2(m-1) - a(2)y(m) \\
\vdots \quad &= \quad \vdots \qquad\qquad\qquad \vdots \\
z_{n-2}(m) &= b(n-1)x(m) + z_{n-1}(m-1) - a(n-1)y(m) \\
z_{n-1}(m) &= b(n)x(m) - a(n)y(m)
\end{aligned}
$$

The input-output description of this filtering operation in the z-transform domain is a rational transfer function,

$$
Y(z) = \frac{b(1) + b(2)z^{-1} + \ldots + b(nb+1)z^{-nb}}{1 + a(2)z^{-1} + \ldots + a(na+1)z^{-na}} X(z)
$$

See Also

`filter2`

`filtfilt`, `filtic` in the Signal Processing Toolbox

References

[1] Oppenheim, A. V. and R.W. Schafer. *Discrete-Time Signal Processing*, Englewood Cliffs, NJ: Prentice-Hall, 1989, pp. 311-312.

Purpose

Shape frequency content of time series

Syntax

```
ts2 = filter(ts1,b,a)
ts2 = filter(ts1,b,a,Index)
```

Description

`ts2 = filter(ts1,b,a)` applies the transfer function filter $b(z^{-1})/a(z^{-1})$ to the data in the `timeseries` object `ts1`.

`b` and `a` are the coefficient arrays of the transfer function numerator and denominator, respectively.

`ts2 = filter(ts1,b,a,Index)` uses the optional `Index` integer array to specify the columns or rows to filter. When `ts.IsTimeFirst` is `true`, `Index` specifies one or more data columns. When `ts.IsTimeFirst` is `false`, Index specifies one or more data rows.

Remarks

The time-series data must be uniformly sampled to use this filter.

The following function

```
y = filter(b,a,x)
```

creates filtered data `y` by processing the data in vector `x` with the filter described by vectors `a` and `b`.

The `filter` function is a general tapped delay-line filter, described by the difference equation

$$\begin{aligned} a(1)y(n) = {} & b(1)x(n) + b(2)x(n-1) + \ldots + b(nb)x(n-nb+1) \\ & -a(2)y(n-1) - \ldots - a(N_a)y(n-N_b+1) \end{aligned}$$

Here, n is the index of the current sample, N_a is the order of the polynomial described by vector `a`, and N_b is the order of the polynomial described by vector `b`. The output $y(n)$ is a linear combination of current and previous inputs, $x(n)$ $x(n\text{-}1)$..., and previous outputs, $y(n\text{-}1)$ $y(n\text{-}2)$... .

You use the discrete filter to shape the data by applying a transfer function to the input signal.

Depending on your objectives, the transfer function you choose might alter both the amplitude and the phase of the variations in the data at different frequencies to produce either a smoother or a rougher output.

In digital signal processing (DSP), it is customary to write transfer functions as rational expressions in z^{-1} and to order the numerator and denominator terms in ascending powers of z^{-1}.

Taking the z-transform of the difference equation

$$a(1)y(n) = b(1)x(n) + b(2)x(n-1) + \ldots + b(nb)x(n-nb+1) - a(2)y(n-1) - \ldots - a(na)y(n-na+1)$$

results in the transfer function

$$Y(z) = H(z^{-1})X(z) = \frac{b(1) + b(2)z^{-1} + \ldots + b(nb)z^{-nb+1}}{a(1) + a(2)z^{-1} + \ldots + a(na)z^{-na+1}}X(z)$$

where $Y(z)$ is the z-transform of the filtered output $y(n)$. The coefficients b and a are unchanged by the z-transform.

Examples

Consider the following transfer function:

$$H(z^{-1}) = \frac{b(z^{-1})}{a(z^{-1})} = \frac{2 + 3z^{-1}}{1 + 0.2z^{-1}}$$

You will apply this transfer function to the data in `count.dat`.

1 Load the matrix `count` into the workspace.

```
load count.dat;
```

2 Create a time-series object based on this matrix.

```
count1=timeseries(count(:,1),[1:24]);
```

3 Enter the coefficients of the denominator ordered in ascending powers of z^{-1} to represent $1 + 0.2z^{-1}$.

```
a = [1 0.2];
```

4 Enter the coefficients of the numerator to represent $2 + 3z^{-1}$.

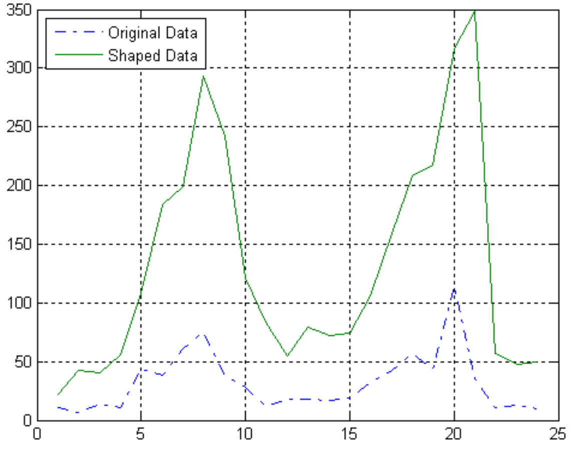
```
b = [2 3];
```

5 Call the filter function.

```
filter_count = filter(count1,b,a)
```

6 Compare the original data and the shaped data with an overlaid plot of the two curves:

```
plot(count1,'-.'), grid on, hold on
plot(filter_count,'-')
legend('Original Data','Shaped Data',2)
```



See Also

idealfilter (timeseries), timeseries, tsprops

Purpose

2-D digital filter

Syntax

```
Y = filter2(h,X)
Y = filter2(h,X,shape)
```

Description

`Y = filter2(h,X)` filters the data in `X` with the two-dimensional FIR filter in the matrix `h`. It computes the result, `Y`, using two-dimensional correlation, and returns the central part of the correlation that is the same size as `X`.

`Y = filter2(h,X,`*`shape`*`)` returns the part of `Y` specified by the `shape` parameter. *`shape`* is a string with one of these values:

'full'	Returns the full two-dimensional correlation. In this case, `Y` is larger than `X`.
'same'	(default) Returns the central part of the correlation. In this case, `Y` is the same size as `X`.
'valid'	Returns only those parts of the correlation that are computed without zero-padded edges. In this case, `Y` is smaller than `X`.

Remarks

Two-dimensional correlation is equivalent to two-dimensional convolution with the filter matrix rotated 180 degrees. See the Algorithm section for more information about how `filter2` performs linear filtering.

Algorithm

Given a matrix `X` and a two-dimensional FIR filter `h`, `filter2` rotates your filter matrix 180 degrees to create a convolution kernel. It then calls `conv2`, the two-dimensional convolution function, to implement the filtering operation.

`filter2` uses `conv2` to compute the full two-dimensional convolution of the FIR filter with the input matrix. By default, `filter2` then extracts the central part of the convolution that is the same size as the input matrix, and returns this as the result. If the `shape` parameter specifies an alternate part of the convolution for the result, `filter2` returns the appropriate part.

See Also

`conv2`, `filter`

find

Purpose

Find indices and values of nonzero elements

Syntax

```
ind = find(X)
ind = find(X, k)
ind = find(X, k, 'first')
ind = find(X, k, 'last')
[row,col] = find(X, ...)
[row,col,v] = find(X, ...)
```

Description

`ind = find(X)` locates all nonzero elements of array `X`, and returns the linear indices of those elements in vector `ind`. If `X` is a row vector, then `ind` is a row vector; otherwise, `ind` is a column vector. If `X` contains no nonzero elements or is an empty array, then `ind` is an empty array.

`ind = find(X, k)` or `ind = find(X, k, 'first')` returns at most the first `k` indices corresponding to the nonzero entries of `X`. `k` must be a positive integer, but it can be of any numeric data type.

`ind = find(X, k, 'last')` returns at most the last `k` indices corresponding to the nonzero entries of `X`.

`[row,col] = find(X, ...)` returns the row and column indices of the nonzero entries in the matrix `X`. This syntax is especially useful when working with sparse matrices. If `X` is an N-dimensional array with N > 2, `col` contains linear indices for the columns. For example, for a 5-by-7-by-3 array `X` with a nonzero element at `X(4,2,3)`, `find` returns 4 in `row` and 16 in `col`. That is, (7 columns in page 1) + (7 columns in page 2) + (2 columns in page 3) = 16.

`[row,col,v] = find(X, ...)` returns a column or row vector `v` of the nonzero entries in `X`, as well as row and column indices. If `X` is a logical expression, then `v` is a logical array. Output `v` contains the non-zero elements of the logical array obtained by evaluating the expression `X`. For example,

```
A= magic(4)
A =
    16     2     3    13
     5    11    10     8
```

```
     9     7     6    12
     4    14    15     1

[r,c,v]= find(A>10);

r', c', v'
ans =
     1     2     4     4     1     3
ans =
     1     2     2     3     4     4
ans =
     1     1     1     1     1     1
```

Here the returned vector `v` is a logical array that contains the nonzero elements of `N` where

```
N=(A>10)
```

Examples

Example 1

```
X = [1 0 4 -3 0 0 0 8 6];
indices = find(X)
```

returns linear indices for the nonzero entries of `X`.

```
indices =
     1     3     4     8     9
```

Example 2

You can use a logical expression to define `X`. For example,

```
find(X > 2)
```

returns linear indices corresponding to the entries of `X` that are greater than 2.

```
ans =
     3     8     9
```

Example 3

The following `find` command

```
X = [3 2 0; -5 0 7; 0 0 1];
[r,c,v] = find(X)
```

returns a vector of row indices of the nonzero entries of `X`

```
r =
     1
     2
     1
     2
     3
```

a vector of column indices of the nonzero entries of `X`

```
c =
     1
     1
     2
     3
     3
```

and a vector containing the nonzero entries of `X`.

```
v =
     3
    -5
     2
     7
     1
```

Example 4

The expression

```
[r,c,v] = find(X>2)
```

returns a vector of row indices of the nonzero entries of `X`

```
r =
     1
     2
```

a vector of column indices of the nonzero entries of `X`

```
c =
     1
     3
```

and a logical array that contains the non zero elements of `N` where `N=(X>2)`.

```
v =
     1
     1
```

Recall that when you use `find` on a logical expression, the output vector `v` does not contain the nonzero entries of the input array. Instead, it contains the nonzero values returned after evaluating the logical expression.

Example 5

Some operations on a vector

```
x = [11  0  33  0  55]';

find(x)
ans =
     1
     3
     5

find(x == 0)
ans =
     2
```

```
     4

find(0 < x & x < 10*pi)
ans =
     1
```

Example 6

For the matrix

```
M = magic(3)
M =
     8     1     6
     3     5     7
     4     9     2

find(M > 3, 4)
```

returns the indices of the first four entries of `M` that are greater than 3.

```
ans =
     1
     3
     5
     6
```

Example 7

If `X` is a vector of all zeros, `find(X)` returns an empty matrix. For example,

```
indices = find([0;0;0])
indices =
   Empty matrix: 0-by-1
```

See Also

`nonzeros`, `sparse`, `colon`, logical operators (elementwise and short-circuit), relational operators, `ind2sub`

Purpose Find all graphics objects

Syntax

```
object_handles = findall(handle_list)
object_handles = findall(handle_list,'property','value',...)
```

Description

`object_handles = findall(handle_list)` returns the handles, including hidden handles, of all objects in the hierarchy under the objects identified in `handle_list`.

`object_handles = findall(handle_list,'property','value',...)` returns the handles of all objects in the hierarchy under the objects identified in `handle_list` that have the specified properties set to the specified values.

Remarks

`findall` is similar to `findobj`, except that it finds objects even if their `HandleVisibility` is set to `off`.

Examples

```
plot(1:10)
xlabel xlab
a = findall(gcf)
b = findobj(gcf)
c = findall(b,'Type','text') % return the xlabel handle twice
d = findobj(b,'Type','text') % can't find the xlabel handle
```

See Also

`allchild`, `findobj`

findfigs

Purpose Find visible offscreen figures

Syntax

```
findfigs
```

Description `findfigs` finds all visible figure windows whose display area is off the screen and positions them on the screen.

A window appears to MATLAB to be offscreen when its display area (the area not covered by the window's title bar, menu bar, and toolbar) does not appear on the screen.

This function is useful when you are bringing an application from a larger monitor to a smaller one (or one with lower resolution). Windows visible on the larger monitor may appear offscreen on a smaller monitor. Using `findfigs` ensures that all windows appear on the screen.

See Also "Finding and Identifying Graphics Objects" on page 1-92 for related functions.

Purpose

Locate graphics objects with specific properties

Syntax

```
h = findobj
h = findobj('PropertyName',PropertyValue,...)
h =
findobj('PropertyName',PropertyValue,'-logicaloperator',
   PropertyName',PropertyValue,...)
h = findobj('-regexp','PropertyName','regexp',...)
h = findobj('-property','PropertyName')
h = findobj(objhandles,...)
h = findobj(objhandles,'-depth',d,...)
h = findobj(objhandles,'flat','PropertyName',PropertyValue,
   ...)
```

Description

`findobj` locates graphics objects and returns their handles. You can limit the search to objects with particular property values and along specific branches of the hierarchy.

`h = findobj` returns the handles of the root object and all its descendants.

`h = findobj('`*`PropertyName`*`',PropertyValue,...)` returns the handles of all graphics objects having the property *`PropertyName`*, set to the value `PropertyValue`. You can specify more than one property/value pair, in which case, `findobj` returns only those objects having all specified values.

`h =`
`findobj('`*`PropertyName`*`',PropertyValue,'-`*`logicaloperator`*`',`
`PropertyName``',PropertyValue,...)` applies the logical operator to the property value matching. Possible values for -*`logicaloperator`* are:

- `-and`
- `-or`
- `-xor`
- `-not`

See the Examples section for examples of how to use these operators. See "Logical Operators" for an explanation of logical operators.

`h = findobj('-regexp','`*`PropertyName`*`','`*`regexp`*`',...)` matches objects using regular expressions as if the value of the property `PropertyName` was passed to the `regexp` function as

```
regexp(PropertyValue,'regexp')
```

If a match occurs, `findobj` returns the object's handle. See the `regexp` function for information on how MATLAB uses regular expressions.

`h = findobj('-property','`*`PropertyName`*`')` finds all objects having the specified property.

`h = findobj(objhandles,...)` restricts the search to objects listed in `objhandles` and their descendants.

`h = findobj(objhandles,'-depth',d,...)` specified the depth of the search. The depth argument `d` controls how many levels under the handles in `objhandles` are traversed. Specifying `d` as `inf` to get the default behavior of all levels. Specify `d` as `0` to get the same behavior as using the `flat` argument.

`h =`
`findobj(objhandles,'flat','`*`PropertyName`*`',PropertyValue,...)` restricts the search to those objects listed in `objhandles` and does not search descendants.

Remarks

`findobj` returns an error if a handle refers to a nonexistent graphics object.

`findobj` correctly matches any legal property value. For example,

```
findobj('Color','r')
```

finds all objects having a `Color` property set to `red`, `r`, or `[1 0 0]`.

When a graphics object is a descendant of more than one object identified in `objhandles`, MATLAB searches the object each time findobj encounters its handle. Therefore, implicit references to a graphics object can result in its handle being returned multiple times.

Examples

Find all line objects in the current axes:

```
h = findobj(gca,'Type','line')
```

Find all objects having a Label set to 'foo' and a String set to 'bar':

```
h = findobj('Label','foo','-and','String','bar');
```

Find all objects whose String is not 'foo' and is not 'bar':

```
h = findobj('-not','String','foo','-not','String','bar');
```

Find all objects having a String set to 'foo' and a Tag set to 'button one' and whose Color is not 'red' or 'blue':

```
h = findobj('String','foo','-and','Tag','button one',...
 '-and','-not',{'Color','red','-or','Color','blue'})
```

Find all objects for which you have assigned a value to the Tag property (that is, the value is not the empty string ''):

```
h = findobj('-regexp','Tag','[^'']')
```

Find all children of the current figure that have their BackgroundColor property set to a certain shade of gray ([.7 .7 .7]). Note that this statement also searches the current figure for the matching property value pair.

```
h = findobj(gcf,'-depth',1,'BackgroundColor',[.7 .7 .7])
```

See Also

copyobj, gcf, gca, gcbo, gco, get, regexp, set

See "Example — Using Logical Operators and Regular Expression" for more examples.

"Finding and Identifying Graphics Objects" on page 1-92 for related functions

findstr

Purpose
Find string within another, longer string

Syntax

```
k = findstr(str1, str2)
```

Description

`k = findstr(str1, str2)` searches the longer of the two input strings for any occurrences of the shorter string, returning the starting index of each such occurrence in the double array `k`. If no occurrences are found, then `findstr` returns the empty array, `[]`.

The search performed by `findstr` is case sensitive. Any leading and trailing blanks in either input string are explicitly included in the comparison.

Unlike the `strfind` function, the order of the input arguments to `findstr` is not important. This can be useful if you are not certain which of the two input strings is the longer one.

Examples

```
s = 'Find the starting indices of the shorter string.';

findstr(s, 'the')
ans =
     6    30

findstr('the', s)
ans =
     6    30
```

See Also

`strfind`, `strmatch`, `strtok`, `strcmp`, `strncmp`, `strcmpi`, `strncmpi`, `regexp`, `regexpi`, `regexprep`

Purpose

MATLAB termination M-file

Description

When MATLAB quits, it runs a script called `finish.m`, if the script exists and is on the MATLAB search path or in the current directory. This is a file you create yourself that instructs MATLAB to perform any final tasks just prior to terminating. For example, you might want to save the data in your workspace to a MAT-file before MATLAB exits.

`finish.m` is invoked whenever you do one of the following:

- Click the Close box ☒ in the MATLAB desktop on Windows or the UNIX equivalent
- Select **Exit MATLAB** from the desktop **File** menu
- Type `quit` or `exit` at the Command Window prompt

Remarks

When using Handle Graphics in `finish.m`, use `uiwait`, `waitfor`, or `drawnow` so that figures are visible. See the reference pages for these functions for more information.

Examples

Two sample `finish.m` files are provided with MATLAB in *`matlabroot`*`/toolbox/local`. Use them to help you create your own `finish.m`, or rename one of the files to `finish.m` and add it to the path to use it:

- `finishsav.m` — Saves the workspace to a MAT-file when MATLAB quits.
- `finishdlg.m` — Displays a dialog allowing you to cancel quitting and saves the workspace. See also the MATLAB general preference for confirmation dialogs for quitting.

See Also

`quit`, `exit`, `startup`

"Quitting MATLAB" in the MATLAB Desktop Tools and Development Environment documentation

Purpose

Information about FITS file

Syntax

```
info = fitsinfo(filename)
```

Description

`info = fitsinfo(filename)` returns the structure, `info`, with fields that contain information about the contents of a Flexible Image Transport System (FITS) file. `filename` is a string enclosed in single quotes that specifies the name of the FITS file.

The `info` structure contains the following fields, listed in the order they appear in the structure. In addition, the info structure can also contain information about any number of optional file components, called *extensions* in FITS terminology. For more information, see "FITS File Extensions" on page 2-1195.

Field Name	Description	Return Type
`Filename`	Name of the file	String
`FileModDate`	File modification date	String
`FileSize`	Size of the file in bytes	Double
`Contents`	List of extensions in the file in the order that they occur	Cell array of strings
`PrimaryData`	Information about the primary data in the FITS file	Structure array

PrimaryData

The `PrimaryData` field is a structure that describes the primary data in the file. The following table lists the fields in the order they appear in the structure.

Field Name	Description	Return Type
`DataType`	Precision of the data	String
`Size`	Array containing the size of each dimension	Double array

Field Name	Description	Return Type
DataSize	Size of the primary data in bytes	Double
MissingDataValue	Value used to represent undefined data	Double
Intercept	Value, used with Slope, to calculate actual pixel values from the array pixel values, using the equation: actual_value = Slope*array_value + Intercept	Double
Slope	Value, used with Intercept, to calculate actual pixel values from the array pixel values, using the equation: actual_value = Slope*array_value + Intercept	Double
Offset	Number of bytes from beginning of the file to the location of the first data value	Double
Keywords	A number-of-keywords-by-3 cell array containing keywords, values, and comments of the header in each column	Cell array of strings

FITS File Extensions

A FITS file can also include optional extensions. If the file contains any of these extensions, the info structure can contain these additional fields.

- AsciiTable — Numeric information in tabular format, stored as ASCII characters

- BinaryTable — Numeric information in tabular format, stored in binary representation
- Image — A multidimensional array of pixels
- Unknown — Nonstandard extension

AsciiTable Extension

The `AsciiTable` structure contains the following fields, listed in the order they appear in the structure.

Field Name	Description	Return Type
`Rows`	Number of rows in the table	Double
`RowSize`	Number of characters in each row	Double
`NFields`	Number of fields in each row	Double array
`FieldFormat`	A 1-by-`NFields` cell containing formats in which each field is encoded. The formats are FORTRAN-77 format codes.	Cell array of strings
`FieldPrecision`	A 1-by-`NFields` cell containing precision of the data in each field	Cell array of strings
`FieldWidth`	A 1-by-`NFields` array containing the number of characters in each field	Double array
`FieldPos`	A 1-by-`NFields` array of numbers representing the starting column for each field	Double array
`DataSize`	Size of the data in the table in bytes	Double
`MissingDataValue`	A 1-by-`NFields` array of numbers used to represent undefined data in each field	Cell array of strings

Field Name	Description	Return Type
`Intercept`	A 1-by-`NFields` array of numbers used along with `Slope` to calculate actual data values from the array data values using the equation: `actual_value = Slope*array_value+Intercept`	Double array
`Slope`	A 1-by-`NFields` array of numbers used with `Intercept` to calculate true data values from the array data values using the equation: `actual_value = Slope*array_value+Intercept`	Double array
`Offset`	Number of bytes from beginning of the file to the location of the first data value in the table	Double
`Keywords`	A number-of-keywords-by-3 cell array containing all the Keywords, Values and Comments in the ASCII table header	Cell array of strings

BinaryTable Extension

The `BinaryTable` structure contains the following fields, listed in the order they appear in the structure.

Field Name	Description	Return Type
`Rows`	Number of rows in the table	Double
`RowSize`	Number of bytes in each row	Double
`NFields`	Number of fields in each row	Double

Field Name	Description	Return Type
FieldFormat	A 1-by-NFields cell array containing the data type of the data in each field. The data type is represented by a FITS binary table format code.	Cell array of strings
FieldPrecision	A 1-by-NFields cell containing precision of the data in each field	Cell array of strings
FieldSize	A 1-by-NFields array, where each element contains the number of values in the Nth field	Double array
DataSize	Size of the data in the Binary Table, in bytes. Includes any data past the main table.	Double
MissingDataValue	An 1-by-NFields array of numbers used to represent undefined data in each field	Cell array of double
Intercept	A 1-by-NFields array of numbers used along with Slope to calculate actual data values from the array data values using the equation: actual_value = slope*array_value+Intercept	Double array
Slope	A 1-by-NFields array of numbers used with Intercept to calculate true data values from the array data values using the equation: actual_value = Slope*array_value+Intercept	Double array

Field Name	Description	Return Type
Offset	Number of bytes from beginning of the file to the location of the first data value	Double
ExtensionSize	Size of any data past the main table, in bytes	Double
ExtensionOffset	Number of bytes from the beginning of the file to any data past the main table	Double
Keywords	A number-of-keywords-by-3 cell array containing all the Keywords, values, and comments in the Binary Table header	Cell array of strings

Image Extension

The `Image` structure contains the following fields, listed in the order they appear in the structure.

Field Name	Description	Return Type
DataType	Precision of the data	String
Size	Array containing sizes of each dimension	Double array
DataSize	Size of the data in the Image extension in bytes	Double
Offset	Number of bytes from the beginning of the file to the first data value	Double
MissingDataValue	Value used to represent undefined data	Double

Field Name	Description	Return Type
Intercept	Value, used with Slope, to calculate actual pixel values from the array pixel values, using the equation: actual_value = Slope*array_value+Intercept	Double
Slope	Value, used with Intercept, to calculate actual pixel values from the array pixel values, using the equation: actual_value = Slope*array_value + Intercept	Double
Keywords	A number-of-keywords-by-3 cell array containing all the Keywords, values, and comments in the Binary Table header	Cell array of strings

Unknown Structure

The Unknown structure contains the following fields, listed in the order they appear in the structure.

Field Name	Description	Return Type
DataType	Precision of the data	String
Size	Sizes of each dimension	Double array
DataSize	Size of the data in nonstandard extensions, in bytes	Double
Offset	Number of bytes from beginning of the file to the first data value	Double

Field Name	Description	Return Type
MissingDataValue	Representation of undefined data	Double
Intercept	Value, used with Slope, to calculate actual data values from the array data values, using the equation: actual_value = Slope*array_value+Intercept	Double
Slope	Value, used with Intercept, to calculate actual data values from the array data values, using the equation: actual_value = Slope*array_value+Intercept	Double
Keywords	A number-of-keywords-by-3 cell array containing all the Keywords, values, and comments in the Binary Table header	Cell array of strings

Example

Use fitsinfo to obtain information about the FITS file tst0012.fits. In addition to its primary data, the file also contains an example of the extensions BinaryTable, Unknown, Image, and AsciiTable.

```
S = fitsinfo('tst0012.fits');
S =
          Filename: [1x71 char]
       FileModDate: '12-Mar-2001 18:37:46'
          FileSize: 109440
          Contents: {'Primary' 'Binary Table' 'Unknown'
'Image' 'ASCII Table'}
       PrimaryData: [1x1 struct]
       BinaryTable: [1x1 struct]
```

```
        Unknown: [1x1 struct]
          Image: [1x1 struct]
     AsciiTable: [1x1 struct]
```

The `PrimaryData` field describes the data in the file. For example, the `Size` field indicates the data is a 102-by-109 matrix.

```
S.PrimaryData
         DataType: 'single'
             Size: [102 109]
         DataSize: 44472
 MissingDataValue: []
        Intercept: 0
            Slope: 1
           Offset: 2880
         Keywords: {25x3 cell}
```

The `AsciiTable` field describes the `AsciiTable` extension. For example, using the `FieldWidth` and `FieldPos` fields you can determine the length and location of each field within a row.

```
S.AsciiTable
ans =
               Rows: 53
            RowSize: 59
            NFields: 8
        FieldFormat: {'A9' 'F6.2' 'I3' 'E10.4' 'D20.15' 'A5' 'A1' 'I4'}
     FieldPrecision: {1x8 cell}
         FieldWidth: [9 6.2000 3 10.4000 20.1500 5 1 4]
           FieldPos: [1 11 18 22 33 54 54 55]
           DataSize: 3127
   MissingDataValue: {'*' '---.--' '  *' [] '*' '*' '*' ''}
          Intercept: [0 0 -70.2000 0 0 0 0 0]
              Slope: [1 1 2.1000 1 1 1 1 1]
             Offset: 103680
           Keywords: {65x3 cell}
```

See Also

`fitsread`

Purpose

Read data from FITS file

Syntax

```
data = fitsread(filename)
data = fitsread(filename, extname)
data = fitsread(filename, extname, index)
data = fitsread(filename, 'raw')
```

Description

`data = fitsread(filename)` reads the primary data of the Flexible Image Transport System (FITS) file specified by `filename`. Undefined data values are replaced by `NaN`. Numeric data are scaled by the slope and intercept values and are always returned in double precision. The `filename` argument is a string enclosed in single quotes.

`data = fitsread(filename, extname)` reads data from a FITS file according to the data array or extension specified in `extname`. You can specify only one `extname`. The valid choices for `extname` are shown in the following table.

Data Arrays or Extensions

extname	Description
'primary'	Read data from the primary data array.
'table'	Read data from the ASCII Table extension.
'bintable'	Read data from the Binary Table extension.
'image'	Read data from the Image extension.
'unknown'	Read data from the Unknown extension.

`data = fitsread(filename, extname, index)` is the same as the above syntax, except that if there is more than one of the specified extension type `extname` in the file, then only the one at the specified `index` is read.

`data = fitsread(filename, 'raw')` reads the primary or extension data of the FITS file, but, unlike the above syntaxes, does not replace undefined data values with NaN and does not scale the data. The data returned has the same class as the data stored in the file.

Example

Read FITS file tst0012.fits into a 109-by-102 matrix called data.

```
data = fitsread('tst0012.fits');

whos data
  Name       Size           Bytes  Class

  data     109x102          88944  double array
```

Here is the beginning of the data read from the file.

```
data(1:5,1:6)
ans =
  135.200  134.9436  134.1752  132.8980  131.1165  128.8378
  137.568  134.9436  134.1752  132.8989  131.1167  126.3343
 135.9946  134.9437  134.1752  132.8989  131.1185  128.1711
 134.0093  134.9440  134.1749  132.8983  131.1201  126.3349
 131.5855  134.9439  134.1749  132.8989  131.1204  126.3356
```

Read only the Binary Table extension from the file.

```
data = fitsread('tst0012.fits', 'bintable')

data =
  Columns 1 through 4
    {11x1 cell}  [11x1 int16]  [11x3 uint8]  [11x2 double]
  Columns 5 through 9
    [11x3 cell]  {11x1 cell}  [11x1 int8]  {11x1 cell}  [11x3 int32]
  Columns 10 through 13
    [11x2 int32]  [11x2 single]  [11x1 double]  [11x1 uint8]
```

See Also

fitsinfo

Purpose

Round toward zero

Syntax

```
B = fix(A)
```

Description

`B = fix(A)` rounds the elements of `A` toward zero, resulting in an array of integers. For complex `A`, 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

fix(a)

ans =
  Columns 1 through 4
  -1.0000        0             3.0000        5.0000

  Columns 5 through 6
   7.0000        2.0000 + 3.0000i
```

See Also

`ceil`, `floor`, `round`

flipdim

Purpose Flip array along specified dimension

Syntax

```
B = flipdim(A,dim)
```

Description

`B = flipdim(A,dim)` returns `A` with dimension `dim` flipped.

When the value of `dim` is `1`, the array is flipped row-wise down. When `dim` is `2`, the array is flipped columnwise left to right. `flipdim(A,1)` is the same as `flipud(A)`, and `flipdim(A,2)` is the same as `fliplr(A)`.

Examples

`flipdim(A,1)` where

```
A =

        1      4
        2      5
        3      6
```

produces

```
        3      6
        2      5
        1      4
```

See Also

`fliplr`, `flipud`, `permute`, `rot90`

Purpose

Flip matrix left to right

Syntax

```
B = fliplr(A)
```

Description

`B = fliplr(A)` returns `A` with columns flipped in the left-right direction, that is, about a vertical axis.

If `A` is a row vector, then `fliplr(A)` returns a vector of the same length with the order of its elements reversed. If `A` is a column vector, then `fliplr(A)` simply returns `A`.

Examples

If `A` is the 3-by-2 matrix,

```
A =
     1     4
     2     5
     3     6
```

then `fliplr(A)` produces

```
     4     1
     5     2
     6     3
```

If `A` is a row vector,

```
A =
     1     3     5     7     9
```

then `fliplr(A)` produces

```
     9     7     5     3     1
```

Limitations

The array being operated on cannot have more than two dimensions. This limitation exists because the axis upon which to flip a multidimensional array would be undefined.

See Also

`flipdim`, `flipud`, `rot90`

flipud

Purpose Flip matrix up to down

Syntax

```
B = flipud(A)
```

Description

`B = flipud(A)` returns `A` with rows flipped in the up-down direction, that is, about a horizontal axis.

If `A` is a column vector, then `flipud(A)` returns a vector of the same length with the order of its elements reversed. If `A` is a row vector, then `flipud(A)` simply returns `A`.

Examples

If `A` is the 3-by-2 matrix,

```
A =
     1     4
     2     5
     3     6
```

then `flipud(A)` produces

```
     3     6
     2     5
     1     4
```

If `A` is a column vector,

```
A =
     3
     5
     7
```

then `flipud(A)` produces

```
A =
     7
     5
     3
```

Limitations

The array being operated on cannot have more than two dimensions. This limitation exists because the axis upon which to flip a multidimensional array would be undefined.

See Also

`flipdim`, `fliplr`, `rot90`

floor

Purpose

Round toward minus infinity

Syntax

```
B = floor(A)
```

Description

`B = floor(A)` rounds the elements of `A` to the nearest integers less than or equal to `A`. For complex `A`, 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

floor(a)

ans =
  Columns 1 through 4
  -2.0000            -1.0000              3.0000              5.0000

  Columns 5 through 6
   7.0000             2.0000 + 3.0000i
```

See Also

`ceil`, `fix`, `round`

Purpose

Count floating-point operations

Description

This is an obsolete function. With the incorporation of LAPACK in MATLAB version 6, counting floating-point operations is no longer practical.

flow

Purpose

Simple function of three variables

Syntax

```
v = flow
v = flow(n)
v = flow(x,y,z)
[x,y,z,v] = flow(...)
```

Description

`flow`, a function of three variables, generates fluid-flow data that is useful for demonstrating `slice`, `interp3`, and other functions that visualize scalar volume data.

`v = flow` produces a 50-by-25-by-25 array.

`v = flow(n)` produces a 2`n`-by-`n`-by-`n` array.

`v = flow(x,y,z)` evaluates the speed profile at the points `x`, `y`, and `z`.

`[x,y,z,v] = flow(...)` returns the coordinates as well as the volume data.

See Also

`slice`, `interp3`

"Volume Visualization" on page 1-101 for related functions

See "Example — Slicing Fluid Flow Data" for an example that uses `flow`.

Purpose

Find minimum of single-variable function on fixed interval

Syntax

```
x = fminbnd(fun,x1,x2)
x = fminbnd(fun,x1,x2,options)
[x,fval] = fminbnd(...)
[x,fval,exitflag] = fminbnd(...)
[x,fval,exitflag,output] = fminbnd(...)
```

Description

`fminbnd` finds the minimum of a function of one variable within a fixed interval.

`x = fminbnd(fun,x1,x2)` returns a value `x` that is a local minimizer of the function that is described in `fun` in the interval `x1 < x < x2`. `fun` is a function handle. See "Function Handles" in the MATLAB Programming documentation for more information.

"Parameterizing Functions Called by Function Functions" in the MATLAB Mathematics documentation, explains how to pass additional parameters to your objective function `fun`.

`x = fminbnd(fun,x1,x2,options)` minimizes with the optimization parameters specified in the structure `options`. You can define these parameters using the `optimset` function. `fminbnd` uses these `options` structure fields:

`Display`	Level of display. `'off'` displays no output; `'iter'` displays output at each iteration; `'final'` displays just the final output; `'notify'` (default) displays output only if the function does not converge.
`FunValCheck`	Check whether objective function values are valid. `'on'` displays an error when the objective function returns a value that is `complex` or `NaN`. `'off'` displays no error.
`MaxFunEvals`	Maximum number of function evaluations allowed.
`MaxIter`	Maximum number of iterations allowed.

`OutputFcn`	User-defined function that is called at each iteration. See "Output Function" in the Optimization Toolbox for more information.
`PlotFcns`	User-defined plot function that is called at each iteration. See "Plot Functions" in the Optimization Toolbox for more information.
`TolX`	Termination tolerance on `x`.

`[x,fval] = fminbnd(...)` returns the value of the objective function computed in `fun` at `x`.

`[x,fval,exitflag] = fminbnd(...)` returns a value `exitflag` that describes the exit condition of `fminbnd`:

`1`	`fminbnd` converged to a solution `x` based on `options.TolX`.
`0`	Maximum number of function evaluations or iterations was reached.
`-1`	Algorithm was terminated by the output function.
`-2`	Bounds are inconsistent (`x1 > x2`).

`[x,fval,exitflag,output] = fminbnd(...)` returns a structure `output` that contains information about the optimization:

`output.algorithm`	Algorithm used
`output.funcCount`	Number of function evaluations
`output.iterations`	Number of iterations
`output.message`	Exit message

Arguments

`fun` is the function to be minimized. `fun` accepts a scalar `x` and returns a scalar `f`, the objective function evaluated at `x`. The function `fun` can be specified as a function handle for an M-file function

```
x = fminbnd(@myfun,x1,x2);
```

where `myfun.m` is an M-file function such as

```
function f = myfun(x)
f = ...          % Compute function value at x.
```

or as a function handle for an anonymous function:

```
x = fminbnd(@(x) sin(x*x),x1,x2);
```

Other arguments are described in the syntax descriptions above.

Examples

`x = fminbnd(@cos,3,4)` computes π to a few decimal places and gives a message on termination.

```
[x,fval,exitflag] = ...
   fminbnd(@cos,3,4,optimset('TolX',1e-12,'Display','off'))
```

computes π to about 12 decimal places, suppresses output, returns the function value at `x`, and returns an `exitflag` of 1.

The argument `fun` can also be a function handle for an anonymous function. For example, to find the minimum of the function $f(x) = x^3 - 2x - 5$ on the interval `(0,2)`, create an anonymous function `f`

```
f = @(x)x.^3-2*x-5;
```

Then invoke `fminbnd` with

```
x = fminbnd(f, 0, 2)
```

The result is

```
x =
    0.8165
```

The value of the function at the minimum is

```
y = f(x)

y =
   -6.0887
```

If fun is parameterized, you can use anonymous functions to capture the problem-dependent parameters. For example, suppose you want to minimize the objective function myfun defined by the following M-file function.

```
function f = myfun(x,a)
f = (x - a)^2;
```

Note that myfun has an extra parameter a, so you cannot pass it directly to fminbind. To optimize for a specific value of a, such as a = 1.5.

1 Assign the value to a.

   ```
   a = 1.5; % define parameter first
   ```

2 Call fminbnd with a one-argument anonymous function that captures that value of a and calls myfun with two arguments:

   ```
   x = fminbnd(@(x) myfun(x,a),0,1)
   ```

Algorithm

fminbnd is an M-file. The algorithm is based on golden section search and parabolic interpolation. Unless the left endpoint x_1 is very close to the right endpoint x_2, fminbnd never evaluates fun at the endpoints, so fun need only be defined for x in the interval $x_1 < x < x_2$. If the minimum actually occurs at x_1 or x_2, fminbnd returns an interior point at a distance of no more than 2*TolX from x_1 or x_2, where TolX is the termination tolerance. See [1] or [2] for details about the algorithm.

Limitations

The function to be minimized must be continuous. fminbnd may only give local solutions.

fminbnd often exhibits slow convergence when the solution is on a boundary of the interval.

`fminbnd` only handles real variables.

See Also

`fminsearch`, `fzero`, `optimset`, `function_handle` (`@`), anonymous function

References

[1] Forsythe, G. E., M. A. Malcolm, and C. B. Moler, *Computer Methods for Mathematical Computations*, Prentice-Hall, 1976.

[2] Brent, Richard. P., *Algorithms for Minimization without Derivatives*, Prentice-Hall, Englewood Cliffs, New Jersey, 1973

fminsearch

Purpose

Find minimum of unconstrained multivariable function using derivative-free method

Syntax

```
x = fminsearch(fun,x0)
x = fminsearch(fun,x0,options)
[x,fval] = fminsearch(...)
[x,fval,exitflag] = fminsearch(...)
[x,fval,exitflag,output] = fminsearch(...)
```

Description

`fminsearch` finds the minimum of a scalar function of several variables, starting at an initial estimate. This is generally referred to as *unconstrained nonlinear optimization*.

`x = fminsearch(fun,x0)` starts at the point `x0` and finds a local minimum `x` of the function described in `fun`. `x0` can be a scalar, vector, or matrix. `fun` is a function handle. See “Function Handles” in the MATLAB Programming documentation for more information.

“Parameterizing Functions Called by Function Functions” in the MATLAB Mathematics documentation, explains how to pass additional parameters to your objective function `fun`. See also “Example 2” on page 2-1317 and “Example 3” on page 2-1317 below.

`x = fminsearch(fun,x0,options)` minimizes with the optimization parameters specified in the structure `options`. You can define these parameters using the `optimset` function. `fminsearch` uses these `options` structure fields:

`Display`	Level of display. `'off'` displays no output; `'iter'` displays output at each iteration; `'final'` displays just the final output; `'notify'` (default) displays output only if the function does not converge.
`FunValCheck`	Check whether objective function values are valid. `'on'` displays an error when the objective function returns a value that is `complex`, `Inf` or `NaN`. `'off'` (the default) displays no error.
`MaxFunEvals`	Maximum number of function evaluations allowed

MaxIter	Maximum number of iterations allowed
OutputFcn	User-defined function that is called at each iteration. See "Output Function" in the Optimization Toolbox for more information.
PlotFcns	User-defined plot function that is called at each iteration. See "Plot Functions" in the Optimization Toolbox for more information.
TolFun	Termination tolerance on the function value
TolX	Termination tolerance on x

[x,fval] = fminsearch(...) returns in fval the value of the objective function fun at the solution x.

[x,fval,exitflag] = fminsearch(...) returns a value exitflag that describes the exit condition of fminsearch:

1	fminsearch converged to a solution x.
0	Maximum number of function evaluations or iterations was reached.
-1	Algorithm was terminated by the output function.

[x,fval,exitflag,output] = fminsearch(...) returns a structure output that contains information about the optimization:

output.algorithm	Algorithm used
output.funcCount	Number of function evaluations
output.iterations	Number of iterations
output.message	Exit message

Arguments

fun is the function to be minimized. It accepts an input x and returns a scalar f, the objective function evaluated at x. The function fun can be specified as a function handle for an M-file function

```
x = fminsearch(@myfun, x0)
```

where myfun is an M-file function such as

```
function f = myfun(x)
f = ...            % Compute function value at x
```

or as a function handle for an anonymous function, such as

```
x = fminsearch(@(x)sin(x^2), x0);
```

Other arguments are described in the syntax descriptions above.

Examples

Example 1

A classic test example for multidimensional minimization is the Rosenbrock banana function

$$f(x) = 100(x_2 - x_1^2)^2 + (1 - x_1)^2$$

The minimum is at (1,1) and has the value 0. The traditional starting point is (-1.2,1). The anonymous function shown here defines the function and returns a function handle called banana:

```
banana = @(x)100*(x(2)-x(1)^2)^2+(1-x(1))^2;
```

Pass the function handle to fminsearch:

```
[x,fval] = fminsearch(banana,[-1.2, 1])
```

This produces

```
x =

    1.0000    1.0000

fval =

    8.1777e-010
```

This indicates that the minimizer was found to at least four decimal places with a value near zero.

Example 2

If fun is parameterized, you can use anonymous functions to capture the problem-dependent parameters. For example, suppose you want to minimize the objective function myfun defined by the following M-file function.

```
function f = myfun(x,a)
f = x(1)^2 + a*x(2)^2;
```

Note that myfun has an extra parameter a, so you cannot pass it directly to fminsearch. To optimize for a specific value of a, such as a = 1.5.

1. Assign the value to a.

   ```
   a = 1.5; % define parameter first
   ```

2. Call fminsearch with a one-argument anonymous function that captures that value of a and calls myfun with two arguments:

   ```
   x = fminsearch(@(x) myfun(x,a),[0,1])
   ```

Example 3

You can modify the first example by adding a parameter a to the second term of the banana function:

$$f(x) = 100(x_2 - x_1^2)^2 + (a - x_1)^2$$

This changes the location of the minimum to the point [a,a^2]. To minimize this function for a specific value of a, for example a = sqrt(2), create a one-argument anonymous function that captures the value of a.

```
a = sqrt(2);
banana = @(x)100*(x(2)-x(1)^2)^2+(a-x(1))^2;
```

Then the statement

```
[x,fval] = fminsearch(banana, [-1.2, 1], ...
   optimset('TolX',1e-8));
```

seeks the minimum [sqrt(2), 2] to an accuracy higher than the default on x.

Algorithm

fminsearch uses the simplex search method of [1]. This is a direct search method that does not use numerical or analytic gradients.

If n is the length of x, a simplex in n-dimensional space is characterized by the n+1 distinct vectors that are its vertices. In two-space, a simplex is a triangle; in three-space, it is a pyramid. At each step of the search, a new point in or near the current simplex is generated. The function value at the new point is compared with the function's values at the vertices of the simplex and, usually, one of the vertices is replaced by the new point, giving a new simplex. This step is repeated until the diameter of the simplex is less than the specified tolerance.

Limitations

fminsearch can often handle discontinuity, particularly if it does not occur near the solution. fminsearch may only give local solutions.

fminsearch only minimizes over the real numbers, that is, x must only consist of real numbers and $f(x)$ must only return real numbers. When x has complex variables, they must be split into real and imaginary parts.

See Also

fminbnd, optimset, function_handle (@), anonymous function

References

[1] Lagarias, J.C., J. A. Reeds, M. H. Wright, and P. E. Wright, "Convergence Properties of the Nelder-Mead Simplex Method in Low Dimensions," *SIAM Journal of Optimization*, Vol. 9 Number 1, pp. 112-147, 1998.

Purpose

Open file, or obtain information about open files

Syntax

```
fid = fopen(filename)
fid = fopen(filename, permission)
fid = fopen(filename, permission_tmode)
[fid, message] = fopen(filename, permission)
[fid, message] = fopen(filename, permission, machineformat)
[fid, message] = fopen(filename, permission, machineformat,
   encoding)
fids = fopen('all')
[filename, permission, machineformat, encoding] = fopen(fid)
```

Description

`fid = fopen(filename)` opens the file `filename` for read access. (On Windows systems, `fopen` opens files for binary read access.) The `filename` argument is a string enclosed in single quotes. It can be a `MATLABPATH` relative partial pathname if the file is opened for reading only. A relative path is always searched for first with respect to the current directory. If it is not found, and reading only is specified or implied, then `fopen` does an additional search of the `MATLABPATH`.

`fid` is a scalar MATLAB integer, called a file identifier. You use the `fid` as the first argument to other file input/output routines. If `fopen` cannot open the file, it returns `-1`. Two file identifiers are automatically available and need not be opened. They are `fid=1` (standard output) and `fid=2` (standard error).

`fid = fopen(filename, permission)` opens the file `filename` in the specified `permission`. The `permission` argument can be any of the following:

Permission Specifiers

Permission	Description
'r'	Open file for reading (default).
'w'	Open file, or create new file, for writing; discard existing contents, if any.

Permission	Description
'a'	Open file, or create new file, for writing; append data to the end of the file.
'r+'	Open file for reading and writing.
'w+'	Open file, or create new file, for reading and writing; discard existing contents, if any.
'a+'	Open file, or create new file, for reading and writing; append data to the end of the file.
'A'	Append without automatic flushing; used with tape drives.
'W'	Write without automatic flushing; used with tape drives.

Note If the file is opened in update mode ('+'), an input command like `fread`, `fscanf`, `fgets`, or `fgetl` cannot be immediately followed by an output command like `fwrite` or `fprintf` without an intervening `fseek` or `frewind`. The reverse is also true: that is, an output command like `fwrite` or `fprintf` cannot be immediately followed by an input command like `fread`, `fscanf`, `fgets`, or `fgetl` without an intervening `fseek` or `frewind`.

`fid = fopen(filename, permission_tmode)` on Windows systems, opens the file in text mode instead of binary mode (the default). The `permission_tmode` argument consists of any of the specifiers shown in the Permission Specifiers on page 2-1223 table above, followed by the letter `t`, for example `'rt'` or `'wt+`. On UNIX, text and binary mode are the same.

Binary and Text Modes

Mode	Behavior
Binary	No characters are given special treatment.
Text	On a read operation, whenever MATLAB encounters a carriage return followed by a newline character, it removes the carriage return from the input. On a write or append operation, MATLAB inserts a carriage return before any newline character.

`[fid, message] = fopen(filename, permission)` opens a file as above. If it cannot open the file, `fid` equals `-1` and `message` contains a system-dependent error message. If `fopen` successfully opens a file, the value of `message` is empty.

`[fid, message] = fopen(filename, permission, machineformat)` opens the file with the specified `permission` and treats data read using `fread` or data written using `fwrite` as having a format given by `machineformat`. `machineformat` is one of the following strings:

Full Precision Support

'ieee be' or 'b'	IEEE floating point with big-endian byte ordering
'ieee le' or 'l'	IEEE floating point with little-endian byte ordering
'ieee-be.l64' or 's'	IEEE floating point with big-endian byte ordering and 64-bit long data type
'ieee-le.l64' or 'a'	IEEE floating point with little-endian byte ordering and 64-bit long data type
'native' or 'n'	Numeric format of the machine on which MATLAB is running (the default)

'vaxd' or 'd'	VAX D floating point and VAX ordering
'vaxg' or 'g'	VAX G floating point and VAX ordering

Limited Precision Support: (double or equivalent)

'cray' or 'c'	Cray floating point with big-endian byte ordering

`[fid, message] = fopen(filename, permission, machineformat, encoding)` opens the specified file using the specified `permission` and `machineformat`. `encoding` is a string that specifies the character encoding scheme associated with the file. It must be the empty string (`''`) or a name or alias for an encoding scheme. Some examples are `'UTF-8'`, `'latin1'`, `'US-ASCII'`, and `'Shift_JIS'`. For common names and aliases, see the Web site `http://www.iana.org/assignments/character-sets`. If `encoding` is unspecified or is the empty string (`''`), MATLAB's default encoding scheme is used.

`fids = fopen('all')` returns a row vector containing the file identifiers of all open files, not including `1` and `2` (standard output and standard error). The number of elements in the vector is equal to the number of open files.

`[filename, permission, machineformat, encoding] = fopen(fid)` returns the `filename`, `permission`, `machineformat`, and `encoding` values used by MATLAB when it opened the file associated with identifier `fid`. MATLAB does not determine these output values by reading information from the opened file. For any of these parameters that were not specified when the file was opened, MATLAB returns its default value. The `encoding` string is a standard character encoding scheme name that may not be the same as the `encoding` argument used in the call to `fopen` that opened the file. An invalid `fid` returns empty strings for all output arguments.

The `'W'` and `'A'` modes do not automatically perform a flush of the current output buffer after output operations.

Examples

The example uses `fopen` to open a file and then passes the `fid` returned by `fopen` to other file I/O functions to read data from the file and then close the file.

```
fid = fopen('fgetl.m');
while 1
    tline = fgetl(fid);
    if ~ischar(tline),   break,   end
    disp(tline)
end
fclose(fid);
```

See Also

`fclose`, `ferror`, `fprintf`, `fread`, `fscanf`, `fseek`, `ftell`, `fwrite`

fopen (serial)

Purpose

Connect serial port object to device

Syntax

```
fopen(obj)
```

Arguments

`obj`	A serial port object or an array of serial port objects.

Description

`fopen(obj)` connects `obj` to the device.

Remarks

Before you can perform a read or write operation, `obj` must be connected to the device with the `fopen` function. When `obj` is connected to the device:

- Data remaining in the input buffer or the output buffer is flushed.
- The `Status` property is set to `open`.
- The `BytesAvailable`, `ValuesReceived`, `ValuesSent`, and `BytesToOutput` properties are set to 0.

An error is returned if you attempt to perform a read or write operation while `obj` is not connected to the device. You can connect only one serial port object to a given device.

Some properties are read-only while the serial port object is open (connected), and must be configured before using `fopen`. Examples include `InputBufferSize` and `OutputBufferSize`. Refer to the property reference pages to determine which properties have this constraint.

The values for some properties are verified only after `obj` is connected to the device. If any of these properties are incorrectly configured, then an error is returned when `fopen` is issued and `obj` is not connected to the device. Properties of this type include `BaudRate`, and are associated with device settings.

If you use the `help` command to display help for `fopen`, then you need to supply the pathname shown below.

```
help serial/fopen
```

Example

This example creates the serial port object `s`, connects `s` to the device using `fopen`, writes and reads text data, and then disconnects `s` from the device.

```
s = serial('COM1');
fopen(s)
fprintf(s,'*IDN?')
idn = fscanf(s);
fclose(s)
```

See Also

Functions

`fclose`

Properties

`BytesAvailable`, `BytesToOutput`, `Status`, `ValuesReceived`, `ValuesSent`

for

Purpose

Execute block of code specified number of times

Syntax

```
for x=initval:endval, statements, end
for x=initval:stepval:endval, statements, end
```

Description

`for x=`*`initval`*`:`*`endval`*`, `*`statements`*`, end` repeatedly executes one or more MATLAB *`statements`* in a loop. Loop counter variable `x` is initialized to value `initval` at the start of the first pass through the loop, and automatically increments by 1 each time through the loop. The program makes repeated passes through *`statements`* until either `x` has incremented to the value *`endval`*, or MATLAB encounters a `break`, or `return` instruction, thus forcing an immediately exit of the loop. If MATLAB encounters a `continue` statement in the loop code, it immediately exits the current pass at the location of the `continue` statement, skipping any remaining code in that pass, and begins another pass at the start of the loop *`statements`* with the value of the loop counter incremented by 1.

The values `initval` and `endval` must be real numbers or arrays of real numbers, or can also be calls to functions that return the same. The value assigned to `x` is often used in the code within the loop, however it is recommended that you do not assign to `x` in the loop code.

`for x=`*`initval`*`:`*`stepval`*`:`*`endval`*`, `*`statements`*`, end` is the same as the above syntax, except that loop counter `x` is incremented (or decremented when *`stepval`* is negative) by the value *`stepval`* on each iteration through the loop. The value `stepval` must be a real number or can also be a call to a function that returns a real number.

The general format is

```
for variable = initval:endval
    statement
    ...
    statement
end
```

The scope of the for statement is always terminated with a matching end.

See "Program Control Statements" in the MATLAB Programming documentation for more information on controlling the flow of your program code.

Examples

Assume k has already been assigned a value. Create the Hilbert matrix, using zeros to preallocate the matrix to conserve memory:

```
a = zeros(k,k)  % Preallocate matrix
for m = 1:k
    for n = 1:k
        a(m,n) = 1/(m+n -1);
    end
end
```

Step s with increments of -0.1:

```
for s = 1.0: -0.1: 0.0,..., end
```

Step s with values 1, 5, 8, and 17:

```
for s = [1,5,8,17], ..., end
```

Successively set e to the unit n-vectors:

```
for e = eye(n), ..., end
```

The line

```
for V = A, ..., end
```

has the same effect as

```
for k = 1:n, V = A(:,k); ..., end
```

except k is also set here.

See Also

end, while, break, continue, return, if, switch, colon

format

Purpose

Set display format for output

Graphical Interface

As an alternative to `format`, use preferences. Select **Preferences** from the **File** menu in the MATLAB desktop and use **Command Window** preferences.

Syntax

```
format
format type
format('type')
```

Description

Use the `format` function to control the output format of numeric values displayed in the Command Window.

Note The `format` function affects only how numbers are displayed, not how MATLAB computes or saves them.

`format` by itself, changes the output format to the default appropriate for the class of the variable currently being used. For floating-point variables, for example, the default is `format short` (i.e., 5-digit scaled, fixed-point values).

`format` *`type`* changes the format to the specified *`type`*. The tables shown below list the allowable values for *`type`*.

`format('`*`type`*`')` is the function form of the syntax.

The tables below show the allowable values for *`type`*, and provides an example for each type using `pi`.

Use these format types to switch between different output display formats for floating-point variables.

Type	Result
short	Scaled fixed point format, with 4 digits after the decimal point. For example, 3.1416
long	Scaled fixed point format with 14 to 15 digits after the decimal point for double; and 7 digits after the decimal point for single. For example, 3.14159265358979
short e	Floating point format, with 4 digits after the decimal point. For example, 3.1416e+000
long e	Floating point format, with 14 to 15 digits after the decimal point for double; and 7 digits after the decimal point for single. For example, 3.141592653589793e+000
short g	Best of fixed or floating point, with 4 digits after the decimal point. For example, 3.1416
long g	Best of fixed or floating point, with 14 to 15 digits after the decimal point for double; and 7 digits after the decimal point for single. For example, 3.14159265358979
short eng	Engineering format that has 4 digits after the decimal point, and a power that is a multiple of three. For example, 3.1416e+000
long eng	Engineering format that has exactly 16 significant digits and a power that is a multiple of three. For example, 3.14159265358979e+000

Use these format types to switch between different output display formats for all numeric variables.

Value for type	Result
+	+, -, blank
bank	Fixed dollars and cents. For example, 3.14

Value for type	Result
hex	Hexadecimal (hexadecimal representation of a binary double-precision number). For example, 400921fb54442d18
rat	Ratio of small integers. For example, 355/113

Use these format types to affect the spacing in the display of all variables.

Value for type	Result	Example

`compact`	Suppresses excess line feeds to show more output in a single screen. Contrast with `loose`.	`theta = pi/2`
		`theta=`
		`1.5708`

`loose`	Adds linefeeds to make output more readable. Contrast with `compact`.	`theta = pi/2`
		`theta=`
		`1.5708`

Remarks

Computations on floating-point variables, namely `single` or `double`, are done in appropriate floating-point precision, no matter how those variables are displayed. Computations on integer variables are done natively in integer.

MATLAB always displays integer variables to the appropriate number of digits for the class. For example, MATLAB uses three digits to display numbers of type `int8` (i.e., -128:127). Setting `format` to `short` or `long` does not affect the display of integer variables.

The specified format applies only to the current MATLAB session. To maintain a format across sessions, use MATLAB preferences.

To see which `type` is currently in use, type

```
get(0,'Format')
```

To see if `compact` or `loose` formatting is currently selected, type

```
get(0,'FormatSpacing').
```

Examples

Example 1

Change the format to `long` by typing

```
format long
```

View the result for the value of `pi` by typing

```
pi
ans =
   3.14159265358979
```

View the current format by typing

```
get(0,'format')
ans =
   long
```

Set the format to `short e` by typing

```
format short e
```

or use the function form of the syntax

```
format('short','e')
```

Example 2

When the format is set to `short`, both `pi` and `single(pi)` display as 5-digit values:

```
format short

pi
ans =
    3.1416

single(pi)
ans =
    3.1416
```

Now set format to `long`, and `pi` displays a 15-digit value while `single(pi)` display an 8-digit value:

```
format long

pi
ans =
    3.14159265358979

single(pi)
ans =
    3.1415927
```

Example 3

Set the format to its default, and display the maximum values for integers and real numbers in MATLAB:

```
format

intmax('uint64')
ans =
   18446744073709551615

realmax
ans =
  1.7977e+308
```

Now change the format to hexadecimal, and display these same values:

```
format hex

intmax('uint64')
ans =
   ffffffffffffffff

realmax
ans =
   7fefffffffffffff
```

The hexadecimal display corresponds to the internal representation of the value. It is not the same as the hexadecimal notation in the C programming language.

Example 4

This example illustrates the `short eng` and `long eng` formats. The value assigned to variable `A` increases by a multiple of 10 each time through the `for` loop.

```
A = 5.123456789;

for k=1:10
   disp(A)
   A = A * 10;
end
```

The values displayed for `A` are shown here. The power of 10 is always a multiple of 3. The value itself is expressed in 5 or more digits for the `short eng` format, and in exactly 15 digits for `long eng`:

```
   format short eng              format long eng

     5.1235e+000              5.12345678900000e+000
    51.2346e+000             51.2345678900000e+000
   512.3457e+000            512.345678900000e+000
     5.1235e+003              5.12345678900000e+003
    51.2346e+003             51.2345678900000e+003
   512.3457e+003            512.345678900000e+003
     5.1235e+006              5.12345678900000e+006
    51.2346e+006             51.2345678900000e+006
   512.3457e+006            512.345678900000e+006
     5.1235e+009              5.12345678900000e+009
```

Algorithms

If the largest element of a matrix is larger than 10^3 or smaller than 10^{-3}, MATLAB applies a common scale factor for the short and long formats. The function `format +` displays +, -, and blank characters for positive, negative, and zero elements. `format hex` displays the hexadecimal representation of a binary double-precision number. `format rat` uses a continued fraction algorithm to approximate floating-point values by ratios of small integers. See `rat.m` for the complete code.

See Also

`disp`, `display`, `isnumeric`, `isfloat`, `isinteger`, `floor`, `sprintf`, `fprintf`, `num2str`, `rat`, `spy`

Purpose

Plot function between specified limits

Syntax

```
fplot(fun,limits)
fplot(fun,limits,LineSpec)
fplot(fun,limits,tol)
fplot(fun,limits,tol,LineSpec)
fplot(fun,limits,n)
fplot(fun,lims,...)
fplot(axes_handle,...)
[X,Y] = fplot(fun,limits,...)
```

Description

`fplot` plots a function between specified limits. The function must be of the form $y = f(x)$, where x is a vector whose range specifies the limits, and `y` is a vector the same size as `x` and contains the function's value at the points in x (see the first example). If the function returns more than one value for a given x, then y is a matrix whose columns contain each component of $f(x)$ (see the second example).

`fplot(fun,limits)` plots `fun` between the limits specified by `limits`. `limits` is a vector specifying the x-axis limits (`[xmin xmax]`), or the x- and y-axes limits, (`[xmin xmax ymin ymax]`).

`fun` must be

- The name of an M-file function
- A string with variable `x` that may be passed to `eval`, such as `'sin(x)'`, `'diric(x,10)'`, or `'[sin(x),cos(x)]'`
- A function handle for an M-file function or an anonymous function (see "Function Handles" and "Anonymous Functions" for more information)

The function $f(x)$ must return a row vector for each element of vector x. For example, if $f(x)$ returns `[f1(x),f2(x),f3(x)]` then for input `[x1;x2]` the function should return the matrix

```
f1(x1) f2(x1) f3(x1)
f1(x2) f2(x2) f3(x2)
```

`fplot(fun,limits,LineSpec)` plots `fun` using the line specification `LineSpec`.

`fplot(fun,limits,tol)` plots `fun` using the relative error tolerance `tol` (the default is `2e-3`, i.e., 0.2 percent accuracy).

`fplot(fun,limits,tol,LineSpec)` plots `fun` using the relative error tolerance `tol` and a line specification that determines line type, marker symbol, and color. See `LineSpec` for more information.

`fplot(fun,limits,n)` with `n >= 1` plots the function with a minimum of `n+1` points. The default `n` is `1`. The maximum step size is restricted to be `(1/n)*(xmax-xmin)`.

`fplot(fun,lims,...)` accepts combinations of the optional arguments `tol`, `n`, and `LineSpec`, in any order.

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

`[X,Y] = fplot(fun,limits,...)` returns the abscissas and ordinates for `fun` in `X` and `Y`. No plot is drawn on the screen; however, you can plot the function using `plot(X,Y)`.

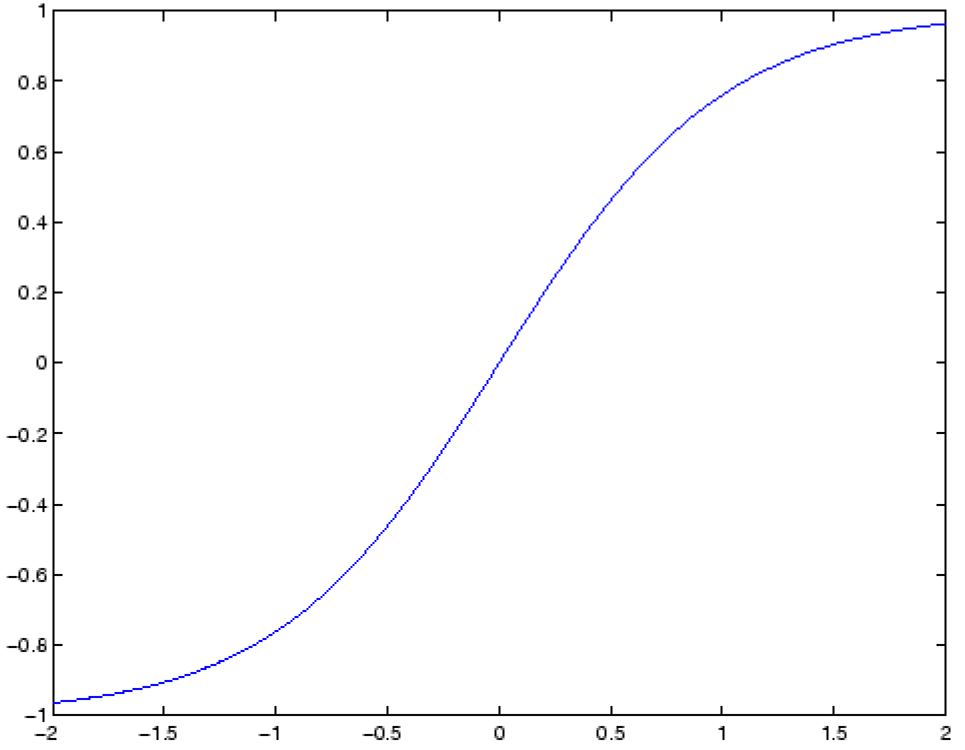
Remarks

`fplot` uses adaptive step control to produce a representative graph, concentrating its evaluation in regions where the function's rate of change is the greatest.

Examples

Plot the hyperbolic tangent function from -2 to 2:

```
fnch = @tanh;
fplot(fnch,[-2 2])
```



Create an M-file, `myfun`, that returns a two-column matrix:

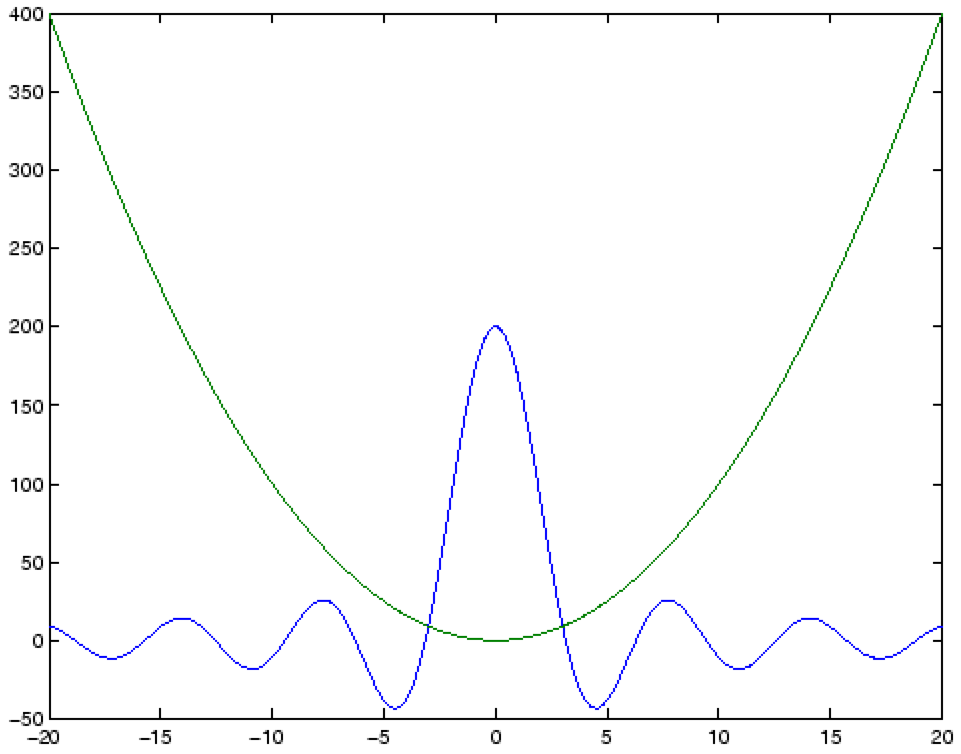
```
function Y = myfun(x)
Y(:,1) = 200*sin(x(:))./x(:);
Y(:,2) = x(:).^2;
```

Create a function handle pointing to `myfun`:

```
fh = @myfun;
```

Plot the function with the statement

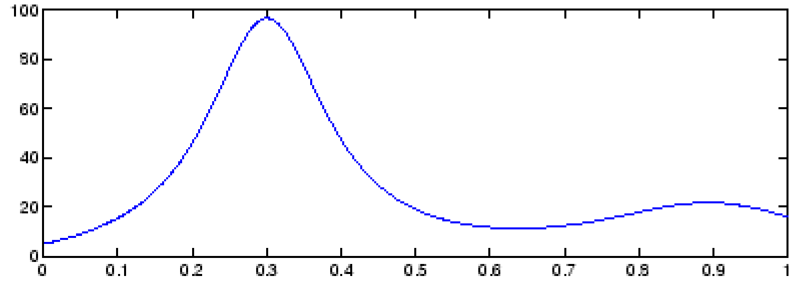
```
fplot(fh,[-20 20])
```

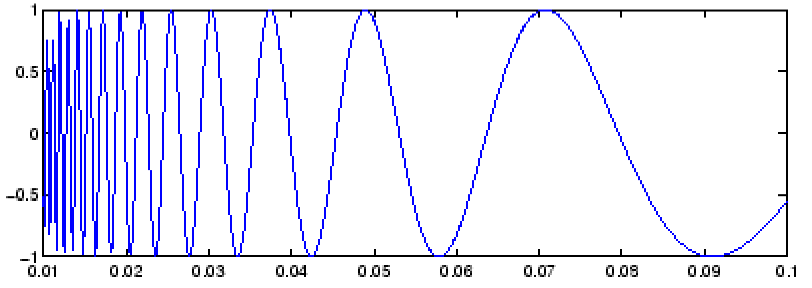


Additional Example

This example passes function handles to `fplot`, one created from a MATLAB function and the other created from an anonymous function.

```
hmp = @humps;
subplot(2,1,1);fplot(hmp,[0 1])
sn = @(x) sin(1./x);
subplot(2,1,2);fplot(sn,[.01 .1])
```





See Also

`eval`, `ezplot`, `feval`, `LineSpec`, `plot`

"Function Plots" on page 1-88 for related functions

"Plotting Mathematical Functions" for more examples

Purpose

Write formatted data to file

Syntax

```
count = fprintf(fid, format, A, ...)
```

Description

`count = fprintf(fid, format, A, ...)` formats the data in the real part of matrix `A` (and in any additional matrix arguments) under control of the specified `format` string, and writes it to the file associated with file identifier `fid`. `fprintf` returns a count of the number of bytes written.

Argument `fid` is an integer file identifier obtained from `fopen`. (It can also be `1` for standard output (the screen) or `2` for standard error. See `fopen` for more information.) Omitting `fid` causes output to appear on the screen.

See "Formatting Strings" in the MATLAB Programming documentation for more detailed information on using string formatting commands.

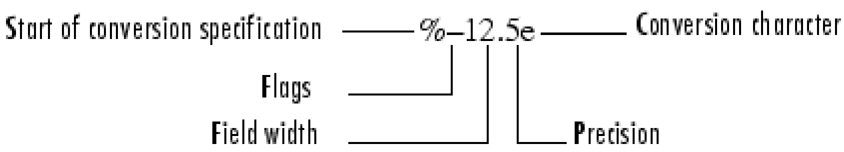
Format String

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
Minus sign ( )	Left-justifies the converted argument in its field	`%-5.2d`
Plus sign (+)	Always prints a sign character (+ or)	`%+5.2d`
Space character	Inserts a space before the value	`% 5.2d`
Zero (0)	Pads with zeros rather than spaces	`%05.2d`

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 digit string specifying the minimum number of digits to be printed	`%6f`
Precision	A digit string including a period (`.`) specifying the number of digits to be printed to the right of the decimal point	`%6.2f`

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
%i	Decimal notation (signed)
%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)

Conversion characters %o, %u, %x, and %X support subtype specifiers. See Remarks for more information.

Escape Characters

This table lists the escape character sequences you use to specify nonprinting characters in a format specification.

Character	Description
\b	Backspace
\f	Form feed
\n	New line

Character	Description
`\r`	Carriage return
`\t`	Horizontal tab
`\\`	Backslash
`\'' or ''` (two single quotes)	Single quotation mark
`%%`	Percent character

Remarks

When writing text to a file on Windows, it is recommended that you open the file in write-text mode (e.g., `fopen(file_id, 'wt')`). This ensures that lines in the file are terminated in such a way as to be compatible with all applications that might use the file.

MATLAB writes characters using the encoding scheme associated with the file. See `fopen` for more information.

The `fprintf` function behaves like its ANSI C language namesake with these exceptions and extensions:

- If you use `fprintf` 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` function 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 `'%bx'`.
`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 `fprintf` function is vectorized for nonscalar arguments. The function recycles the format string through the elements of `A` (columnwise) until all the elements are used up. The function then continues in a similar manner through any additional matrix arguments.

Note `fprintf` displays negative zero (`-0`) differently on some platforms, as shown in the following table.

	Conversion Character		
Platform	**%e or %E**	**%f**	**%g or %G**
PC	0.000000e+000	0.000000	0
Others	-0.000000e+00	-0.000000	-0

Examples

Example 1

Create a text file called `exp.txt` containing a short table of the exponential function. (On Windows platforms, it is recommended that you use `fopen` with the mode set to `'wt'` to open a text file for writing.)

```
x = 0:.1:1;
y = [x; exp(x)];
fid = fopen('exp.txt', 'wt');
fprintf(fid, '%6.2f %12.8f\n', y);
```

```
fclose(fid)
```

Now examine the contents of exp.txt:

```
type exp.txt
   0.00    1.00000000
   0.10    1.10517092
       ...
   1.00    2.71828183
```

Example 2

The command

```
fprintf( ...
  'A unit circle has circumference %g radians.\n', 2*pi)
```

displays a line on the screen:

```
A unit circle has circumference 6.283186 radians.
```

Example 3

To insert a single quotation mark in a string, use two single quotation marks together. For example,

```
fprintf(1,'It''s Friday.\n')
```

displays on the screen

```
It's Friday.
```

Example 4

Use fprintf to display a hyperlink on the screen. For example,

```
site = '"http://www.mathworks.com"';
title = 'The MathWorks Web Site';
fprintf(['<a href = ' site '>' title '</a>'])
```

creates the hyperlink

```
The Mathworks Web Site
```

in the Command Window. Click on this link to display The MathWorks home page in a MATLAB Web browser.

Example 5

The commands

```
B = [8.8  7.7; 8800  7700]
fprintf(1, 'X is %6.2f meters or %8.3f mm\n', 9.9, 9900, B)
```

display the lines

```
X is 9.90 meters or 9900.000 mm
X is 8.80 meters or 8800.000 mm
X is 7.70 meters or 7700.000 mm
```

Example 6

Explicitly convert MATLAB double-precision variables to integer values for use with an integer conversion specifier. For instance, to convert signed 32-bit data to hexadecimal format,

```
a = [6 10 14 44];
fprintf('%9X\n', a + (a<0)*2^32)
        6
        A
        E
       2C
```

See Also

`disp`, `fclose`, `ferror`, `fopen`, `fread`, `fscanf`, `fseek`, `ftell`, `fwrite`

References

[1] Kernighan, B.W., and D.M. Ritchie, *The C Programming Language*, Second Edition, Prentice-Hall, Inc., 1988.

[2] ANSI specification X3.159-1989: "Programming Language C," ANSI, 1430 Broadway, New York, NY 10018.

fprintf (serial)

Purpose

Write text to device

Syntax

```
fprintf(obj,'cmd')
fprintf(obj,'format','cmd')
fprintf(obj,'cmd','mode')
fprintf(obj,'format','cmd','mode')
```

Arguments

`obj`	A serial port object.
`'cmd'`	The string written to the device.
`'format'`	C language conversion specification.
`'mode'`	Specifies whether data is written synchronously or asynchronously.

Description

`fprintf(obj,'cmd')` writes the string `cmd` to the device connected to `obj`. The default format is `%s\n`. The write operation is synchronous and blocks the command line until execution is complete.

`fprintf(obj,'format','cmd')` writes the string using the format specified by *`format`*. *`format`* is a C language conversion specification. Conversion specifications involve the `%` character and the conversion characters d, i, o, u, x, X, f, e, E, g, G, c, and s. Refer to the `sprintf` file I/O format specifications or a C manual for more information.

`fprintf(obj,'cmd','mode')` writes the string with command line access specified by *`mode`*. If *`mode`* is `sync`, `cmd` is written synchronously and the command line is blocked. If *`mode`* is `async`, `cmd` is written asynchronously and the command line is not blocked. If *`mode`* is not specified, the write operation is synchronous.

`fprintf(obj,'format','cmd','mode')` writes the string using the specified format. If *`mode`* is `sync`, `cmd` is written synchronously. If *`mode`* is `async`, `cmd` is written asynchronously.

Remarks

Before you can write text to the device, it must be connected to `obj` with the `fclose` function. A connected serial port object has a `Status` property value of `open`. An error is returned if you attempt to perform a write operation while `obj` is not connected to the device.

The `ValuesSent` property value is increased by the number of values written each time `fprintf` is issued.

An error occurs if the output buffer cannot hold all the data to be written. You can specify the size of the output buffer with the `OutputBufferSize` property.

If you use the `help` command to display help for `fprintf`, then you need to supply the pathname shown below.

```
help serial/fprintf
```

Synchronous Versus Asynchronous Write Operations

By default, text is written to the device synchronously and the command line is blocked until the operation completes. You can perform an asynchronous write by configuring the *`mode`* input argument to be `async`. For asynchronous writes:

- The `BytesToOutput` property value is continuously updated to reflect the number of bytes in the output buffer.
- The M-file callback function specified for the `OutputEmptyFcn` property is executed when the output buffer is empty.

You can determine whether an asynchronous write operation is in progress with the `TransferStatus` property.

Synchronous and asynchronous write operations are discussed in more detail in Controlling Access to the MATLAB Command Line.

Rules for Completing a Write Operation with fprintf

A synchronous or asynchronous write operation using `fprintf` completes when:

- The specified data is written.

- The time specified by the `Timeout` property passes.

Additionally, you can stop an asynchronous write operation with the `stopasync` function.

Rules for Writing the Terminator

All occurrences of `\n` in `cmd` are replaced with the `Terminator` property value. Therefore, when using the default format `%s\n`, all commands written to the device will end with this property value. The terminator required by your device will be described in its documentation.

Example

Create the serial port object `s`, connect `s` to a Tektronix TDS 210 oscilloscope, and write the `RS232?` command with the `fprintf` function. `RS232?` instructs the scope to return serial port communications settings.

```
s = serial('COM1');
fopen(s)
fprintf(s,'RS232?')
```

Because the default format for `fprintf` is `%s\n`, the terminator specified by the `Terminator` property was automatically written. However, in some cases you might want to suppress writing the terminator. To do so, you must explicitly specify a format for the data that does not include the terminator, or configure the terminator to empty.

```
fprintf(s,'%s','RS232?')
```

See Also

Functions

`fopen`, `fwrite`, `stopasync`

Properties

`BytesToOutput`, `OutputBufferSize`, `OutputEmptyFcn`, `Status`,`TransferStatus`, `ValuesSent`

Purpose

Convert movie frame to indexed image

Syntax

```
[X,Map] = frame2im(F)
```

Description

`[X,Map] = frame2im(F)` converts the single movie frame `F` into the indexed image `X` and associated colormap `Map`. The functions `getframe` and `im2frame` create a movie frame. If the frame contains true-color data, then `Map` is empty.

See Also

`getframe`, `im2frame`, `movie`

"Bit-Mapped Images" on page 1-91 for related functions

frameedit

Purpose

Edit print frames for Simulink and Stateflow block diagrams

Syntax

```
frameedit
frameedit filename
```

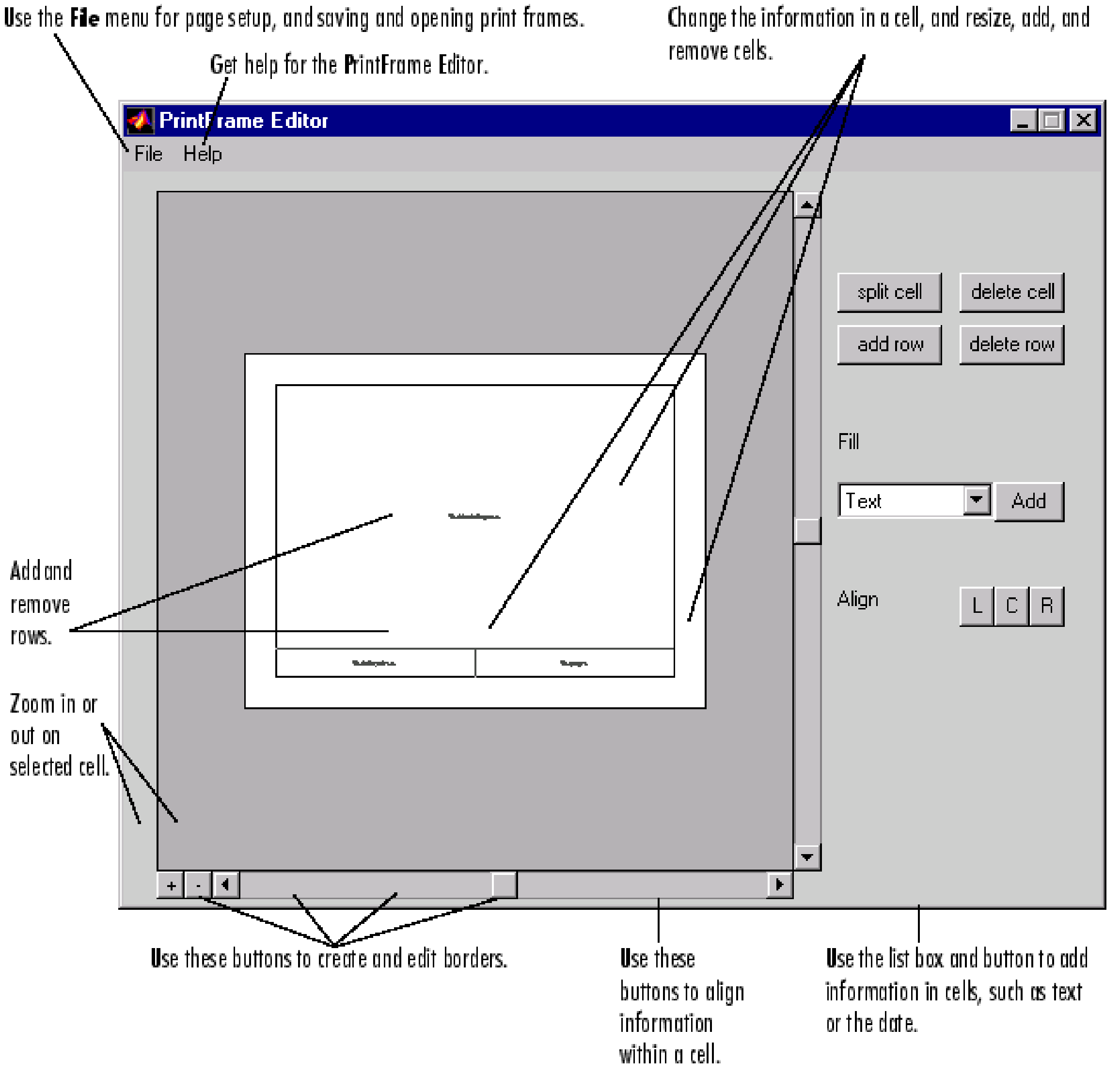
Description

`frameedit` starts the PrintFrame Editor, a graphical user interface you use to create borders for Simulink and Stateflow block diagrams. With no argument, `frameedit` opens the **PrintFrame Editor** window with a new file.

`frameedit filename` opens the **PrintFrame Editor** window with the specified filename, where `filename` is a figure file (`.fig`) previously created and saved using `frameedit`.

Remarks

This illustrates the main features of the PrintFrame Editor.



Closing the PrintFrame Editor

To close the **PrintFrame Editor** window, click the close box in the upper right corner, or select **Close** from the **File** menu.

Printing Simulink Block Diagrams with Print Frames

Select **Print** from the Simulink **File** menu. Check the **Frame** box and supply the filename for the print frame you want to use. Click **OK** in the **Print** dialog box.

Getting Help for the PrintFrame Editor

For further instructions on using the PrintFrame Editor, select **PrintFrame Editor Help** from the **Help** menu in the PrintFrame Editor.

Purpose

Read binary data from file

Syntax

```
A = fread(fid)
A = fread(fid, count)
A = fread(fid, count, precision)
A = fread(fid, count, precision, skip)
A = fread(fid, count, precision, skip, machineformat)
[A, count] = fread(...)
```

Description

`A = fread(fid)` reads data in binary format from the file specified by `fid` into matrix `A`. Open the file using `fopen` before calling `fread`. The `fid` argument is the integer file identifier obtained from the `fopen` operation. MATLAB reads the file from beginning to end, and then positions the file pointer at the end of the file (see `feof` for details).

Note `fread` is intended primarily for binary data. When reading text files, use the `fgetl` function.

`A = fread(fid, count)` reads the number of elements specified by count. At the end of the `fread`, MATLAB sets the file pointer to the next byte to be read. A subsequent fread will begin at the location of the file pointer. See "Specifying the Number of Elements" on page 2-1260, below.

Note In the following syntaxes, the `count` and `skip` arguments are optional. For example, `fread(fid, precision)` is a valid syntax.

`A = fread(fid, count, precision)` reads the file according to the data format specified by the string `precision`. This argument commonly contains a data type specifier such as `int` or `float`, followed by an integer giving the size in bits. See "Specifying precision" on page 2-1260 and "Specifying Output Format" on page 2-1262, below.

A = fread(fid, count, precision, skip) includes an optional skip argument that specifies the number of bytes to skip after each precision value is read. If precision specifies a bit format like 'bitN' or 'ubitN', the skip argument is interpreted as the number of bits to skip. See "Specifying a Skip Value" on page 2-1263, below.

A = fread(fid, count, precision, skip, machineformat) treats the data read as having a format given by machineformat. You can obtain the machineformat argument from the output of the fopen function. See fopen for possible values for machineformat.

[A, count] = fread(...) returns the data read from the file in A, and the number of elements successfully read in count.

Specifying the Number of Elements

Valid options for count are

n	Reads n elements into a column vector.
inf	Reads to the end of the file, resulting in a column vector containing the same number of elements as are in the file. If using inf results in an "out of memory" error, specify a numeric count value.
[m,n]	Reads enough elements to fill an m-by-n matrix, filling in elements in column order, padding with zeros if the file is too small to fill the matrix. n can be specified as inf, but m cannot.

Specifying precision

Any of the strings in the following table, either the MATLAB version or their C or Fortran equivalent, can be used for precision. If precision is not specified, MATLAB uses the default, which is 'uint8'.

MATLAB	C or Fortran	Interpretation
'schar'	'signed char'	Signed integer; 8 bits
'uchar'	'unsigned char'	Unsigned integer; 8 bits

MATLAB	C or Fortran	Interpretation
'int8'	'integer*1'	Integer; 8 bits
'int16'	'integer*2'	Integer; 16 bits
'int32'	'integer*4'	Integer; 32 bits
'int64'	'integer*8'	Integer; 64 bits
'uint8'	'integer*1'	Unsigned integer; 8 bits
'uint16'	'integer*2'	Unsigned integer; 16 bits
'uint32'	'integer*4'	Unsigned integer; 32 bits
'uint64'	'integer*8'	Unsigned integer; 64 bits
'float32'	'real*4'	Floating-point; 32 bits
'float64'	'real*8'	Floating-point; 64 bits
'double'	'real*8'	Floating-point; 64 bits

The following platform-dependent formats are also supported, but they are not guaranteed to be the same size on all platforms.

MATLAB	C or Fortran	Interpretation
'char'	'char*1'	Character
'short'	'short'	Integer; 16 bits
'int'	'int'	Integer; 32 bits
'long'	'long'	Integer; 32 or 64 bits
'ushort'	'unsigned short'	Unsigned integer; 16 bits
'uint'	'unsigned int'	Unsigned integer; 32 bits
'ulong'	'unsigned long'	Unsigned integer; 32 or 64 bits
'float'	'float'	Floating-point; 32 bits

Note If the format is `'char'` or `'char*1'`, MATLAB reads characters using the encoding scheme associated with the file. See `fopen` for more information.

The following formats map to an input stream of bits rather than bytes.

MATLAB	C or Fortran	Interpretation
'bitN'	-	Signed integer; N bits (1 ≤ N ≤ 64)
'ubitN'	-	Unsigned integer; N bits (1 ≤ N ≤ 64)

Specifying Output Format

By default, numeric and character values are returned in class `double` arrays. To return these values stored in classes other than `double`, create your `format` argument by first specifying your source format, then following it with the characters "=>," and finally specifying your destination format. You are not required to use the exact name of a MATLAB class type for destination. (See `class` for details). `fread` translates the name to the most appropriate MATLAB class type. If the source and destination formats are the same, the following shorthand notation can be used.

```
*source
```

which means

```
source=>source
```

For example, `'*uint16'` is the same as `'uint16=>uint16'`.

Note You can also use the `*source` notation with an input stream that is specified as a number of bits (e.g., `bit4` or `ubit18`). MATLAB translates this into an output type that is a signed or unsigned integer (depending on the input type), and that is large enough to hold all of the bits in the source format. For example, `*ubit18` does not translate to `ubit18=>ubit18`, but instead to `ubit18=>uint32`.

This table shows some example precision format strings.

’`uint8=>uint8`’	Read in unsigned 8-bit integers and save them in an unsigned 8-bit integer array.
’`*uint8`’	Shorthand version of the above.
’`bit4=>int8`’	Read in signed 4-bit integers packed in bytes and save them in a signed 8-bit array. Each 4-bit integer becomes an 8-bit integer.
’`double=>real*4`’	Read in doubles, convert, and save as a 32-bit floating-point array.

Specifying a Skip Value

When `skip` is used, the `precision` string can contain a positive integer repetition factor of the form `'N*'`, which prefixes the source format specification, such as `'40*uchar'`.

Note Do not confuse the asterisk (*) used in the repetition factor with the asterisk used as precision format shorthand. The format string `'40*uchar'` is equivalent to `'40*uchar=>double'`, not `'40*uchar=>uchar'`.

When `skip` is specified, `fread` reads in, at most, a repetition factor number of values (default is 1), skips the amount of input specified by the `skip` argument, reads in another block of values, again skips input, and so on, until `count` number of values have been read. If a `skip` argument is not specified, the repetition factor is ignored. Use the repetition factor with the `skip` argument to extract data in noncontiguous fields from fixed-length records.

Remarks

If the input stream is bytes and `fread` reaches the end of file (see `feof`) in the middle of reading the number of bytes required for an element, the partial result is ignored. However, if the input stream is bits, then the partial result is returned as the last value. If an error occurs before reaching the end of file, only full elements read up to that point are used.

Examples

Example 1

The file `alphabet.txt` contains the 26 letters of the English alphabet, all capitalized. Open the file for read access with `fopen`, and read the first five elements into output `c`. Because a precision has not been specified, MATLAB uses the default precision of `uint8`, and the output is numeric:

```
fid = fopen('alphabet.txt', 'r');
c = fread(fid, 5)'
c =
    65    66    67    68    69
fclose(fid);
```

This time, specify that you want each element read as an unsigned 8-bit integer and output as a character. (Using a precision of `'char=>char'` or `'*char'` will produce the same result):

```
fid = fopen('alphabet.txt', 'r');
c = fread(fid, 5, 'uint8=>char')'
c =
    ABCDE
fclose(fid);
```

When you leave out the optional count argument, MATLAB reads the file to the end, `A` through `Z`:

```
fid = fopen('alphabet.txt', 'r');
c = fread(fid, '*char')'
c =
    ABCDEFGHIJKLMNOPQRSTUVWXYZ
fclose(fid);
```

The `fopen` function positions the file pointer at the start of the file. So the first `fread` in this example reads the first five elements in the file, and then repositions the file pointer at the beginning of the next element. For this reason, the next `fread` picks up where the previous `fread` left off, at the character `F`.

```
fid = fopen('alphabet.txt', 'r');
c1 = fread(fid, 5, '*char');
c2 = fread(fid, 8, '*char');
c3 = fread(fid, 5, '*char');
fclose(fid);

sprintf('%c', c1, ' * ', c2, ' * ', c3)
ans =
   ABCDE * FGHIJKLM * NOPQR
```

Skip two elements between each read by specifying a `skip` argument of `2`:

```
fid = fopen('alphabet.txt', 'r');
c = fread(fid, '*char', 2);    % Skip 2 bytes per read
fclose(fid);

sprintf('%c', c)
ans =
   ADGJMPSVY
```

Example 2

This command displays the complete M-file containing this `fread` help entry:

```
type fread.m
```

To simulate this command using `fread`, enter the following:

```
fid = fopen('fread.m', 'r');
F = fread(fid, '*char')';
fclose(fid);
```

In the example, the `fread` command assumes the default size, `'inf'`, and precision `'*char'` (the same as `'char=>char'`). `fread` reads the entire file. To display the result as readable text, the column vector is transposed to a row vector.

Example 3

As another example,

```
s = fread(fid, 120, '40*uchar=>uchar', 8);
```

reads in 120 bytes in blocks of 40, each separated by 8 bytes. Note that the class type of `s` is `'uint8'` since it is the appropriate class corresponding to the destination format `'uchar'`. Also, since 40 evenly divides 120, the last block read is a full block, which means that a final skip is done before the command is finished. If the last block read is not a full block, then `fread` does not finish with a skip.

See `fopen` for information about reading big and little-endian files.

Example 4

Invoke the `fopen` function with just an `fid` input argument to obtain the machine format for the file. You can see that this file was written in IEEE floating point with little-endian byte ordering (`'ieee-le'`) format:

```
fid = fopen('A1.dat', 'r');

[fname, mode, mformat] = fopen(fid);
mformat
mformat =
   ieee-le
```

Use the MATLAB format function (not related to the machine format type) to have MATLAB display output using hexadecimal:

```
format hex
```

Now use the machineformat input with fread to read the data from the file using the same format:

```
x = fread(fid, 6, 'uint64', 'ieee-le')
x =
   4260800000002000
   0000000000000000
   4282000000180000
   0000000000000000
   42ca5e0000258000
   42f0000464d45200
fclose(fid);
```

Change the machine format to IEEE floating point with big-endian byte ordering ('ieee-be') and verify that you get different results:

```
fid = fopen('A1.dat', 'r');
x = fread(fid, 6, 'uint64', 'ieee-be')
x =
   4370000008400000
   0000000000000000
   4308000200100000
   0000000000000000
   4352c0002f0d0000
   43c022a6a3000000
fclose(fid);
```

Example 5

This example reads some Japanese text from a file that uses the Shift-JIS character encoding scheme. It creates a string of Unicode characters, str, and displays the string. Note that the computer must be configured to display Japanese (e.g., a Japanese Windows machine) for the output of disp(str) to be correct.

```
fid = fopen('japanese.txt', 'r', 'n', 'Shift_JIS');
str = fread(fid, '*char')';
```

```
fclose(fid);
disp(str);
```

See Also

fgetl, fscanf, fwrite, fprintf, fopen, fclose, fseek, ftell, feof

Purpose

Read binary data from device

Syntax

```
A = fread(obj)
A = fread(obj,size,'precision')
[A,count] = fread(...)
[A,count,msg] = fread(...)
```

Arguments

`obj`	A serial port object.
`size`	The number of values to read.
`'precision'`	The number of bits read for each value, and the interpretation of the bits as character, integer, or floating-point values.
`A`	Binary data returned from the device.
`count`	The number of values read.
`msg`	A message indicating if the read operation was unsuccessful.

Description

`A = fread(obj)` and A = fread(obj,size) read binary data from the device connected to `obj`, and returns the data to `A`. The maximum number of values to read is specified by `size`. If `size` is not specified, the maximum number of values to read is determined by the object's `InputBufferSize` property. Valid options for `size` are:

`n`	Read at most `n` values into a column vector.
`[m,n]`	Read at most m-by-n values filling an m–by–n matrix in column order.

`size` cannot be `inf`, and an error is returned if the specified number of values cannot be stored in the input buffer. You specify the size, in bytes, of the input buffer with the `InputBufferSize` property. A value is defined as a byte multiplied by the *`precision`* (see below).

`A = fread(obj,size,'precision')` reads binary data with precision specified by *`precision`*.

`precision` controls the number of bits read for each value and the interpretation of those bits as integer, floating-point, or character values. If *`precision`* is not specified, `uchar` (an 8-bit unsigned character) is used. By default, numeric values are returned in double-precision arrays. The supported values for *`precision`* are listed below in Remarks.

`[A,count] = fread(...)` returns the number of values read to `count`.

`[A,count,msg] = fread(...)` returns a warning message to `msg` if the read operation was unsuccessful.

Remarks

Before you can read data from 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 to perform a read operation while `obj` is not connected to the device.

If `msg` is not included as an output argument and the read operation was not successful, then a warning message is returned to the command line.

The `ValuesReceived` property value is increased by the number of values read, each time `fread` is issued.

If you use the `help` command to display help for `fread`, then you need to supply the pathname shown below.

```
help serial/fread
```

Rules for Completing a Binary Read Operation

A read operation with `fread` blocks access to the MATLAB command line until:

- The specified number of values are read.
- The time specified by the `Timeout` property passes.

Note The `Terminator` property is not used for binary read operations.

Supported Precisions

The supported values for *`precision`* are listed below.

Data Type	Precision	Interpretation
Character	`uchar`	8-bit unsigned character
	`schar`	8-bit signed character
	`char`	8-bit signed or unsigned character
Integer	`int8`	8-bit integer
	`int16`	16-bit integer
	`int32`	32-bit integer
	`uint8`	8-bit unsigned integer
	`uint16`	16-bit unsigned integer
	`uint32`	32-bit unsigned integer
	`short`	16-bit integer
	`int`	32-bit integer
	`long`	32- or 64-bit integer
	`ushort`	16-bit unsigned integer
	`uint`	32-bit unsigned integer
	`ulong`	32- or 64-bit unsigned integer

Data Type	Precision	Interpretation
Floating-point	single	32-bit floating point
	float32	32-bit floating point
	float	32-bit floating point
	double	64-bit floating point
	float64	64-bit floating point

See Also

Functions

fgetl, fgets, fopen, fscanf

Properties

BytesAvailable, BytesAvailableFcn, InputBufferSize, Status, Terminator, ValuesReceived

Purpose

Frequency spacing for frequency response

Syntax

```
[f1,f2] = freqspace(n)
[f1,f2] = freqspace([m n])
[x1,y1] = freqspace(...,'meshgrid')
f = freqspace(N)
f = freqspace(N,'whole')
```

Description

`freqspace` returns the implied frequency range for equally spaced frequency responses. `freqspace` is useful when creating desired frequency responses for various one- and two-dimensional applications.

`[f1,f2] = freqspace(n)` returns the two-dimensional frequency vectors `f1` and `f2` for an `n`-by-`n` matrix.

For `n` odd, both `f1` and `f2` are `[-n+1:2:n-1]/n`.

For `n` even, both `f1` and `f2` are `[-n:2:n-2]/n`.

`[f1,f2] = freqspace([m n])` returns the two-dimensional frequency vectors `f1` and `f2` for an `m`-by-`n` matrix.

`[x1,y1] = freqspace(...,'meshgrid')` is equivalent to

```
[f1,f2] = freqspace(...);
[x1,y1] = meshgrid(f1,f2);
```

`f = freqspace(N)` returns the one-dimensional frequency vector `f` assuming `N` evenly spaced points around the unit circle. For `N` even or odd, `f` is `(0:2/N:1)`. For `N` even, `freqspace` therefore returns `(N+2)/2` points. For `N` odd, it returns `(N+1)/2` points.

`f = freqspace(N,'whole')` returns `N` evenly spaced points around the whole unit circle. In this case, `f` is `0:2/N:2*(N-1)/N`.

See Also

`meshgrid`

frewind

Purpose Move file position indicator to beginning of open file

Syntax

```
frewind(fid)
```

Description `frewind(fid)` sets the file position indicator to the beginning of the file specified by `fid`, an integer file identifier obtained from `fopen`.

Remarks Rewinding a `fid` associated with a tape device might not work even though `frewind` does not generate an error message.

See Also `fclose`, `ferror`, `fopen`, `fprintf`, `fread`, `fscanf`, `fseek`, `ftell`, `fwrite`

Purpose

Read formatted data from file

Syntax

```
A = fscanf(fid, format)
[A,count] = fscanf(fid, format, size)
```

Description

`A = fscanf(fid, format)` reads data from the file specified by `fid`, converts it according to the specified `format` string, and returns it in matrix `A`. Argument `fid` is an integer file identifier obtained from `fopen`. `format` is a string specifying the format of the data to be read. See "Remarks" for details.

`[A,count] = fscanf(fid, format, size)` reads the amount of data specified by `size`, converts it according to the specified `format` string, and returns it along with a `count` of values successfully read. `size` is an argument that determines how much data is read. Valid options are

`n`	Read at most `n` numbers, characters, or strings.
`inf`	Read to the end of the file.
`[m,n]`	Read at most `(m*n)` numbers, characters, or strings. Fill a matrix of at most `m` rows in column order. `n` can be `inf`, but `m` cannot.

Characteristics of the output matrix `A` depend on the values read from the file and on the `size` argument. If fscanf reads only numbers, and if `size` is not of the form `[m,n]`, matrix `A` is a column vector of numbers. If fscanf 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.

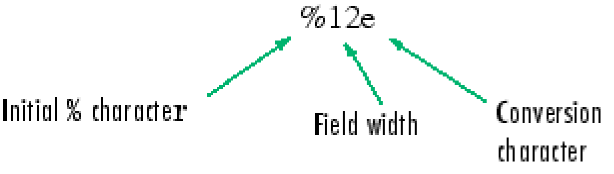
`fscanf` differs from its C language namesake `fscanf()` in an important respect — it is *vectorized* to return a matrix argument. The `format` string is cycled through the file until the first of these conditions occurs:

- The `format` string fails to match the data in the file
- The amount of data specified by `size` is read
- The end of the file is reached

Remarks

When MATLAB reads a specified file, it attempts to match the data in the file 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. If `%*d`, then the value that matches `d` is ignored and is not stored.
A digit string	Maximum field width. For example, `%10d`.
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

`%c`	Sequence of characters; number specified by field width
`%d`	Base 10 integers
`%e`, `%f`, `%g`	Floating-point numbers
`%i`	Defaults to 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
%s	A series of non-white-space characters
%u	Signed decimal integer
%x	Signed hexadecimal integer
[...]	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 fscanf 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.

MATLAB reads characters using the encoding scheme associated with the file. See fopen for more information. If the format string contains ordinary characters, MATLAB matches each of those characters with a character read from the file after converting both to the MATLAB internal representation of characters.

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 fscanf to read numbers from the file are %d, %e, %f, %g, %i, %o, %u, and %x. When fscanf reads only numbers from the file, the elements of the output matrix A are numbers.

When there is no size argument or the size argument is inf, fscanf reads to the end of the file. 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, fscanf reads at most n numbers from the file. 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], fscanf reads at most (m*n) numbers from the file. The output matrix contains at most m rows and n columns. fscanf 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 `fscanf` to read characters and strings from the file are `%c` and `%s`. When `fscanf` reads only characters and strings from the file, the elements of the output matrix `A` are characters. When fscanf 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`, `fscanf` reads to the end of the file. 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`, `fscanf` reads at most `n` character or string values from the file. 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]`, `fscanf` reads at most `(m*n)` character or string values from the file. The output matrix contains at most `m` rows. `fscanf` 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 `fscanf` reads a combination of numbers and either characters or strings from the file, 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 `fscanf` 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`, `fscanf` reads to the end of the file. 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`, `fscanf` reads at most `n` number, character, or string values from the file. The output matrix contains at most `n` rows. `fscanf` 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]`, `fscanf` reads at most `(m*n)` number, character, or string values from the file. The output matrix contains at most `m` rows. `fscanf` 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 `fscanf` actually reads a combination of numbers and either characters or strings from the file. 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`), `fscanf` might actually read only numbers or only characters or strings. If `fscanf` reads only numbers, see "Output Characteristics: Only Numeric Values Read" on page 2-1277. If `fscanf` reads only characters or strings, see "Output Characteristics: Only Character Values Read" on page 2-1278.

Examples

An example in `fprintf` generates a text file called `exp.txt` that looks like

```
0.00    1.00000000
0.10    1.10517092
...
```

```
1.00    2.71828183
```

Read this file back into a two-column MATLAB matrix:

```
fid = fopen('exp.txt', 'r');
a = fscanf(fid, '%g %g', [2 inf])    % It has two rows now.
a = a';
fclose(fid)
```

See Also

`fgetl`, `fgets`, `fread`, `fprintf`, `fscanf`, `input`, `sscanf`, `textread`

Purpose

Read data from device, and format as text

Syntax

```
A = fscanf(obj)
A = fscanf(obj,'format')
A = fscanf(obj,'format',size)
[A,count] = fscanf(...)
[A,count,msg] = fscanf(...)
```

Arguments

`obj`	A serial port object.
`'format'`	C language conversion specification.
`size`	The number of values to read.
`A`	Data read from the device and formatted as text.
`count`	The number of values read.
`msg`	A message indicating if the read operation was unsuccessful.

Description

`A = fscanf(obj)` reads data from the device connected to `obj`, and returns it to `A`. The data is converted to text using the `%c` format.

`A = fscanf(obj,'format')` reads data and converts it according to *`format`*. *`format`* is a C language conversion specification. Conversion specifications involve the `%` character and the conversion characters d, i, o, u, x, X, f, e, E, g, G, c, and s. Refer to the `sscanf` file I/O format specifications or a C manual for more information.

`A = fscanf(obj,'format',size)` reads the number of values specified by `size`. Valid options for `size` are:

`n`	Read at most `n` values into a column vector.
`[m,n]`	Read at most m-by-n values filling an m–by–n matrix in column order.

size cannot be inf, and an error is returned if the specified number of values cannot be stored in the input buffer. If size is not of the form [m,n], and a character conversion is specified, then A is returned as a row vector. You specify the size, in bytes, of the input buffer with the InputBufferSize property. An ASCII value is one byte.

[A,count] = fscanf(...) returns the number of values read to count.

[A,count,msg] = fscanf(...) returns a warning message to msg if the read operation did not complete successfully.

Remarks

Before you can read data from 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 to perform a read operation while obj is not connected to the device.

If msg is not included as an output argument and the read operation was not successful, then a warning message is returned to the command line.

The ValuesReceived property value is increased by the number of values read – including the terminator – each time fscanf is issued.

If you use the help command to display help for fscanf, then you need to supply the pathname shown below.

```
help serial/fscanf
```

Rules for Completing a Read Operation with fscanf

A read operation with fscanf blocks access to the MATLAB command line until:

- The terminator specified by the Terminator property is read.
- The time specified by the Timeout property passes.
- The number of values specified by size is read.
- The input buffer is filled (unless size is specified)

Example

Create the serial port object s and connect s to a Tektronix TDS 210 oscilloscope, which is displaying sine wave.

```
s = serial('COM1');
fopen(s)
```

Use the fprintf function to configure the scope to measure the peak-to-peak voltage of the sine wave, return the measurement type, and return the peak-to-peak voltage.

```
fprintf(s,'MEASUREMENT:IMMED:TYPE PK2PK')
fprintf(s,'MEASUREMENT:IMMED:TYPE?')
fprintf(s,'MEASUREMENT:IMMED:VALUE?')
```

Because the default value for the ReadAsyncMode property is continuous, data associated with the two query commands is automatically returned to the input buffer.

```
s.BytesAvailable
ans =
    21
```

Use fscanf to read the measurement type. The operation will complete when the first terminator is read.

```
meas = fscanf(s)
meas =
PK2PK
```

Use fscanf to read the peak-to-peak voltage as a floating-point number, and exclude the terminator.

```
pk2pk = fscanf(s,'%e',14)
pk2pk =
    2.0200
```

Disconnect s from the scope, and remove s from memory and the workspace.

```
fclose(s)
delete(s)
clear s
```

See Also

Functions

fgetl, fgets, fopen, fread, strread

Properties

BytesAvailable, BytesAvailableFcn, InputBufferSize, Status, Terminator, Timeout

Purpose Set file position indicator

Syntax

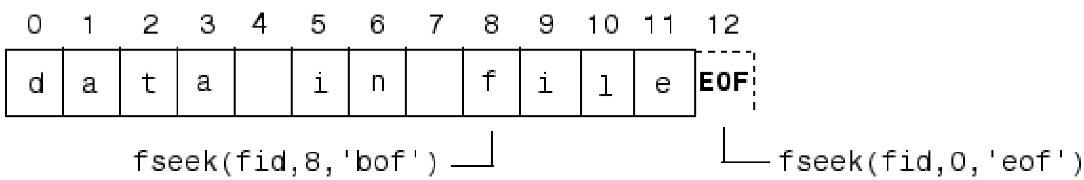
```
status = fseek(fid, offset, origin)
```

Description

`status = fseek(fid, offset, origin)` repositions the file position indicator in the file with the given `fid` to the byte with the specified `offset` relative to `origin`.

For a file having `n` bytes, the bytes are numbered from `0` to `n-1`. The position immediately following the last byte is the end-of-file, or `eof`, position. You would seek to the `eof` position if you wanted to add data to the end of a file.

This figure represents a file having 12 bytes, numbered 0 through 11. The first command shown seeks to the ninth byte of data in the file. The second command seeks just past the end of the file data, to the `eof` position.



`fseek` does not seek beyond the end of file `eof` position. If you attempt to seek beyond `eof`, MATLAB returns an error status.

Arguments

`fid` An integer file identifier obtained from `fopen`

`offset` A value that is interpreted as follows,

`offset > 0`	Move position indicator `offset` bytes toward the end of the file.
`offset = 0`	Do not change position.

	`offset < 0`	Move position indicator `offset` bytes toward the beginning of the file.
`origin`	A string whose legal values are	
	'bof'	-1: Beginning of file
	'cof'	0: Current position in file
	'eof'	1: End of file
`status`	A returned value that is 0 if the `fseek` operation is successful and -1 if it fails. If an error occurs, use the function `ferror` to get more information.	

Examples

This example opens the file `test1.dat`, seeks to the 20th byte, reads fifty 32-bit unsigned integers into variable `A`, and closes the file. It then opens a second file, `test2.dat`, seeks to the end-of-file position, appends the data in `A` to the end of this file, and closes the file.

```
fid = fopen('test1.dat', 'r');
fseek(fid, 19, 'bof');
A = fread(fid, 50, 'uint32');
fclose(fid);

fid = fopen('test2.dat', 'r+');
fseek(fid, 0, 'eof');
fwrite(fid, A, 'uint32');
fclose(fid);
```

See Also

`fopen`, `fclose`, `ferror`, `fprintf`, `fread`, `fscanf`, `ftell`, `fwrite`

Purpose

File position indicator

Syntax

```
position = ftell(fid)
```

Description

`position = ftell(fid)` returns the location of the file position indicator for the file specified by `fid`, an integer file identifier obtained from `fopen`. The `position` is a nonnegative, zero-based integer specified in bytes from the beginning of the file. A returned value of `-1` for `position` indicates that the query was unsuccessful; use `ferror` to determine the nature of the error.

Remarks

`ftell` is likely to return an invalid `position` when *all* of the following are true. This is due to the way in which the Microsoft Windows C library currently handles its `ftell` and `fgetpos` commands:

- The file you are currently operating on is an ASCII text file.
- The file was written on a UNIX-based system, or uses the UNIX-style line terminator: a line feed (with no carriage return) at the end of each line of text. (This is the default output format for MATLAB functions `dlmwrite` and `csvwrite`.)
- You are reading the file on a Windows system.
- You opened the file with the `fopen` function with `mode` set to `'rt'`.
- The `ftell` command is directly preceded by an `fgets` or `fgetl` command.

Note that this does not affect the ability to accurately read from and write to this type of file from MATLAB.

See Also

`fclose`, `ferror`, `fopen`, `fprintf`, `fread`, `fscanf`, `fseek`, `fwrite`

Purpose

Connect to FTP server, creating FTP object

Syntax

```
f = ftp('host','username','password')
```

Description

`f = ftp('host','username','password')` connects to the FTP server, `host`, creating the FTP object, `f`. If a username and password are not required for an anonymous connection, only use the `host` argument. Specify an alternate port by separating it from `host` using a colon (:). After running `ftp`, perform file operation functions on the FTP object, `f`, using methods such as `cd` and others listed under "See Also." When you're finished using the server, run `close (ftp)` to close the connection.

The `ftp` function is based on code from the Apache Jakarta Project.

Examples

Connect Without Username

Connect to `ftp.mathworks.com`, which does not require a username or password. Assign the resulting FTP object to `tmw`. You can access this FTP site to experiment with the FTP functions.

```
tmw=ftp('ftp.mathworks.com')
```

MATLAB returns

```
tmw =
 FTP Object
  host: ftp.mathworks.com
  user: anonymous
   dir: /
  mode: binary
```

Connect to Specified Port

To connect to port 34, type

```
tmw=ftp('ftp.mathworks.com:34')
```

Connect with Username

Connect to `ftp.testsite.com` and assign the resulting FTP object to `test`.

```
test=ftp('ftp.testsite.com','myname','mypassword')
```

MATLAB returns

```
test =
 FTP Object
  host: ftp.testsite.com
  user: myname
   dir: /
  mode: binary
  myname@ftp.testsite.com
  /
```

See Also

`ascii`, `binary`, `cd (ftp)`, `close (ftp)`, `delete (ftp)`, `dir (ftp)`, `mget`, `mkdir (ftp)`, `mput`, `rename`, `rmdir (ftp)`

full

Purpose

Convert sparse matrix to full matrix

Syntax

```
A = full(S)
```

Description

`A = full(S)` converts a sparse matrix `S` to full storage organization. If `S` is a full matrix, it is left unchanged. If `A` is full, `issparse(A)` is `0`.

Remarks

Let `X` be an `m`-by-`n` matrix with `nz = nnz(X)` nonzero entries. Then `full(X)` requires space to store `m*n` real numbers while `sparse(X)` requires space to store `nz` real numbers and `(nz+n)` integers.

On most computers, a real number requires twice as much storage as an integer. On such computers, `sparse(X)` requires less storage than `full(X)` if the density, `nnz/prod(size(X))`, is less than one third. Operations on sparse matrices, however, require more execution time per element than those on full matrices, so density should be considerably less than two-thirds before sparse storage is used.

Examples

Here is an example of a sparse matrix with a density of about two-thirds. `sparse(S)` and `full(S)` require about the same number of bytes of storage.

```
S = sparse(+(rand(200,200) < 2/3));
A = full(S);
whos
Name    Size    Bytes     Class
  A    200X200 320000 double array
  S    200X200 318432 double array (sparse)
```

See Also

`issparse`, `sparse`

Purpose Build full filename from parts

Syntax

```
f = fullfile(dir1, dir2, ..., filename)
```

Description

`f = fullfile(dir1, dir2, ..., filename)` builds a full file specification `f` from the directories and filename specified. Input arguments `dir1`, `dir2`, etc. and `filename` are each a string enclosed in single quotes. The output of the `fullfile` command is conceptually equivalent to

```
f = [dir1 filesep dir2 filesep ... filesep filename]
```

except that care is taken to handle the cases when the directories begin or end with a directory separator.

Examples

To create the full filename from a disk name, directories, and filename,

```
f = fullfile('C:', 'Applications', 'matlab', 'myfun.m')
f =
C:\Applications\matlab\myfun.m
```

The following examples both produce the same result on UNIX, but only the second one works on all platforms.

```
fullfile(matlabroot, 'toolbox/matlab/general/Contents.m')
fullfile(matlabroot, 'toolbox', 'matlab', 'general', ...
        'Contents.m')
```

See Also

`fileparts`, `filesep`, `path`, `pathsep`, `genpath`

func2str

Purpose

Construct function name string from function handle

Syntax

`func2str(fhandle)`

Description

`func2str(fhandle)` constructs a string `s` that holds the name of the function to which the function handle `fhandle` belongs.

When you need to perform a string operation, such as compare or display, on a function handle, you can use `func2str` to construct a string bearing the function name.

The `func2str` command does not operate on nonscalar function handles. Passing a nonscalar function handle to `func2str` results in an error.

Examples

Example 1

Convert a `sin` function handle to a string:

```
fhandle = @sin;

func2str(fhandle)
ans =
    sin
```

Example 2

The `catcherr` function shown here accepts function handle and data arguments and attempts to evaluate the function through its handle. If the function fails to execute, `catcherr` uses `sprintf` to display an error message giving the name of the failing function. The function name must be a string for `sprintf` to display it. The code derives the function name from the function handle using `func2str`:

```
function catcherr(func, data)
try
    ans = func(data);
    disp('Answer is:');
    ans
catch
```

```
    disp(sprintf('Error executing function ''%s''\n', ...
        func2str(func)))
end
```

The first call to catcherr passes a handle to the round function and a valid data argument. This call succeeds and returns the expected answer. The second call passes the same function handle and an improper data type (a MATLAB structure). This time, round fails, causing catcherr to display an error message that includes the failing function name:

```
catcherr(@round, 5.432)
ans =
Answer is 5

xstruct.value = 5.432;
catcherr(@round, xstruct)
Error executing function "round"
```

See Also

function_handle, str2func, functions

function

Purpose

Declare M-file function

Syntax

```
function [out1, out2, ...] = funname(in1, in2, ...)
```

Description

`function [out1, out2, ...]  = funname(in1, in2, ...)` defines function `funname` that accepts inputs `in1`, `in2`, etc. and returns outputs `out1`, `out2`, etc.

You add new functions to the MATLAB vocabulary by expressing them in terms of existing functions. The existing commands and functions that compose the new function reside in a text file called an *M-file*.

M-files can be either *scripts* or *functions*. Scripts are simply files containing a sequence of MATLAB statements. Functions make use of their own local variables and accept input arguments.

The name of an M-file begins with an alphabetic character and has a filename extension of `.m`. The M-file name, less its extension, is what MATLAB searches for when you try to use the script or function.

A line at the top of a function M-file contains the syntax definition. The name of a function, as defined in the first line of the M-file, should be the same as the name of the file without the `.m` extension.

The variables within the body of the function are all local variables.

A *subfunction*,visible only to the other functions in the same file, is created by defining a new function with the `function` keyword after the body of the preceding function or subfunction. Subfunctions are not visible outside the file where they are defined.

You can terminate any function with an `end` statement but, in most cases, this is optional. `end` statements are required only in M-files that employ one or more nested functions. Within such an M-file, *every* function (including primary, nested, private, and subfunctions) must be terminated with an `end` statement. You can terminate any function type with `end`, but doing so is not required unless the M-file contains a nested function.

Functions normally return when the end of the function is reached. Use a `return` statement to force an early return.

When MATLAB does not recognize a function by name, it searches for a file of the same name on disk. If the function is found, MATLAB compiles it into memory for subsequent use. The section "Determining Which Function Is Called" in the MATLAB Programming documentation explains how MATLAB interprets variable and function names that you enter, and also covers the precedence used in function dispatching.

When you call an M-file function from the command line or from within another M-file, MATLAB parses the function and stores it in memory. The parsed function remains in memory until cleared with the `clear` command or you `quit` MATLAB. The `pcode` command performs the parsing step and stores the result on the disk as a P-file to be loaded later.

Examples

Example 1

The existence of a file on disk called `stat.m` containing this code defines a new function called `stat` that calculates the mean and standard deviation of a vector:

```
function [mean,stdev] = stat(x)
n = length(x);
mean = sum(x)/n;
stdev = sqrt(sum((x-mean).^2/n));
```

Example 2

`avg` is a subfunction within the file `stat.m`:

```
function [mean,stdev] = stat(x)
n = length(x);
mean = avg(x,n);
stdev = sqrt(sum((x-avg(x,n)).^2)/n);

function mean = avg(x,n)
mean = sum(x)/n;
```

See Also

`nargin`, `nargout`, `pcode`, `varargin`, `varargout`, `what`

function_handle (@)

Purpose

Handle used in calling functions indirectly

Syntax

```
handle = @functionname
handle = @(arglist)anonymous_function
```

Description

`handle = @functionname` returns a handle to the specified MATLAB function.

A function handle is a MATLAB value that provides a means of calling a function indirectly. You can pass function handles in calls to other functions (often called *function functions*). You can also store function handles in data structures for later use (for example, as Handle Graphics callbacks). A function handle is one of the standard MATLAB data types.

At the time you create a function handle, the function you specify must be on the MATLAB path and in the current scope. This condition does not apply when you evaluate the function handle. You can, for example, execute a subfunction from a separate (out-of-scope) M-file using a function handle as long as the handle was created within the subfunction's M-file (in-scope).

`handle = @(arglist)anonymous_function` constructs an anonymous function and returns a `handle` to that function. The body of the function, to the right of the parentheses, is a single MATLAB statement or command. `arglist` is a comma-separated list of input arguments. Execute the function by calling it by means of the function handle, `handle`.

Remarks

The function handle is a standard MATLAB data type. As such, you can manipulate and operate on function handles in the same manner as on other MATLAB data types. This includes using function handles in structures and cell arrays:

```
S.a = @sin;  S.b = @cos;  S.c = @tan;
C = {@sin, @cos, @tan};
```

However, standard matrices or arrays of function handles are not supported:

```
A = [@sin, @cos, @tan];        % This is not supported
```

For nonoverloaded functions, subfunctions, and private functions, a function handle references just the one function specified in the `@functionname` syntax. When you evaluate an overloaded function by means of its handle, the arguments the handle is evaluated with determine the actual function that MATLAB dispatches to.

Use `isa(h, 'function_handle')` to see if variable `h` is a function handle.

Examples

Example 1 — Constructing a Handle to a Named Function

The following example creates a function handle for the `humps` function and assigns it to the variable `fhandle`.

```
fhandle = @humps;
```

Pass the handle to another function in the same way you would pass any argument. This example passes the function handle just created to `fminbnd`, which then minimizes over the interval `[0.3, 1]`.

```
x = fminbnd(fhandle, 0.3, 1)
x =
    0.6370
```

The `fminbnd` function evaluates the `@humps` function handle. A small portion of the `fminbnd` M-file is shown below. In line 1, the `funfcn` input parameter receives the function handle `@humps` that was passed in. The statement, in line 113, evaluates the handle.

```
1    function [xf,fval,exitflag,output] = ...
         fminbnd(funfcn,ax,bx,options,varargin)
            .
            .
            .
```

```
113  fx = funfcn(x,varargin{:});
```

Example 2 — Constructing a Handle to an Anonymous Function

The statement below creates an anonymous function that finds the square of a number. When you call this function, MATLAB assigns the value you pass in to variable `x`, and then uses `x` in the equation `x.^2`:

```
sqr = @(x) x.^2;
```

The `@` operator constructs a function handle for this function, and assigns the handle to the output variable `sqr`. As with any function handle, you execute the function associated with it by specifying the variable that contains the handle, followed by a comma-separated argument list in parentheses. The syntax is

```
fhandle(arg1, arg2, ..., argN)
```

To execute the `sqr` function defined above, type

```
a = sqr(5)
a =
   25
```

Because `sqr` is a function handle, you can pass it in an argument list to other functions. The code shown here passes the `sqr` anonymous function to the MATLAB `quad` function to compute its integral from zero to one:

```
quad(sqr, 0, 1)
ans =
   0.3333
```

See Also

`str2func`, `func2str`, `functions`, `isa`

Purpose

Information about function handle

Syntax

```
S = functions(funhandle)
```

Description

`S = functions(funhandle)` returns, in MATLAB structure `S`, the function name, type, filename, and other information for the function handle stored in the variable `funhandle`.

`functions` does not operate on nonscalar function handles. Passing a nonscalar function handle to `functions` results in an error.

Caution The `functions` function is provided for querying and debugging purposes. Because its behavior may change in subsequent releases, you should not rely upon it for programming purposes.

This table lists the standard fields of the return structure.

Field Name	Field Description
`function`	Function name
`type`	Function type (e.g., simple, overloaded)
`file`	The file to be executed when the function handle is evaluated with a nonoverloaded data type

Remarks

For handles to functions that overload one of the standard MATLAB data types, like `double` or `char`, the structure returned by `functions` contains an additional field named `methods`. The `methods` field is a substructure containing one field name for each MATLAB class that overloads the function. The value of each field is the path and name of the file that defines the method.

Examples

Example 1

To obtain information on a function handle for the `poly` function, type

```
f = functions(@poly)
f =
    function: 'poly'
        type: 'simple'
        file:  '$matlabroot\toolbox\matlab\polyfun\poly.m'
```

(The term `$matlabroot` used in this example stands for the file specification of the directory in which MATLAB software is installed for your system. Your output will display this file specification.)

Access individual fields of the returned structure using dot selection notation:

```
f.type
ans =
   simple
```

Example 2

The function `get_handles` returns function handles for a subfunction and private function in output arguments `s` and `p` respectively:

```
function [s, p] = get_handles
s = @mysubfun;
p = @myprivatefun;
%
function mysubfun
disp 'Executing subfunction mysubfun'
```

Call `get_handles` to obtain the two function handles, and then pass each to the `functions` function. MATLAB returns information in a structure having the fields `function`, `type`, `file`, and `parentage`. The `file` field contains the file specification for the subfunction or private function:

```
[fsub fprv] = get_handles;

functions(fsub)
ans =
```

```
      function: 'mysubfun'
          type: 'scopedfunction'
          file: 'c:\matlab\get_handles.m'
     parentage: {'mysubfun'  'get_handles'}

functions(fprv)
ans =
      function: 'myprivatefun'
          type: 'scopedfunction'
          file: 'c:\matlab\private\myprivatefun.m'
     parentage: {'myprivatefun'}
```

Example 3

In this example, the function `get_handles_nested.m` contains a nested function `nestfun`. This function has a single output which is a function handle to the nested function:

```
function handle = get_handles_nested(A)
nestfun(A);

   function y = nestfun(x)
   y = x + 1;
   end

handle = @nestfun;
end
```

Call this function to get the handle to the nested function. Use this handle as the input to `functions` to return the information shown here. Note that the `function` field of the return structure contains the names of the nested function and the function in which it is nested in the format. Also note that `functions` returns a `workspace` field containing the variables that are in context at the time you call this function by its handle:

```
fh = get_handles_nested(5);

fhinfo = functions(fh)
```

```
fhinfo =
     function: 'get_handles_nested/nestfun'
         type: 'nested'
         file: 'c:\matlab\get_handles_nested.m'
    workspace: [1x1 struct]

fhinfo.workspace
ans =
    handle: @get_handles_nested/nestfun
         A: 5
```

See Also

function_handle

Purpose

Evaluate general matrix function

Syntax

```
F = funm(A,fun)
F = funm(A, fun, options)
[F, exitflag] = funm(...)
[F, exitflag, output] = funm(...)
```

Description

`F = funm(A,fun)` evaluates the user-defined function `fun` at the square matrix argument `A`. `F = fun(x, k)` must accept a vector `x` and an integer `k`, and return a vector `f` of the same size of `x`, where `f(i)` is the `k`th derivative of the function `fun` evaluated at `x(i)`. The function represented by fun must have a Taylor series with an infinite radius of convergence, except for `fun = @log`, which is treated as a special case.

You can also use `funm` to evaluate the special functions listed in the following table at the matrix `A`.

Function	Syntax for Evaluating Function at Matrix A
`exp`	`funm(A, @exp)`
`log`	`funm(A, @log)`
`sin`	`funm(A, @sin)`
`cos`	`funm(A, @cos)`
`sinh`	`funm(A, @sinh)`
`cosh`	`funm(A, @cosh)`

For matrix square roots, use `sqrtm(A)` instead. For matrix exponentials, which of `expm(A)` or `funm(A, @exp)` is the more accurate depends on the matrix `A`.

“Parameterizing Functions Called by Function Functions”, in the online MATLAB Mathematics documentation, explains how to provide additional parameters to the function `fun`, if necessary.

`F = funm(A, fun, options)` sets the algorithm's parameters to the values in the structure `options`. The following table lists the fields of `options`.

Field	Description	Values
options.TolBlk	Level of display	'off' (default), 'on', 'verbose'
options.TolTay	Tolerance for blocking Schur form	Positive scalar. The default is eps.
options.MaxTerms	Maximum number of Tayor series terms	Positive integer. The default is 250.
options.MaxSqrt	When computing a logarithm, maximum number of square roots computed in inverse scaling and squaring method.	Positive integer. The default is 100.
options.Ord	Specifies the ordering of the Schur form T.	A vector of length length(A). options.Ord(i) is the index of the block into which T(i,i) is placed. The default is [].

[F, exitflag] = funm(...) returns a scalar exitflag that describes the exit condition of funm. exitflag can have the following values:

- 0 — The algorithm was successful.
- 1 — One or more Taylor series evaluations did not converge. However, the computed value of F might still be accurate.

[F, exitflag, output] = funm(...) returns a structure output with the following fields:

Field	Description
`output.terms`	Vector for which `output.terms(i)` is the number of Taylor series terms used when evaluating the ith block, or, in the case of the logarithm, the number of square roots.
`output.ind`	Cell array for which the `(i,j)` block of the reordered Schur factor `T` is `T(output.ind{i}, output.ind{j})`.
`output.ord`	Ordering of the Schur form, as passed to `ordschur`
`output.T`	Reordered Schur form

If the Schur form is diagonal then `output = struct('terms',ones(n,1),'ind',{1:n})`.

Examples

Example 1

The following command computes the matrix sine of the 3-by-3 magic matrix.

```
F=funm(magic(3), @sin)

F =

   -0.3850    1.0191    0.0162
    0.6179    0.2168   -0.1844
    0.4173   -0.5856    0.8185
```

Example 2

The statements

```
S = funm(X,@sin);
C = funm(X,@cos);
```

produce the same results to within roundoff error as

```
E = expm(i*X);
C = real(E);
S = imag(E);
```

In either case, the results satisfy `S*S+C*C = I`, where `I = eye(size(X))`.

Example 3

To compute the function `exp(x) + cos(x)` at `A` with one call to `funm`, use

```
F = funm(A,@fun_expcos)
```

where `fun_expcos` is the following M-file function.

```
function f = fun_expcos(x, k)
% Return kth derivative of exp + cos at X.
        g = mod(ceil(k/2),2);
        if mod(k,2)
           f = exp(x) + sin(x)*(-1)^g;
        else
           f = exp(x) + cos(x)*(-1)^g;
        end
```

Algorithm

The algorithm `funm` uses is described in [1].

See Also

`expm`, `logm`, `sqrtm`, `function_handle` (`@`)

References

[1] Davies, P. I. and N. J. Higham, "A Schur-Parlett algorithm for computing matrix functions," *SIAM J. Matrix Anal. Appl.*, Vol. 25, Number 2, pp. 464-485, 2003.

[2] Golub, G. H. and C. F. Van Loan, *Matrix Computation*, Third Edition, Johns Hopkins University Press, 1996, p. 384.

[3] Moler, C. B. and C. F. Van Loan, “Nineteen Dubious Ways to Compute the Exponential of a Matrix, Twenty-Five Years Later” *SIAM Review 20*, Vol. 45, Number 1, pp. 1-47, 2003.

fwrite

Purpose

Write binary data to file

Syntax

```
count = fwrite(fid, A)
count = fwrite(fid, A, precision)
count = fwrite(fid, A, precision, skip)
count = fwrite(fid, A, precision, skip, machineformat)
```

Description

`count = fwrite(fid, A)` writes the elements of matrix `A` to the specified file. The data is written to the file in column order, and a `count` is kept of the number of elements written successfully.

`fid` is an integer file identifier obtained from `fopen`, or `1` for standard output or `2` for standard error.

`count = fwrite(fid, A, precision)` writes the elements of matrix `A` to the specified file, translating MATLAB values to the specified `precision`.

`precision` controls the form and size of the result. See `fread` for a list of allowed precisions. If `precision` is not specified, MATLAB uses the default, which is `'uint8'`. For `'bitN'` or `'ubitN'` precisions, `fwrite` sets all bits in `A` when the value is out of range. If the precision is `'char'` or `'char*1'`, MATLAB writes characters using the encoding scheme associated with the file. See `fopen` for more information.

`count = fwrite(fid, A, precision, skip)` includes an optional `skip` argument that specifies the number of bytes to skip before each `precision` value is written. With the `skip` argument present, `fwrite` skips and writes one value, skips and writes another value, etc., until all of `A` is written. If `precision` is a bit format like `'bitN'` or `'ubitN'`, `skip` is specified in bits. This is useful for inserting data into noncontiguous fields in fixed-length records.

`count = fwrite(fid, A, precision, skip, machineformat)` treats the data written as having a format given by `machineformat`. You can obtain the `machineformat` argument from the output of the `fopen` function. See `fopen` for possible values for `machineformat`.

Remarks

You cannot view or `type` the contents of the file you are writing with `fwrite` until you close the file with the `fclose` function.

Examples

Example 1

This example creates a 100-byte binary file containing the 25 elements of the 5-by-5 magic square, stored as 4-byte integers:

```
fid = fopen('magic5.bin', 'wb');
fwrite(fid, magic(5), 'integer*4')
```

Example 2

This example takes a string of Unicode characters, `str`, which contains Japanese text, and writes the string into a file using the Shift-JIS character encoding scheme:

```
fid = fopen('japanese_out.txt', 'w', 'n', 'Shift_JIS');
fwrite(fid, str, 'char');
fclose(fid);
```

See Also

`fclose`, `ferror`, `fopen`, `fprintf`, `fread`, `fscanf`, `fseek`, `ftell`

fwrite (serial)

Purpose

Write binary data to device

Syntax

```
fwrite(obj,A)
fwrite(obj,A,'precision')
fwrite(obj,A,'mode')
fwrite(obj,A,'precision','mode')
```

Arguments

`obj`	A serial port object.
`A`	The binary data written to the device.
'*precision*'	The number of bits written for each value, and the interpretation of the bits as character, integer, or floating-point values.
'*mode*'	Specifies whether data is written synchronously or asynchronously.

Description

`fwrite(obj,A)` writes the binary data `A` to the device connected to `obj`.

`fwrite(obj,A,'`*precision*`')` writes binary data with precision specified by *precision*.

precision controls the number of bits written for each value and the interpretation of those bits as integer, floating-point, or character values. If *precision* is not specified, `uchar` (an 8-bit unsigned character) is used. The supported values for *precision* are listed below in Remarks.

`fwrite(obj,A,'`*mode*`')` writes binary data with command line access specified by *mode*. If *mode* is `sync`, `A` is written synchronously and the command line is blocked. If *mode* is `async`, `A` is written asynchronously and the command line is not blocked. If *mode* is not specified, the write operation is synchronous.

`fwrite(obj,A,'`*precision*`','`*mode*`')` writes binary data with precision specified by *precision* and command line access specified by *mode*.

Remarks

Before you can write data to 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 to perform a write operation while `obj` is not connected to the device.

The `ValuesSent` property value is increased by the number of values written each time `fwrite` is issued.

An error occurs if the output buffer cannot hold all the data to be written. You can specify the size of the output buffer with the `OutputBufferSize` property.

If you use the `help` command to display help for `fwrite`, then you need to supply the pathname shown below.

```
help serial/fwrite
```

Synchronous Versus Asynchronous Write Operations

By default, data is written to the device synchronously and the command line is blocked until the operation completes. You can perform an asynchronous write by configuring the *mode* input argument to be `async`. For asynchronous writes:

- The `BytesToOutput` property value is continuously updated to reflect the number of bytes in the output buffer.
- The M-file callback function specified for the `OutputEmptyFcn` property is executed when the output buffer is empty.

You can determine whether an asynchronous write operation is in progress with the `TransferStatus` property.

Synchronous and asynchronous write operations are discussed in more detail in Writing Data.

Rules for Completing a Write Operation with fwrite

A binary write operation using `fwrite` completes when:

- The specified data is written.

- The time specified by the `Timeout` property passes.

Note The `Terminator` property is not used with binary write operations.

Supported Precisions

The supported values for *`precision`* are listed below.

Data Type	Precision	Interpretation
Character	`uchar`	8-bit unsigned character
	`schar`	8-bit signed character
	`char`	8-bit signed or unsigned character
Integer	`int8`	8-bit integer
	`int16`	16-bit integer
	`int32`	32-bit integer
	`uint8`	8-bit unsigned integer
	`uint16`	16-bit unsigned integer
	`uint32`	32-bit unsigned integer
	`short`	16-bit integer
	`int`	32-bit integer
	`long`	32- or 64-bit integer
	`ushort`	16-bit unsigned integer
	`uint`	32-bit unsigned integer
	`ulong`	32- or 64-bit unsigned integer

Data Type	Precision	Interpretation
Floating-point	`single`	32-bit floating point
	`float32`	32-bit floating point
	`float`	32-bit floating point
	`double`	64-bit floating point
	`float64`	64-bit floating point

See Also

Functions

`fopen`, `fprintf`

Properties

`BytesToOutput`, `OutputBufferSize`, `OutputEmptyFcn`, `Status`, `Timeout`, `TransferStatus`, `ValuesSent`

Purpose

Find root of continuous function of one variable

Syntax

```
x = fzero(fun,x0)
x = fzero(fun,x0,options)
[x,fval] = fzero(...)
[x,fval,exitflag] = fzero(...)
[x,fval,exitflag,output] = fzero(...)
```

Description

`x = fzero(fun,x0)` tries to find a zero of `fun` near `x0`, if `x0` is a scalar. `fun` is a function handle. See "Function Handles" in the MATLAB Programming documentation for more information. The value `x` returned by `fzero` is near a point where `fun` changes sign, or `NaN` if the search fails. In this case, the search terminates when the search interval is expanded until an `Inf`, `NaN`, or complex value is found.

"Parameterizing Functions Called by Function Functions" in the MATLAB Mathematics documentation, explains how to pass additional parameters to your objective function `fun`. See also "Example 2" on page 2-1317 and "Example 3" on page 2-1317 below.

If `x0` is a vector of length two, `fzero` assumes `x0` is an interval where the sign of `fun(x0(1))` differs from the sign of `fun(x0(2))`. An error occurs if this is not true. Calling `fzero` with such an interval guarantees `fzero` will return a value near a point where `fun` changes sign.

`x = fzero(fun,x0,options)` minimizes with the optimization parameters specified in the structure `options`. You can define these parameters using the `optimset` function. `fzero` uses these `options` structure fields:

Display	Level of display. 'off' displays no output; 'iter' displays output at each iteration; 'final' displays just the final output; 'notify' (default) displays output only if the function does not converge.
FunValCheck	Check whether objective function values are valid. 'on' displays an error when the objective function returns a value that is complex or NaN. 'off' (the default) displays no error.
OutputFcn	User-defined function that is called at each iteration. See "Output Function" in the Optimization Toolbox for more information.
PlotFcns	User-defined plot function that is called at each iteration. See "Plot Functions" in the Optimization Toolbox for more information.
TolX	Termination tolerance on x

[x,fval] = fzero(...) returns the value of the objective function fun at the solution x.

[x,fval,exitflag] = fzero(...) returns a value exitflag that describes the exit condition of fzero:

1	Function converged to a solution x.
-1	Algorithm was terminated by the output function.
-3	NaN or Inf function value was encountered during search for an interval containing a sign change.
-4	Complex function value was encountered during search for an interval containing a sign change.
-5	fzero might have converged to a singular point.

[x,fval,exitflag,output] = fzero(...) returns a structure output that contains information about the optimization:

`output.algorithm`	Algorithm used
`output.funcCount`	Number of function evaluations
`output.intervaliterations`	Number of iterations taken to find an interval
`output.iterations`	Number of zero-finding iterations
`output.message`	Exit message

Note For the purposes of this command, zeros are considered to be points where the function actually crosses, not just touches, the *x*-axis.

Arguments

`fun` is the function whose zero is to be computed. It accepts a vector `x` and returns a scalar `f`, the objective function evaluated at `x`. The function `fun` can be specified as a function handle for an M-file function

```
x = fzero(@myfun,x0);
```

where `myfun` is an M-file function such as

```
function f = myfun(x)
f = ...            % Compute function value at x
```

or as a function handle for an anonymous function:

```
x = fzero(@(x)sin(x*x),x0);
```

Other arguments are described in the syntax descriptions above.

Examples

Example 1

Calculate π by finding the zero of the sine function near 3.

```
x = fzero(@sin,3)
x =
    3.1416
```

Example 2

To find the zero of cosine between 1 and 2

```
x = fzero(@cos,[1 2])
x =
    1.5708
```

Note that `cos(1)` and `cos(2)` differ in sign.

Example 3

To find a zero of the function $f(x) = x^3 - 2x - 5$

write an anonymous function `f`:

```
f = @(x)x.^3-2*x-5;
```

Then find the zero near 2:

```
z = fzero(f,2)
z =
    2.0946
```

Because this function is a polynomial, the statement `roots([1 0 -2 -5])` finds the same real zero, and a complex conjugate pair of zeros.

```
    2.0946
   -1.0473 + 1.1359i
   -1.0473 - 1.1359i
```

If `fun` is parameterized, you can use anonymous functions to capture the problem-dependent parameters. For example, suppose you want to minimize the objective function `myfun` defined by the following M-file function.

```
function f = myfun(x,a)
f = cos(a*x);
```

Note that `myfun` has an extra parameter `a`, so you cannot pass it directly to `fzero`. To optimize for a specific value of `a`, such as `a = 2`.

1 Assign the value to `a`.

```
a = 2; % define parameter first
```

2 Call `fzero` with a one-argument anonymous function that captures that value of `a` and calls `myfun` with two arguments:

```
x = fzero(@(x) myfun(x,a),0.1)
```

Algorithm

The `fzero` command is an M-file. The algorithm, which was originated by T. Dekker, uses a combination of bisection, secant, and inverse quadratic interpolation methods. An Algol 60 version, with some improvements, is given in [1]. A Fortran version, upon which the `fzero` M-file is based, is in [2].

Limitations

The `fzero` command finds a point where the function changes sign. If the function is *continuous*, this is also a point where the function has a value near zero. If the function is not continuous, `fzero` may return values that are discontinuous points instead of zeros. For example, `fzero(@tan,1)` returns `1.5708`, a discontinuous point in `tan`.

Furthermore, the `fzero` command defines a *zero* as a point where the function crosses the x-axis. Points where the function touches, but does not cross, the x-axis are not valid zeros. For example, `y = x.^2` is a parabola that touches the x-axis at 0. Because the function never crosses the x-axis, however, no zero is found. For functions with no valid zeros, `fzero` executes until `Inf`, `NaN`, or a complex value is detected.

See Also

`roots`, `fminbnd`, `optimset`, `function_handle` (`@`), "Anonymous Functions"

References

[1] Brent, R., *Algorithms for Minimization Without Derivatives*, Prentice-Hall, 1973.

[2] Forsythe, G. E., M. A. Malcolm, and C. B. Moler, *Computer Methods for Mathematical Computations*, Prentice-Hall, 1976.

gallery

Purpose

Test matrices

Syntax

```
[A,B,C,...] = gallery(matname,P1,P2,...)
[A,B,C,...] = gallery(matname,P1,P2,...,classname)
gallery(3)
gallery(5)
```

Description

`[A,B,C,...] = gallery(matname,P1,P2,...)` returns the test matrices specified by the quoted string `matname`. The `matname` input is the name of a matrix family selected from the table below. `P1,P2,...` are input parameters required by the individual matrix family. The number of optional parameters `P1,P2,...` used in the calling syntax varies from matrix to matrix. The exact calling syntaxes are detailed in the individual matrix descriptions below.

`[A,B,C,...] = gallery(matname,P1,P2,...,classname)` produces a matrix of class `classname`. The `classname` input is a quoted string that must be either `'single'` or `'double'`. If `classname` is not specified, then the class of the matrix is determined from those arguments among `P1,P2,...` that do not specify dimensions or select an option. If any of these arguments is of class `single` then the matrix is `single`; otherwise the matrix is `double`.

`gallery(3)` is a badly conditioned 3-by-3 matrix and `gallery(5)` is an interesting eigenvalue problem.

The gallery holds over fifty different test matrix functions useful for testing algorithms and other purposes.

Test Matrices			
binomial	cauchy	chebspec	chebvand
chow	circul	clement	compar
condex	cycol	dorr	dramadah
fiedler	forsythe	frank	gearmat
gcdmat	grcar	hanowa	house

Test Matrices			
invhess	invol	ipjfact	jordbloc
kahan	kms	krylov	lauchli
lehmer	leslie	lesp	lotkin
minij	moler	neumann	orthog
parter	pei	poisson	prolate
randcolu	randcorr	randhess	randjorth
rando	randsvd	redheff	riemann
ris	smoke	toeppd	tridiag
triw	wathen	wilk	

binomial — Multiple of involutory matrix

`A = gallery('binomial',n)` returns an `n`-by-`n` matrix,with integer entries such that `A^2 = 2^(n-1)*eye(n)`.

Thus, `B = A*2^((1-n)/2)` is involutory, that is, `B^2 = eye(n)`.

cauchy — Cauchy matrix

`C = gallery('cauchy',x,y)` returns an `n`-by-`n` matrix, `C(i,j) = 1/(x(i)+y(j))`. Arguments `x` and `y` are vectors of length `n`. If you pass in scalars for `x` and `y`, they are interpreted as vectors `1:x` and `1:y`.

`C = gallery('cauchy',x)` returns the same as above with `y = x`. That is, the command returns `C(i,j) = 1/(x(i)+x(j))`.

Explicit formulas are known for the inverse and determinant of a Cauchy matrix. The determinant `det(C)` is nonzero if `x` and `y` both have distinct elements. `C` is totally positive if `0 < x(1) <... < x(n)` and `0 < y(1) < ... < y(n)`.

chebspec — Chebyshev spectral differentiation matrix

`C = gallery('chebspec',n,switch)` returns a Chebyshev spectral differentiation matrix of order `n`. Argument `switch` is a variable that determines the character of the output matrix. By default, `switch = 0`.

For `switch = 0` ("no boundary conditions"), `C` is nilpotent (`C^n = 0`) and has the null vector `ones(n,1)`. The matrix `C` is similar to a Jordan block of size `n` with eigenvalue zero.

For `switch = 1`, `C` is nonsingular and well-conditioned, and its eigenvalues have negative real parts.

The eigenvector matrix of the Chebyshev spectral differentiation matrix is ill-conditioned.

chebvand — Vandermonde-like matrix for the Chebyshev polynomials

`C = gallery('chebvand',p)` produces the (primal) Chebyshev Vandermonde matrix based on the vector of points `p`, which define where the Chebyshev polynomial is calculated.

`C = gallery('chebvand',m,p)` where `m` is scalar, produces a rectangular version of the above, with `m` rows.

If `p` is a vector, then $C(i, j) = T_{i-1}(p(j))$ where T_{i-1} is the Chebyshev polynomial of degree *i*-1. If `p` is a scalar, then `p` equally spaced points on the interval `[0,1]` are used to calculate `C`.

chow — Singular Toeplitz lower Hessenberg matrix

`A = gallery('chow',n,alpha,delta)` returns `A` such that `A = H(alpha) + delta*eye(n)`, where $H_{i,j}(\alpha) = \alpha^{(i-j+1)}$ and argument `n` is the order of the Chow matrix. Default value for scalars `alpha` and `delta` are `1` and `0`, respectively.

`H(alpha)` has `p = floor(n/2)` eigenvalues that are equal to zero. The rest of the eigenvalues are equal to `4*alpha*cos(k*pi/(n+2))^2, k=1:n-p`.

circul — Circulant matrix

`C = gallery('circul',v)` returns the circulant matrix whose first row is the vector `v`.

A circulant matrix has the property that each row is obtained from the previous one by cyclically permuting the entries one step forward. It is a special Toeplitz matrix in which the diagonals "wrap around."

If `v` is a scalar, then `C = gallery('circul',1:v)`.

The eigensystem of `C` (`n`-by-`n`) is known explicitly: If `t` is an `n`th root of unity, then the inner product of `v` and $w = [1\ t\ t^2 \ldots t^{(n-1)}]$ is an eigenvalue of `C` and `w(n:-1:1)` is an eigenvector.

clement — Tridiagonal matrix with zero diagonal entries

`A = gallery('clement',n,sym)` returns an `n`-by-`n` tridiagonal matrix with zeros on its main diagonal and known eigenvalues. It is singular if order `n` is odd. About 64 percent of the entries of the inverse are zero. The eigenvalues include plus and minus the numbers `n-1`, `n-3`, `n-5`, `...`, as well as (for odd `n`) a final eigenvalue of `1` or `0`.

Argument `sym` determines whether the Clement matrix is symmetric. For `sym = 0` (the default) the matrix is nonsymmetric, while for `sym = 1`, it is symmetric.

compar — Comparison matrices

`A = gallery('compar',A,1)` returns `A` with each diagonal element replaced by its absolute value, and each off-diagonal element replaced by minus the absolute value of the largest element in absolute value in its row. However, if `A` is triangular `compar(A,1)` is too.

`gallery('compar',A)` is `diag(B) - tril(B,-1) - triu(B,1)`, where `B = abs(A)`. `compar(A)` is often denoted by $\mathrm{M}(A)$ in the literature.

`gallery('compar',A,0)` is the same as `gallery('compar',A)`.

condex — Counter-examples to matrix condition number estimators

A = gallery('condex',n,k,theta) returns a "counter-example" matrix to a condition estimator. It has order n and scalar parameter theta (default 100).

The matrix, its natural size, and the estimator to which it applies are specified by k:

k = 1	4-by-4	LINPACK
k = 2	3-by-3	LINPACK
k = 3	arbitrary	LINPACK (rcond) (independent of theta)
k = 4	n >= 4	LAPACK (RCOND) (default). It is the inverse of this matrix that is a counter-example.

If n is not equal to the natural size of the matrix, then the matrix is padded out with an identity matrix to order n.

cycol — Matrix whose columns repeat cyclically

A = gallery('cycol',[m n],k) returns an m-by-n matrix with cyclically repeating columns, where one "cycle" consists of randn(m,k). Thus, the rank of matrix A cannot exceed k, and k must be a scalar.

Argument k defaults to round(n/4), and need not evenly divide n.

A = gallery('cycol',n,k), where n is a scalar, is the same as gallery('cycol',[n n],k).

dorr — Diagonally dominant, ill-conditioned, tridiagonal matrix

[c,d,e] = gallery('dorr',n,theta) returns the vectors defining an n-by-n, row diagonally dominant, tridiagonal matrix that is ill-conditioned for small nonnegative values of theta. The default value of theta is 0.01. The Dorr matrix itself is the same as gallery('tridiag',c,d,e).

`A = gallery('dorr',n,theta)` returns the matrix itself, rather than the defining vectors.

dramadah — Matrix of zeros and ones whose inverse has large integer entries

`A = gallery('dramadah',n,k)` returns an `n`-by-`n` matrix of `0`'s and `1`'s for which `mu(A) = norm(inv(A),'fro')` is relatively large, although not necessarily maximal. An anti-Hadamard matrix `A` is a matrix with elements `0` or `1` for which `mu(A)` is maximal.

`n` and `k` must both be scalars. Argument `k` determines the character of the output matrix:

k = 1	Default. `A` is Toeplitz, with `abs(det(A)) = 1`, and `mu(A) > c(1.75)^n`, where `c` is a constant. The inverse of `A` has integer entries.
k = 2	`A` is upper triangular and Toeplitz. The inverse of `A` has integer entries.
k = 3	`A` has maximal determinant among lower Hessenberg (0,1) matrices. `det(A)` = the `n`th Fibonacci number. `A` is Toeplitz. The eigenvalues have an interesting distribution in the complex plane.

fiedler — Symmetric matrix

`A = gallery('fiedler',c)`, where `c` is a length `n` vector, returns the `n`-by-`n` symmetric matrix with elements `abs(n(i)-n(j))`. For scalar `c`, `A = gallery('fiedler',1:c)`.

Matrix `A` has a dominant positive eigenvalue and all the other eigenvalues are negative.

Explicit formulas for `inv(A)` and `det(A)` are given in [Todd, J., *Basic Numerical Mathematics*, Vol. 2: Numerical Algebra, Birkhauser, Basel, and Academic Press, New York, 1977, p. 159] and attributed to Fiedler. These indicate that `inv(A)` is tridiagonal except for nonzero `(1,n)` and `(n,1)` elements.

forsythe — Perturbed Jordan block

A = gallery('forsythe',n,alpha,lambda) returns the n-by-n matrix equal to the Jordan block with eigenvalue lambda, excepting that A(n,1) = alpha. The default values of scalars alpha and lambda are sqrt(eps) and 0, respectively.

The characteristic polynomial of A is given by:

```
det(A-t*I) = (lambda-t)^N - alpha*(-1)^n.
```

frank — Matrix with ill-conditioned eigenvalues

F = gallery('frank',n,k) returns the Frank matrix of order n. It is upper Hessenberg with determinant 1. If k = 1, the elements are reflected about the anti-diagonal (1,n) — (n,1). The eigenvalues of F may be obtained in terms of the zeros of the Hermite polynomials. They are positive and occur in reciprocal pairs; thus if n is odd, 1 is an eigenvalue. F has floor(n/2) ill-conditioned eigenvalues — the smaller ones.

gcdmat — Greatest common divisor matrix

A = gallery('gcdmat',n) returns the n-by-n matrix with (i,j) entry gcd(i,j). Matrix A is symmetric positive definite, and A.^r is symmetric positive semidefinite for all nonnegative r.

gearmat — Gear matrix

A = gallery('gearmat',n,i,j) returns the n-by-n matrix with ones on the sub- and super-diagonals, sign(i) in the (1,abs(i)) position, sign(j) in the (n,n+1-abs(j)) position, and zeros everywhere else. Arguments i and j default to n and -n, respectively.

Matrix A is singular, can have double and triple eigenvalues, and can be defective.

All eigenvalues are of the form 2*cos(a) and the eigenvectors are of the form [sin(w+a), sin(w+2*a), ..., sin(w+n*a)], where a and w are given in Gear, C. W., "A Simple Set of Test Matrices for Eigenvalue Programs," *Math. Comp.*, Vol. 23 (1969), pp. 119-125.

grcar — Toeplitz matrix with sensitive eigenvalues

A = gallery('grcar',n,k) returns an n-by-n Toeplitz matrix with -1s on the subdiagonal, 1s on the diagonal, and k superdiagonals of 1s. The default is k = 3. The eigenvalues are sensitive.

hanowa — Matrix whose eigenvalues lie on a vertical line in the complex plane

A = gallery('hanowa',n,d) returns an n-by-n block 2-by-2 matrix of the form:

```
[d*eye(m)   -diag(1:m)
diag(1:m)   d*eye(m)]
```

Argument n is an even integer n=2*m. Matrix A has complex eigenvalues of the form d ± k*i, for 1 <= k <= m. The default value of d is -1.

house — Householder matrix

[v,beta,s] = gallery('house',x,k) takes x, an n-element column vector, and returns V and beta such that H*x = s*e1. In this expression, e1 is the first column of eye(n), abs(s) = norm(x), and H = eye(n) - beta*V*V' is a Householder matrix.

k determines the sign of s:

k = 0	sign(s) = -sign(x(1)) (default)
k = 1	sign(s) = sign(x(1))
k = 2	sign(s) = 1 (x must be real)

If x is complex, then sign(x) = x./abs(x) when x is nonzero.

If x = 0, or if x = alpha*e1 (alpha >= 0) and either k = 1 or k = 2, then V = 0, beta = 1, and s = x(1). In this case, H is the identity matrix, which is not strictly a Householder matrix.

[v, beta] = gallery('house',x) takes x, a scalar or n-element column vector, and returns v and beta such that eye(n,n) -

`beta*v*v'` is a Householder matrix. A Householder matrix `H` satisfies the relationship

```
H*x = -sign(x(1))*norm(x)*e1
```

where `e1` is the first column of `eye(n,n)`. Note that if `x` is complex, then `sign(x) exp(i*arg(x))` (which equals `x./abs(x)` when `x` is nonzero).

If `x = 0`, then `v = 0` and `beta = 1`.

invhess — Inverse of an upper Hessenberg matrix

`A = gallery('invhess',x,y)`, where `x` is a length `n` vector and `y` is a length `n-1` vector, returns the matrix whose lower triangle agrees with that of `ones(n,1)*x'` and whose strict upper triangle agrees with that of `[1 y]*ones(1,n)`.

The matrix is nonsingular if `x(1) ~= 0` and `x(i+1) ~= y(i)` for all `i`, and its inverse is an upper Hessenberg matrix. Argument `y` defaults to `-x(1:n-1)`.

If `x` is a scalar, `invhess(x)` is the same as `invhess(1:x)`.

invol — Involutory matrix

`A = gallery('invol',n)` returns an `n`-by-`n` involutory `(A*A = eye(n))` and ill-conditioned matrix. It is a diagonally scaled version of `hilb(n)`.

`B = (eye(n)-A)/2` and `B = (eye(n)+A)/2` are idempotent `(B*B = B)`.

ipjfact — Hankel matrix with factorial elements

`[A,d] = gallery('ipjfact',n,k)` returns `A`, an `n`-by-`n` Hankel matrix, and `d`, the determinant of `A`, which is known explicitly. If `k = 0` (the default), then the elements of `A` are `A(i,j) = (i+j)!` If `k = 1`, then the elements of `A` are `A(i,j) 1/(i+j)`.

Note that the inverse of `A` is also known explicitly.

jordbloc — Jordan block

`A = gallery('jordbloc',n,lambda)` returns the `n`-by-`n` Jordan block with eigenvalue `lambda`. The default value for `lambda` is `1`.

kahan — Upper trapezoidal matrix

`A = gallery('kahan',n,theta,pert)` returns an upper trapezoidal matrix that has interesting properties regarding estimation of condition and rank.

If `n` is a two-element vector, then `A` is `n(1)`-by-`n(2)`; otherwise, `A` is `n`-by-`n`. The useful range of `theta` is `0 < theta < pi`, with a default value of `1.2`.

To ensure that the QR factorization with column pivoting does not interchange columns in the presence of rounding errors, the diagonal is perturbed by `pert*eps*diag([n:-1:1])`. The default `pert` is `25`, which ensures no interchanges for `gallery('kahan',n)` up to at least `n = 90` in IEEE arithmetic.

kms — Kac-Murdock-Szego Toeplitz matrix

`A = gallery('kms',n,rho)` returns the `n`-by-`n` Kac-Murdock-Szego Toeplitz matrix such that `A(i,j) = rho^(abs(i-j))`, for real `rho`.

For complex `rho`, the same formula holds except that elements below the diagonal are conjugated. `rho` defaults to 0.5.

The KMS matrix `A` has these properties:

- An LDL' factorization with `L inv(gallery('triw',n,-rho,1))'`, and `D(i,i) (1-abs(rho)^2)*eye(n)`, except `D(1,1) = 1`.
- Positive definite if and only if `0 < abs(rho) < 1`.
- The inverse `inv(A)` is tridiagonal.

krylov — Krylov matrix

`B = gallery('krylov',A,x,j)` returns the Krylov matrix

```
[x, Ax, A^2x, ..., A^(j-1)x]
```

where `A` is an `n`-by-`n` matrix and `x` is a length `n` vector. The defaults are `x ones(n,1)`, and `j = n`.

`B = gallery('krylov',n)` is the same as `gallery('krylov',(randn(n))`.

lauchli — Rectangular matrix

`A = gallery('lauchli',n,mu)` returns the `(n+1)`-by-`n` matrix

```
[ones(1,n); mu*eye(n)]
```

The Lauchli matrix is a well-known example in least squares and other problems that indicates the dangers of forming `A'*A`. Argument `mu` defaults to `sqrt(eps)`.

lehmer — Symmetric positive definite matrix

`A = gallery('lehmer',n)` returns the symmetric positive definite `n`-by-`n` matrix such that `A(i,j) = i/j` for `j >= i`.

The Lehmer matrix `A` has these properties:

- `A` is totally nonnegative.
- The inverse `inv(A)` is tridiagonal and explicitly known.
- The order `n <= cond(A) <= 4*n*n`.

leslie —

`L = gallery('leslie',a,b)` is the `n`-by-`n` matrix from the Leslie population model with average birth numbers `a(1:n)` and survival rates `b(1:n-1)`. It is zero, apart from the first row (which contains the `a(i)`) and the first subdiagonal (which contains the `b(i)`). For a valid model, the `a(i)` are nonnegative and the `b(i)` are positive and bounded by 1, i.e., `0 < b(i) <= 1`.

`L = gallery('leslie',n)` generates the Leslie matrix with `a = ones(n,1)`, `b = ones(n-1,1)`.

lesp — Tridiagonal matrix with real, sensitive eigenvalues

`A = gallery('lesp',n)` returns an `n`-by-`n` matrix whose eigenvalues are real and smoothly distributed in the interval approximately `[-2*N-3.5, -4.5]`.

The sensitivities of the eigenvalues increase exponentially as the eigenvalues grow more negative. The matrix is similar to the symmetric tridiagonal matrix with the same diagonal entries and with off-diagonal entries 1, via a similarity transformation with `D = diag(1!,2!,...,n!)`.

lotkin — Lotkin matrix

`A = gallery('lotkin',n)` returns the Hilbert matrix with its first row altered to all ones. The Lotkin matrix `A` is nonsymmetric, ill-conditioned, and has many negative eigenvalues of small magnitude. Its inverse has integer entries and is known explicitly.

minij — Symmetric positive definite matrix

`A = gallery('minij',n)` returns the `n`-by-`n` symmetric positive definite matrix with `A(i,j) = min(i,j)`.

The `minij` matrix has these properties:

- The inverse `inv(A)` is tridiagonal and equal to `-1` times the second difference matrix, except its `(n,n)` element is `1`.
- Givens' matrix, `2*A-ones(size(A))`, has tridiagonal inverse and eigenvalues `0.5*sec((2*r-1)*pi/(4*n))^2`, where `r=1:n`.
- `(n+1)*ones(size(A))-A` has elements that are `max(i,j)` and a tridiagonal inverse.

moler — Symmetric positive definite matrix

`A = gallery('moler',n,alpha)` returns the symmetric positive definite `n`-by-`n` matrix `U'*U`, where `U = gallery('triw',n,alpha)`.

For the default `alpha` = `-1`, `A(i,j) = min(i,j)-2`, and `A(i,i) = i`. One of the eigenvalues of `A` is small.

neumann — Singular matrix from the discrete Neumann problem (sparse)

`C = gallery('neumann',n)` returns the sparse `n`-by-`n` singular, row diagonally dominant matrix resulting from discretizing the Neumann problem with the usual five-point operator on a regular mesh.

Argument n is a perfect square integer $n = m^2$ or a two-element vector. C is sparse and has a one-dimensional null space with null vector ones(n,1).

orthog — Orthogonal and nearly orthogonal matrices

Q = gallery('orthog',n,k) returns the kth type of matrix of order n, where k > 0 selects exactly orthogonal matrices, and k < 0 selects diagonal scalings of orthogonal matrices. Available types are:

k = 1	Q(i,j) = sqrt(2/(n+1)) * sin(i*j*pi/(n+1)) Symmetric eigenvector matrix for second difference matrix. This is the default.
k = 2	Q(i,j) = 2/(sqrt(2*n+1)) * sin(2*i*j*pi/(2*n+1)) Symmetric.
k = 3	Q(r,s) = exp(2*pi*i*(r-1)*(s-1)/n) / sqrt(n) Unitary, the Fourier matrix. Q^4 is the identity. This is essentially the same matrix as fft(eye(n))/sqrt(n)!
k = 4	Helmert matrix: a permutation of a lower Hessenberg matrix, whose first row is ones(1:n)/sqrt(n).
k = 5	Q(i,j) = sin(2*pi*(i-1)*(j-1)/n) + cos(2*pi*(i-1)*(j-1)/n) Symmetric matrix arising in the Hartley transform.
k = 6	Q(i,j) = sqrt(2/n)*cos((i-1/2)*(j-1/2)*pi/n) Symmetric matrix arising as a discrete cosine transform.

k = -1	Q(i,j) = cos((i-1)*(j-1)*pi/(n-1)) Chebyshev Vandermonde-like matrix, based on extrema of T(n-1).
k = -2	Q(i,j) = cos((i-1)*(j-1/2)*pi/n)) Chebyshev Vandermonde-like matrix, based on zeros of T(n).

parter — Toeplitz matrix with singular values near pi

C = gallery('parter',n) returns the matrix C such that C(i,j) = 1/(i-j+0.5).

C is a Cauchy matrix and a Toeplitz matrix. Most of the singular values of C are very close to pi.

pei — Pei matrix

A = gallery('pei',n,alpha), where alpha is a scalar, returns the symmetric matrix alpha*eye(n) + ones(n). The default for alpha is 1. The matrix is singular for alpha equal to either 0 or -n.

poisson — Block tridiagonal matrix from Poisson's equation (sparse)

A = gallery('poisson',n) returns the block tridiagonal (sparse) matrix of order n^2 resulting from discretizing Poisson's equation with the 5-point operator on an n-by-n mesh.

prolate — Symmetric, ill-conditioned Toeplitz matrix

A = gallery('prolate',n,w) returns the n-by-n prolate matrix with parameter w. It is a symmetric Toeplitz matrix.

If 0 < w < 0.5 then A is positive definite

- The eigenvalues of A are distinct, lie in (0,1), and tend to cluster around 0 and 1.
- The default value of w is 0.25.

randcolu — Random matrix with normalized cols and specified singular values

`A = gallery('randcolu',n)` is a random `n`-by-`n` matrix with columns of unit 2-norm, with random singular values whose squares are from a uniform distribution.

`A'*A` is a correlation matrix of the form produced by `gallery('randcorr',n)`.

`gallery('randcolu',x)` where `x` is an `n`-vector (`n` > 1), produces a random `n`-by-`n` matrix having singular values given by the vector `x`. The vector `x` must have nonnegative elements whose sum of squares is `n`.

`gallery('randcolu',x,m)` where `m >= n`, produces an `m`-by-`n` matrix.

`gallery('randcolu',x,m,k)` provides a further option:

`k = 0`	`diag(x)` is initially subjected to a random two-sided orthogonal transformation, and then a sequence of Givens rotations is applied (default).
`k = 1`	The initial transformation is omitted. This is much faster, but the resulting matrix may have zero entries.

For more information, see:

[1] Davies, P. I. and N. J. Higham, “Numerically Stable Generation of Correlation Matrices and Their Factors,” *BIT*, Vol. 40, 2000, pp. 640-651.

randcorr — Random correlation matrix with specified eigenvalues

`gallery('randcorr',n)` is a random `n`-by-`n` correlation matrix with random eigenvalues from a uniform distribution. A correlation matrix is a symmetric positive semidefinite matrix with `1`s on the diagonal (see `corrcoef`).

`gallery('randcorr',x)` produces a random correlation matrix having eigenvalues given by the vector `x`, where `length(x) > 1`. The vector `x` must have nonnegative elements summing to `length(x)`.

`gallery('randcorr',x,k)` provides a further option:

`k = 0`	The diagonal matrix of eigenvalues is initially subjected to a random orthogonal similarity transformation, and then a sequence of Givens rotations is applied (default).
`k = 1`	The initial transformation is omitted. This is much faster, but the resulting matrix may have some zero entries.

For more information, see:

[1] Bendel, R. B. and M. R. Mickey, "Population Correlation Matrices for Sampling Experiments," *Commun. Statist. Simulation Comput.*, B7, 1978, pp. 163-182.

[2] Davies, P. I. and N. J. Higham, "Numerically Stable Generation of Correlation Matrices and Their Factors," *BIT*, Vol. 40, 2000, pp. 640-651.

randhess — Random, orthogonal upper Hessenberg matrix

`H = gallery('randhess',n)` returns an `n`-by-`n` real, random, orthogonal upper Hessenberg matrix.

`H = gallery('randhess',x)` if `x` is an arbitrary, real, length `n` vector with `n > 1`, constructs `H` nonrandomly using the elements of `x` as parameters.

Matrix `H` is constructed via a product of `n-1` Givens rotations.

randjorth — Random J-orthogonal matrix

`A = gallery('randjorth', n)`, for a positive integer `n`, produces a random `n`-by-`n` `J`-orthogonal matrix `A`, where

- `J = blkdiag(eye(ceil(n/2)),-eye(floor(n/2)))`
- `cond(A) = sqrt(1/eps)`

`J`-orthogonality means that A'*J*A = J. Such matrices are sometimes called *hyperbolic*.

`A = gallery('randjorth', n, m)`, for positive integers `n` and `m`, produces a random (`n+m`)-by-(`n+m`) `J`-orthogonal matrix `A`, where

- `J = blkdiag(eye(n),-eye(m))`
- `cond(A) = sqrt(1/eps)`

`A = gallery('randjorth',n,m,c,symm,method)`

uses the following optional input arguments:

- `c` — Specifies `cond(A)` to be the scalar `c`.
- `symm` — Enforces symmetry if the scalar `symm` is nonzero.
- `method` — calls `qr` to perform the underlying orthogonal transformations if the scalar `method` is nonzero. A call to `qr` is much faster than the default method for large dimensions

rando — Random matrix composed of elements -1, 0 or 1

`A = gallery('rando',n,k)` returns a random `n`-by-`n` matrix with elements from one of the following discrete distributions:

`k = 1`	`A(i,j)` = `0` or `1` with equal probability (default).
`k = 2`	`A(i,j)` = `-1` or `1` with equal probability.
`k = 3`	`A(i,j)` = `-1`, `0` or `1` with equal probability.

Argument `n` may be a two-element vector, in which case the matrix is `n(1)`-by-`n(2)`.

randsvd — Random matrix with preassigned singular values

A = gallery('randsvd',n,kappa,mode,kl,ku) returns a banded (multidiagonal) random matrix of order n with cond(A) = kappa and singular values from the distribution mode. If n is a two-element vector, A is n(1)-by-n(2).

Arguments kl and ku specify the number of lower and upper off-diagonals, respectively, in A. If they are omitted, a full matrix is produced. If only kl is present, ku defaults to kl.

Distribution mode can be:

1	One large singular value.
2	One small singular value.
3	Geometrically distributed singular values (default).
4	Arithmetically distributed singular values.
5	Random singular values with uniformly distributed logarithm.
< 0	If mode is -1, -2, -3, -4, or -5, then randsvd treats mode as abs(mode), except that in the original matrix of singular values the order of the diagonal entries is reversed: small to large instead of large to small.

Condition number kappa defaults to sqrt(1/eps). In the special case where kappa < 0, A is a random, full, symmetric, positive definite matrix with cond(A) = -kappa and eigenvalues distributed according to mode. Arguments kl and ku, if present, are ignored.

A = gallery('randsvd',n,kappa,mode,kl,ku,method) specifies how the computations are carried out. method = 0 is the default, while method = 1 uses an alternative method that is much faster for large dimensions, even though it uses more flops.

redheff — Redheffer's matrix of 1s and 0s

A = gallery('redheff',n) returns an n-by-n matrix of 0's and 1's defined by A(i,j) = 1, if j = 1 or if i divides j, and A(i,j) = 0 otherwise.

The Redheffer matrix has these properties:

- `(n-floor(log2(n)))-1` eigenvalues equal to `1`
- A real eigenvalue (the spectral radius) approximately `sqrt(n)`
- A negative eigenvalue approximately `-sqrt(n)`
- The remaining eigenvalues are provably “small.”
- The Riemann hypothesis is true if and only if $\det(A) = O(n^{\frac{1}{2}+\varepsilon})$ for every epsilon `> 0`.

Barrett and Jarvis conjecture that “the small eigenvalues all lie inside the unit circle `abs(Z) = 1`,” and a proof of this conjecture, together with a proof that some eigenvalue tends to zero as `n` tends to infinity, would yield a new proof of the prime number theorem.

riemann — Matrix associated with the Riemann hypothesis

`A = gallery('riemann',n)` returns an `n`-by-`n` matrix for which the Riemann hypothesis is true if and only if

$$\det(A) = O(n!n^{-\frac{1}{2}+\varepsilon})$$

for every $\varepsilon > 0$.

The Riemann matrix is defined by:

```
A = B(2:n+1,2:n+1)
```

where `B(i,j) = i-1` if `i` divides `j`, and `B(i,j) = -1` otherwise.

The Riemann matrix has these properties:

- Each eigenvalue `e(i)` satisfies `abs(e(i)) <= m-1/m`, where `m = n+1`.
- `i <= e(i) <= i+1` with at most `m-sqrt(m)` exceptions.
- All integers in the interval `(m/3, m/2]` are eigenvalues.

ris — Symmetric Hankel matrix

`A = gallery('ris',n)` returns a symmetric `n`-by-`n` Hankel matrix with elements

```
A(i,j) = 0.5/(n-i-j+1.5)
```

The eigenvalues of `A` cluster around $\pi/2$ and $-\pi/2$. This matrix was invented by F.N. Ris.

smoke — Complex matrix with a 'smoke ring' pseudospectrum

`A = gallery('smoke',n)` returns an `n`-by-`n` matrix with `1`'s on the superdiagonal, `1` in the `(n,1)` position, and powers of roots of unity along the diagonal.

`A = gallery('smoke',n,1)` returns the same except that element `A(n,1)` is zero.

The eigenvalues of `gallery('smoke',n,1)` are the `n`th roots of unity; those of `gallery('smoke',n)` are the `n`th roots of unity times `2^(1/n)`.

toeppd — Symmetric positive definite Toeplitz matrix

`A = gallery('toeppd',n,m,w,theta)` returns an `n`-by-`n` symmetric, positive semi-definite (SPD) Toeplitz matrix composed of the sum of `m` rank 2 (or, for certain `theta`, rank 1) SPD Toeplitz matrices. Specifically,

```
T = w(1)*T(theta(1)) + ... + w(m)*T(theta(m))
```

where `T(theta(k))` has `(i,j)` element `cos(2*pi*theta(k)*(i-j))`.

By default: `m = n`, `w = rand(m,1)`, and `theta = rand(m,1)`.

toeppen — Pentadiagonal Toeplitz matrix (sparse)

`P = gallery('toeppen',n,a,b,c,d,e)` returns the `n`-by-`n` sparse, pentadiagonal Toeplitz matrix with the diagonals: `P(3,1) = a`, `P(2,1) = b`, `P(1,1) = c`, `P(1,2) = d`, and `P(1,3) = e`, where `a`, `b`, `c`, `d`, and `e` are scalars.

By default, (a,b,c,d,e) = (1,-10,0,10,1), yielding a matrix of Rutishauser. This matrix has eigenvalues lying approximately on the line segment 2*cos(2*t) + 20*i*sin(t).

tridiag — Tridiagonal matrix (sparse)

A = gallery('tridiag',c,d,e) returns the tridiagonal matrix with subdiagonal c, diagonal d, and superdiagonal e. Vectors c and e must have length(d)-1.

A = gallery('tridiag',n,c,d,e), where c, d, and e are all scalars, yields the Toeplitz tridiagonal matrix of order n with subdiagonal elements c, diagonal elements d, and superdiagonal elements e. This matrix has eigenvalues

```
d + 2*sqrt(c*e)*cos(k*pi/(n+1))
```

where k = 1:n. (see [1].)

A = gallery('tridiag',n) is the same as A = gallery('tridiag',n,-1,2,-1), which is a symmetric positive definite M-matrix (the negative of the second difference matrix).

triw — Upper triangular matrix discussed by Wilkinson and others

A = gallery('triw',n,alpha,k) returns the upper triangular matrix with ones on the diagonal and alphas on the first k >= 0 superdiagonals.

Order n may be a 2-element vector, in which case the matrix is n(1)-by-n(2) and upper trapezoidal.

Ostrowski ["On the Spectrum of a One-parametric Family of Matrices," *J. Reine Angew. Math.,* 1954] shows that

```
cond(gallery('triw',n,2)) = cot(pi/(4*n))^2,
```

and, for large abs(alpha), cond(gallery('triw',n,alpha)) is approximately abs(alpha)^n*sin(pi/(4*n-2)).

Adding `-2^(2-n)` to the `(n,1)` element makes `triw(n)` singular, as does adding `-2^(1-n)` to all the elements in the first column.

wathen — Finite element matrix (sparse, random entries)

`A = gallery('wathen',nx,ny)` returns a sparse, random, `n`-by-`n` finite element matrix where `n = 3*nx*ny + 2*nx + 2*ny + 1`.

Matrix `A` is precisely the "consistent mass matrix" for a regular `nx`-by-`ny` grid of 8-node (serendipity) elements in two dimensions. `A` is symmetric, positive definite for any (positive) values of the "density," `rho(nx,ny)`, which is chosen randomly in this routine.

`A = gallery('wathen',nx,ny,1)` returns a diagonally scaled matrix such that

```
0.25 <= eig(inv(D)*A) <= 4.5
```

where `D = diag(diag(A))` for any positive integers `nx` and `ny` and any densities `rho(nx,ny)`.

wilk — Various matrices devised or discussed by Wilkinson

`[A,b] = gallery('wilk',n)` returns a different matrix or linear system depending on the value of `n`.

`n = 3`	Upper triangular system `Ux=b` illustrating inaccurate solution.
`n = 4`	Lower triangular system `Lx=b`, ill-conditioned.
`n = 5`	`hilb(6)(1:5,2:6)*1.8144`. A symmetric positive definite matrix.
`n = 21`	`W21+`, a tridiagonal matrix. eigenvalue problem. For more detail, see [2].

See Also

`hadamard`, `hilb`, `invhilb`, `magic`, `wilkinson`

References

[1] The MATLAB gallery of test matrices is based upon the work of Nicholas J. Higham at the Department of Mathematics,

University of Manchester, Manchester, England. Additional detail on these matrices is documented in *The Test Matrix Toolbox for MATLAB* by N. J. Higham, September, 1995. This report is available via anonymous ftp from The MathWorks at `http://www.mathworks.com/access/pub/testmatrix.ps` or on the Web at `ftp://ftp.ma.man.ac.uk/pub/narep`. Further background can be found in the book *Accuracy and Stability of Numerical Algorithms,* Nicholas J. Higham, SIAM, 1996.

[2] Wilkinson, J. H., *The Algebraic Eigenvalue Problem*, Oxford University Press, London, 1965, p.308.

Purpose

Gamma functions

Syntax

```
Y = gamma(A)
Y = gammainc(X,A)
Y = gammainc(X,A,tail)
Y = gammaln(A)
```

Definition

The gamma function is defined by the integral:

$$\Gamma(a) = \int_0^{\infty} e^{-t} t^{a-1} dt$$

The gamma function interpolates the factorial function. For integer n:

```
gamma(n+1) = n! = prod(1:n)
```

The incomplete gamma function is:

$$P(x, a) = \frac{1}{\Gamma(a)} \int_0^{x} e^{-t} t^{a-1} dt$$

For any a>=0, gammainc(x,a) approaches 1 as x approaches infinity. For small x and a, gammainc(x,a) is approximately equal to x^a, so gammainc(0,0) = 1.

Description

Y = gamma(A) returns the gamma function at the elements of A. A must be real.

Y = gammainc(X,A) returns the incomplete gamma function of corresponding elements of X and A. Arguments X and A must be real and the same size (or either can be scalar).

Y = gammainc(X,A,tail) specifies the tail of the incomplete gamma function when X is non-negative. The choices are for tail are 'lower' (the default) and 'upper'. The upper incomplete gamma function is defined as

```
1 - gammainc(x,a)
```

Note When `X` is negative, `Y` can be inaccurate for `abs(X)>A+1`.

`Y = gammaln(A)` returns the logarithm of the `gamma` function, `gammaln(A) = log(gamma(A))`. The `gammaln` command avoids the underflow and overflow that may occur if it is computed directly using `log(gamma(A))`.

Algorithm

The computations of `gamma` and `gammaln` are based on algorithms outlined in [1]. Several different minimax rational approximations are used depending upon the value of `A`. Computation of the incomplete `gamma` function is based on the algorithm in [2].

References

[1] Cody, J., *An Overview of Software Development for Special Functions*, Lecture Notes in Mathematics, 506, Numerical Analysis Dundee, G. A. Watson (ed.), Springer Verlag, Berlin, 1976.

[2] Abramowitz, M. and I.A. Stegun, *Handbook of Mathematical Functions*, National Bureau of Standards, Applied Math. Series #55, Dover Publications, 1965, sec. 6.5.

Purpose

Current axes handle

Syntax

```
h = gca
```

Description

`h = gca` returns the handle to the current axes for the current figure. If no axes exists, MATLAB creates one and returns its handle. You can use the statement

```
get(gcf,'CurrentAxes')
```

if you do not want MATLAB to create an axes if one does not already exist.

Current Axes

The current axes is the target for graphics output when you create axes children. The current axes is typically the last axes used for plotting or the last axes clicked on by the mouse. Graphics commands such as `plot`, `text`, and `surf` draw their results in the current axes. Changing the current figure also changes the current axes.

See Also

`axes`, `cla`, `gcf`, `findobj`

figure `CurrentAxes` property

"Finding and Identifying Graphics Objects" on page 1-92 for related functions

gcbf

Purpose Handle of figure containing object whose callback is executing

Syntax

```
fig = gcbf
```

Description

`fig = gcbf` returns the handle of the figure that contains the object whose callback is currently executing. This object can be the figure itself, in which case, `gcbf` returns the figure's handle.

When no callback is executing, `gcbf` returns the empty matrix, `[]`.

The value returned by `gcbf` is identical to the `figure` output argument returned by `gcbo`.

See Also `gcbo`, `gco`, `gcf`, `gca`

Purpose

Handle of object whose callback is executing

Syntax

```
h = gcbo
[h,figure] = gcbo
```

Description

`h = gcbo` returns the handle of the graphics object whose callback is executing.

`[h,figure] = gcbo` returns the handle of the current callback object and the handle of the figure containing this object.

Remarks

MATLAB stores the handle of the object whose callback is executing in the root `CallbackObject` property. If a callback interrupts another callback, MATLAB replaces the `CallbackObject` value with the handle of the object whose callback is interrupting. When that callback completes, MATLAB restores the handle of the object whose callback was interrupted.

The root `CallbackObject` property is read only, so its value is always valid at any time during callback execution. The root `CurrentFigure` property, and the figure `CurrentAxes` and `CurrentObject` properties (returned by `gcf`, `gca`, and `gco`, respectively) are user settable, so they can change during the execution of a callback, especially if that callback is interrupted by another callback. Therefore, those functions are not reliable indicators of which object's callback is executing.

When you write callback routines for the `CreateFcn` and `DeleteFcn` of any object and the figure `ResizeFcn`, you must use `gcbo` since those callbacks do not update the root's `CurrentFigure` property, or the figure's `CurrentObject` or `CurrentAxes` properties; they only update the root's `CallbackObject` property.

When no callbacks are executing, `gcbo` returns `[]` (an empty matrix).

See Also

`gca`, `gcf`, `gco`, `rootobject`

"Finding and Identifying Graphics Objects" on page 1-92 for related functions.

gcd

Purpose Greatest common divisor

Syntax

```
G = gcd(A,B)
[G,C,D] = gcd(A,B)
```

Description

`G = gcd(A,B)` returns an array containing the greatest common divisors of the corresponding elements of integer arrays `A` and `B`. By convention, `gcd(0,0)` returns a value of `0`; all other inputs return positive integers for `G`.

`[G,C,D] = gcd(A,B)` returns both the greatest common divisor array `G`, and the arrays `C` and `D`, which satisfy the equation: `A(i).*C(i) + B(i).*D(i) = G(i)`. These are useful for solving Diophantine equations and computing elementary Hermite transformations.

Examples

The first example involves elementary Hermite transformations.

For any two integers `a` and `b` there is a 2-by-2 matrix `E` with integer entries and determinant = `1` (a *unimodular* matrix) such that:

```
E * [a;b] = [g,0],
```

where `g` is the greatest common divisor of `a` and `b` as returned by the command `[g,c,d] = gcd(a,b)`.

The matrix `E` equals:

```
c       d
-b/g    a/g
```

In the case where `a = 2` and `b = 4`:

```
[g,c,d] = gcd(2,4)
g =
     2
c =
     1
d =
     0
```

So that

```
E =
     1     0
    -2     1
```

In the next example, we solve for `x` and `y` in the Diophantine equation `30x + 56y = 8`.

```
[g,c,d] = gcd(30,56)
g =
      2
c =
     -13
d =
      7
```

By the definition, for scalars `c` and `d`:

```
30(-13) + 56(7) = 2,
```

Multiplying through by 8/2:

```
30(-13*4) + 56(7*4) = 8
```

Comparing this to the original equation, a solution can be read by inspection:

```
x = (-13*4) = -52; y = (7*4) = 28
```

See Also

`lcm`

References

[1] Knuth, Donald, *The Art of Computer Programming*, Vol. 2, Addison-Wesley: Reading MA, 1973. Section 4.5.2, Algorithm X.

Purpose

Current figure handle

Syntax

```
h = gcf
```

Description

`h = gcf` returns the handle of the current figure. The current figure is the figure window in which graphics commands such as `plot`, `title`, and `surf` draw their results. If no figure exists, MATLAB creates one and returns its handle. You can use the statement

```
get(0,'CurrentFigure')
```

if you do not want MATLAB to create a figure if one does not already exist.

See Also

`clf`, `figure`, `gca`

Root `CurrentFigure` property

"Finding and Identifying Graphics Objects" on page 1-92 for related functions

Purpose Handle of current object

Syntax

```
h = gco
h = gco(figure_handle)
```

Description `h = gco` *returns* the handle of the current object.

`h = gco(figure_handle)` returns the value of the current object for the figure specified by `figure_handle`.

Remarks The current object is the last object clicked on, excluding `uimenus`. If the mouse click did not occur over a figure child object, the figure becomes the current object. MATLAB stores the handle of the current object in the figure's `CurrentObject` property.

The `CurrentObject` of the `CurrentFigure` does not always indicate the object whose callback is being executed. Interruptions of callbacks by other callbacks can change the `CurrentObject` or even the `CurrentFigure`. Some callbacks, such as `CreateFcn` and `DeleteFcn`, and uimenu `Callback`, intentionally do not update `CurrentFigure` or `CurrentObject`.

`gcbo` provides the only completely reliable way to retrieve the handle to the object whose callback is executing, at any point in the `callback` function, regardless of the type of callback or of any previous interruptions.

Examples This statement returns the handle to the current object in figure window 2:

```
h = gco(2)
```

See Also `gca`, `gcbo`, `gcf`

The `root` object description

"Finding and Identifying Graphics Objects" on page 1-92 for related functions

Purpose

Test for greater than or equal to

Syntax

```
A >= B
ge(A, B)
```

Description

`A >= B` compares each element of array `A` with the corresponding element of array `B`, and returns an array with elements set to logical 1 (`true`) where `A` is greater than or equal to `B`, or set to logical 0 (`false`) where `A` is less than `B`. Each input of the expression can be an array or a scalar value.

If both `A` and `B` are scalar (i.e., 1-by-1 matrices), then MATLAB returns a scalar value.

If both `A` and `B` are nonscalar arrays, then these arrays must have the same dimensions, and MATLAB returns an array of the same dimensions as `A` and `B`.

If one input is scalar and the other a nonscalar array, then the scalar input is treated as if it were an array having the same dimensions as the nonscalar input array. In other words, if input `A` is the number 100, and `B` is a 3-by-5 matrix, then `A` is treated as if it were a 3-by-5 matrix of elements, each set to 100. MATLAB returns an array of the same dimensions as the nonscalar input array.

`ge(A, B)` is called for the syntax `A >= B` when either `A` or `B` is an object.

Examples

Create two 6-by-6 matrices, `A` and `B`, and locate those elements of `A` that are greater than or equal to the corresponding elements of `B`:

```
A = magic(6);
B = repmat(3*magic(3), 2, 2);

A >= B
ans =
     1     0     0     1     1     1
     0     1     0     1     1     1
     1     0     0     1     1     1
     0     1     1     0     1     0
```

```
     1     0     1     1     0     0
     0     1     1     1     0     1
```

See Also

`gt`, `eq`, `le`, `lt`, `ne`, "Relational Operators"

genpath

Purpose Generate path string

Syntax

```
genpath
genpath directory
p = genpath('directory')
```

Description

`genpath` returns a path string formed by recursively adding all the directories below `matlabroot/toolbox`.

`genpath directory` returns a path string formed by recursively adding all the directories below `directory`.

`p = genpath('directory')` returns the path string to variable, `p`.

Examples

You generate a path that includes `matlabroot/toolbox/images` and all directories below that with the following command:

```
p = genpath(fullfile(matlabroot,'toolbox','images'))
```

```
p =

   matlabroot\toolbox\images;matlabroot\toolbox\images\
   images;matlabroot\toolbox\images\images\ja;
   matlabroot\toolbox\images\imdemos;matlabroot\
   toolbox\images\imdemos\ja;
```

You can also use `genpath` in conjunction with `addpath` to add subdirectories to the path from the command line. The following example adds the `/control` directory and its subdirectories to the current path.

```
%  Display the current path
path

                  MATLABPATH

        K:\toolbox\matlab\general
        K:\toolbox\matlab\ops
        K:\toolbox\matlab\lang
```

```
      K:\toolbox\matlab\elmat
      K:\toolbox\matlab\elfun
                :
                :
                :

% Use GENPATH to add /control and its subdirectories
addpath(genpath('K:/toolbox/control'))


% Display the new path
path

              MATLABPATH

      K:\toolbox\control
      K:\toolbox\control\ctrlutil
      K:\toolbox\control\control
      K:\toolbox\control\ctrlguis
      K:\toolbox\control\ctrldemos
      K:\toolbox\matlab\general
      K:\toolbox\matlab\ops
      K:\toolbox\matlab\lang
      K:\toolbox\matlab\elmat
      K:\toolbox\matlab\elfun
                :
                :
                :
```

See Also

addpath, path, pathdef, pathsep, pathtool, rehash, restoredefaultpath, rmpath, savepath

"Search Path" in the MATLAB Desktop Tools and Development Environment documentation

genvarname

Purpose

Construct valid variable name from string

Syntax

```
varname = genvarname(str)
varname = genvarname(str, exclusions)
```

Description

`varname = genvarname(str)` constructs a string `varname` that is similar to or the same as the `str` input, and can be used as a valid variable name. `str` can be a single character array or a cell array of strings. If `str` is a cell array of strings, `genvarname` returns a cell array of strings in `varname`. The strings in a cell array returned by `genvarname` are guaranteed to be different from each other.

`varname = genvarname(str, exclusions)` returns a valid variable name that is different from any name listed in the `exclusions` input. The `exclusions` input can be a single character array or a cell array of strings. Specify the function `who` in the `exclusions` character array to create a variable name that will be unique in the current MATLAB workapace (see "Example 4" on page 2-1358, below).

Note `genvarname` returns a string that can be used as a variable name. It does not create a variable in the MATLAB workspace. You cannot, therefore, assign a value to the output of `genvarname`.

Remarks

A valid MATLAB variable name is a character string of letters, digits, and underscores, such that the first character is a letter, and the length of the string is less than or equal to the value returned by the `namelengthmax` function. Any string that exceeds `namelengthmax` is truncated in the `varname` output. See "Example 6" on page 2-1359, below.

The variable name returned by `genvarname` is not guaranteed to be different from other variable names currently in the MATLAB workspace unless you use the `exclusions` input in the manner shown in "Example 4" on page 2-1358, below.

If you use genvarname to generate a field name for a structure, MATLAB does create a variable for the structure and field in the MATLAB workspace. See “Example 3” on page 2-1357, below.

If the str input contains any whitespace characters, genvarname removes then and capitalizes the next alphabetic character in str. If str contains any nonalphanumeric characters, genvarname translates these characters into their hexadecimal value.

Examples

Example 1

Create four similar variable name strings that do not conflict with each other:

```
v = genvarname({'A', 'A', 'A', 'A'})
v =
    'A'    'A1'    'A2'    'A3'
```

Example 2

Read a column header hdr from worksheet trial2 in Excel spreadsheet myproj_apr23:

```
[data hdr] = xlsread('myproj_apr23.xls', 'trial2');
```

Make a variable name from the text of the column header that will not conflict with other names:

```
v = genvarname(['Column ' hdr{1,3}]);
```

Assign data taken from the spreadsheet to the variable in the MATLAB workspace:

```
eval([v '= data(1:7, 3);']);
```

Example 3

Collect readings from an instrument once every minute over the period of an hour into different fields of a structure. genvarname not only generates unique fieldname strings, but also creates the structure and fields in the MATLAB workspace:

```
for k = 1:60
record.(genvarname(['reading' datestr(clock, 'HHMMSS')])) = takeReading;
pause(60)
end
```

After the program ends, display the recorded data from the workspace:

```
record
record =
    reading090446: 27.3960
    reading090546: 23.4890
    reading090646: 21.1140
    reading090746: 23.0730
    reading090846: 28.5650
         .
         .
         .
```

Example 4

Generate variable names that are unique in the MATLAB workspace by putting the output from the `who` function in the `exclusions` list.

```
for k = 1:5
   t = clock;
   pause(uint8(rand * 10));
   v = genvarname('time_elapsed', who);
   eval([v ' = etime(clock,t)'])
   end
```

As this code runs, you can see that the variables created by `genvarname` are unique in the workspace:

```
time_elapsed =
    5.0070
time_elapsed1 =
    2.0030
time_elapsed2 =
    7.0010
```

```
time_elapsed3 =
    8.0010
time_elapsed4 =
    3.0040
```

After the program completes, use the who function to view the workspace variables:

```
who

k            time_elapsed   time_elapsed2  time_elapsed4
t            time_elapsed1  time_elapsed3  v
```

Example 5

If you try to make a variable name from a MATLAB keyword, genvarname creates a variable name string that capitalizes the keyword and precedes it with the letter x:

```
v = genvarname('global')
v =
   xGlobal
```

Example 6

If you enter a string that is longer than the value returned by the namelengthmax function, genvarname truncates the resulting variable name string:

```
namelengthmax
ans =
    63

vstr = genvarname(sprintf('%s%s', ...
   'This name truncates because it contains ', ...
   'more than the maximum number of characters'))
vstr =
ThisNameTruncatesBecauseItContainsMoreThanTheMaximumNumberOfCha
```

See Also

isvarname, iskeyword, isletter, namelengthmax, who, regexp

get

Purpose

Query object properties

Syntax

```
get(h)
get(h,'PropertyName')
<m-by-n value cell array> = get(H,pn)
a = get(h)
a = get(0,'Factory')
a = get(0,'FactoryObjectTypePropertyName')
a = get(h,'Default')
a = get(h,'DefaultObjectTypePropertyName')
```

Description

`get(h)` returns all properties of the graphics object identified by the handle `h` and their current values.

`get(h,'PropertyName')` returns the value of the property `'PropertyName'` of the graphics object identified by `h`.

`<m-by-n value cell array> = get(H,pn)` returns *n* property values for *m* graphics objects in the *m*-by-*n* cell array, where `m = length(H)` and *n* is equal to the number of property names contained in `pn`.

`a = get(h)` returns a structure whose field names are the object's property names and whose values are the current values of the corresponding properties. `h` must be a scalar. If you do not specify an output argument, MATLAB displays the information on the screen.

`a = get(0,'Factory')` returns the factory-defined values of all user-settable properties. `a` is a structure array whose field names are the object property names and whose field values are the values of the corresponding properties. If you do not specify an output argument, MATLAB displays the information on the screen.

`a = get(0,'FactoryObjectTypePropertyName')` returns the factory-defined value of the named property for the specified object type. The argument *`FactoryObjectTypePropertyName`* is the word `Factory` concatenated with the object type (e.g., `Figure`) and the property name (e.g., `Color`).

`FactoryFigureColor` `a = get(h,'Default')` returns all default values currently defined on object `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. If you do not specify an output argument, MATLAB displays the information on the screen.

`a = get(h,'Default`*`ObjectTypePropertyName`*`')` returns the factory-defined value of the named property for the specified object type. The argument *`DefaultObjectTypePropertyName`* is the word `Default` concatenated with the object type (e.g., `Figure`) and the property name (e.g., `Color`).

```
DefaultFigureColor
```

Examples

You can obtain the default value of the `LineWidth` property for line graphics objects defined on the root level with the statement

```
get(0,'DefaultLineLineWidth')
ans =
  0.5000
```

To query a set of properties on all axes children, define a cell array of property names:

```
props = {'HandleVisibility', 'Interruptible';
  'SelectionHighlight', 'Type'};
output = get(get(gca,'Children'),props);
```

The variable `output` is a cell array of dimension `length(get(gca,'Children')`-by-4.

For example, type

```
patch;surface;text;line
output = get(get(gca,'Children'),props)
output =
 'on'    'on'    'on'    'line'
 'on'    'off'   'on'    'text'
 'on'    'on'    'on'    'surface'
 'on'    'on'    'on'    'patch'
```

See Also

`findobj`, `gca`, `gcf`, `gco`, `set`

Handle Graphics Properties

"Finding and Identifying Graphics Objects" on page 1-92 for related functions

Purpose

Get property value from interface, or display properties

Syntax

```
V = h.get
V = h.get('propertyname')
V = get(h, ...)
```

Description

`V = h.get` returns a list of all properties and their values for the object or interface, `h`.

`V = h.get('propertyname')` returns the value of the property specified in the string, `propertyname`.

`V = get(h, ...)` is an alternate syntax for the same operation.

Remarks

The meaning and type of the return value is dependent upon the specific property being retrieved. The object's documentation should describe the specific meaning of the return value. MATLAB may convert the data type of the return value. See "Handling COM Data in MATLAB" in the External Interfaces documentation for a description of how MATLAB converts COM data types.

Examples

Create a COM server running Microsoft Excel:

```
e = actxserver ('Excel.Application');
```

Retrieve a single property value:

```
e.Path
ans =
   D:\Applications\MSOffice\Office
```

Retrieve a list of all properties for the `CommandBars` interface:

```
c = e.CommandBars.get
ans =
              Application: [1x1
Interface.excel.application.CommandBars.Application]
                  Creator: 1.4808e+009
```

```
                  ActionControl: []
                  ActiveMenuBar: [1x1
Interface.excel.application.CommandBars.ActiveMenuBar]
                          Count: 94
                DisplayTooltips: 1
          DisplayKeysInTooltips: 0
                   LargeButtons: 0
             MenuAnimationStyle: 'msoMenuAnimationNone'
                         Parent: [1x1
Interface.excel.application.CommandBars.Parent]
                  AdaptiveMenus: 0
                   DisplayFonts: 1
```

See Also

set, inspect, isprop, addproperty, deleteproperty

Purpose

Serial port object properties

Syntax

```
get(obj)
out = get(obj)
out = get(obj,'PropertyName')
```

Arguments

`obj`	A serial port object or an array of serial port objects.
`'PropertyName'`	A property name or a cell array of property names.
`out`	A single property value, a structure of property values, or a cell array of property values.

Description

`get(obj)` returns all property names and their current values to the command line for `obj`.

`out = get(obj)` returns the structure `out` where each field name is the name of a property of `obj`, and each field contains the value of that property.

`out = get(obj,'PropertyName')` returns the value `out` of the property specified by *PropertyName* for `obj`. If *PropertyName* is replaced by a 1-by-n or n-by-1 cell array of strings containing property names, then `get` returns a 1-by-n cell array of values to `out`. If `obj` is an array of serial port objects, then `out` will be a m-by-n cell array of property values where `m` is equal to the length of `obj` and `n` is equal to the number of properties specified.

Remarks

Refer to Displaying Property Names and Property Values for a list of serial port object properties that you can return with `get`.

When you specify a property name, you can do so without regard to case, and you can make use of property name completion. For example, if `s` is a serial port object, then these commands are all valid.

```
out = get(s,'BaudRate');
```

```
out = get(s,'baudrate');
out = get(s,'BAUD');
```

If you use the help command to display help for get, then you need to supply the pathname shown below.

```
help serial/get
```

Example

This example illustrates some of the ways you can use get to return property values for the serial port object s.

```
s = serial('COM1');
out1 = get(s);
out2 = get(s,{'BaudRate','DataBits'});
get(s,'Parity')
ans =
none
```

See Also

Functions

set

Purpose

Timer object properties

Syntax

```
get(obj)
V = get(obj)
V = get(obj,'PropertyName')
```

Description

`get(obj)` displays all property names and their current values for the timer object `obj`. `obj` must be a single timer object.

`V = get(obj)` returns a structure, `V`, where each field name is the name of a property of `obj` and each field contains the value of that property. If `obj` is an M-by-1 vector of timer objects, V is an M-by-1 array of structures.

`V = get(obj,'`*`PropertyName`*`')` returns the value, `V`, of the timer object property specified in *`PropertyName`*.

If *`PropertyName`* is a 1-by-N or N-by-1 cell array of strings containing property names, `V` is a 1-by-N cell array of values. If `obj` is a vector of timer objects, `V` is an M-by-N cell array of property values where M is equal to the length of `obj` and N is equal to the number of properties specified.

Examples

```
t = timer;
get(t)
       AveragePeriod: NaN
            BusyMode: 'drop'
            ErrorFcn: ''
       ExecutionMode: 'singleShot'
       InstantPeriod: NaN
                Name: 'timer-1'
    ObjectVisibility: 'on'
              Period: 1
             Running: 'off'
          StartDelay: 1
            StartFcn: ''
             StopFcn: ''
                 Tag: ''
```

```
      TasksExecuted: 0
     TasksToExecute: Inf
           TimerFcn: ''
               Type: 'timer'
           UserData: []
get(t, {'StartDelay','Period'})
ans =

    [0]    [1]
```

See Also

timer, set(timer)

Purpose

Query `timeseries` object property values

Syntax

```
value = get(ts,'PropertyName')
get(ts)
```

Description

`value = get(ts,'PropertyName')` returns the value of the specified property of the `timeseries` object. The following syntax is equivalent:

```
value = ts.PropertyName
```

`get(ts)` displays all properties and values of the time series `ts`.

See Also

`set (timeseries)`, `timeseries`, `tsprops`

get (tscollection)

Purpose Query `tscollection` object property values

Syntax

```
value = get(tsc,'PropertyName')
```

Description

`value = get(tsc,'PropertyName')` returns the value of the specified property of the `tscollection` object tsc. The following syntax is equivalent:

```
value = tsc.PropertyName
```

`get(tsc)` displays all properties and values of the `tscollection` object tsc.

See Also `set (tscollection)`, `tscollection`

Purpose

Extract date-string time vector into cell array

Syntax

```
getabstime(ts)
```

Description

`getabstime(ts)` extracts the time vector from the `timeseries` object `ts` as a cell array of date strings. To define the time vector relative to a calendar date, set the `TimeInfo.StartDate` property of the `timeseries` object. When the `TimeInfo.StartDate` format is a valid `datestr` format, the output strings from `getabstime` have the same format.

Examples

The following example shows how to extract a time vector as a cell array of date strings from a `timeseries` object.

1. Create a `timeseries` object.

   ```
   ts = timeseries([3 6 8 0 10]);
   ```

   The default time vector for `ts` is [0 1 2 3 4], which starts at 0 and increases in 1-second increments. The length of the time vector is equal to the length of the data.

2. Set the `StartDate` property.

   ```
   ts.TimeInfo.StartDate = '10/27/2005 07:05:36';
   ```

3. Extract the time vector.

   ```
   getabstime(ts)

   ans =

       '27-Oct-2005 07:05:36'
       '27-Oct-2005 07:05:37'
       '27-Oct-2005 07:05:38'
       '27-Oct-2005 07:05:39'
       '27-Oct-2005 07:05:40'
   ```

4 Change the date-string format of the time vector.

```
ts.TimeInfo.Format = 'mm/dd/yy'
```

5 Extract the time vector with the new date-string format.

```
getabstime(ts)

ans =

    '10/27/05'
    '10/27/05'
    '10/27/05'
    '10/27/05'
    '10/27/05'
```

See Also

`setabstime (timeseries)`, `timeseries`, `tsprops`

Purpose

Extract date-string time vector into cell array

Syntax

```
getabstime(tsc)
```

Description

`getabstime(tsc)` extracts the time vector from the `tscollection` object tsc as a cell array of date strings. To define the time vector relative to a calendar date, set the `TimeInfo.StartDate` property of the time-series collection. When the `TimeInfo.StartDate` format is a valid `datestr` format, the output strings from `getabstime` have the same format.

Examples

1 Create a `tscollection` object.

```
tsc = tscollection(timeseries([3 6 8 0 10]));
```

2 Set the `StartDate` property.

```
tsc.TimeInfo.StartDate = '10/27/2005 07:05:36';
```

3 Extract a vector of absolute time values.

```
getabstime(tsc)

ans =

    '27-Oct-2005 07:05:36'
    '27-Oct-2005 07:05:37'
    '27-Oct-2005 07:05:38'
    '27-Oct-2005 07:05:39'
    '27-Oct-2005 07:05:40'
```

4 Change the date-string format of the time vector.

```
tsc.TimeInfo.Format = 'mm/dd/yy';
```

5 Extract the time vector with the new date-string format.

```
getabstime(tsc)
```

```
ans =

    '10/27/05'
    '10/27/05'
    '10/27/05'
    '10/27/05'
    '10/27/05'
```

See Also

`datestr`, `setabstime (tscollection)`, `tscollection`

Purpose Value of application-defined data

Syntax

```
value = getappdata(h,name)
values = getappdata(h)
```

Description `value = getappdata(h,name)` gets the value of the application-defined data with the name specified by `name`, in the object with handle `h`. If the application-defined data does not exist, MATLAB returns an empty matrix in `value`.

`values = getappdata(h)` returns all application-defined data for the object with handle `h`.

See Also `setappdata`, `rmappdata`, `isappdata`

GetCharArray

Purpose

Get character array from server

Syntax

MATLAB Client

```
string = h.GetCharArray('varname', 'workspace')
string = GetCharArray(h, 'varname', 'workspace')
string = invoke(h, 'GetCharArray', 'varname', 'workspace')
```

Method Signature

```
HRESULT GetCharArray ([in] BSTR varName, [in] BSTR Workspace,
[out, retval] BSTR *mlString)
```

Visual Basic Client

```
GetCharArray(varname As String, workspace As String) As String
```

Description

`GetCharArray` gets the character array stored in the variable `varname` from the specified `workspace` of the server attached to handle `h` and returns it in `string`. The *`workspace`* argument can be either `base` or `global`.

Remarks

If you want output from `GetCharArray` to be displayed at the client window, you must specify an output variable (e.g., `string`).

Server function names, like `GetCharArray`, 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.

Examples

Assign a string to variable `str` in the base workspace of the server using `PutCharArray`. Read it back in the client with `GetCharArray`.

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

```
Dim Matlab As Object
Dim S As String
Matlab = CreateObject("matlab.application")
Matlab.PutCharArray("str", "base",
   "He jests at scars that never felt a wound.")
S =  Matlab.GetCharArray("str", "base")
```

See Also

PutCharArray, GetWorkspaceData, PutWorkspaceData, GetVariable, Execute

getdatasamplesize

Purpose

Size of data sample in `timeseries` object

Syntax

`getdatasamplesize(ts)`

Description

`getdatasamplesize(ts)` returns the size of each data sample in a `timeseries` object.

Remarks

A time-series *data sample* consists of one or more scalar values recorded at a specific time. The number of data samples in is the same as the length of the time vector.

Examples

The following example shows how to get the size of a data sample in a `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','VehicleCount')
```

3 Get the size of the data sample for this `timeseries` object.

```
getdatasamplesize(count_ts)

ans =

     1     3
```

The size of each data sample in `count_ts` is 1-by-3, which means that each data sample is stored as a row with three values.

See Also

`addsample`, `size (timeseries)`, `tsprops`

Purpose Environment variable

Syntax

```
getenv 'name'
N = getenv('name')
```

Description

`getenv 'name'` searches the underlying operating system's environment list for a string of the form `name=value`, where `name` is the input string. If found, MATLAB returns the string `value`. If the specified name cannot be found, an empty matrix is returned.

`N = getenv('name')` returns `value` to the variable `N`.

Examples

```
os = getenv('OS')

os =
Windows_NT
```

See Also `setenv`, `computer`, `pwd`, `ver`, `path`

getfield

Purpose

Field of structure array

Syntax

```
f = getfield(s,'field')
f = getfield(s, {i,j}, 'field', {k})
```

Description

`f = getfield(s,'field')`, where `s` is a 1-by-1 structure, returns the contents of the specified field. This is equivalent to the syntax `f = s.field`.

If `s` is a structure having dimensions greater than 1-by-1, `getfield` returns the first of all output values requested in the call. That is, for structure array `s(m,n)`, `getfield` returns `f = s(1,1).field`.

`f = getfield(s, {i,j}, 'field', {k})` returns the contents of the specified field. This is equivalent to the syntax `f = s(i,j).field(k)`. 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.

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
```

Then the command `f = getfield(mystr, {2,1}, 'name')` yields

```
f =
   gertrude
```

To list the contents of all name (or other) fields, embed `getfield` in a loop.

```
for k = 1:2
    name{k} = getfield(mystr, {k,1}, 'name');
end
name

name =

    'alice'    'gertrude'
```

The following example starts out by creating a structure using the standard structure syntax. It then reads the fields of the structure, using `getfield` with variable and quoted field names and additional subscripting arguments.

```
class = 5;     student = 'John_Doe';
grades(class).John_Doe.Math(10,21:30) = ...
             [85, 89, 76, 93, 85, 91, 68, 84, 95, 73];
```

Use `getfield` to access the structure fields.

```
getfield(grades, {class}, student, 'Math', {10,21:30})

ans =
   85   89   76   93   85   91   68   84   95   73
```

See Also

`setfield`, `fieldnames`, `isfield`, `orderfields`, `rmfield`, "Using Dynamic Field Names"

Purpose

Capture movie frame

Syntax

```
getframe
F = getframe
F = getframe(h)
F = getframe(h,rect)
```

Description

`getframe` returns a movie frame. The frame is a snapshot (pixmap) of the current axes or figure.

`F = getframe` gets a frame from the current axes.

`F = getframe(h)` gets a frame from the figure or axes identified by handle `h`.

`F = getframe(h,rect)` specifies a rectangular area from which to copy the pixmap. `rect` is relative to the lower left corner of the figure or axes `h`, in pixel units. `rect` is a four-element vector in the form `[left bottom width height]`, where `width` and `height` define the dimensions of the rectangle.

`getframe` returns a movie frame, which is a structure having two fields:

- `cdata` — The image data stored as a matrix of `uint8` values. The dimensions of `F.cdata` are height-by-width-by-3.
- `colormap` — The colormap stored as an n-by-3 matrix of doubles. `F.colormap` is empty on true color systems.

To capture an image, use this approach:

```
F = getframe(gcf);
image(F.cdata)
colormap(F.colormap)
```

Remarks

`getframe` is usually used in a `for` loop to assemble an array of movie frames for playback using `movie`. For example,

```
for j = 1:n plotting commands
 F(j) = getframe;
```

```
end
movie(F)
```

If you are capturing frames of a plot that takes a long time to generate or are repeatedly calling `getframe` in a loop, make sure that your computer's screen saver does not activate and that your monitor does not turn off for the duration of the capture; otherwise one or more of the captured frames can contain graphics from your screen saver or nothing at all.

Note In situations where MATLAB is running on a virtual desktop that is not currently visible on your monitor, calls to `getframe` will complete, but will capture a region on your monitor that corresponds to the position occupied by the figure or axes on the hidden desktop. Therefore, make sure that the window to be captured by `getframe` exists on the currently active desktop.

Capture Regions

Note that `F = getframe` returns the contents of the current axes, exclusive of the axis labels, title, or tick labels. `F = getframe(gcf)` captures the entire interior of the current figure window. To capture the figure window menu, use the form `F = getframe(h,rect)` with a rectangle sized to include the menu.

Resolution of Captured Frames

The resolution of the framed image depends on the size of the axes in pixels when `getframe` is called. As the `getframe` command takes a snapshot of the screen, if the axes is small in size (e.g., because you have restricted the view to a window within the axes), `getframe` will capture fewer screen pixels, and the captured image might have poor resolution if enlarged for display.

Examples

Make the `peaks` function vibrate.

```
Z = peaks; surf(Z)
```

```
axis tight
set(gca,'nextplot','replacechildren');
for j = 1:20
    surf(sin(2*pi*j/20)*Z,Z)
    F(j) = getframe;
end
movie(F,20) % Play the movie twenty times
```

See Also

frame2im, image, im2frame, movie

"Bit-Mapped Images" on page 1-91 for related functions

Purpose

Get matrix from server

Syntax

MATLAB Client

```
[xreal ximag] = h.GetFullMatrix('varname', 'workspace',
zreal, zimag)
[xreal ximag] = GetFullMatrix(h, 'varname', 'workspace',
zreal, zimag)
[xreal ximag] = invoke(h, 'GetFullMatrix', 'varname', 'workspace',
zreal, zimag)
```

Method Signature

```
GetFullMatrix([in] BSTR varname,
[in] BSTR workspace, [in, out] SAFEARRAY(double) *pr,
[in, out] SAFEARRAY(double) *pi)
```

Visual Basic Client

```
GetFullMatrix(varname As String, workspace As String,
[out] XReal As Double, [out] XImag As Double
```

Note `GetFullMatrix` works only with values of type `double`. Use `GetVariable` or `GetWorkspaceData` for other types.

Description

`GetFullMatrix` gets the matrix stored in the variable `varname` from the specified `workspace` of the server attached to handle `h` and returns the real part in `xreal` and the imaginary part in `ximag`. The *`workspace`* argument can be either `base` or `global`.

The `zreal` and `zimag` arguments are matrices of the same size as the real and imaginary matrices (`xreal` and `ximag`) being returned from the server. The `zreal` and `zimag` matrices are commonly set to zero (see example below).

Remarks

If you want output from `GetFullMatrix` to be displayed at the client window, you must specify one or both output variables (e.g., `xreal` and/or `ximag`).

Server function names, like GetFullMatrix, 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.

Examples

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.

MATLAB Client

```
h = actxserver('matlab.application');
h.PutFullMatrix('M','base',rand(5),zeros(5));

MReal = h.GetFullMatrix('M','base',zeros(5),zeros(5))
MReal =
    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 Result As String
Dim XReal(4,4) As Double
Dim XImag(4,4) As Double

MatLab = CreateObject("matlab.application")
Result = MatLab.Execute("M = rand(5);")
MatLab.GetFullMatrix("M","base",XReal,XImag)
```

See Also

`PutFullMatrix`, `GetWorkspaceData`, `PutWorkspaceData`, `GetVariable`, `Execute`

getinterpmethod

Purpose

Interpolation method for `timeseries` object

Syntax

`getinterpmethod(ts)`

Description

`getinterpmethod(ts)` returns the interpolation method as a string that is used by the `timeseries` object `ts`. Predefined interpolation methods are `'zoh'` (zero-order hold) and `'linear'` (linear interpolation). The method strings are case sensitive.

Examples

1 Create a `timeseries` object.

```
ts = timeseries(rand(5));
```

2 Get the interpolation method for this object.

```
getinterpmethod(ts)

ans =

     linear
```

See Also

`setinterpmethod`, `timeseries`, `tsprops`

Purpose

Get component position in pixels

Syntax

```
position = getpixelposition(handle)
position = getpixelposition(handle,recursive)
```

Description

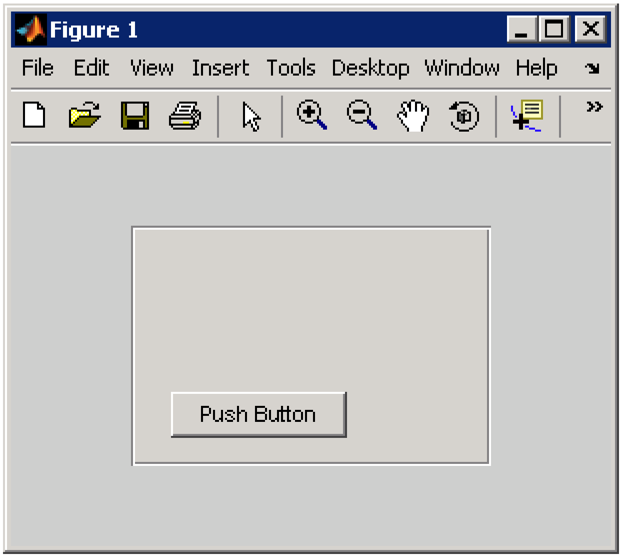
`position = getpixelposition(handle)` gets the position, in pixel units, of the component with handle `handle`. The `position` is returned as a four-element vector that specifies the location and size of the component: [distance from left, distance from bottom, width, height].

`position = getpixelposition(handle,recursive)` gets the position as above. If `recursive` is true, the returned position is relative to the parent figure of `handle`.

Example

This example creates a push button within a panel, and then retrieves its position, in pixels, relative to the panel.

```
f = figure('Position',[300 300 300 200]);
p = uipanel('Position',[.2 .2 .6 .6];
h1 = uicontrol(p,'Style','PushButton','Units','Normalized',...
             'String','Push Button','Position',[.1 .1 .5 .2]);
pos1 = getpixelposition(h1)

pos1 =
     18.6000   12.6000   88.0000   23.2000
```



The following statement retrieves the position of the push button, in pixels, relative to the figure.

```
pos1 = getpixelposition(h1,true)

pos1 =
        79.6000   53.6000   88.0000   23.2000
```

See Also

`setpixelposition`, `uicontrol`, `uipanel`

Purpose Preference

Syntax

```
getpref('group','pref')
getpref('group','pref',default)
getpref('group',{'pref1','pref2',...'prefn'})
getpref('group',{'pref1',...'prefn'},{default1,...defaultn})
getpref('group')
getpref
```

Description

`getpref('group','pref')` returns the value for the preference specified by `group` and `pref`. It is an error to get a preference that does not exist.

`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. `'ApplicationOnePrefs'`. The input argument `pref` identifies an individual preference in that group, and must be a legal variable name.

`getpref('group','pref',default)` returns the current value if the preference specified by `group` and `pref` exists. Otherwise creates the preference with the specified default value and returns that value.

`getpref('group',{'pref1','pref2',...'prefn'})` returns a cell array containing the values for the preferences specified by `group` and the cell array of preference names. The return value is the same size as the input cell array. It is an error if any of the preferences do not exist.

`getpref('group',{'pref1',...'prefn'},{default1,...defaultn})` returns a cell array with the current values of the preferences specified by `group` and the cell array of preference names. Any preference that does not exist is created with the specified default value and returned.

`getpref('group')` returns the names and values of all preferences in the `group` as a structure.

`getpref` returns all groups and preferences as a structure.

Note Preference values are persistent and maintain their values between MATLAB sessions. Where they are stored is system dependent.

Examples

Example 1

```
addpref('mytoolbox','version','1.0')
getpref('mytoolbox','version')

ans =
     1.0
```

Example 2

```
rmpref('mytoolbox','version')
getpref('mytoolbox','version','1.0');
getpref('mytoolbox','version')

ans =
     1.0
```

See Also

`addpref`, `ispref`, `rmpref`, `setpref`, `uigetpref`, `uisetpref`

Purpose

Data quality descriptions

Syntax

```
getqualitydesc(ts)
```

Description

`getqualitydesc(ts)` returns a cell array of data quality descriptions based on the `Quality` values you assigned to a `timeseries` object `ts`.

Examples

1. Create a `timeseries` object with `Data`, `Time`, and `Quality` values, respectively.

```
ts = timeseries([3; 4.2; 5; 6.1; 8], 1:5, [1; 0; 1; 0; 1]);
```

2. Set the `QualityInfo` property, consisting of `Code` and `Description`.

```
ts.QualityInfo.Code = [0 1];
ts.QualityInfo.Description = {'good' 'bad'};
```

3. Get the data quality description strings for `ts`.

```
getqualitydesc(ts)

ans =

    'bad'
    'good'
    'bad'
    'good'
    'bad'
```

See Also

`tsprops`

getsampleusingtime (timeseries)

Purpose Extract data samples into new `timeseries` object

Syntax

```
ts2 = getsampleusingtime(ts1,Time)
ts2 = getsampleusingtime(ts1,StartTime,EndTime)
```

Description `ts2 = getsampleusingtime(ts1,Time)` returns a new `timeseries` object `ts2` with a single sample corresponding to the time Time in ts1.

`ts2 = getsampleusingtime(ts1,StartTime,EndTime)` returns a new `timeseries` object `ts2` with samples between the times `StartTime` and `EndTime` in ts1.

Remarks When the time vector in ts1 is numeric, `StartTime` and `EndTime` must also be numeric. When the times in `ts1` are date strings and the `StartTime` and `EndTime` values are numeric, then the `StartTime` and `EndTime` values are treated as `datenum` values.

See Also `timeseries`

Purpose

Extract data samples into new `tscollection` object

Syntax

```
tsc2 = getsampleusingtime(tsc1,Time)
tsc2 = getsampleusingtime(tsc1,StartTime,EndTime)
```

Description

`tsc2 = getsampleusingtime(tsc1,Time)` returns a new `tscollection` tsc2 with a single sample corresponding to Time in tsc1.

`tsc2 = getsampleusingtime(tsc1,StartTime,EndTime)` returns a new `tscollection` tsc2 with samples between the times StartTime and EndTime in tsc1.

Remarks

When the time vector in ts1 is numeric, `StartTime` and `EndTime` must also be numeric. When the times in ts1 are date strings and the `StartTime` and `EndTime` values are numeric, then the `StartTime` and `EndTime` values are treated as `datenum` values.

See Also

`tscollection`

gettimeseriesnames

Purpose Cell array of names of `timeseries` objects in `tscollection` object

Syntax

```
names = gettimeseriesnames(tsc)
```

Description `names = gettimeseriesnames(tsc)` returns `names` of `timeseries` objects in a `tscollection` object `tsc`. `names` is a cell array of strings.

Examples

1 Create `timeseries` objects `a` and `b`.

```
a = timeseries(rand(1000,1),'name','position');
b = timeseries(rand(1000,1),'name','response');
```

2 Create a `tscollection` object that includes these two time series.

```
tsc = tscollection({a,b});
```

3 Get the names of the `timeseries` objects in `tsc`.

```
names = gettimeseriesnames(tsc)

names =

    'position'    'response'
```

See Also `timeseries`, `tscollection`, `tsprops`

Purpose New `timeseries` object with samples occurring at or after event

Syntax

```
ts1 = gettsafteratevent(ts,event)
ts1 = gettsafteratevent(ts,event,n)
```

Description `ts1 = gettsafteratevent(ts,event)` returns a new `timeseries` object ts1 with samples occurring at and after an event in ts, where event can be either a `tsdata.event` object or a string. When event is a `tsdata.event` object, the time defined by event is used. When event is a string, the first `tsdata.event` object in the `Events` property of the time series ts that matches the event name specifies the time.

`ts1 = gettsafteratevent(ts,event,n)` returns a new `timeseries` object ts1 with samples at and after an event in ts, where n is the number of the event occurrence with a matching event name.

Remarks When the `timeseries` object `ts` contains date strings and `event` uses numeric time, the time selected by the `event` is treated as a date that is calculated relative to the `StartDate` property in `ts.TimeInfo`.

When `ts` uses numeric time and `event` uses calendar dates, the time selected by the `event` is treated as a numeric value that is not associated with a calendar date.

See Also `gettsafterevent`, `gettsbeforeevent`, `gettsbetweenevents`, `tsdata.event`, `tsprops`

gettsafterevent

Purpose

New `timeseries` object with samples occurring after event

Syntax

```
ts1 = gettsafterevent(ts,event)
ts1 = ttsafterevent(ts,event,n)
```

Description

`ts1 = gettsafterevent(ts,event)` returns a new `timeseries` object ts1 with samples occurring after an event in ts, where event can be either a `tsdata.event` object or a string. When event is a `tsdata.event` object, the time defined by event is used. When event is a string, the first `tsdata.event` object in the `Events` property of `ts` that matches the event name specifies the time.

`ts1 = ttsafterevent(ts,event,n)` returns a new `timeseries` object `ts1` with samples occurring after an event in time series `ts`, where `n` is the number of the event occurrence with a matching event name.

Remarks

When the `timeseries` object `ts` contains date strings and `event` uses numeric time, the time selected by the `event` is treated as a date that is calculated relative to the `StartDate` property in `ts.TimeInfo`.

When `ts` uses numeric time and `event` uses calendar dates, the time selected by the `event` is treated as a numeric value that is not associated with a calendar date.

See Also

`gettsafteratevent`, `gettsbeforeevent`, `gettsbetweenevents`, `tsdata.event`, `tsprops`

Purpose

New `timeseries` object with samples occurring at event

Syntax

```
ts1 = gettsatevent(ts,event)
ts1 = gettsatevent(ts,event,n)
```

Description

`ts1 = gettsatevent(ts,event)` returns a new `timeseries` object `ts1` with samples occurring at an event in `ts`, where event can be either a `tsdata.event` object or a string. When event is a `tsdata.event` object, the time defined by event is used. When event is a string, the first `tsdata.event` object in the `Events` property of `ts` that matches the event name specifies the time.

`ts1 = gettsatevent(ts,event,n)` returns a new time series `ts1` with samples occurring at an event in time series `ts`, where n is the number of the event occurrence with a matching event name.

Remarks

When the `timeseries` object `ts` contains date strings and `event` uses numeric time, the time selected by the `event` is treated as a date that is calculated relative to the `StartDate` property in the `ts.TimeInfo`.

When `ts` uses numeric time and `event` uses calendar dates, the time selected by the `event` is treated as a numeric value that is not associated with a calendar date.

See Also

`gettsafterevent`, `gettsafteratevent`, `gettsbeforeevent`, `gettsbetweenevents`, `tsdata.event`, `tsprops`

gettsbeforeatevent

Purpose

New `timeseries` object with samples occurring before or at event

Syntax

```
ts1 = gettsbeforeatevent(ts,event)
ts1 = gettsbeforeatevent(ts,event,n)
```

Description

`ts1 = gettsbeforeatevent(ts,event)` returns a new `timeseries` object `ts1` with samples occurring at and before an event in `ts`, where event can be either a `tsdata.event` object or a string. When event is a `tsdata.event` object, the time defined by event is used. When event is a string, the first `tsdata.event` object in the `Events` property of `ts` that matches the event name specifies the time.

`ts1 = gettsbeforeatevent(ts,event,n)` returns a new `timeseries` object `ts1` with samples occurring at and before an event in time series `ts`, where n is the number of the event occurrence with a matching event name.

Remarks

When the `timeseries` object `ts` contains date strings and `event` uses numeric time, the time selected by the `event` is treated as a date that is calculated relative to the `StartDate` property in `ts.TimeInfo`.

When `ts` uses numeric time and `event` uses calendar dates, the time selected by the `event` is treated as a numeric value that is not associated with a calendar date.

See Also

`gettsafterevent`, `gettsbeforeevent`, `gettsbetweenevents`, `tsdata.event`, `tsprops`

Purpose

New `timeseries` object with samples occurring before event

Syntax

```
ts1 = gettsbeforeevent(ts,event)
ts1 = gettsbeforeevent(ts,event,n)
```

Description

`ts1 = gettsbeforeevent(ts,event)` returns a new `timeseries` object `ts1` with samples occurring before an event in `ts`, where event can be either a `tsdata.event` object or a string. When event is a `tsdata.event` object, the time defined by event is used. When event is a string, the first `tsdata.event` object in the `Events` property of `ts` that matches the event name specifies the time.

`ts1 = gettsbeforeevent(ts,event,n)` returns a new `timeseries` object `ts1` with samples occurring before an event in `ts`, where n is the number of the event occurrence with a matching event name.

Remarks

When the `timeseries` object `ts` contains date strings and `event` uses numeric time, the time selected by the `event` is treated as a date that is calculated relative to the `StartDate` property in `ts.TimeInfo`.

When `ts` uses numeric time and `event` uses calendar dates, the time selected by the `event` is treated as a numeric value that is not associated with a calendar date.

See Also

`gettsafterevent`, `gettsbeforeatevent`, `gettsbetweenevents`, `tsdata.event`, `tsprops`

gettsbetweenevents

Purpose

New `timeseries` object with samples occurring between events

Syntax

```
ts1 = gettsbetweenevents(ts,event1,event2)
ts1 = gettsbetweenevents(ts,event1,event2,n1,n2)
```

Description

`ts1 = gettsbetweenevents(ts,event1,event2)` returns a new `timeseries` object ts1 with samples occurring between events in `ts`, where `event1` and `event2` can be either a `tsdata.event` object or a string. When `event1` and `event2` are `tsdata.event` objects, the time defined by the events is used. When `event1` and `event2` are strings, the first `tsdata.event` object in the `Events` property of `ts` that matches the event names specifies the time.

`ts1 = gettsbetweenevents(ts,event1,event2,n1,n2)` returns a new `timeseries` object ts1 with samples occurring between events in `ts`, where `n1` and `n2` are the `n`th occurrences of the events with matching event names.

Remarks

When the `timeseries` object `ts` contains date strings and `event` uses numeric time, the time selected by the `event` is treated as a date that is calculated relative to the `StartDate` property in `ts.TimeInfo`.

When `ts` uses numeric time and `event` uses calendar dates, the time selected by the `event` is treated as a numeric value that is not associated with a calendar date.

See Also

`gettsafterevent`, `gettsbeforeevent`, `tsdata.event`, `tsprops`

Purpose

Get data from variable in server workspace

Syntax

MATLAB Client

```
D = h.GetVariable('varname', 'workspace')
D = GetVariable(h, 'varname', 'workspace')
D = invoke(h, 'GetVariable', 'varname', 'workspace')
```

Method Signature

```
HRESULT GetVariable([in] BSTR varname, [in] BSTR workspace,
[out, retval] VARIANT* pdata)
```

Visual Basic Client

```
GetVariable(varname As String, workspace As String) As Object
```

Description

`GetVariable` returns the data stored in the specified variable from the specified workspace of the server. Each syntax in the MATLAB Client section produce the same result. Note that the dot notation (`h.GetVariable`) is case sensitive.

`varname` from the specified `workspace` of the server that is attached to handle `h`. The *`workspace`* argument can be either `base` or `global`.

`varname` — the name of the variable whose data is returned

`workspace` — the workspace containing the variable can be either:

- `base` is the base workspace of the server
- `global` is the global workspace of the server (see `global` for more information about how to access variables in the global workspace).

Note `GetVariable` works on all MATLAB data types except sparse arrays, structures, and function handles.

Remarks

You can use `GetVariable` in place of `GetWorkspaceData`, `GetFullMatrix` and `GetCharArray` to get data stored in workspace variables when you need a result returned explicitly (which might be required by some scripting languages).

Examples

This example assigns a cell array to the variable C1 in the base workspace of the server, and then read it back with GetVariable, assigning it to a new variable C2.

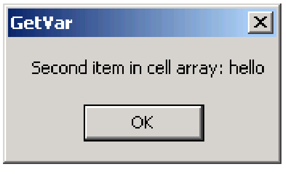
MATLAB Client

```
h = actxserver('matlab.application');
h.PutWorkspaceData('C1', 'base', {25.72, 'hello', rand(4)});
C2 = h.GetVariable('C1','base')
C2 =
    [25.7200]    'hello'    [4x4 double]
```

Visual Basic.net Client

```
Dim Matlab As Object
Dim Result As String
Dim C2 As Object
Matlab = CreateObject("matlab.application")
Result = Matlab.Execute("C1 = {25.72, 'hello', rand(4)};")
C2 = Matlab.GetVariable("C1", "base")
MsgBox("Second item in cell array: " & C2(0, 1))
```

The Visual Basic Client example creates a message box displaying the second element in the cell array, which is the string hello.



See Also

GetWorkspaceData, PutWorkspaceData, GetFullMatrix, PutFullMatrix, GetCharArray, PutCharArray, Execute

Purpose

Get data from server workspace

Syntax

MATLAB Client

```
D = h.GetWorkspaceData('varname', 'workspace')
D = GetWorkspaceData(h, 'varname', 'workspace')
D = invoke(h, 'GetWorkspaceData', 'varname', 'workspace')
```

Method Signature

```
HRESULT GetWorkspaceData([in] BSTR varname, [in] BSTR workspace,
[out] VARIANT* pdata)
```

Visual Basic Client

```
GetWorkspaceData(varname As String, workspace As String) As Object
```

Description

`GetWorkspaceData` gets the data stored in the variable `varname` from the specified `workspace` of the server attached to handle `h` and returns it in output argument `D`. The *`workspace`* argument can be either `base` or `global`.

Note `GetWorkspaceData` works on all MATLAB data types except sparse arrays, structures, and function handles.

Remarks

You can use `GetWorkspaceData` in place of `GetFullMatrix` and `GetCharArray` to get numeric and character array data respectively.

If you want output from `GetWorkspaceData` to be displayed at the client window, you must specify an output variable.

Server function names, like `GetWorkspaceData`, 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

Assign a cell array to variable C1 in the base workspace of the server, and then read it back with GetWorkspaceData.

MATLAB Client

```
h = actxserver('matlab.application');
h.PutWorkspaceData('C1', 'base', ...
                   {25.72, 'hello', rand(4)});
C2 = h.GetWorkspaceData('C1', 'base')

C2 =
    [25.7200]    'hello'    [4x4 double]
```

Visual Basic.net Client

```
Dim Matlab, C2 As Object
Dim Result As String
Matlab = CreateObject("matlab.application")
Result = MatLab.Execute("C1 = {25.72, 'hello', rand(4)};")
Matlab.GetWorkspaceData("C1", "base", C2)
```

See Also

PutWorkspaceData, GetFullMatrix, PutFullMatrix, GetCharArray, PutCharArray, GetVariable, Execute

Purpose Graphical input from mouse or cursor

Syntax

```
[x,y] = ginput(n)
[x,y] = ginput
[x,y,button] = ginput(...)
```

Description `ginput` enables you to select points from the figure using the mouse for cursor positioning. The figure must have focus before `ginput` receives input.

`[x,y] = ginput(n)` enables you to select `n` points from the current axes and returns the *x*- and *y*-coordinates in the column vectors `x` and `y`, respectively. Press the **Return** key to terminate the input before entering `n` points.

`[x,y] = ginput` gathers an unlimited number of points until you press the **Return** key.

Note Clicking an axes makes that axes the current axes. Although you may set the current axes before calling `ginput`, whichever axes the user clicks becomes the current axes and `ginput` returns points relative to that axes. For example, if a user selects points from multiple axes, the results returned are relative to the different axes' coordinate systems.

`[x,y,button] = ginput(...)` returns the *x*-coordinates, the *y*-coordinates, and the button or key designation. `button` is a vector of integers indicating which mouse buttons you pressed (1 for left, 2 for middle, 3 for right), or ASCII numbers indicating which keys on the keyboard you pressed.

Examples Pick 10 two-dimensional points from the figure window.

```
[x,y] = ginput(10)
```

Position the cursor with the mouse. Enter data points by pressing a mouse button or a key on the keyboard. To terminate input before entering 10 points, press the **Return** key.

See Also

`gtext`

"Interactive Plotting" for an example

"Developing User Interfaces" on page 1-104 for related functions

Purpose Declare global variables

Syntax

```
global X Y Z
```

Description `global X Y Z` defines `X`, `Y`, and `Z` as global in scope.

Ordinarily, each MATLAB function, defined by an M-file, has its own local variables, which are separate from those of other functions, and from those of the base workspace. However, if several functions, and possibly the base workspace, all declare a particular name as global, they all share a single copy of that variable. Any assignment to that variable, in any function, is available to all the functions declaring it global.

If the global variable does not exist the first time you issue the `global` statement, it is initialized to the empty matrix.

If a variable with the same name as the global variable already exists in the current workspace, MATLAB issues a warning and changes the value of that variable to match the global.

Remarks Use `clear global` *`variable`* to clear a global variable from the global workspace. Use `clear` *`variable`* to clear the global link from the current workspace without affecting the value of the global.

To use a global within a callback, declare the global, use it, then clear the global link from the workspace. This avoids declaring the global after it has been referenced. For example,

```
uicontrol('style', 'pushbutton', 'CallBack',   ...
           'global MY_GLOBAL, disp(MY_GLOBAL),  ...
            MY_GLOBAL = MY_GLOBAL+1,           ...
            clear MY_GLOBAL', 'string','count')
```

There is no function form of the global command (i.e., you cannot use parentheses and quote the variable names).

Examples Here is the code for the functions `tic` and `toc` (some comments abridged). These functions manipulate a stopwatch-like timer. The global variable TICTOC is shared by the two functions, but it is invisible in the base workspace or in any other functions that do not declare it.

```
function tic
%    TIC Start a stopwatch timer.
%        TIC; any stuff; TOC
%    prints the time required.
%    See also: TOC, CLOCK.
global TICTOC
TICTOC = clock;

function t = toc
%    TOC Read the stopwatch timer.
%    TOC prints the elapsed time since TIC was used.
%    t = TOC; saves elapsed time in t, does not print.
%    See also: TIC, ETIME.
global TICTOC
if nargout < 1
    elapsed_time = etime(clock, TICTOC)
else
    t = etime(clock, TICTOC);
end
```

See Also

clear, isglobal, who

Purpose

Generalized minimum residual method (with restarts)

Syntax

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

Description

`x = gmres(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)` returns `A*x`. See "Function Handles" in the MATLAB Programming documentation for more information. For this syntax, `gmres` does not restart; the maximum number of iterations is `min(n,10)`.

"Parameterizing Functions Called by Function 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 `gmres` converges, a message to that effect is displayed. If `gmres` fails to converge after the maximum number of iterations or halts for any reason, a warning message is printed displaying the relative residual `norm(b-A*x)/norm(b)` and the iteration number at which the method stopped or failed.

`gmres(A,b,restart)` restarts the method every `restart` inner iterations. The maximum number of outer iterations is `min(n/restart,10)`. The maximum number of total iterations is `restart*min(n/restart,10)`. If `restart` is `n` or `[]`, then `gmres` does not restart and the maximum number of total iterations is `min(n,10)`.

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

gmres(A,b,restart,tol,maxit) specifies the maximum number of outer iterations, i.e., the total number of iterations does not exceed restart*maxit. If maxit is [] then gmres uses the default, min(n/restart,10). If restart is n or [], then the maximum number of total iterations is maxit (instead of restart*maxit).

gmres(A,b,restart,tol,maxit,M) and gmres(A,b,restart,tol,maxit,M1,M2) use preconditioner M or M = M1*M2 and effectively solve the system inv(M)*A*x = inv(M)*b for x. If M is [] then gmres applies no preconditioner. M can be a function handle mfun such that mfun(x) returns M\x.

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

[x,flag] = gmres(A,b,...) also returns a convergence flag:

flag = 0	gmres converged to the desired tolerance tol within maxit outer iterations.
flag = 1	gmres iterated maxit times but did not converge.
flag = 2	Preconditioner M was ill-conditioned.
flag = 3	gmres stagnated. (Two consecutive iterates were the same.)

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] = gmres(A,b,...) also returns the relative residual norm(b-A*x)/norm(b). If flag is 0, relres <= tol.

[x,flag,relres,iter] = gmres(A,b,...) also returns both the outer and inner iteration numbers at which x was computed, where 0 <= iter(1) <= maxit and 0 <= iter(2) <= restart.

[x,flag,relres,iter,resvec] = gmres(A,b,...) also returns a vector of the residual norms at each inner iteration, including norm(b-A*x0).

Examples

Example 1

```
A = gallery('wilk',21);
b = sum(A,2);
tol = 1e-12;
maxit = 15;
M1 = diag([10:-1:1 1 1:10]);

x = gmres(A,b,10,tol,maxit,M1);
```

displays the following message:

```
gmres(10) converged at outer iteration 2 (inner iteration 9) to
a solution with relative residual 3.3e-013
```

Example 2

This example replaces the matrix A in Example 1 with a handle to a matrix-vector product function afun, and the preconditioner M1 with a handle to a backsolve function mfun. The example is contained in an M-file run_gmres that

- Calls gmres with the function handle @afun as its first argument.
- Contains afun and mfun as nested functions, so that all variables in run_gmres are available to afun and mfun.

The following shows the code for run_gmres:

```
function x1 = run_gmres
n = 21;
A = gallery('wilk',n);
b = sum(A,2);
tol = 1e-12;  maxit = 15;
x1 = gmres(@afun,b,10,tol,maxit,@mfun);
```

```
    function y = afun(x)
        y = [0; x(1:n-1)] + ...
              [((n-1)/2:-1:0)'; (1:(n-1)/2)'].*x + ...
              [x(2:n); 0];
    end

    function y = mfun(r)
        y = r ./ [((n-1)/2:-1:1)'; 1; (1:(n-1)/2)'];
    end
end
```

When you enter

```
x1 = run_gmres;
```

MATLAB displays the message

```
gmres(10) converged at outer iteration 2 (inner iteration 9) to
a solution with relative residual 3.3e-013
```

Example 3

```
load west0479
A = west0479
b = sum(A,2)
[x,flag] = gmres(A,b,5)
```

`flag` is 1 because `gmres` does not converge to the default tolerance `1e-6` within the default 10 outer iterations.

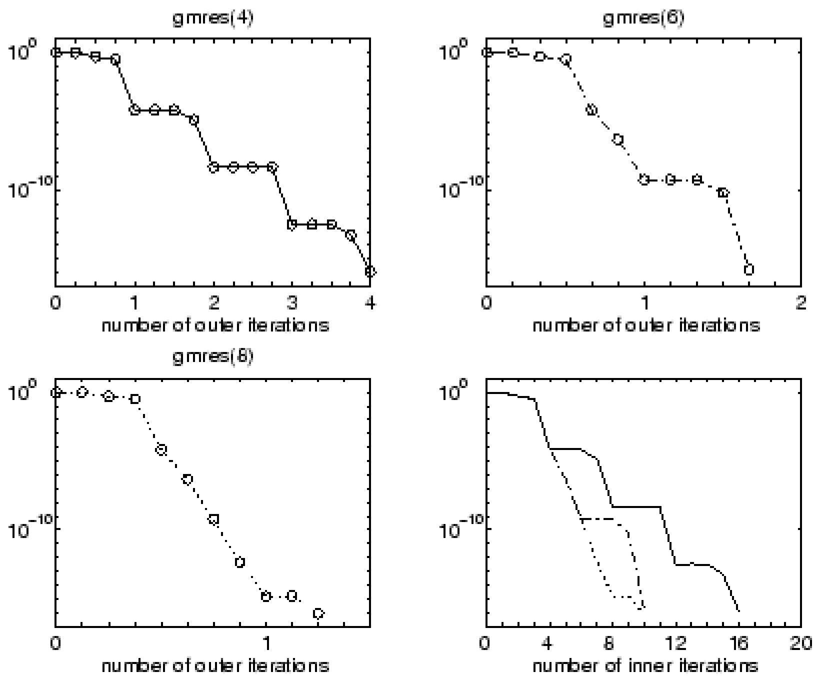
```
[L1,U1] = luinc(A,1e-5);
[x1,flag1] = gmres(A,b,5,1e-6,5,L1,U1);
```

`flag1` is 2 because the upper triangular `U1` has a zero on its diagonal, and `gmres` 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);
```

```
tol = 1e-15;
[x4,flag4,relres4,iter4,resvec4] = gmres(A,b,4,tol,5,L2,U2);
[x6,flag6,relres6,iter6,resvec6] = gmres(A,b,6,tol,3,L2,U2);
[x8,flag8,relres8,iter8,resvec8] = gmres(A,b,8,tol,3,L2,U2);
```

`flag4`, `flag6`, and `flag8` are all `0` because `gmres` converged when restarted at iterations 4, 6, and 8 while preconditioned by the incomplete LU factorization with a drop tolerance of `1e-6`. This is verified by the plots of outer iteration number against relative residual. A combined plot of all three clearly shows the restarting at iterations 4 and 6. The total number of iterations computed may be more for lower values of `restart`, but the number of length `n` vectors stored is fewer, and the amount of work done in the method decreases proportionally.



See Also

`bicg`, `bicgstab`, `cgs`, `lsqr`, `ilu`, `luinc`, `minres`, `pcg`, `qmr`, `symmlq` `function_handle` (@), `mldivide` (\)

References

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

Saad, Youcef and Martin H. Schultz, "GMRES: A generalized minimal residual algorithm for solving nonsymmetric linear systems," *SIAM J. Sci. Stat. Comput.*, July 1986, Vol. 7, No. 3, pp. 856-869.

Purpose

Plot nodes and links representing adjacency matrix

Syntax

```
gplot(A,Coordinates)
gplot(A,Coordinates,LineSpec)
```

Description

The `gplot` function graphs a set of coordinates using an adjacency matrix.

`gplot(A,Coordinates)` plots a graph of the nodes defined in `Coordinates` according to the *n*-by-*n* adjacency matrix `A`, where *n* is the number of nodes. `Coordinates` is an *n*-by-2 matrix, where *n* is the number of nodes and each coordinate pair represents one node.

`gplot(A,Coordinates,`*`LineSpec`*`)` plots the nodes using the line type, marker symbol, and color specified by *`LineSpec`*.

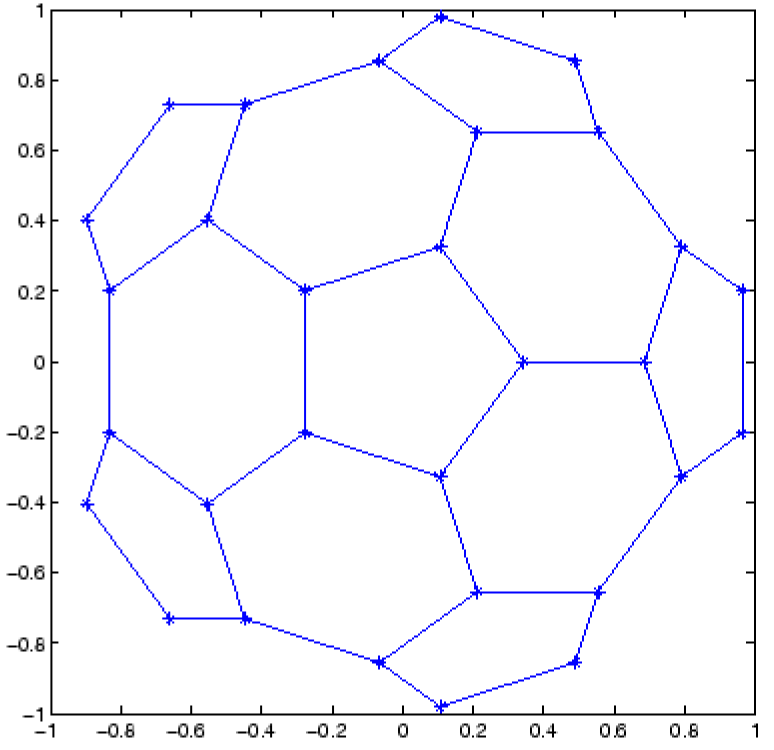
Remarks

For two-dimensional data, `Coordinates(i,:)  = [x(i) y(i)]` denotes node `i`, and `Coordinates(j,:)  = [x(j)y(j)]` denotes node `j`. If node `i` and node `j` are connected, `A(i,j)` or `A(j,i)` is nonzero; otherwise, `A(i,j)` and `A(j,i)` are zero.

Examples

To draw half of a Bucky ball with asterisks at each node,

```
k = 1:30;
[B,XY] = bucky;
gplot(B(k,k),XY(k,:),'-*')
axis square
```



See Also

`LineSpec`, `sparse`, `spy`

"Tree Operations" on page 1-39 for related functions

Purpose

MATLAB code from M-files published to HTML

Syntax

```
grabcode('name.html')
grabcode('urlname')
codeString = grabcode('name.html')
```

Description

`grabcode('name.html')` copies MATLAB code from the file `name.html` and pastes it into an untitled document in the Editor/Debugger. Use `grabcode` to get MATLAB code from demos or other published M-files when the M-file source code is not readily available. The file `name.html` was created by publishing `name.m`, an M-file containing cells. The MATLAB code from `name.m` is included at the end of `name.html` as HTML comments.

`grabcode('urlname')` copies MATLAB code from the `urlname` location and pastes it into an untitled document in the Editor/Debugger.

`codeString = grabcode('name.html')` get MATLAB code from the file `name.html` and assigns it the variable `codeString`.

Examples

Run

```
sineWaveString = grabcode('d:/mymfiles/sine_wave_.html')
```

and MATLAB displays

```
sineWaveString =

%% Simple Sine Wave Plot

%% Part One: Calculate Sine Wave
% Define the range |x|.
% Calculate the sine |y| over that range.
x = 0:.01:6*pi;
y = sin(x);

%% Part Two: Plot Sine Wave
% Graph the result.
```

```
plot(x,y)
```

See Also

`demo`, `publish`

Purpose

Numerical gradient

Syntax

```
FX = gradient(F)
[FX,FY] = gradient(F)
[FX,FY,FZ,...] = gradient(F)
[...] = gradient(F,h)
[...] = gradient(F,h1,h2,...)
```

Definition

The *gradient* of a function of two variables, $F(x, y)$, is defined as

$$\nabla F = \frac{\partial F}{\partial x}\hat{i} + \frac{\partial F}{\partial y}\hat{j}$$

and can be thought of as a collection of vectors pointing in the direction of increasing values of F. In MATLAB, numerical gradients (differences) can be computed for functions with any number of variables. For a function of N variables, $F(x, y, z, \ldots)$,

$$\nabla F = \frac{\partial F}{\partial x}\hat{i} + \frac{\partial F}{\partial y}\hat{j} + \frac{\partial F}{\partial z}\hat{k} + \ldots$$

Description

`FX = gradient(F)` where `F` is a vector returns the one-dimensional numerical gradient of `F`. `FX` corresponds to $\partial F/\partial x$, the differences in x (horizontal) direction.

`[FX,FY] = gradient(F)` where `F` is a matrix returns the x and y components of the two-dimensional numerical gradient. `FX` corresponds to $\partial F/\partial x$, the differences in x (horizontal) direction. `FY` corresponds to $\partial F/\partial y$, the differences in the y (vertical) direction. The spacing between points in each direction is assumed to be one.

`[FX,FY,FZ,...] = gradient(F)` where `F` has `N dimensions` returns the `N` components of the gradient of `F`. There are two ways to control the spacing between values in `F`:

- A single spacing value, `h`, specifies the spacing between points in every direction.

- `N` spacing values (`h1,h2,...`) specifies the spacing for each dimension of `F`. Scalar spacing parameters specify a constant spacing for each dimension. Vector parameters specify the coordinates of the values along corresponding dimensions of `F`. In this case, the length of the vector must match the size of the corresponding dimension.

Note The first output `FX` is always the gradient along the 2nd dimension of `F`, going across columns. The second output `FY` is always the gradient along the 1st dimension of `F`, going across rows. For the third output `FZ` and the outputs that follow, the Nth output is the gradient along the Nth dimension of `F`.

`[...] = gradient(F,h)` where `h` is a scalar uses `h` as the spacing between points in each direction.

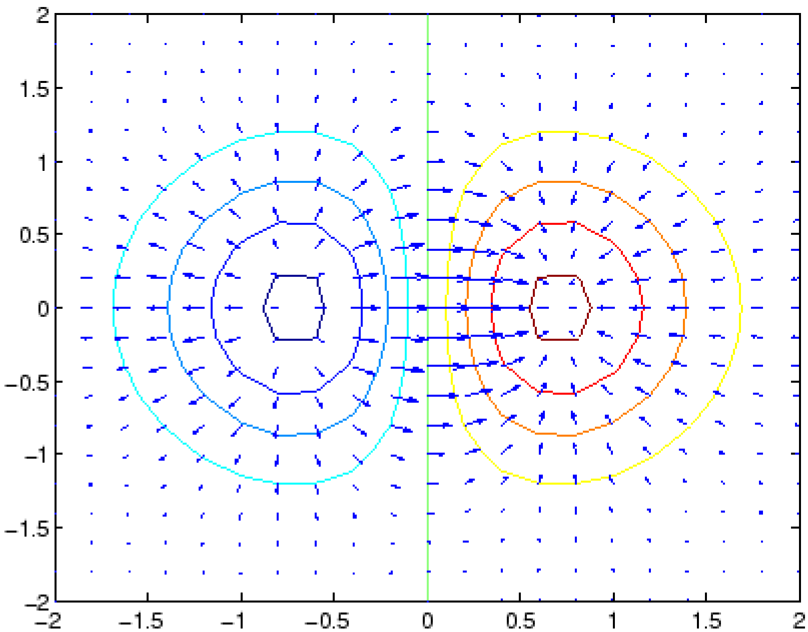
`[...] = gradient(F,h1,h2,...)` with `N` spacing parameters specifies the spacing for each dimension of `F`.

Examples

The statements

```
v = -2:0.2:2;
[x,y] = meshgrid(v);
z = x .* exp(-x.^2 - y.^2);
[px,py] = gradient(z,.2,.2);
contour(v,v,z), hold on, quiver(v,v,px,py), hold off
```

produce



Given,

```
F(:,:,1) = magic(3); F(:,:,2) = pascal(3);
gradient(F)
```

takes `dx = dy = dz = 1`.

```
[PX,PY,PZ] = gradient(F,0.2,0.1,0.2)
```

takes `dx = 0.2`, `dy = 0.1`, and `dz = 0.2`.

See Also

`del2`, `diff`

graymon

Purpose

Set default figure properties for grayscale monitors

Syntax

```
graymon
```

Description

`graymon` sets defaults for graphics properties to produce more legible displays for grayscale monitors.

See Also

`axes`, `figure`

"Color Operations" on page 1-97 for related functions

Purpose

Grid lines for 2-D and 3-D plots

GUI Alternative

To control the presence and appearance of grid lines on a graph, use the Property Editor, one of the plotting tools . For details, see The Property Editor in the MATLAB Graphics documentation.

Syntax

```
grid on
grid off
grid
grid(axes_handle,...)
grid minor
```

Description

The `grid` function turns the current axes' grid lines on and off.

`grid on` adds major grid lines to the current axes.

`grid off` removes major and minor grid lines from the current axes.

`grid` toggles the major grid visibility state.

`grid(axes_handle,...)` uses the axes specified by `axes_handle` instead of the current axes.

Algorithm

`grid` sets the `XGrid`, `YGrid`, and `ZGrid` properties of the axes.

`grid minor` sets the `XMinorGrid`, `YMinorGrid`, and `ZMinorGrid` properties of the axes.

You can set the grid lines for just one axis using the `set` command and the individual property. For example,

```
set(axes_handle,'XGrid','on')
```

turns on only *x*-axis grid lines.

You can set grid line width with the axes `LineWidth` property.

See Also

`box`, `axes`, `set`

The properties of axes objects

"Axes Operations" on page 1-95 for related functions

Purpose

Data gridding

Syntax

```
ZI = griddata(x,y,z,XI,YI)
[XI,YI,ZI] = griddata(x,y,z,XI,YI)
[...] = griddata(...,method)
[...] = griddata(...,method,options)
```

Description

`ZI = griddata(x,y,z,XI,YI)` fits a surface of the form `z = f(x,y)` to the data in the (usually) nonuniformly spaced vectors `(x,y,z)`. `griddata` interpolates this surface at the points specified by `(XI,YI)` to produce `ZI`. The surface always passes through the data points. `XI` and `YI` usually form a uniform grid (as produced by `meshgrid`).

`XI` can be a row vector, in which case it specifies a matrix with constant columns. Similarly, `YI` can be a column vector, and it specifies a matrix with constant rows.

`[XI,YI,ZI] = griddata(x,y,z,XI,YI)` returns the interpolated matrix `ZI` as above, and also returns the matrices `XI` and `YI` formed from row vector `XI` and column vector `yi`. These latter are the same as the matrices returned by `meshgrid`.

`[...]  = griddata(...,method)` uses the specified interpolation method:

’linear’	Triangle-based linear interpolation (default)
’cubic’	Triangle-based cubic interpolation
’nearest’	Nearest neighbor interpolation
’v4’	MATLAB 4 `griddata` method

The `method` defines the type of surface fit to the data. The `'cubic'` and `'v4'` methods produce smooth surfaces while `'linear'` and `'nearest'` have discontinuities in the first and zero’th derivatives, respectively. All the methods except `'v4'` are based on a Delaunay triangulation of the data. If `method` is `[]`, then the default `'linear'` method is used.

`[...]  = griddata(...,method,options)` specifies a cell array of strings `options` to be used in Qhull via `delaunayn`. If `options` is `[]`, the default `delaunayn` options are used. If `options` is `{''}`, no options are used, not even the default.

Occasionally, `griddata` might return points on or very near the convex hull of the data as `NaN`s. This is because roundoff in the computations sometimes makes it difficult to determine if a point near the boundary is in the convex hull.

Remarks

`XI` and `YI` can be matrices, in which case `griddata` returns the values for the corresponding points `(XI(i,j),YI(i,j))`. Alternatively, you can pass in the row and column vectors `xi` and `yi`, respectively. In this case, `griddata` interprets these vectors as if they were matrices produced by the command `meshgrid(xi,yi)`.

Examples

Sample a function at 100 random points between `±2.0`:

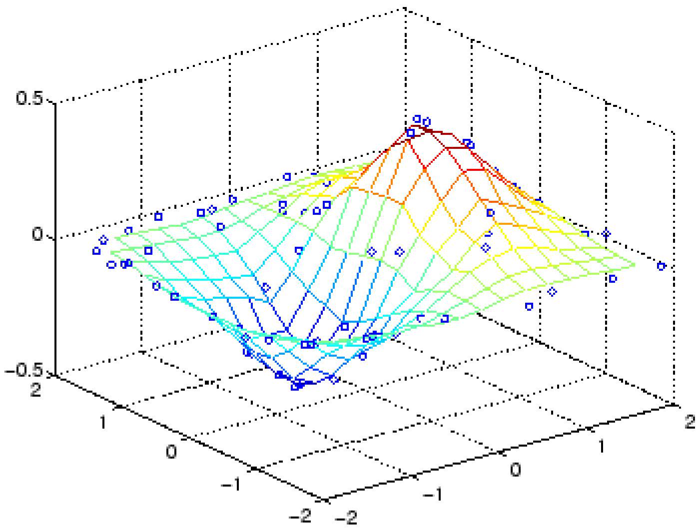
```
rand('seed',0)
x = rand(100,1)*4-2;  y = rand(100,1)*4-2;
z = x.*exp(-x.^2-y.^2);
```

`x`, `y`, and `z` are now vectors containing nonuniformly sampled data. Define a regular grid, and grid the data to it:

```
ti = -2:.25:2;
[XI,YI] = meshgrid(ti,ti);
ZI = griddata(x,y,z,XI,YI);
```

Plot the gridded data along with the nonuniform data points used to generate it:

```
mesh(XI,YI,ZI), hold
plot3(x,y,z,'o'), hold off
```



Algorithm

The `griddata(...,'v4')` command uses the method documented in [2]. The other `griddata` methods are based on 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

`delaunay`, `griddata3`, `griddatan`, `interp2`, `meshgrid`

References

[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. Available in PDF format at http://www.acm.org/pubs/citations/journals/toms/1996-22-4/p469-barber/.

[2] Sandwell, David T., "Biharmonic Spline Interpolation of GEOS-3 and SEASAT Altimeter Data", *Geophysical Research Letters*, 14, 2, 139-142,1987.

[3] Watson, David E., *Contouring: A Guide to the Analysis and Display of Spatial Data*, Tarrytown, NY: Pergamon (Elsevier Science, Inc.): 1992.

Purpose

Data gridding and hypersurface fitting for 3-D data

Syntax

```
w = griddata3(x,y,z,v,xi,yi,zi)
w = griddata3(x,y,z,v,xi,yi,zi,method)
w = griddata3(x,y,z,v,xi,yi,zi,method,options)
```

Description

`w = griddata3(x,y,z,v,xi,yi,zi)` fits a hypersurface of the form $w = f(x, y, z)$ to the data in the (usually) nonuniformly spaced vectors (`x`, `y`, `z`, `v`). `griddata3` interpolates this hypersurface at the points specified by (`xi`,`yi`,`zi`) to produce `w`. `w` is the same size as `xi`, `yi`, and `zi`.

(`xi`,`yi`,`zi`) is usually a uniform grid (as produced by `meshgrid`) and is where `griddata3` gets its name.

`w = griddata3(x,y,z,v,xi,yi,zi,method)` defines the type of surface that is fit to the data, where `method` is either:

'linear'	Tesselation-based linear interpolation (default)
'nearest'	Nearest neighbor interpolation

If `method` is `[]`, the default `'linear'` method is used.

`w = griddata3(x,y,z,v,xi,yi,zi,method,options)` specifies a cell array of strings `options` to be used in Qhull via `delaunayn`.

If `options` is `[]`, the default options are used. If `options` is `{''}`, no options are used, not even the default.

Examples

Create vectors `x`, `y`, and `z` containing nonuniformly sampled data:

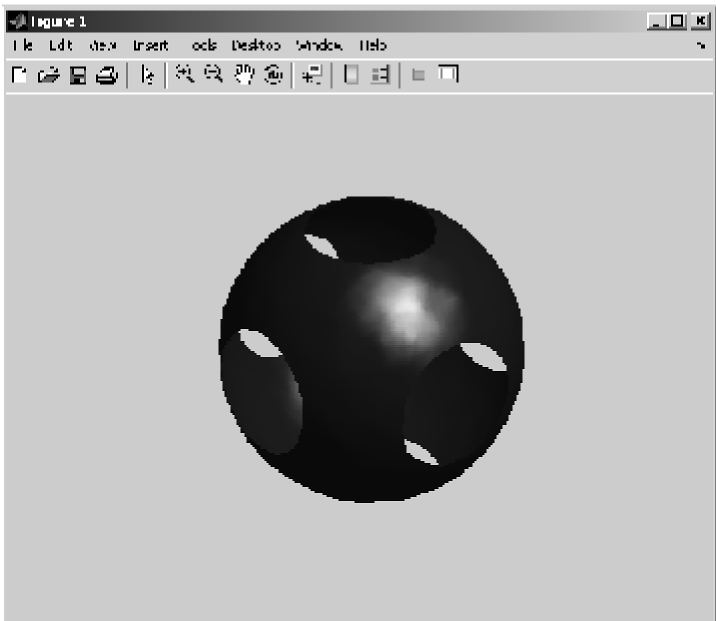
```
rand('state',0);
x = 2*rand(5000,1)-1;
y = 2*rand(5000,1)-1;
z = 2*rand(5000,1)-1;
v = x.^2 + y.^2 + z.^2;
```

Define a regular grid, and grid the data to it:

```
d = -0.8:0.05:0.8;
[xi,yi,zi] = meshgrid(d,d,d);
w = griddata3(x,y,z,v,xi,yi,zi);
```

Since it is difficult to visualize 4D data sets, use isosurface at 0.8:

```
p = patch(isosurface(xi,yi,zi,w,0.8));
isonormals(xi,yi,zi,w,p);
set(p,'FaceColor','blue','EdgeColor','none');
view(3), axis equal, axis off, camlight, lighting phong
```



Algorithm

The `griddata3` methods are based on 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

`delaunayn`, `griddata`, `griddatan`, `meshgrid`

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. Available in PDF format at `http://www.acm.org/pubs/citations/journals/toms/1996-22-4/p469-barber/`.

griddatan

Purpose

Data gridding and hypersurface fitting (dimension >= 2)

Syntax

```
yi = griddatan(X,y,xi)
yi = griddatan(x,y,z,v,xi,yi,zi,method)
```

Description

`yi = griddatan(X,y,xi)` fits a hyper-surface of the form $y = f(X)$ to the data in the (usually) nonuniformly-spaced vectors (`X`, `y`). `griddatan` interpolates this hyper-surface at the points specified by `xi` to produce `yi`. `xi` can be nonuniform.

`X` is of dimension `m`-by-`n`, representing `m` points in n-dimensional space. `y` is of dimension `m`-by-`1`, representing `m` values of the hyper-surface f(`X`). `xi` is a vector of size `p`-by-`n`, representing `p` points in the n-dimensional space whose surface value is to be fitted. `yi` is a vector of length `p` approximating the values f(`xi`). The hypersurface always goes through the data points (`X`,`y`). `xi` is usually a uniform grid (as produced by `meshgrid`).

`yi = griddatan(x,y,z,v,xi,yi,zi,method)` defines the type of surface fit to the data, where `'method'` is one of:

'linear'	Tessellation-based linear interpolation (default)
'nearest'	Nearest neighbor interpolation

All the methods are based on a Delaunay tessellation of the data.

If `method` is `[]`, the default `'linear'` method is used.

`yi = griddatan(x,y,z,v,xi,yi,zi,method,options)` specifies a cell array of strings `options` to be used in Qhull via `delaunayn`.

If `options` is `[]`, the default options are used. If `options` is `{''}`, no options are used, not even the default.

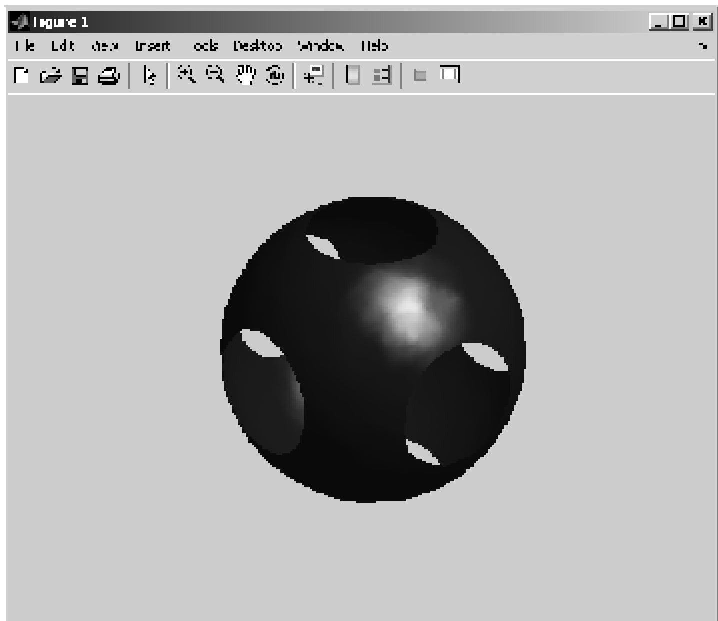
Examples

```
rand('state',0)
X = 2*rand(5000,3)-1;
Y = sum(X.^2,2);
d = -0.8:0.05:0.8;
```

```
[y0,x0,z0] = ndgrid(d,d,d);
XI = [x0(:) y0(:) z0(:)];
YI = griddatan(X,Y,XI);
```

Since it is difficult to visualize 4D data sets, use isosurface at 0.8:

```
YI = reshape(YI, size(x0));
p = patch(isosurface(x0,y0,z0,YI,0.8));
isonormals(x0,y0,z0,YI,p);
set(p,'FaceColor','blue','EdgeColor','none');
view(3), axis equal, axis off, camlight, lighting phong
```



Algorithm

The `griddatan` methods are based on 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 delaunayn, griddata, griddata3, meshgrid

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. Available in PDF format at http://www.acm.org/pubs/citations/journals/toms/1996-22-4/p469-barber/.

Purpose

Generalized singular value decomposition

Syntax

```
[U,V,X,C,S] = gsvd(A,B)
sigma = gsvd(A,B)
```

Description

`[U,V,X,C,S] = gsvd(A,B)` returns unitary matrices `U` and `V`, a (usually) square matrix `X`, and nonnegative diagonal matrices `C` and `S` so that

```
A = U*C*X'
B = V*S*X'
C'*C + S'*S = I
```

`A` and `B` must have the same number of columns, but may have different numbers of rows. If `A` is `m`-by-`p` and `B` is `n`-by-`p`, then `U` is `m`-by-`m`, `V` is `n`-by-`n` and `X` is `p`-by-`q` where `q = min(m+n,p)`.

`sigma = gsvd(A,B)` returns the vector of generalized singular values, `sqrt(diag(C'*C)./diag(S'*S))`.

The nonzero elements of `S` are always on its main diagonal. If `m >= p` the nonzero elements of `C` are also on its main diagonal. But if `m < p`, the nonzero diagonal of `C` is `diag(C,p-m)`. This allows the diagonal elements to be ordered so that the generalized singular values are nondecreasing.

`gsvd(A,B,0)`, with three input arguments and either `m` or `n >= p`, produces the "economy-sized"decomposition where the resulting `U` and `V` have at most `p` columns, and `C` and `S` have at most `p` rows. The generalized singular values are `diag(C)./diag(S)`.

When `B` is square and nonsingular, the generalized singular values, `gsvd(A,B)`, are equal to the ordinary singular values, `svd(A/B)`, but they are sorted in the opposite order. Their reciprocals are `gsvd(B,A)`.

In this formulation of the `gsvd`, no assumptions are made about the individual ranks of `A` or `B`. The matrix `X` has full rank if and only if the matrix `[A;B]` has full rank. In fact, `svd(X)` and `cond(X)` are equal to `svd([A;B])` and `cond([A;B])`. Other formulations, eg. G. Golub and

C. Van Loan [1], require that `null(A)` and `null(B)` do not overlap and replace `X` by `inv(X)` or `inv(X')`.

Note, however, that when `null(A)` and `null(B)` do overlap, the nonzero elements of `C` and `S` are not uniquely determined.

Examples

Example 1

The matrices have at least as many rows as columns.

```
A = reshape(1:15,5,3)
B = magic(3)
A =
         1     6    11
         2     7    12
         3     8    13
         4     9    14
         5    10    15
B =
         8     1     6
         3     5     7
         4     9     2
```

The statement

```
[U,V,X,C,S] = gsvd(A,B)
```

produces a 5-by-5 orthogonal `U`, a 3-by-3 orthogonal `V`, a 3-by-3 nonsingular `X`,

```
X =
        2.8284   -9.3761   -6.9346
       -5.6569   -8.3071  -18.3301
        2.8284   -7.2381  -29.7256
```

and

```
C =
        0.0000         0         0
```

```
                0    0.3155         0
                0         0    0.9807
                0         0         0
                0         0         0
S =
           1.0000         0         0
                0    0.9489         0
                0         0    0.1957
```

Since `A` is rank deficient, the first diagonal element of `C` is zero.

The economy sized decomposition,

```
[U,V,X,C,S] = gsvd(A,B,0)
```

produces a 5-by-3 matrix `U` and a 3-by-3 matrix `C`.

```
U =
           0.5700   -0.6457   -0.4279
          -0.7455   -0.3296   -0.4375
          -0.1702   -0.0135   -0.4470
           0.2966    0.3026   -0.4566
           0.0490    0.6187   -0.4661

C =
           0.0000         0         0
                0    0.3155         0
                0         0    0.9807
```

The other three matrices, `V`, `X`, and `S` are the same as those obtained with the full decomposition.

The generalized singular values are the ratios of the diagonal elements of `C` and `S`.

```
sigma = gsvd(A,B)
sigma =
           0.0000
           0.3325
```

```
         5.0123
```

These values are a reordering of the ordinary singular values

```
svd(A/B)
ans =
         5.0123
         0.3325
         0.0000
```

Example 2

The matrices have at least as many columns as rows.

```
A = reshape(1:15,3,5)
B = magic(5)
A =

     1     4     7    10    13
         2     5     8    11    14
         3     6     9    12    15
B =
    17    24     1     8    15
        23     5     7    14    16
         4     6    13    20    22
        10    12    19    21     3
        11    18    25     2     9
```

The statement

```
[U,V,X,C,S] = gsvd(A,B)
```

produces a 3-by-3 orthogonal U, a 5-by-5 orthogonal V, a 5-by-5 nonsingular X and

```
C =
              0         0    0.0000         0         0
              0         0         0    0.0439         0
              0         0         0         0    0.7432
```

```
S =
        1.0000         0         0         0         0
             0    1.0000         0         0         0
             0         0    1.0000         0         0
             0         0         0    0.9990         0
             0         0         0         0    0.6690
```

In this situation, the nonzero diagonal of `C` is `diag(C,2)`. The generalized singular values include three zeros.

```
sigma = gsvd(A,B)
sigma =
             0
             0
        0.0000
        0.0439
        1.1109
```

Reversing the roles of `A` and `B` reciprocates these values, producing two infinities.

```
gsvd(B,A)
ans =
      1.0e+016 *

        0.0000
        0.0000
        4.4126
           Inf
           Inf
```

Algorithm

The generalized singular value decomposition uses the C-S decomposition described in [1], as well as the built-in `svd` and `qr` functions. The C-S decomposition is implemented in a subfunction in the `gsvd` M-file.

Diagnostics

The only warning or error message produced by `gsvd` itself occurs when the two input arguments do not have the same number of columns.

See Also

`qr`, `svd`

References

[1] Golub, Gene H. and Charles Van Loan, *Matrix Computations*, Third Edition, Johns Hopkins University Press, Baltimore, 1996

Purpose

Test for greater than

Syntax

```
A > B
gt(A, B)
```

Description

`A > B` compares each element of array `A` with the corresponding element of array `B`, and returns an array with elements set to logical 1 (`true`) where `A` is greater than `B`, or set to logical 0 (`false`) where `A` is less than or equal to `B`. Each input of the expression can be an array or a scalar value.

If both `A` and `B` are scalar (i.e., 1-by-1 matrices), then MATLAB returns a scalar value.

If both `A` and `B` are nonscalar arrays, then these arrays must have the same dimensions, and MATLAB returns an array of the same dimensions as `A` and `B`.

If one input is scalar and the other a nonscalar array, then the scalar input is treated as if it were an array having the same dimensions as the nonscalar input array. In other words, if input `A` is the number 100, and `B` is a 3-by-5 matrix, then `A` is treated as if it were a 3-by-5 matrix of elements, each set to 100. MATLAB returns an array of the same dimensions as the nonscalar input array.

`gt(A, B)` is called for the syntax `A>B` when either `A` or `B` is an object.

Examples

Create two 6-by-6 matrices, `A` and `B`, and locate those elements of `A` that are greater than the corresponding elements of `B`:

```
A = magic(6);
B = repmat(3*magic(3), 2, 2);

A > B
ans =
     1     0     0     1     1     1
     0     1     0     1     1     1
     1     0     0     1     0     1
     0     1     1     0     1     0
```

```
     1     0     1     1     0     0
     0     1     1     1     0     1
```

See Also

`lt`, `ge`, `le`, `ne`, `eq`, “Relational Operators”

Purpose Mouse placement of text in 2-D view

Syntax

```
gtext('string')
gtext({'string1','string2','string3',...})
gtext({'string1';'string2';'string3';...})
h = gtext(...)
```

Description `gtext` displays a text string in the current figure window after you select a location with the mouse.

`gtext('string')` waits for you to press a mouse button or keyboard key while the pointer is within a figure window. Pressing a mouse button or any key places `'string'` on the plot at the selected location.

`gtext({'string1','string2','string3',...})` places all strings with one click, each on a separate line.

`gtext({'string1';'string2';'string3';...})` places one string per click, in the sequence specified.

`h = gtext(...)` returns the handle to a text graphics object that is placed on the plot at the location you select.

Remarks As you move the pointer into a figure window, the pointer becomes crosshairs to indicate that `gtext` is waiting for you to select a location. `gtext` uses the functions `ginput` and `text`.

Examples Place a label on the current plot:

```
gtext('Note this divergence!')
```

See Also `ginput`, `text`

"Annotating Plots" on page 1-86 for related functions

guidata

Purpose

Store or retrieve GUI data

Syntax

```
guidata(object_handle,data)
data = guidata(object_handle)
```

Description

`guidata(object_handle,data)` stores the variable `data` as GUI data. If `object_handle` is not a figure handle, then the object's parent figure is used. `data` can be any MATLAB variable, but is typically a structure, which enables you to add new fields as required.

`guidata` can manage only one variable at any time. Subsequent calls to `guidata(object_handle,data)` overwrite the previously created version of GUI `data`.

Note for GUIDE Users GUIDE uses `guidata` to store and maintain the `handles` structure. From a GUIDE-generated GUI M-file, do not use `guidata` to store any data other than `handles`. If you do, you may overwrite the `handles` structure and your GUI will not work. If you need to store other data with your GUI, you can add it to the `handles` structure. See GUI Data in the MATLAB documentation.

`data = guidata(object_handle)` returns previously stored data, or an empty matrix if nothing has been stored.

To change the data managed by `guidata`:

1. Get a copy of the data with the command `data = guidata(object_handle)`.
2. Make the desired changes to `data`.
3. Save the changed version of `data` with the command `guidata(object_handle,data)`.

`guidata` provides application developers with a convenient interface to a figure's application data:

- You do not need to create and maintain a hard-coded property name for the application data throughout your source code.
- You can access the data from within a subfunction callback routine using the component's handle (which is returned by `gcbo`), without needing to find the figure's handle.

If you are not using GUIDE, `guidata` is particularly useful in conjunction with `guihandles`, which creates a structure containing the handles of all the components in a GUI.

Examples

In this example, `guidata` is used to save a structure on a GUI figure's application data from within the initialization section of the application M-file. This structure is initially created by `guihandles` and then used to save additional data as well.

```
% create structure of handles
myhandles = guihandles(figure_handle);
% add some additional data
myhandles.numberOfErrors = 0;
% save the structure
guidata(figure_handle,myhandles)
```

You can recall the data from within a subfunction callback routine and then save the structure again:

```
% get the structure in the subfunction
myhandles = guidata(gcbo);
myhandles.numberOfErrors = myhandles.numberOfErrors + 1;
% save the changes to the structure
guidata(gcbo,myhandles)
```

See Also

`guide`, `guihandles`, `getappdata`, `setappdata`

guide

Purpose Open GUI Layout Editor

Syntax

```
guide
guide('filename.fig')
guide('fullpath')
guide(HandleList)
```

Description

`guide` initiates the GUI design environment (GUIDE) tools that allow you to create or edit GUIs interactively.

`guide` opens the GUIDE Quick Start dialog where you can choose to open a previously created GUI or create a new one using one of the provided templates.

`guide('filename.fig')` opens the FIG-file named `filename.fig` for editing if it is on the MATLAB path.

`guide('fullpath')` opens the FIG-file at `fullpath` even if it is not on the MATLAB path.

`guide(HandleList)` opens the content of each of the figures in `HandleList` in a separate copy of the GUIDE design environment.

See Also

`inspect`

Creating GUIs

Purpose Create structure of handles

Syntax

```
handles = guihandles(object_handle)
handles = guihandles
```

Description

`handles = guihandles(object_handle)` returns a structure containing the handles of the objects in a figure, using the value of their `Tag` properties as the fieldnames, with the following caveats:

- Objects are excluded if their `Tag` properties are empty, or are not legal variable names.
- If several objects have the same `Tag`, that field in the structure contains a vector of handles.
- Objects with hidden handles are included in the structure.

`handles = guihandles` returns a structure of handles for the current figure.

See Also

`guidata`, `guide`, `getappdata`, `setappdata`

Purpose

Uncompress GNU zip files

Syntax

```
gunzip(files)
gunzip(files,outputdir)
gunzip(url, ...)
filenames = gunzip(...)
```

Description

`gunzip(files)` uncompresses GNU zip files from the list of files specified in `files`. Directories recursively gunzip all of their content. The output files have the same name, excluding the extension `.gz`, and are written to the same directory as the input files.

`files` is a string or cell array of strings containing a list of files or directories. Individual files that are on the MATLAB path can be specified as partial pathnames. 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 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 filename or partial pathname.

`gunzip(files,outputdir)` writes the gunzipped file into the directory `outputdir`. `outputdir` is created if it does not exist.

`gunzip(url, ...)` extracts the GNU zip contents from an Internet universal resource locator (URL). The URL must include the protocol type (e.g., `'http://'`). The URL is downloaded to the temp directory and deleted.

`filenames = gunzip(...)` gunzips the files and returns the relative pathnames of the gunzipped files in the string cell array `filenames`.

Examples

To gunzip all `.gz` files in the current directory,

```
gunzip('*.gz');
```

To gunzip Cleve Moler's "Numerical Computing with MATLAB" examples to the output directory ncm:

```
url ='http://www.mathworks.com/moler/ncm.tar.gz';
gunzip(url,'ncm')
untar('ncm/ncm.tar','ncm')
```

See Also

gzip, tar, untar, unzip, zip

Purpose

Compress files into GNU zip files

Syntax

```
gzip(files)
gzip(files,outputdir)
filenames = gzip(...)
```

Description

`gzip(files)` creates GNU zip files from the list of files specified in `files`. Directories recursively `gzip` all their contents. Each output gzipped file is written to the same directory as the input file and with the file extension `.gz`.

`files` is a string or cell array of strings containing a list of files or directories to `gzip`. Individual files that are on the MATLAB path can be specified as partial pathnames. 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 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 filename or partial pathname.

`gzip(files,outputdir)` writes the gzipped files into the directory `outputdir`. `outputdir` is created if it does not exist.

`filenames = gzip(...)` gzips the files and returns the relative pathnames of all gzipped files in the string cell array `filenames`.

Example

To `gzip` all `.m` and `.mat` files in the current directory and store the results in the directory `archive`,

```
gzip({'*.m','*.mat'},'archive');
```

See Also

`gunzip`, `tar`, `untar`, `unzip`, `zip`

Purpose

Hadamard matrix

Syntax

```
H = hadamard(n)
```

Description

`H = hadamard(n)` returns the Hadamard matrix of order `n`.

Definition

Hadamard matrices are matrices of `1`'s and `-1`'s whose columns are orthogonal,

```
H'*H = n*I
```

where `[n n]=size(H)` and `I = eye(n,n)` ,.

They have applications in several different areas, including combinatorics, signal processing, and numerical analysis, [1], [2].

An `n`-by-`n` Hadamard matrix with `n > 2` exists only if `rem(n,4) = 0`. This function handles only the cases where `n`, `n/12`, or `n/20` is a power of 2.

Examples

The command `hadamard(4)` produces the 4-by-4 matrix:

```
1     1     1     1
1    -1     1    -1
1     1    -1    -1
1    -1    -1     1
```

See Also

`compan`, `hankel`, `toeplitz`

References

[1] Ryser, H. J., *Combinatorial Mathematics*, John Wiley and Sons, 1963.

[2] Pratt, W. K., *Digital Signal Processing*, John Wiley and Sons, 1978.

hankel

Purpose

Hankel matrix

Syntax

```
H = hankel(c)
H = hankel(c,r)
```

Description

`H = hankel(c)` returns the square Hankel matrix whose first column is `c` and whose elements are zero below the first anti-diagonal.

`H = hankel(c,r)` returns a Hankel matrix whose first column is `c` and whose last row is `r`. If the last element of `c` differs from the first element of `r`, the last element of `c` prevails.

Definition

A Hankel matrix is a matrix that is symmetric and constant across the anti-diagonals, and has elements `h(i,j) = p(i+j-1)`, where vector `p = [c r(2:end)]` completely determines the Hankel matrix.

Examples

A Hankel matrix with anti-diagonal disagreement is

```
c = 1:3; r = 7:10;
h = hankel(c,r)
h =
    1    2    3    8
    2    3    8    9
    3    8    9   10

p = [1 2 3 8 9 10]
```

See Also

`hadamard`, `toeplitz`, `kron`

Purpose

Summary of MATLAB HDF4 capabilities

Description

MATLAB provides a set of low-level functions that enable you to access the HDF4 library developed by the National Center for Supercomputing Applications (NCSA). For information about HDF4, go to the HDF Web page at `http://www.hdfgroup.org`.

Note For information about MATLAB HDF5 capabilities, which is a completely separate, incompatible format, see `hdf5`.

The following table lists all the HDF4 application programming interfaces (APIs) supported by MATLAB with the name of the MATLAB function used to access the API. To use these functions, you must be familiar with the HDF library. For more information about using these MATLAB functions, see Working with Scientific Data Formats.

Application Programming Interface	Description	MATLAB Function
Annotations	Stores, manages, and retrieves text used to describe an HDF file or any of the data structures contained in the file.	`hdfan`
General Raster Images	Stores, manages, and retrieves raster images, their dimensions and palettes. It can also manipulate unattached palettes. Note: Use the MATLAB functions `imread` and `imwrite` with HDF raster image formats.	`hdfdf24`, `hdfdfr8`

Application Programming Interface	Description	MATLAB Function
HDF-EOS	Provides functions to read HDF-EOS grid (GD), point (PT), and swath (SW) data.	`hdfgd`, `hdfpt`, `hdfsw`
HDF Utilities	Provides functions to open and close HDF files and handle errors.	`hdfh`, `hdfhd`, `hdfhe`
MATLAB HDF Utilitie	Provides utility functions that help you work with HDF files in the MATLAB environment.	`hdfml`
Scientific Data	Stores, manages, and retrieves multidimensional arrays of character or numeric data, along with their dimensions and attributes.	`hdfsd`
V Groups	Creates and retrieves groups of other HDF data objects, such as raster images or V data.	`hdfv`
V Data	Stores, manages, and retrieves multivariate data stored as records in a table.	`hdfvf`, `hdfvh`, `hdfvs`

See Also

`hdfinfo`,`hdfread`, `hdftool`, `imread`

Purpose Summary of MATLAB HDF5 capabilities

Description MATLAB provides both high-level and low-level access to HDF5 files. The high-level access functions make it easy to read a data set from an HDF5 file or write a variable from the MATLAB workspace into an HDF5 file. The MATLAB low-level interface provides direct access to the more than 200 functions in the HDF5 library. MATLAB currently supports version HDF5-1.6.5 of the library.

Note For information about MATLAB HDF4 capabilities, which is a completely separate, incompatible format, see `hdf`.

The following sections provide an overview of both this high- and low-level access. To use these MATLAB functions, you must be familiar with HDF5 programming concepts and, when using the low-level functions, details about the functions in the library. To get this information, go to the HDF Web page at `http://www.hdfgroup.org`.

High-level Access

MATLAB includes three functions that provide high-level access to HDF5 files:

- `hdf5info`
- `hdf5read`
- `hdf5write`

Using these functions you can read data and metadata from an HDF5 file and write data from the MATLAB workspace to a file in HDF5 format. For more information about these functions, see their individual reference pages.

Low-level Access

MATLAB provides direct access to the over 200 functions in the HDF5 Library. Using these functions, you can read and write complex datatypes, utilize HDF5 data subsetting capabilities, and take advantage of other features present in the HDF5 library.

The HDF5 library organizes the routines in the library into interfaces. MATLAB organizes the corresponding MATLAB functions into class directories that match these HDF5 library interfaces. For example, the MATLAB functions for the HDF5 Attribute Interface are in the @H5A class directory.

The following table lists all the HDF5 library interfaces in alphabetical order by name. The table includes the name of the associated MATLAB class directory.

HDF5 Library Interface	MATLAB Class Directory	Description
Attribute	`@H5A`	Manipulate metadata associated with data sets or groups
Dataset	`@H5D`	Manipulate multidimensional arrays of data elements, together with supporting metadata
Dataspace	`@H5S`	Define and work with data spaces, which describe the the dimensionality of a data set
Datatype	`@H5T`	Define the type of variable that is stored in a data set
Error	`@H5E`	Handle errors
File	`@H5F`	Access files
Filters and Compression	`@H5Z`	Create inline data filters and data compression
Group	`@H5G`	Organize objects in a file; analogous to a directory structure
Identifier	`@H5I`	Manipulate HDF5 object identifiers

HDF5 Library Interface	MATLAB Class Directory	Description
Library	@H5	General-purpose functions for use with the entire HDF5 library, such as initialization
MATLAB	@H5ML	MATLAB utility functions that are not part of the HDF5 library itself.
Property	@H5P	Manipulate object property lists
Reference	@H5R	Manipulate HDF5 references, which are like UNIX links or Windows shortcuts

In most cases, the syntax of the MATLAB function is identical to the syntax of the HDF5 library function. To get detailed information about the MATLAB syntax of an HDF5 library function, view the help for the individual MATLAB function, as follows:

```
help @H5F/open
```

To view a list of all the MATLAB HDF5 functions in a particular interface, type:

```
help imagesci/@H5F
```

See Also

`hdf`, `hdf5info`, `hdf5read`, `hdf5write`

hdf5info

Purpose

Information about HDF5 file

Syntax

```
fileinfo = hdf5info(filename)
fileinfo = hdf5info(...,'ReadAttributes',BOOL)
[...] = hdf5info(..., 'V71Dimensions', BOOL)
```

Description

`fileinfo = hdf5info(filename)` returns a structure `fileinfo` whose fields contain information about the contents of the HDF5 file `filename`. `filename` is a string that specifies the name of the HDF5 file.

`fileinfo = hdf5info(...,'ReadAttributes',BOOL)` specifies whether `hdf5info` returns the values of the attributes or just information describing the attributes. By default, `hdf5info` reads in attribute values (`BOOL = true`).

`[...]  = hdf5info(..., 'V71Dimensions', BOOL)` specifies whether to report the dimensions of data sets and attributes as they were returned in previous versions of `hdf5info` (MATLAB 7.1 [R14SP3] and earlier). If `BOOL` is true, `hdf5info` swaps the first two dimensions of the data set. This behavior was intended to account for the difference in how HDF5 and MATLAB express array dimenions. HDF5 describes data set dimensions in row-major order; MATLAB stores data in column-major order. However, swapping these dimensions may not correctly reflect the intent of the data in the file and may invalidate metadata. When `BOOL` is false (the default), `hdf5info` returns data dimensions that correctly reflect the data ordering as it is written in the file—each dimension in the output variable matches the same dimension in the file.

Note If you use the `'V71Dimensions'` parameter and intend on passing the `fileinfo` structure returned to the `hdf5read` function, you should also specify the `'V71Dimensions'` parameters with `hdf5read`. If you do not, `hdf5read` uses the new behavior when reading the data set and certain metadata returned by `hdf5info` does not match the actual data returned by `hdf5read`.

Examples

```
fileinfo = hdf5info('example.h5')

fileinfo =

         Filename: 'example.h5'
       LibVersion: '1.4.5'
           Offset: 0
         FileSize: 8172
   GroupHierarchy: [1x1 struct]
```

To get more information about the contents of the HDF5 file, look at the `GroupHierarchy` field in the `fileinfo` structure returned by `hdf5info`.

```
toplevel = fileinfo.GroupHierarchy

toplevel =

      Filename: [1x64 char]
          Name: '/'
        Groups: [1x2 struct]
      Datasets: []
     Datatypes: []
         Links: []
    Attributes: [1x2 struct]
```

To probe further into the file hierarchy, keep examining the `Groups` field.

See also

`hdf5read`, `hdf5write`

hdf5read

Purpose

Read HDF5 file

Syntax

```
data = hdf5read(filename,datasetname)
attr = hdf5read(filename,attributename)
[data, attr] = hdf5read(...,'ReadAttributes',BOOL)
data = hdf5read(hinfo)
[...] = hdf5read(..., 'V71Dimensions', BOOL)
```

Description

`data = hdf5read(filename,datasetname)` reads all the data in the data set `datasetname` that is stored in the HDF5 file `filename` and returns it in the variable `data`. To determine the names of data sets in an HDF5 file, use the `hdf5info` function.

The return value, `data`, is a multidimensional array. `hdf5read` maps HDF5 data types to native MATLAB data types, whenever possible. If it cannot represent the data using MATLAB data types, `hdf5read` uses one of the HDF5 data type objects. For example, if an HDF5 file contains a data set made up of an enumerated data type, `hdf5read` uses the `hdf5.h5enum` object to represent the data in the MATLAB workspace. The `hdf5.h5enum` object has data members that store the enumerations (names), their corresponding values, and the enumerated data. For more information about the HDF5 data type objects, see the `hdf5` reference page.

`attr = hdf5read(filename,attributename)` reads all the metadata in the attribute `attributename`, stored in the HDF5 file `filename`, and returns it in the variable `attr`. To determine the names of attributes in an HDF5 file, use the `hdf5info` function.

`[data, attr] = hdf5read(...,'ReadAttributes',BOOL)` reads all the data, as well as all of the associated attribute information contained within that data set. By default, `BOOL` is false.

`data = hdf5read(hinfo)` reads all of the data in the data set specified in the structure `hinfo` and returns it in the variable `data`. The `hinfo` structure is extracted from the output returned by `hdf5info`, which specifies an HDF5 file and a specific data set.

`[...] = hdf5read(..., 'V71Dimensions', BOOL)` specifies whether to change the majority of data sets read from the file. If `BOOL` is true, `hdf5read` permutes the first two dimensions of the data set, as it did in previous releases (MATLAB 7.1 [R14SP3] and earlier). This behavior was intended to account for the difference in how HDF5 and MATLAB express array dimensions. HDF5 describes data set dimensions in row-major order; MATLAB stores data in column-major order. However, permuting these dimensions may not correctly reflect the intent of the data and may invalidate metadata. When `BOOL` is false (the default), the data dimensions correctly reflect the data ordering as it is written in the file — each dimension in the output variable matches the same dimension in the file.

Examples

Use `hdf5info` to get information about an HDF5 file and then use `hdf5read` to read a data set, using the information structure (`hinfo`) returned by `hdf5info` to specify the data set.

```
hinfo = hdf5info('example.h5');
dset = hdf5read(hinfo.GroupHierarchy.Groups(2).Datasets(1));
```

See Also

`hdf5`, `hdf5info`, `hdf5write`

Purpose

Write data to file in HDF5 format

Syntax

```
hdf5write(filename,location,dataset)
hdf5write(filename,details,dataset)
hdf5write(filename,details,attribute)
hdf5write(filename, details1, dataset1, details2, dataset2,
   ...)
hdf5write(filename,...,'WriteMode',mode,...)
hdf5write(..., 'V71Dimensions', BOOL)
```

Description

`hdf5write(filename,location,dataset)` writes the data `dataset` to the HDF5 file, `filename`. If `filename` does not exist, `hdf5write` creates it. If `filename` exists, `hdf5write` overwrites the existing file, by default, but you can also append data to an existing file using an optional syntax.

`location` defines where to write the data set in the file. HDF5 files are organized in a hierarchical structure similar to a UNIX directory structure. `location` is a string that resembles a UNIX path.

`hdf5write` maps the data in `dataset` to HDF5 data types according to rules outlined below.

`hdf5write(filename,details,dataset)` writes `dataset` to `filename` using the values in the `details` structure. For a data set, the `details` structure can contain the following fields.

Field Name	Description	Data Type
`Location`	Location of the data set in the file	Character array
`Name`	Name to attach to the data set	Character array

`hdf5write(filename,details,attribute)` writes the metadata `attribute` to `filename` using the values in the `details` structure. For an attribute, the `details` structure can contain following fields.

Field Name	Description	Data Type
`AttachedTo`	Location of the object this attribute modifies	Structure array
`AttachType`	Identifies what kind of object this attribute modifies; possible values are `'group'` and `'dataset'`	Character array
`Name`	Name to attach to the data set	Character array

`hdf5write(filename, details1, dataset1, details2, dataset2,...)` writes multiple data sets and associated attributes to `filename` in one operation. Each data set and attribute must have an associated `details` structure.

`hdf5write(filename,...,'WriteMode',mode,...)` specifies whether `hdf5write` overwrites the existing file (the default) or appends data sets and attributes to the file. Possible values for mode are `'overwrite'` and `'append'`.

`hdf5write(..., 'V71Dimensions', BOOL)` specifies whether to change the majority of data sets written to the file. If `BOOL` is true, `hdf5write` permutes the first two dimensions of the data set, as it did in previous releases (MATLAB 7.1 [R14SP3] and earlier). This behavior was intended to account for the difference in how HDF5 and MATLAB express array dimensions. HDF5 describes data set dimensions in row-major order; MATLAB stores data in column-major order. However, permuting these dimensions may not correctly reflect the intent of the data and may invalidate metadata. When `BOOL` is false (the default), the data written to the file correctly reflects the data ordering of the data sets — each dimension in the file's data sets matches the same dimension in the corresponding MATLAB variable.

Data Type Mappings

The following table lists how `hdf5write` maps the data type from the workspace into an HDF5 file. If the data in the workspace that is being written to the file is a MATLAB data type, `hdf5write` uses the following rules when translating MATLAB data into HDF5 data objects.

MATLAB Data Type	HDF5 Data Set or Attribute
Numeric	Corresponding HDF5 native data type. For example, if the workspace data type is `uint8`, the `hdf5write` function writes the data to the file as 8-bit integers. The size of the HDF5 dataspace is the same size as the MATLAB array.
String	Single, null-terminated string
Cell array of strings	Multiple, null-terminated strings, each the same length. Length is determined by the length of the longest string in the cell array. The size of the HDF5 dataspace is the same size as the cell array.
Cell array of numeric data	Numeric array, the same dimensions as the cell array. The elements of the array must all have the same size and type. The data type is determined by the first element in the cell array.
Structure array	HDF5 compound type. Individual fields in the structure employ the same data translation rules for individual data types. For example, a cell array of strings becomes a multiple, null-terminated strings.
HDF5 objects	If the data being written to the file is composed of HDF5 objects, `hdf5write` uses the same data type when writing to the file. For all HDF5 objects, except `HDF5.h5enum` objects, the dataspace has the same dimensions as the array of HDF5 objects passed to the function. For `HDF5.h5enum` objects, the size and dimensions of the data set in the HDF5 file is the same as the object's Data field.

Examples

Write a 5-by-5 data set of `uint8` values to the root group.

```
hdf5write('myfile.h5', '/dataset1', uint8(magic(5)))
```

Write a 2-by-2 string data set in a subgroup.

```
dataset = {'north', 'south'; 'east', 'west'};
hdf5write('myfile2.h5', '/group1/dataset1.1', dataset);
```

Write a data set and attribute to an existing group.

```
dset = single(rand(10,10));
dset_details.Location = '/group1/dataset1.2';
dset_details.Name = 'Random';

attr = 'Some random data';
attr_details.Name = 'Description';
attr_details.AttachedTo = '/group1/dataset1.2/Random';
attr_details.AttachType = 'dataset';

hdf5write('myfile2.h5', dset_details, dset, ...
          attr_details, attr, 'WriteMode', 'append');
```

Write a data set using objects.

```
dset = hdf5.h5array(magic(5));
hdf5write('myfile3.h5', '/g1/objects', dset);
```

See Also

`hdf5`, `hdf5read`, `hdf5info`

hdfinfo

Purpose

Information about HDF4 or HDF-EOS file

Syntax

```
S = hdfinfo(filename)
S = hdfinfo(filename,mode)
```

Description

`S = hdfinfo(filename)` returns a structure `S` whose fields contain information about the contents of an HDF4 or HDF-EOS file. `filename` is a string that specifies the name of the HDF4 file.

`S = hdfinfo(filename,mode)` reads the file as an HDF4 file, if `mode` is `'hdf'`, or as an HDF-EOS file, if `mode` is `'eos'`. If `mode` is `'eos'`, only HDF-EOS data objects are queried. To retrieve information on the entire contents of a file containing both HDF4 and HDF-EOS objects, `mode` must be `'hdf'`.

Note `hdfinfo` can be used on Version 4.x HDF files or Version 2.x HDF-EOS files. To get information about an HDF5 file, use `hdf5info`.

The set of fields in the returned structure `S` depends on the individual file. Fields that can be present in the `S` structure are shown in the following table.

Mode	Field Name	Description	Return Type
`HDF`	`Attributes`	Attributes of the data set	Structure array
	`Description`	Annotation description	Cell array
	`Filename`	Name of the file	String
	`Label`	Annotation label	Cell array
	`Raster8`	Description of 8-bit raster images	Structure array

Mode	Field Name	Description	Return Type
	`Raster24`	Description of 24-bit raster images	Structure array
	`SDS`	Description of scientific data sets	Structure array
	`Vdata`	Description of Vdata sets	Structure array
	`Vgroup`	Description of Vgroups	Structure array
`EOS`	`Filename`	Name of the file	String
	`Grid`	Grid data	Structure array
	`Point`	Point data	Structure array
	`Swath`	Swath data	Structure array

Those fields in the table above that contain structure arrays are further described in the tables shown below.

Fields Common to Returned Structure Arrays

Structure arrays returned by `hdfinfo` contain some common fields. These are shown in the table below. Not all structure arrays will contain all of these fields.

Field Name	Description	Data Type
`Attributes`	Data set attributes. Contains fields `Name` and `Value`.	Structure array
`Description`	Annotation description	Cell array
`Filename`	Name of the file	String
`Label`	Annotation label	Cell array

Field Name	Description	Data Type
`Name`	Name of the data set	String
`Rank`	Number of dimensions of the data set	Double
`Ref`	Data set reference number	Double
`Type`	Type of HDF or HDF-EOS object	String

Fields Specific to Certain Structures

Structure arrays returned by `hdfinfo` also contain fields that are unique to each structure. These are shown in the tables below.

Fields of the Attribute Structure

Field Name	Description	Data Type
`Name`	Attribute name	String
`Value`	Attribute value or description	Numeric or string

Fields of the Raster8 and Raster24 Structures

Field Name	Description	Data Type
`HasPalette`	`1` (`true`) if the image has an associated palette, otherwise `0` (`false`) (8-bit only)	Logical
`Height`	Height of the image, in pixels	Number
`Interlace`	Interlace mode of the image (24-bit only)	String
`Name`	Name of the image	String
`Width`	Width of the image, in pixels	Number

Fields of the SDS Structure

Field Name	Description	Data Type
DataType	Data precision	String
Dims	Dimensions of the data set. Contains fields Name, DataType, Size, Scale, and Attributes. Scale is an array of numbers to place along the dimension and demarcate intervals in the data set.	Structure array
Index	Index of the SDS	Number

Fields of the Vdata Structure

Field Name	Description	Data Type
DataAttributes	Attributes of the entire data set. Contains fields Name and Value.	Structure array
Class	Class name of the data set	String
Fields	Fields of the Vdata. Contains fields Name and Attributes.	Structure array
NumRecords	Number of data set records	Double
IsAttribute	1 (true) if Vdata is an attribute, otherwise 0 (false)	Logical

Fields of the Vgroup Structure

Field Name	Description	Data Type
Class	Class name of the data set	String

Field Name	Description	Data Type
Raster8	Description of the 8-bit raster image	Structure array
Raster24	Description of the 24-bit raster image	Structure array
SDS	Description of the Scientific Data sets	Structure array
Tag	Tag of this Vgroup	Number
Vdata	Description of the Vdata sets	Structure array
Vgroup	Description of the Vgroups	Structure array

Fields of the Grid Structure

Field Name	Description	Data Type
Columns	Number of columns in the grid	Number
DataFields	Description of the data fields in each Grid field of the grid. Contains fields Name, Rank, Dims, NumberType, FillValue, and TileDims.	Structure array
LowerRight	Lower right corner location, in meters	Number
Origin Code	Origin code for the grid	Number
PixRegCode	Pixel registration code	Number

Field Name	Description	Data Type
Projection	Projection code, zone code, sphere code, and projection parameters of the grid. Contains fields ProjCode, ZoneCode, SphereCode, and ProjParam.	Structure
Rows	Number of rows in the grid	Number
UpperLeft	Upper left corner location, in meters	Number

Fields of the Point Structure

Field Name	Description	Data Type
Level	Description of each level of the point. Contains fields Name, NumRecords, FieldNames, DataType, and Index.	Structure

Fields of the Swath Structure

Field Name	Description	Data Type
DataFields	Data fields in the swath. Contains fields Name, Rank, Dims, NumberType, and FillValue.	Structure array
GeolocationFields	Geolocation fields in the swath. Contains fields Name, Rank, Dims, NumberType, and FillValue.	Structure array

Field Name	Description	Data Type
IdxMapInfo	Relationship between indexed elements of the geolocation mapping. Contains fields Map and Size.	Structure
MapInfo	Relationship between data and geolocation fields. Contains fields Map, Offset, and Increment.	Structure

Examples

To retrieve information about the file example.hdf,

```
fileinfo = hdfinfo('example.hdf')

fileinfo =
    Filename: 'example.hdf'
         SDS: [1x1 struct]
       Vdata: [1x1 struct]
```

And to retrieve information from this about the scientific data set in example.hdf,

```
sds_info = fileinfo.SDS

sds_info =
       Filename: 'example.hdf'
           Type: 'Scientific Data Set'
           Name: 'Example SDS'
           Rank: 2
       DataType: 'int16'
     Attributes: []
           Dims: [2x1 struct]
          Label: {}
    Description: {}
          Index: 0
```

See Also

`hdfread`, `hdf`

hdfread

Purpose

Read data from HDF4 or HDF-EOS file

Syntax

```
data = hdfread(filename, datasetname)
data = hdfread(hinfo.fieldname)
data = hdfread(...,param1,value1,param2,value2,...)
[data,map] = hdfread(...)
```

Description

`data = hdfread(filename, datasetname)` returns all the data in the data set specified by `datasetname` from the HDF4 or HDF-EOS file specified by `filename`. To determine the name of a data set in an HDF4 file, use the `hdfinfo` function.

Note `hdfread` can be used on Version 4.x HDF files or Version 2.x HDF-EOS files. To read data from and HDF5 file, use `hdf5read`.

`data = hdfread(hinfo.`*`fieldname`*`)` returns all the data in the data set specified by `hinfo.`*`fieldname`*, where `hinfo` is the structure returned by the `hdfinfo` function and *`fieldname`* is the name of a field in the structure that relates to a particular type of data set. For example, to read an HDF scientific data set, specify the `SDS` field, as in `hinfo.SDS`. To read HDF V data, specify the `Vdata` field, as in `hinfo.Vdata`. `hdfread` can get the name of the HDF file from these structures.

`data = hdfread(...,param1,value1,param2,value2,...)` returns subsets of the data according to the specified parameter and value pairs. See the tables below to find the valid parameters and values for different types of data sets.

`[data,map] = hdfread(...)` returns the image `data` and the colormap `map` for an 8-bit raster image.

Subsetting Parameters

The following tables show the subsetting parameters that can be used with the `hdfread` function for certain types of HDF4 data. These data types are

- HDF Scientific Data (SD)
- HDF Vdata (V)
- HDF-EOS Grid Data
- HDF-EOS Point Data
- HDF-EOS Swath Data

Note the following:

- If a parameter requires multiple values, the values must be stored in a cell array. For example, the `'Index'` parameter requires three values: `start`, `stride`, and `edge`. Enclose these values in curly braces as a cell array.

```
hdfread(dataset_name, 'Index', {start,stride,edge})
```

- All values that are indices are 1-based.

Subsetting Parameters for HDF Scientific Data (SD) Data Sets

When you are working with HDF SD files, `hdfread` supports the parameters listed in this table.

Parameter	Description
'Index'	Three-element cell array, {start,stride,edge}, specifying the location, range, and values to be read from the data set • start — A 1-based array specifying the position in the file to begin reading Default: 1, start at the first element of each dimension. The values specified must not exceed the size of any dimension of the data set. • stride — A 1-based array specifying the interval between the values to read Default: 1, read every element of the data set. • edge — A 1-based array specifying the length of each dimension to read Default: An array containing the lengths of the corresponding dimensions

For example, this code reads the data set Example SDS from the HDF file example.hdf. The 'Index' parameter specifies that hdfread start reading data at the beginning of each dimension, read until the end of each dimension, but only read every other data value in the first dimension.

```
hdfread('example.hdf','Example SDS', ...
                     'Index', {[], [2 1], []})
```

Subsetting Parameters for HDF Vdata Sets

When you are working with HDF Vdata files, hdfread supports these parameters.

Parameter	Description
'Fields'	Text string specifying the name of the data set field to be read from. When specifying multiple field names, use a comma-separated list.
'FirstRecord'	1-based number specifying the record from which to begin reading
'NumRecords'	Number specifying the total number of records to read

For example, this code reads the Vdata set `Example Vdata` from the HDF file `example.hdf`.

```
hdfread('example.hdf', 'Example Vdata', 'FirstRecord', 400,...
        'NumRecords', 50)
```

Subsetting Parameters for HDF-EOS Grid Data

When you are working with HDF-EOS grid data, `hdfread` supports three types of parameters:

- Required parameters
- Optional parameters
- Mutually exclusive parameters — You can only specify one of these parameters in a call to `hdfread`, and you cannot use these parameters in combination with any optional parameter.

Parameter	Description
Required Parameter	
'Fields'	String naming the data set field to be read. You can specify only one field name for a Grid data set.
Mutually Exclusive Optional Parameters	

Parameter	Description
'Index'	Three-element cell array, {start,stride,edge}, specifying the location, range, and values to be read from the data set start — An array specifying the position in the file to begin reading Default: 1, start at the first element of each dimension. The values must not exceed the size of any dimension of the data set. stride — An array specifying the interval between the values to read Default: 1, read every element of the data set. edge — An array specifying the length of each dimension to read Default: An array containing the lengths of the corresponding dimensions
'Interpolate'	Two-element cell array, {longitude,latitude}, specifying the longitude and latitude points that define a region for bilinear interpolation. Each element is an N-length vector specifying longitude and latitude coordinates.
'Pixels'	Two-element cell array, {longitude,latitude}, specifying the longitude and latitude coordinates that define a region. Each element is an N-length vector specifying longitude and latitude coordinates. This region is converted into pixel rows and columns with the origin in the upper left corner of the grid. Note: This is the pixel equivalent of reading a 'Box' region.
'Tile'	Vector specifying the coordinates of the tile to read, for HDF-EOS Grid files that support tiles
Optional Parameters	
'Box'	Two-element cell array, {longitude,latitude}, specifying the longitude and latitude coordinates that define a region. longitude and latitude are each two-element vectors specifying longitude and latitude coordinates.

Parameter	Description
'Time'	Two-element cell array, [start stop], where start and stop are numbers that specify the start and end-point for a period of time
'Vertical'	Two-element cell array, {dimension, range} dimension — String specifying the name of the data set field to be read from. You can specify only one field name for a Grid data set. range — Two-element array specifying the minimum and maximum range for the subset. If dimension is a dimension name, then range specifies the range of elements to extract. If dimension is a field name, then range specifies the range of values to extract. 'Vertical' subsetting can be used alone or in conjunction with 'Box' or 'Time'. To subset a region along multiple dimensions, vertical subsetting can be used up to eight times in one call to hdfread.

For example,

```
hdfread(grid_dataset, 'Fields', fieldname, ...
                'Vertical', {dimension, [min, max]})
```

Subsetting Parameters for HDF-EOS Point Data

When you are working with HDF-EOS Point data, hdfread has two required parameters and three optional parameters.

Parameter	Description
Required Parameters	
'Fields'	String naming the data set field to be read. For multiple field names, use a comma-separated list.
'Level'	1-based number specifying which level to read from in an HDF-EOS Point data set
Optional Parameters	

Parameter	Description
'Box'	Two-element cell array, {longitude,latitude}, specifying the longitude and latitude coordinates that define a region. longitude and latitude are each two-element vectors specifying longitude and latitude coordinates.
'RecordNumbers'	Vector specifying the record numbers to read
'Time'	Two-element cell array, [start stop], where start and stop are numbers that specify the start and endpoint for a period of time

For example,

```
hdfread(point_dataset, 'Fields', {field1, field2}, ...
        'Level', level, 'RecordNumbers', [1:50, 200:250])
```

Subsetting Parameters for HDF-EOS Swath Data

When you are working with HDF-EOS Swath data, hdfread supports three types of parameters:

- Required parameters
- Optional parameters
- Mutually exclusive

You can only use one of the mutually exclusive parameters in a call to hdfread, and you cannot use these parameters in combination with any optional parameter.

Parameter	Description
Required Parameter	
'Fields'	String naming the data set field to be read. You can specify only one field name for a Swath data set.
Mutually Exclusive Optional Parameters	

Parameter	Description
'Index'	Three-element cell array, {start,stride,edge}, specifying the location, range, and values to be read from the data set • start — An array specifying the position in the file to begin reading Default: 1, start at the first element of each dimension. The values must not exceed the size of any dimension of the data set. • stride — An array specifying the interval between the values to read Default: 1, read every element of the data set. • edge — An array specifying the length of each dimension to read Default: An array containing the lengths of the corresponding dimensions
'Time'	Three-element cell array, {start, stop, mode}, where start and stop specify the beginning and the endpoint for a period of time, and mode is a string defining the criterion for the inclusion of a cross track in a region. The cross track is within a region if any of these conditions is met: • Its midpoint is within the box (mode='midpoint'). • Either endpoint is within the box (mode='endpoint'). • Any point is within the box (mode='anypoint').
Optional Parameters	

Parameter	Description
'Box'	Three-element cell array, {longitude, latitude, mode} specifying the longitude and latitude coordinates that define a region. longitude and latitude are two-element vectors that specify longitude and latitude coordinates. mode is a string defining the criterion for the inclusion of a cross track in a region. The cross track is within a region if any of these conditions is met: • Its midpoint is within the box (mode='midpoint'). • Either endpoint is within the box (mode='endpoint'). • Any point is within the box (mode='anypoint').
'ExtMode'	String specifying whether geolocation fields and data fields must be in the same swath (mode='internal'), or can be in different swaths (mode='external') Note: mode is only used when extracting a time period or a region.
'Vertical'	Two-element cell array, {dimension, range} • dimension is a string specifying either a dimension name or field name to subset the data by. • range is a two-element vector specifying the minimum and maximum range for the subset. If dimension is a dimension name, then range specifies the range of elements to extract. If dimension is a field name, then range specifies the range of values to extract. 'Vertical' subsetting can be used alone or in conjunction with 'Box' or 'Time'. To subset a region along multiple dimensions, vertical subsetting can be used up to eight times in one call to hdfread.

For example,

```
hdfread('example.hdf', swath_dataset, 'Fields', fieldname, ...
```

```
'Time', {start, stop, 'midpoint'})
```

Examples

Example 1

Specify the name of the HDF file and the name of the data set. This example reads a data set named 'Example SDS' from a sample HDF file.

```
data = hdfread('example.hdf', 'Example SDS')
```

Example 2

Use data returned by hdfinfo to specify the data set to read.

1. Call hdfinfo to retrieve information about the contents of the HDF file.

   ```
   fileinfo = hdfinfo('example.hdf')
   fileinfo =

       Filename: 'N:\toolbox\matlab\demos\example.hdf'
            SDS: [1x1 struct]
          Vdata: [1x1 struct]
   ```

2. Extract the structure containing information about the particular data set you want to import from the data returned by hdfinfo. The example uses the structure in the SDS field to retrieve a scientific data set.

   ```
   sds_info = fileinfo.SDS
   sds_info =

         Filename: 'N:\toolbox\matlab\demos\example.hdf'
             Type: 'Scientific Data Set'
             Name: 'Example SDS'
             Rank: 2
         DataType: 'int16'
       Attributes: []
             Dims: [2x1 struct]
            Label: {}
   ```

```
        Description: {}
              Index: 0
```

3 You can pass this structure to `hdfread` to import the data in the data set.

```
data = hdfread(sds_info)
```

Example 3

You can use the information returned by `hdfinfo` to check the size of the data set.

```
sds_info.Dims.Size
ans =
    16
ans =
     5
```

Using the `'index'` parameter with `hdfread`, you can read a subset of the data in the data set. This example specifies a starting index of `[3 3]`, an interval of 1 between values (`[]` meaning the default value of 1), and a length of 10 rows and 2 columns.

```
data = hdfread(sds_info, 'Index', {[3 3],[],[10 2]});

data(:,1)
ans =
     7
     8
     9
    10
    11
    12
    13
    14
    15
    16
```

```
data(:,2)
ans =
     8
     9
    10
    11
    12
    13
    14
    15
    16
    17
```

Example 4

This example uses the `Vdata` field from the information returned by `hdfinfo` to read two fields of the data, `Idx` and `Temp`.

```
info = hdfinfo('example.hdf');

data = hdfread(info.Vdata,...
   'Fields',{'Idx','Temp'})

data =
    [1x10 int16]
    [1x10 int16]

index = data{1,1};
temp = data{2,1};

temp(1:6)
ans =
     0    12     3     5    10    -1
```

See Also

`hdfinfo`, `hdf`

Purpose

Browse and import data from HDF4 or HDF-EOS files

Syntax

```
hdftool
hdftool(filename)
h = hdftool(...)
```

Description

`hdftool` starts the HDF Import Tool, a graphical user interface used to browse the contents of HDF4 and HDF-EOS files and import data and subsets of data from these files. To open an HDF4 or HDF-EOS file, select **Open** from the **File** menu. You can open multiple files in the HDF Import Tool by selecting **Open** from the **File** menu.

`hdftool(filename)` opens the HDF4 or HDF-EOS file specified by `filename` in the HDF Import Tool.

`h = hdftool(...)` returns a handle `h` to the HDF Import Tool. To close the tool from the command line, use `close(h)`.

Example

```
hdftool('example.hdf');
```

See Also

`hdf`, `hdfinfo`, `hdfread`, `uiimport`

Purpose

Help for MATLAB functions in Command Window

GUI Alternatives

Use the Help browser **Contents** for a product to view **Functions — Alphabetical List** or **Functions — By Category**, or run `doc functionname` to view more extensive help for a function in the Help browser.

Syntax

```
help
help /
help functionname
help modelname.mdl
help toolboxname
help toolboxname/functionname
help classname.methodname
help classname
help syntax
t = help('topic')
```

Description

`help` lists all primary help topics in the Command Window. Each main help topic corresponds to a directory name on the MATLAB search path.

`help /` lists all operators and special characters, along with their descriptions.

`help functionname` displays M-file help, which is a brief description and the syntax for `functionname`, in the Command Window. The output includes a link to `doc functionname`, which displays the reference page in the Help browser, often providing additional information. Output also includes see also links, which display help in the Command Window for related functions. If `functionname` is overloaded, that is, appears in multiple directories on the search path, `help` displays the M-file help for the first `functionname` found on the search path, and displays a hyperlinked list of the overloaded functions and their directories. If `functionname` is also the name of a toolbox, `help` also displays a list of subdirectories and hyperlinked list of functions in the toolbox, as defined in the `Contents.m` file for the toolbox.

`help modelname.mdl` displays the complete description for the MDL-file `modelname` as defined in **Model Properties > Description**. If Simulink is installed, you do not need to specify the `.mdl` extension.

`help toolboxname` displays the `Contents.m` file for the specified directory named `toolboxname`, where `Contents.m` contains a list and corresponding description of M-files in `toolboxname` — see the Remarks topic, "Creating Contents Files for Your Own M-File Directories" on page 2-1492. It is not necessary to give the full pathname of the directory; the last component, or the last several components, are sufficient. If `toolboxname` is also a function name, help also displays the M-file help for the function `toolboxname`.

`help toolboxname/functionname` displays the M-file help for the `functionname` that resides in the `toolboxname` directory. Use this form to get direct help for an overloaded function.

`help classname.methodname` displays help for the method `methodname` of the fully qualified class `classname`. If you do not know the fully qualified class for the method, use `class(obj)`, where `methodname` is of the same class as the object `obj`.

`help classname` displays help for the fully qualified class `classname`.

`help` **`syntax`** displays M-file help describing the syntax used in MATLAB commands and functions.

`t = help('topic')` returns the help text for `topic` as a string, with each line separated by `/n`, where `topic` is any allowable argument for `help`.

Note M-file help displayed in the Command Window uses all uppercase characters for the function and variable names to make them stand out from the rest of the text. When typing function names, however, use lowercase characters. Some functions for interfacing to Java do use mixed case; the M-file help accurately reflects that and you should use mixed case when typing them. For example, the `javaObject` function uses mixed case.

Remarks

To prevent long descriptions from scrolling off the screen before you have time to read them, enter `more on`, and then enter the `help` statement.

Creating Online Help for Your Own M-Files

The MATLAB help system, like MATLAB itself, is highly extensible. You can write help descriptions for your own M-files and toolboxes using the same self-documenting method that MATLAB M-files and toolboxes use.

The `help` function lists all help topics by displaying the first line (the H1 line) of the contents files in each directory on the MATLAB search path. The contents files are the M-files named `Contents.m` within each directory.

Typing `helptopic` , where `topic` is a directory name, displays the comment lines in the `Contents.m` file located in that directory. If a contents file does not exist, `help` displays the H1 lines of all the files in the directory.

Typing `help topic`, where `topic` is a function name, displays help for the function by listing the first contiguous comment lines in the M-file `topic.m`.

Create self-documenting online help for your own M-files by entering text on one or more contiguous comment lines, beginning with the second line of the file (first line if it is a script). For example, the function `soundspeed.m` begins with

```
function c=soundspeed(s,t,p)
% soundspeed computes the speed of sound in water
% where c is the speed of sound in water in m/s

t = 0:.1:35;
```

When you execute `help soundspeed`, MATLAB displays

```
soundspeed computes the speed of sound in water
where c is the speed of sound in water in m/s
```

These lines are the first block of contiguous comment lines. After the first contiguous comment lines, enter an executable statement or blank line, which effectively ends the help section. Any later comments in the M-file do not appear when you type `help` for the function.

The first comment line in any M-file (the H1 line) is special. It should contain the function name and a brief description of the function. The `lookfor` function searches and displays this line, and `help` displays these lines in directories that do not contain a `Contents.m` file. For the `soundspeed` example, the H1 line is

```
% soundspeed computes speed of sound in water
```

Use the "Help Report" to help you create and manage M-file help for your own files.

Creating Contents Files for Your Own M-File Directories

A `Contents.m` file is provided for each M-file directory included with the MATLAB software. If you create directories in which to store your own M-files, it is a good practice to create `Contents.m` files for them, too. Use the "Contents Report" to help you create and maintain your own `Contents.m` files.

Examples

`help close` displays help for the `close` function.

`help database/close` displays help for the `close` function in Database Toolbox.

`help datafeed` displays help for Datafeed Toolbox.

`help database` lists the functions in Database Toolbox and displays help for the `database` function, because there are a function and a toolbox called `database`.

`help general` lists all functions in the directory *`matlabroot`*`/toolbox/matlab/general`. This illustrates how to specify a relative partial pathname rather than a full pathname.

`help f14_dap` displays the description of the Simulink `f14_dap.mdl` model file (Simulink must be installed.).

`t = help('close')` gets help for the function `close` and stores it as a string in `t`.

See Also

`class`, `doc`, `docsearch`, `helpbrowser`, `helpwin`, `lookfor`, `more`, `partialpath`, `path`, `what`, `which`, `whos`

helpbrowser

Purpose

Open Help browser to access all online documentation and demos

GUI Alternatives

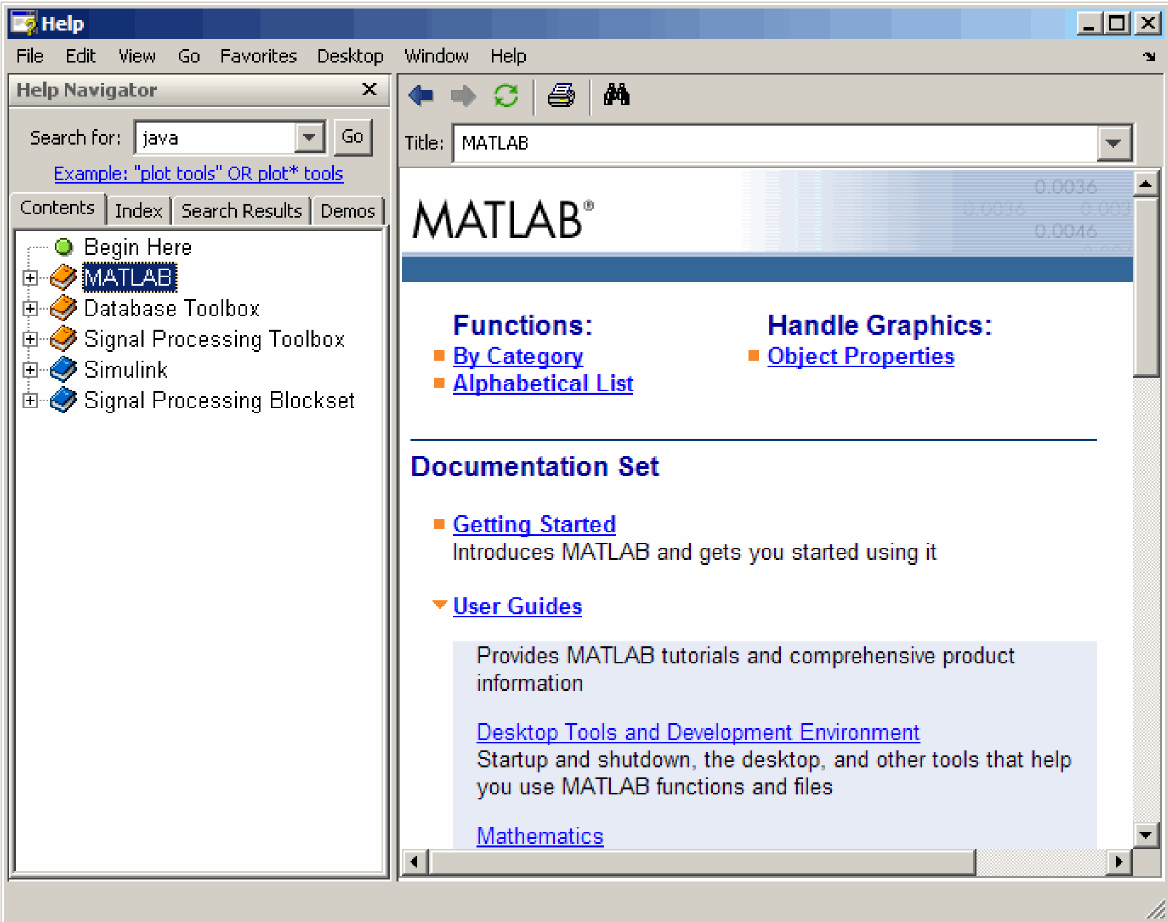
As an alternative to the `helpbrowser` function, select **Desktop > Help** or click the Help button on the toolbar in the MATLAB desktop.

Syntax

```
helpbrowser
```

Description

`helpbrowser` displays the Help browser, providing direct access to a comprehensive library of online documentation, including reference pages and user guides. If the Help browser was previously opened in the current session, `helpbrowser` shows the last page viewed; otherwise it shows the **Begin Here** page. For details, see the “Help Browser Overview” topic in the MATLAB Desktop Tools and Development Environment documentation.



See Also

`builddocsearchdb`, `doc`, `docopt`, `docsearch`, `help`, `helpdesk`, `helpwin`, `lookfor`, `web`

helpdesk

Purpose

Open Help browser

Syntax

```
helpdesk
```

Description

`helpdesk` displays the Help browser and shows the "Begin Here" page. In previous releases, `helpdesk` displayed the Help Desk, which was the precursor to the Help browser. In a future release, the `helpdesk` function will be phased out — use the `doc` or `helpbrowser` function instead.

See Also

`doc`, `helpbrowser`

Purpose

Create and open help dialog box

Syntax

```
helpdlg
helpdlg('helpstring')
helpdlg('helpstring','dlgname')
h = helpdlg(...)
```

Description

`helpdlg` creates a nonmodal help dialog box or brings the named help dialog box to the front.

Note A nonmodal dialog box enables the user to interact with other windows before responding. For more information, see `WindowStyle` in the MATLAB Figure Properties.

`helpdlg` displays a dialog box named `'Help Dialog'` containing the string `'This is the default help string.'`

`helpdlg('helpstring')` displays a dialog box named `'Help Dialog'` containing the string specified by `'helpstring'`.

`helpdlg('helpstring','dlgname')` displays a dialog box named `'dlgname'` containing the string `'helpstring'`.

`h = helpdlg(...)` returns the handle of the dialog box.

Remarks

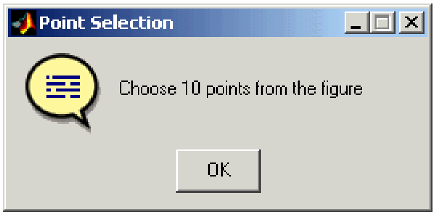
MATLAB wraps the text in `'helpstring'` to fit the width of the dialog box. The dialog box remains on your screen until you press the **OK** button or the **Enter** key. After either of these actions, the help dialog box disappears.

Examples

The statement

```
helpdlg('Choose 10 points from the figure','Point Selection');
```

displays this dialog box:



See Also

`dialog`, `errordlg`, `inputdlg`, `listdlg`, `msgbox`, `questdlg`, `warndlg`

`figure`, `uiwait`, `uiresume`

"Predefined Dialog Boxes" on page 1-103 for related functions

Purpose

Provide access to M-file help for all functions

Syntax

```
helpwin
helpwin topic
```

Description

`helpwin` lists topics for groups of functions in the Help browser. It shows brief descriptions of the topics and provides links to display M-file help for the functions in the Help browser. You cannot follow links in the `helpwin` list of functions if MATLAB is busy (for example, running a program).

`helpwin topic` displays help information for the topic in the Help browser. If `topic` is a directory, it displays all functions in the directory. If `topic` is a function, `helpwin` displays M-file help for that function in the Help browser. From the page, you can access a list of directories (**Default Topics** link) as well as the reference page help for the function (**Go to online doc** link). You cannot follow links in the `helpwin` list of functions if MATLAB is busy (for example, running a program).

Examples

Typing

```
helpwin datafun
```

displays the functions in the `datafun` directory and a brief description of each.

Typing

```
helpwin fft
```

displays the M-file help for the `fft` function in the Help browser.

See Also

`doc`, `docopt`, `help`, `helpbrowser`, `lookfor`, `web`

hess

Purpose

Hessenberg form of matrix

Syntax

```
H = hess(A)
[P,H] = hess(A)
[AA,BB,Q,Z] = HESS(A,B)
```

Description

`H = hess(A)` finds `H`, the Hessenberg form of matrix `A`.

`[P,H] = hess(A)` produces a Hessenberg matrix `H` and a unitary matrix `P` so that `A = P*H*P'` and `P'*P = eye(size(A))`.

`[AA,BB,Q,Z] = HESS(A,B)` for square matrices `A` and `B`, produces an upper Hessenberg matrix `AA`, an upper triangular matrix `BB`, and unitary matrices `Q` and `Z` such that `Q*A*Z = AA` and `Q*B*Z = BB`.

Definition

A Hessenberg matrix is zero below the first subdiagonal. If the matrix is symmetric or Hermitian, the form is tridiagonal. This matrix has the same eigenvalues as the original, but less computation is needed to reveal them.

Examples

`H` is a 3-by-3 eigenvalue test matrix:

```
H =
    -149     -50    -154
     537     180     546
     -27      -9     -25
```

Its Hessenberg form introduces a single zero in the (3,1) position:

```
hess(H) =
    -149.0000    42.2037   -156.3165
    -537.6783   152.5511   -554.9272
            0     0.0728      2.4489
```

Algorithm

Inputs of Type Double

For inputs of type double, `hess` uses the following LAPACK routines to compute the Hessenberg form of a matrix:

Matrix A	Routine
Real symmetric	DSYTRD DSYTRD, DORGTR, (with output P)
Real nonsymmetric	DGEHRD DGEHRD, DORGHR (with output P)
Complex Hermitian	ZHETRD ZHETRD, ZUNGTR (with output P)
Complex non-Hermitian	ZGEHRD ZGEHRD, ZUNGHR (with output P)

Inputs of Type Single

For inputs of type `single`, `hess` uses the following LAPACK routines to compute the Hessenberg form of a matrix:

Matrix A	Routine
Real symmetric	SSYTRD SSYTRD, DORGTR, (with output P)
Real nonsymmetric	SGEHRD SGEHRD, SORGHR (with output P)
Complex Hermitian	CHETRD CHETRD, CUNGTR (with output P)
Complex non-Hermitian	CGEHRD CGEHRD, CUNGHR (with output P)

See Also

`eig`, `qz`, `schur`

References

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 Convert hexadecimal number string to decimal number

Syntax

```
d = hex2dec('hex_value')
```

Description `d = hex2dec('hex_value')` converts *hex_value* to its floating-point integer representation. The argument *hex_value* is a hexadecimal integer stored in a MATLAB string. The value of *hex_value* must be smaller than hexadecimal `10,000,000,000,000`.

If *hex_value* is a character array, each row is interpreted as a hexadecimal string.

Examples

```
hex2dec('3ff')

ans =

        1023
```

For a character array `S`,

```
S =
0FF
2DE
123
hex2dec(S)

ans =

255
734
291
```

See Also `dec2hex`, `format`, `hex2num`, `sprintf`

hex2num

Purpose Convert hexadecimal number string to double-precision number

Syntax

```
n = hex2num(S)
```

Description `n = hex2num(S)`, where `S` is a 16 character string representing a hexadecimal number, returns the IEEE double-precision floating-point number `n` that it represents. Fewer than 16 characters are padded on the right with zeros. If `S` is a character array, each row is interpreted as a double-precision number.

`NaN`s, infinities and denorms are handled correctly.

Example

```
hex2num('400921fb54442d18')
```

returns `Pi`.

```
hex2num('bff')
```

returns

```
ans =

     -1
```

See Also `num2hex`, `hex2dec`, `sprintf`, `format`

Purpose

Export figure

GUI Alternative

Use the **File —> Saveas** on the figure window menu to access the **Export Setup** GUI. Use **Edit —> Copy Figure** to copy the figure's contents to your system's clipboard. For details, see How to Print or Export in the MATLAB Graphics documentation.

Syntax

```
hgexport(h,filename)
hgexport(h,'-clipboard')
```

Description

`hgexport(h,filename)` writes figure `h` to the file `filename`.

`hgexport(h,'-clipboard')` writes figure `h` to the Windows clipboard.

The format in which the figure is exported is determined by which renderer you use. The Painters renderer generates a metafile. The ZBuffer and OpenGL renderers generate a bitmap.

See Also

`print`

hggroup

Purpose Create hggroup object

Syntax

Description An hggroup object can be the parent of any axes children except light objects, as well as other hggroup objects. You can use hggroup objects to form a group of objects that can be treated as a single object with respect to the following cases:

- Visible — Setting the hggroup object's `Visible` property also sets each child object's `Visible` property to the same value.
- Selectable — Setting each hggroup child object's `HitTest` property to `off` enables you to select all children by clicking any child object.
- Current object — Setting each hggroup child object's `HitTest` property to `off` enables the hggroup object to become the current object when any child object is picked. See the next section for an example.

Examples This example defines a callback for the `ButtonDownFcn` property of an hggroup object. In order for the hggroup to receive the mouse button down event that executes the `ButtonDownFcn` callback, the `HitTest` properties of all the line objects must be set to `off`. The event is then passed up the hierarchy to the hggroup.

The following function creates a random set of lines that are parented to an hggroup object. The subfunction `set_lines` defines a callback that executes when the mouse button is pressed over any of the lines. The callback simply increases the widths of all the lines by 1 with each button press.

Note If you are using the MATLAB help browser, you can run this example or open it in the MATLAB editor.

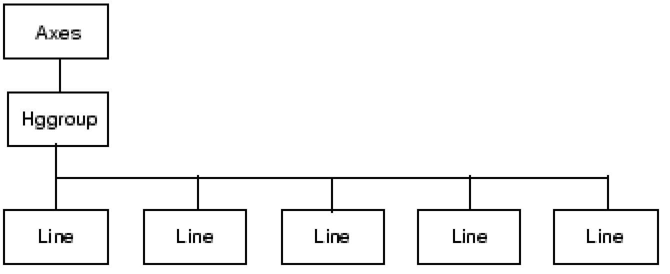
```
function doc_hggroup
```

```
hg = hggroup('ButtonDownFcn',@set_lines);
hl  = line(randn(5),randn(5),'HitTest','off','Parent',hg);

function set_lines(cb,eventdata)
hl = get(cb,'Children');% cb is handle of hggroup object
lw = get(hl,'LineWidth');% get current line widths
set(hl,{'LineWidth'},num2cell([lw{:}]+1,[5,1])')
```

Note that selecting any one of the lines selects all the lines. (To select an object, enable plot edit mode by selecting **Plot Edit** from the **Tools** menu.)

Instance Diagram for This Example

The following diagram shows the object hierarchy created by this example.



Hggroup Properties

Setting Default Properties

You can set default hggroup properties on the axes, figure, and root levels.

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

where *`Property`* is the name of the `hggroup` property whose default value you want to set and `PropertyValue` is the value you are specifying. Use `set` and `get` to access the hggroup properties.

See Also

`hgtransform`

"Group Objects" for more information and examples.

"Function Handle Callbacks" for information on how to use function handles to define callbacks.

`Hggroup Properties` for property descriptions

Purpose

Hggroup properties

Modifying Properties

You can set and query graphics object properties using the `set` and `get` commands.

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

See "Group Objects" for general information on this type of object.

Hggroup Property Descriptions

This section provides a description of properties. Curly braces { } enclose default values.

`BeingDeleted`

`on | {off}` Read Only

This object is being deleted. The `BeingDeleted` property provides a mechanism that you can use to determine whether 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`

functional 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 children of the hggroup object. Define the `ButtonDownFcn` as a function handle. The function must define at least two input arguments (handle of figure associated with the mouse button press and an empty event structure).

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

`Children`

array of graphics object handles

Children of the hggroup object. An array containing the handles of all objects parented to the hggroup object (whether visible or not).

Note that if a child object's `HandleVisibility` property is set to `callback` or `off`, its handle does not appear in the hggroup `Children` property unless you set the Root `ShowHiddenHandles` property to `on`:

```
set(0,'ShowHiddenHandles','on')
```

`Clipping`
: `{on} | off`

Clipping mode. MATLAB clips stairs plots to the axes plot box by default. If you set `Clipping` to `off`, lines might be displayed outside the axes plot box.

`CreateFcn`
: functional handle, cell array containing function handle and additional arguments, or string (not recommended)

Callback executed during object creation. This property defines a callback function that executes when MATLAB creates an hggroup object. You must define this property as a default value for hggroup objects or in a call to the `hggroup` function to create a new hggroup object. For example, the statement

```
set(0,'DefaulthggroupCreateFcn',@myCreateFcn)
```

defines a default value on the root level that applies to every hggroup object created in that MATLAB session. Whenever you create an hggroup object, the function associated with the function handle `@myCreateFcn` executes.

MATLAB executes the callback after setting all the hggroup object's properties. Setting the `CreateFcn` property on an existing hggroup 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`

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

Callback executed during object deletion. A callback function that executes when the hggroup object is deleted (e.g., this might happen when you issue a `delete` command on the hggroup 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 passed by MATLAB as the first argument to the callback function and is 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.

See the `BeingDeleted` property for related information.

`EraseMode`

`{normal} | none | xor | background`

Erase mode. This property controls the technique MATLAB uses to draw and erase hggroup child 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.

- 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.

Set the axes background color with the axes Color property. Set the figure background color with the figure Color property.

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 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 the hggroup object.

- `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.

`HitTest`
`{on} | off`

Pickable by mouse click. `HitTest` determines whether the hggroup 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 hggroup child objects. Note that to pick the hggroup object, its children must have their `HitTest` property set to `off`.

If the hggroup object's `HitTest` is `off`, clicking it picks the object behind it.

`Interruptible`
`{on} | off`

Callback routine interruption mode. The `Interruptible` property controls whether an hggroup object 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 an hggroup 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.

`Parent`
: axes handle

Parent of hggroup object. This property contains the handle of the hggroup object's parent object. The parent of an hggroup 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 you set this property to `on`, MATLAB displays selection handles at the corners and midpoints of hggroup child objects if the `SelectionHighlight` property is also `on` (the default).

`SelectionHighlight`
: `{on} | off`

Objects are highlighted when selected. When the `Selected` property is `on`, MATLAB indicates the selected state by drawing selection handles on the hggroup child objects. 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 global variables or pass them as arguments between callbacks.

For example, you might create an hggroup object and set the Tag property:

```
t = hggroup('Tag','group1')
```

When you want to access the object, you can use findobj to find its handle. For example,

```
h = findobj('Tag','group1');
```

Type
string (read only)

Type of graphics object. This property contains a string that identifies the class of graphics object. For hggroup 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 the hggroup object. Assign this property the handle of a uicontextmenu object created in the hggroup object's figure. Use the uicontextmenu function to create the context menu. MATLAB displays the context menu whenever you right-click the hggroup object.

UserData
array

User-specified data. This property can be any data you want to associate with the hggroup object (including cell arrays and structures). The hggroup object does not set values for this property, but you can access it using the `set` and `get` functions.

`Visible`

`{on} | off`

Visibility of hggroup object and its children. By default, hggroup object visibility is `on`. This means all children of the hggroup are visible unless the child object's `Visible` property is set to `off`. Setting an hggroup object's `Visible` property to `off` also makes its children invisible.

Purpose

Load Handle Graphics object hierarchy from file

GUI Alternative

Use the **File —> Open** on the figure window menu to access figure files with the **Open** dialog.

Syntax

```
h = hgload('filename')
[h,old_prop_values] = hgload(...,property_structure)
hgload(...,'all')
```

Description

`h = hgload('filename')` loads Handle Graphics objects and its children if any from the FIG-file specified by `filename` and returns handles to the top-level objects. If `filename` contains no extension, then MATLAB adds the `.fig` extension.

`[h,old_prop_values] = hgload(...,property_structure)` verrides the properties on the top-level objects stored in the FIG-file with the values in `property_structure`, and returns their previous values in `old_prop_values`.

`property_structure` must be a structure having field names that correspond to property names and values that are the new property values.

`old_prop_values` is a cell array equal in length to `h`, containing the old values of the overridden properties for each object. Each cell contains a structure having field names that are property names, each of which contains the original value of each property that has been changed. Any property specified in `property_structure` that is not a property of a top-level object in the FIG-file is not included in `old_prop_values`.

`hgload(...,'all')` overrides the default behavior, which does not reload nonserializable objects saved in the file. These objects include the default toolbars and default menus.

Nonserializable objects (such as the default toolbars and the default menus) are normally not reloaded because they are loaded from different files at figure creation time. This allows revisions of the default menus and toolbars to occur without affecting existing FIG-files.

Passing the string `all` to `hgload` ensures that any nonserializable objects contained in the file are also reloaded.

Note that, by default, `hgsave` excludes nonserializable objects from the FIG-file unless you use the `all` flag.

See Also

`hgsave`, `open`

"Figure Windows" on page 1-94 for related functions

Purpose

Save Handle Graphics object hierarchy to file

GUI Alternative

Use the **File —> Saveas** on the figure window menu to access the Export Setup GUI. For details, see How to Print or Export in the MATLAB Graphics documentation.

Syntax

```
hgsave('filename')
hgsave(h,'filename')
hgsave(...,'all')
hgsave(...,'-v6')
```

Description

`hgsave('filename')` saves the current figure to a file named `filename`.

`hgsave(h,'filename')` saves the objects identified by the array of handles `h` to a file named `filename`. If you do not specify an extension for `filename`, then MATLAB adds the extension `.fig`. If `h` is a vector, none of the handles in `h` may be ancestors or descendents of any other handles in `h`.

`hgsave(...,'all')` overrides the default behavior, which does not save nonserializable objects. Nonserializable objects include the default toolbars and default menus. This allows revisions of the default menus and toolbars to occur without affecting existing FIG-files and also reduces the size of FIG-files. Passing the string `all` to `hgsave` ensures that nonserializable objects are also saved.

Note: the default behavior of `hgload` is to ignore nonserializable objects in the file at load time. This behavior can be overwritten using the `all` argument with `hgload`.

`hgsave(...,'-v6')` saves the FIG-file in a format that can be loaded by versions prior to MATLAB 7.

Full Backward Compatibility

When creating a figure you want to save and use in a MATLAB version prior to MATLAB 7, use the `'v6'` option with the plotting function and the `'-v6'` option for `hgsave`. Check the reference page for the plotting function you are using for more information.

See "Plot Objects and Backward Compatibility" for more information.

See Also

`hgload`, `open`, `save`

"Figure Windows" on page 1-94 for related functions

Purpose

Create hgtransform graphics object

Syntax

```
h = hgtransform
h = hgtransform('PropertyName',propertyvalue,...)
```

Description

`h = hgtransform` creates an hgtransform object and returns its handle.

`h = hgtransform('PropertyName',propertyvalue,...)` creates an hgtransform object with the property value settings specified in the argument list.

Hgtransform objects can contain other objects and thereby enable you to treat the hgtransform and its children as a single entity with respect to visibility, size, orientation, etc. You can group objects together by parenting them to a single hgtransform object (i.e., setting the object's `Parent` property to the hgtransform object's handle). For example,

```
h = hgtransform;
surface('Parent',h,...)
```

The primary advantage of parenting objects to an hgtransform object is that it provides the ability to perform *transforms* (e.g., translation, scaling, rotation, etc.) on the child objects in unison.

The parent of an hgtransform object is either an axes object or another hgtransform.

Although you cannot see an hgtransform object, setting its `Visible` property to `off` makes all its children invisible as well.

Exceptions and Limitations

- An hgtransform object can be the parent of any number axes children objects belonging to the same axes, with the exception of light objects.
- hgtransform objects can never be the parent of axes objects and therefore can contain objects only from a single axes.
- hgtransform objects can be the parent of other hgtransform objects within the same axes.

- You cannot transform image objects because images are not true 3-D objects. Texture mapping the image data to a surface `CData` enables you to produce the effect of transforming an image in 3-D space.

Note Many plotting functions clear the axes (i.e., remove axes children) before drawing the graph. Clearing the axes also deletes any hgtransform objects in the axes.

More Information

- The references in the "See Also" on page 2-1528 section for information on types of transforms
- The "Examples" on page 2-1524 section provides examples that illustrate the use of transforms.

Examples

Transforming a Group of Objects

This example shows how to create a 3-D star with a group of surface objects parented to a single hgtransform object. The hgtransform object is then rotated about the *z*-axis while its size is scaled.

Note If you are using the MATLAB help browser, you can run this example or open it in the MATLAB editor.

---

1 Create an axes and adjust the view. Set the axes limits to prevent auto limit selection during scaling.

```
ax = axes('XLim',[-1.5 1.5],'YLim',[-1.5 1.5],...
 'ZLim',[-1.5 1.5]);
view(3); grid on; axis equal
```

2 Create the objects you want to parent to the hgtransform object.

```
[x y z] = cylinder([.2 0]);
```

```
h(1) = surface(x,y,z,'FaceColor','red');
h(2) = surface(x,y,-z,'FaceColor','green');
h(3) = surface(z,x,y,'FaceColor','blue');
h(4) = surface(-z,x,y,'FaceColor','cyan');
h(5) = surface(y,z,x,'FaceColor','magenta');
h(6) = surface(y,-z,x,'FaceColor','yellow');
```

3 Create an hgtransform object and parent the surface objects to it.

```
t = hgtransform('Parent',ax);
set(h,'Parent',t)
```

4 Select a renderer and show the objects.

```
set(gcf,'Renderer','opengl')
drawnow
```

5 Initialize the rotation and scaling matrix to the identity matrix (`eye`).

```
Rz = eye(4);
Sxy = Rz;
```

6 Form the *z*-axis rotation matrix and the scaling matrix. Rotate 360 degrees (2*pi radians) and scale by using the increasing values of r.

```
for r = 1:.1:2*pi
 % Z-axis rotation matrix
 Rz = makehgtform('zrotate',r);
 % Scaling matrix
 Sxy = makehgtform('scale',r/4);
 % Concatenate the transforms and
 % set the hgtransform Matrix property
    set(t,'Matrix',Rz*Sxy)
    drawnow
end
pause(1)
```

7 Reset to the original orientation and size using the identity matrix.

```
set(t,'Matrix',eye(4))
```

Transforming Objects Independently

This example creates two hgtransform objects to illustrate how each can be transformed independently within the same axes. One of the hgtransform objects has been moved (by translation) away from the origin.

Note If you are using the MATLAB help browser, you can run this example or open it in the MATLAB editor.

---

1 Create and set up the axes object that will be the parent of both hgtransform objects. Set the limits to accommodate the translated object.

```
ax = axes('XLim',[-2 1],'YLim',[-2 1],'ZLim',[-1 1]);
view(3); grid on; axis equal
```

2 Create the surface objects to group.

```
[x y z] = cylinder([.3 0]);
h(1) = surface(x,y,z,'FaceColor','red');
h(2) = surface(x,y,-z,'FaceColor','green');
h(3) = surface(z,x,y,'FaceColor','blue');
h(4) = surface(-z,x,y,'FaceColor','cyan');
h(5) = surface(y,z,x,'FaceColor','magenta');
h(6) = surface(y,-z,x,'FaceColor','yellow');
```

3 Create the hgtransform objects and parent them to the same axes.

```
t1 = hgtransform('Parent',ax);
t2 = hgtransform('Parent',ax);
```

4 Set the renderer to use OpenGL.

```
set(gcf,'Renderer','opengl')
```

5 Parent the surfaces to hgtransform t1, then copy the surface objects and parent the copies to hgtransform t2.

```
set(h,'Parent',t1)
h2 = copyobj(h,t2);
```

6 Translate the second hgtransform object away from the first hgtransform object and display the result.

```
Txy = makehgtform('translate',[-1.5 -1.5 0]);
set(t2,'Matrix',Txy)
drawnow
```

7 Rotate both hgtransform objects in opposite directions. Hgtransform t2 has already been translated away from the origin, so to rotate it about its *z*-axis you must first translate it to its original position. You can do this with the identity matrix (eye).

```
% rotate 10 times (2pi radians = 1 rotation)
for r = 1:.1:20*pi
 % Form z-axis rotation matrix
 Rz = makehgtform('zrotate',r);
 % Set transforms for both hgtransform objects
 set(t1,'Matrix',Rz)
 set(t2,'Matrix',Txy*inv(Rz)*I)
 drawnow
end
```

Setting Default Properties

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

```
set(0,'DefaultHgtransformPropertyName',propertyvalue,...)
set(gcf,'DefaultHgtransformPropertyName',propertyvalue,...)
set(gca,'DefaultHgtransformPropertyName',propertyvalue,...)
```

where *PropertyName* is the name of the hgtransform property and propertyvalue is the value you are specifying. Use set and get to access hgtransform properties.

See Also

`hggroup`, `makehgtform`

For more information about transforms, see Tomas Moller and Eric Haines, *Real-Time Rendering*, A K Peters, Ltd., 1999.

"Group Objects" for more information and examples.

`Hgtransform Properties` for property descriptions

Purpose

Hgtransform properties

Modifying Properties

You can set and query graphics object properties using the `set` and `get` commands.

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

See "Group Objects" for general information on this type of object.

Hgtransform Property Descriptions

This section provides a description of properties. Curly braces { } enclose default values.

`BeingDeleted`
`on | {off}` Read Only

This object is being deleted. The `BeingDeleted` property provides a mechanism that you can use to determine whether 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 callback functions. If there is a callback 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`

functional 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 within the extent of the hgtransform object, but not over another graphics object. The extent of an hgtransform object is the smallest rectangle that encloses all the children. Note that you cannot execute the hgtransform object's button down function if it has no children.

Define the `ButtonDownFcn` as a function handle. The function must define at least two input arguments (handle of figure associated with the mouse button press and an empty event structure).

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

`Children`

array of graphics object handles

Children of the hgtransform object. An array containing the handles of all graphics objects parented to the hgtransform object (whether visible or not).

The graphics objects that can be children of an hgtransform are images, lights, lines, patches, rectangles, surfaces, and text. You can change the order of the handles and thereby change the stacking of the objects on the display.

Note that if a child object's `HandleVisibility` property is set to `callback` or `off`, its handle does not show up in the hgtransform `Children` property unless you set the Root `ShowHiddenHandles` property to `on`.

`Clipping`
`{on} | off`

This property has no effect on hgtransform objects.

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

Callback executed during object creation. This property defines a callback function that executes when MATLAB creates an hgtransform object. You must define this property as a default value for hgtransform objects. For example, the statement

```
set(0,'DefaultHgtransformCreateFcn',@myCreateFcn)
```

defines a default value on the root level that applies to every hgtransform object created in a MATLAB session. Whenever you create an hgtransform object, the function associated with the function handle `@myCreateFcn` executes.

MATLAB executes the callback after setting all the hgtransform object's properties. Setting the `CreateFcn` property on an existing hgtransform 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 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`

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

Callback executed during object deletion. A callback function that executes when the hgtransform object is deleted (e.g., this might happen when you issue a `delete` command on the hgtransform 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 passed by MATLAB as the first argument to the callback function and is accessible 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.

`EraseMode`

`{normal} | none | xor | background`

Erase mode. This property controls the technique MATLAB uses to draw and erase hgtransform child objects (light objects have no erase mode). 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.

  Set the axes background color with the axes `Color` property. Set the figure background color with the figure `Color` property.

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 operation on a pixel color and 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 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 the hgtransform object.

- `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.

`HitTest`
`{on} | off`

Pickable by mouse click. `HitTest` determines whether the hgtransform object can become the current object (as returned by the `gco` command and the figure `CurrentObject` property) as a result of a mouse click within the limits of the hgtransform object. If `HitTest` is `off`, clicking the hgtransform picks the object behind it.

`Interruptible`
`{on} | off`

Callback routine interruption mode. The `Interruptible` property controls whether an hgtransform object 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 an hgtransform 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.

`Matrix`

4-by-4 matrix

Transformation matrix applied to hgtransform object and its children. The hgtransform object applies the transformation matrix to all its children.

See "Group Objects" for more information and examples.

`Parent`

figure handle

Parent of hgtransform object. This property contains the handle of the hgtransform object's parent object. The parent of an hgtransform 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 you set this property to `on`, MATLAB displays selection handles on all child objects of the hgtransform if the `SelectionHighlight` property is also `on` (the default).

`SelectionHighlight`

`{on} | off`

Objects are highlighted when selected. When the `Selected` property is `on`, MATLAB indicates the selected state by drawing selection handles on the objects parented to the hgtransform. 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 global variables or pass them as arguments between callbacks.

For example, you might create an hgtransform object and set the `Tag` property:

```
t = hgtransform('Tag','subgroup1')
```

When you want to access the hgtransform object to add another object, you can use `findobj` to find the hgtransform object's handle. The following statement adds a line to `subgroup1` (assuming `x` and `y` are defined).

```
line('XData',x,'YData',y,'Parent',findobj('Tag','subgroup1'))
```

`Type`
string (read only)

Type of graphics object. This property contains a string that identifies the class of graphics object. For hgtransform objects, `Type` is set to '`hgtransform`'. The following statement finds all the hgtransform objects in the current axes.

```
t = findobj(gca,'Type','hgtransform');
```

`UIContextMenu`
handle of a uicontextmenu object

Associate a context menu with the hgtransform object. Assign this property the handle of a uicontextmenu object created in the hgtransform object's figure. Use the `uicontextmenu` function to create the context menu. MATLAB displays the context menu whenever you right-click over the extent of the hgtransform object.

`UserData`
array

User-specified data. This property can be any data you want to associate with the hgtransform object (including cell arrays and structures). The hgtransform object does not set values for this property, but you can access it using the `set` and `get` functions.

`Visible`
`{on} | off`

Visibility of hgtransform object and its children. By default, hgtransform object visibility is `on`. This means all children of the hgtransform are visible unless the child object's `Visible` property is set to `off`. Setting an hgtransform object's `Visible` property to `off` also makes its children invisible.

Purpose Remove hidden lines from mesh plot

Syntax

```
hidden on
hidden off
hidden
```

Description Hidden line removal draws only those lines that are not obscured by other objects in the field of view.

`hidden on` turns on hidden line removal for the current graph so lines in the back of a mesh are hidden by those in front. This is the default behavior.

`hidden off` turns off hidden line removal for the current graph.

`hidden` toggles the hidden line removal state.

Algorithm `hidden on` sets the `FaceColor` property of a surface graphics object to the background `Color` of the axes (or of the figure if axes `Color` is `none`).

Examples Set hidden line removal `off` and `on` while displaying the `peaks` function.

```
mesh(peaks)
hidden off
hidden on
```

See Also `shading`, `mesh`

The surface properties `FaceColor` and `EdgeColor`

"Creating Surfaces and Meshes" on page 1-96 for related functions

hilb

Purpose
Hilbert matrix

Syntax
```
H = hilb(n)
```

Description
`H = hilb(n)` returns the Hilbert matrix of order `n`.

Definition
The Hilbert matrix is a notable example of a poorly conditioned matrix [1]. The elements of the Hilbert matrices are $H(i, j) = 1/(i + j - 1)$.

Examples
Even the fourth-order Hilbert matrix shows signs of poor conditioning.

```
cond(hilb(4)) =
    1.5514e+04
```

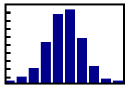
Note See the M-file for a good example of efficient MATLAB programming where conventional `for` loops are replaced by vectorized statements.

See Also
`invhilb`

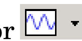
References
[1] Forsythe, G. E. and C. B. Moler, *Computer Solution of Linear Algebraic Systems*, Prentice-Hall, 1967, Chapter 19.

Purpose

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

```
n = hist(Y)
n = hist(Y,x)
n = hist(Y,nbins)
[n,xout] = hist(...)
hist(...)
hist(axes_handle,...)
```

Description

A histogram shows the distribution of data values.

`n = hist(Y)` bins the elements in vector `Y` into 10 equally spaced containers and returns the number of elements in each container as a row vector. If `Y` is an `m`-by-`p` matrix, `hist` treats the columns of `Y` as vectors and returns a 10-by-`p` matrix `n`. Each column of `n` contains the results for the corresponding column of `Y`. No elements of `Y` can be complex.

`n = hist(Y,x)` where `x` is a vector, returns the distribution of `Y` among `length(x)` bins with centers specified by `x`. For example, if `x` is a 5-element vector, `hist` distributes the elements of `Y` into five bins centered on the *x*-axis at the elements in `x`, none of which can be complex. Note: use `histc` if it is more natural to specify bin edges instead of centers.

`n = hist(Y,nbins)` where `nbins` is a scalar, uses `nbins` number of bins.

[n,xout] = hist(...) returns vectors n and xout containing the frequency counts and the bin locations. You can use bar(xout,n) to plot the histogram.

hist(...) without output arguments produces a histogram plot of the output described above. hist distributes the bins along the *x*-axis between the minimum and maximum values of Y.

hist(axes_handle,...) plots into the axes with handle axes_handle instead of the current axes (gca).

Remarks

All elements in vector Y or in one column of matrix Y are grouped according to their numeric range. Each group is shown as one bin.

The histogram's *x*-axis reflects the range of values in Y. The histogram's *y*-axis shows the number of elements that fall within the groups; therefore, the *y*-axis ranges from 0 to the greatest number of elements deposited in any bin. The *x*-range of the leftmost and rightmost bins extends to include the entire data range in the case when the user-specified range does not cover the data range. If you want a plot in which this does not happen (that is, all bins have equal width), you can create a histogram-like display using the bar command.

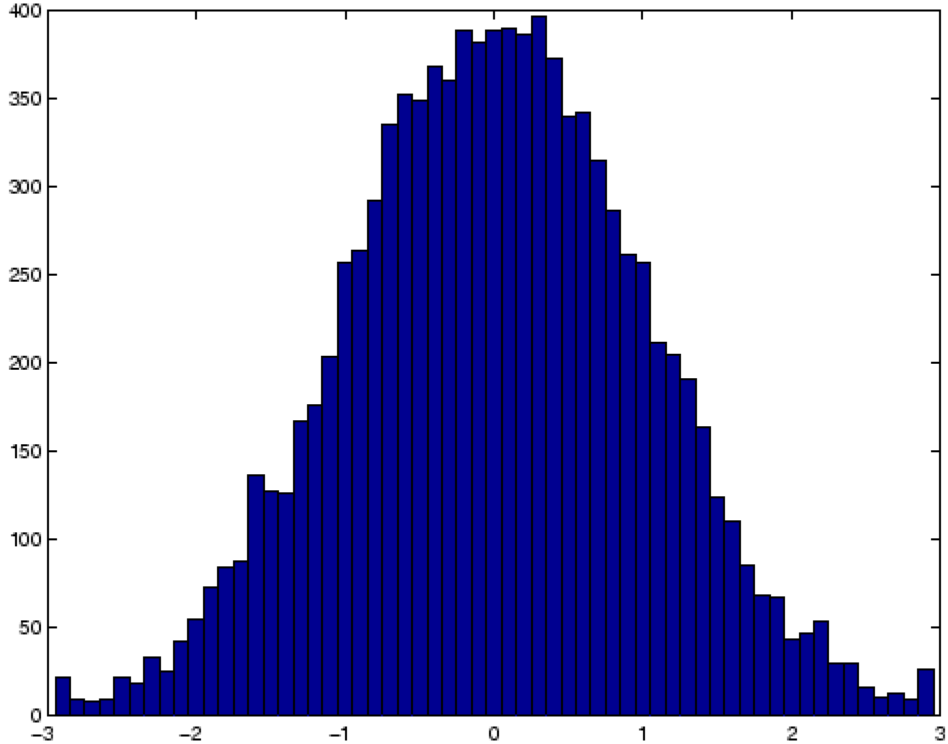
The hist function does not work with data that contain inf values.

The histogram is created with a patch graphics object. If you want to change the color of the graph, you can set patch properties. See the examples for more information. By default, the graph color is controlled by the current colormap, which maps the bin color to the first color in the colormap.

Examples

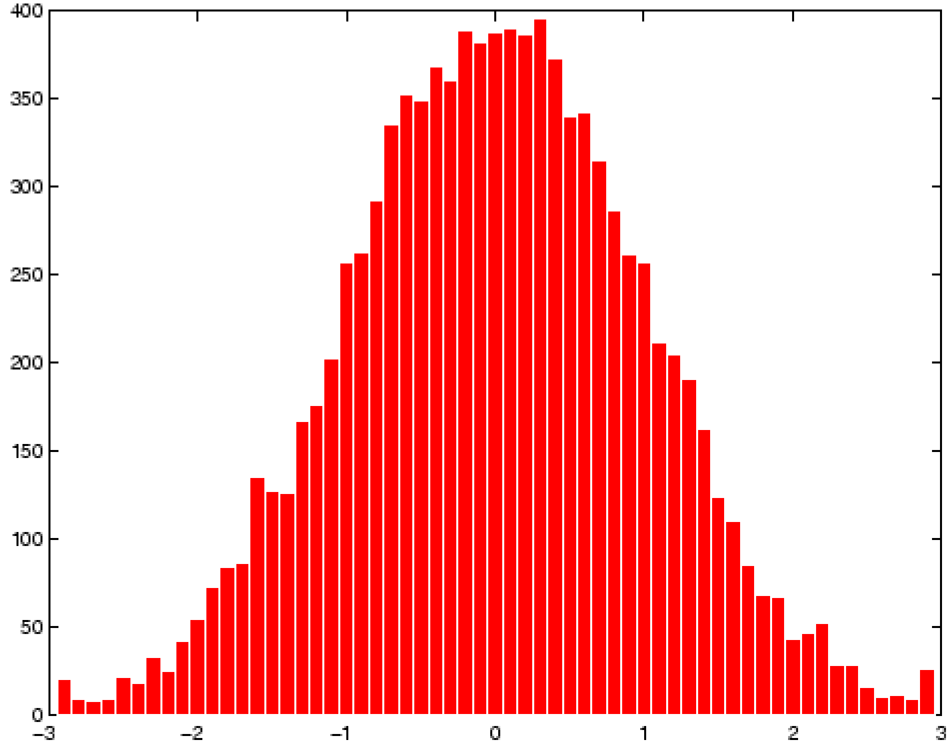
Generate a bell-curve histogram from Gaussian data.

```
x = -2.9:0.1:2.9;
y = randn(10000,1);
hist(y,x)
```



Change the color of the graph so that the bins are red and the edges of the bins are white.

```
h = findobj(gca,'Type','patch');
set(h,'FaceColor','r','EdgeColor','w')
```



See Also

`bar`, `ColorSpec`, `histc`, `mode`, `patch`, `rose`, `stairs`

"Specialized Plotting" on page 1-87 for related functions

"Histograms" for examples

Purpose

Histogram count

Syntax

```
n = histc(x,edges)
n = histc(x,edges,dim)
[n,bin] = histc(...)
```

Description

`n = histc(x,edges)` counts the number of values in vector `x` that fall between the elements in the `edges` vector (which must contain monotonically nondecreasing values). `n` is a `length(edges)` vector containing these counts. No elements of `x` can be complex.

`n(k)` counts the value `x(i)` if `edges(k) <= x(i) < edges(k+1)`. The last bin counts any values of `x` that match `edges(end)`. Values outside the values in `edges` are not counted. Use `-inf` and `inf` in `edges` to include all non-`NaN` values.

For matrices, `histc(x,edges)` returns a matrix of column histogram counts. For N-D arrays, `histc(x,edges)` operates along the first nonsingleton dimension.

`n = histc(x,edges,dim)` operates along the dimension `dim`.

`[n,bin] = histc(...)` also returns an index matrix `bin`. If `x` is a vector, `n(k) = sum(bin==k)`. `bin` is zero for out of range values. If `x` is an `M`-by-`N` matrix, then

```
for j=1:N,
n(k,j) = sum(bin(:,j)==k);
end
```

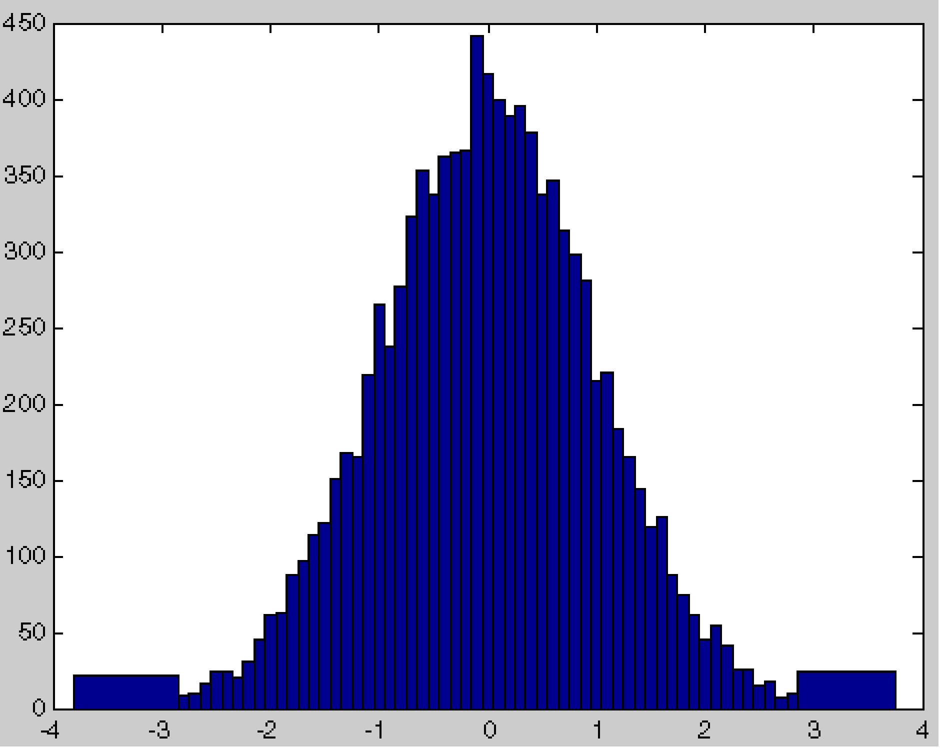
To plot the histogram, use the `bar` command.

Examples

Generate a cumulative histogram of a distribution.

Consider the following distribution:

```
x = -2.9:0.1:2.9;
y = randn(10000,1);
figure(1), hist(y,x)
```



Calculate number of elements in each bin

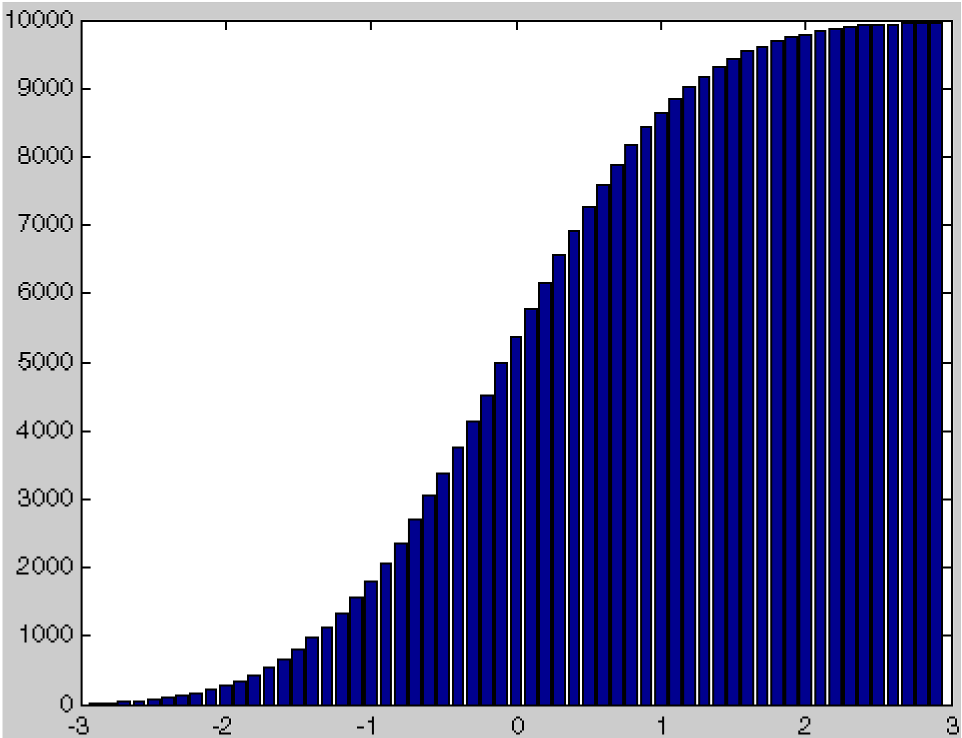
```
n_elements = histc(y,x);
```

Calculate the cumulative sum of these elements using `cumsum`

```
c_elements = cumsum(n_elements)
```

Plot the cumulative histogram

```
figure(2),bar(x,c_elements)
```



See Also

`hist`, `mode`

"Specialized Plotting" on page 1-87 for related functions

hold

Purpose

Retain current graph in figure

Syntax

```
hold on
hold off
hold all
hold
hold(axes_handle,...)
```

Description

The `hold` function determines whether new graphics objects are added to the graph or replace objects in the graph.

`hold on` retains the current plot and certain axes properties so that subsequent graphing commands add to the existing graph.

`hold off` resets axes properties to their defaults before drawing new plots. `hold off` is the default.

`hold all` holds the plot and the current line color and line style so that subsequent plotting commands do not reset the `ColorOrder` and `LineStyleOrder` property values to the beginning of the list. Plotting commands continue cycling through the predefined colors and linestyles from where the last plot stopped in the list.

`hold` toggles the hold state between adding to the graph and replacing the graph.

`hold(axes_handle,...)` applies the hold to the axes identified by the handle `axes_handle`.

Remarks

Test the hold state using the `ishold` function.

Although the hold state is `on`, some axes properties change to accommodate additional graphics objects. For example, the axes' limits increase when the data requires them to do so.

The `hold` function sets the `NextPlot` property of the current figure and the current axes. If several axes objects exist in a figure window, each axes has its own hold state. `hold` also creates an axes if one does not exist.

`hold on` sets the `NextPlot` property of the current figure and axes to `add`.

`hold off` sets the `NextPlot` property of the current axes to `replace`.

`hold` toggles the `NextPlot` property between the `add` and `replace` states.

See Also

`axis`, `cla`, `ishold`, `newplot`

The `NextPlot` property of axes and figure graphics objects

"Basic Plots and Graphs" on page 1-85 for related functions

home

Purpose

Move cursor to upper-left corner of Command Window

Syntax

```
home
```

Description

`home` moves the cursor to the upper-left corner of the Command Window. You can use the scroll bar to see the history of previous functions.

Examples

Use `home` in an M-file to return the cursor to the upper-left corner of the screen.

See Also

`clc`

Purpose

Concatenate arrays horizontally

Syntax

```
C = horzcat(A1, A2, ...)
```

Description

`C = horzcat(A1, A2, ...)` horizontally concatenates matrices `A1`, `A2`, and so on. All matrices in the argument list must have the same number of rows.

`horzcat` concatenates N-dimensional arrays along the second dimension. The first and remaining dimensions must match.

MATLAB calls `C = horzcat(A1, A2,...)` for the syntax `C = [A1 A2 ...]` when any of `A1`, `A2`, etc., is an object.

Examples

Create a 3-by-5 matrix, `A`, and a 3-by-3 matrix, `B`. Then horizontally concatenate `A` and `B`.

```
A = magic(5);            % Create 3-by-5 matrix, A
A(4:5,:) = []

A =

    17    24     1     8    15
    23     5     7    14    16
     4     6    13    20    22


B = magic(3)*100       % Create 3-by-3 matrix, B

B =

   800   100   600
   300   500   700
   400   900   200


C = horzcat(A, B)      % Horizontally concatenate A and B
```

```
C =

    17    24     1     8    15   800   100   600
    23     5     7    14    16   300   500   700
     4     6    13    20    22   400   900   200
```

See Also `vertcat`, `cat`

horzcat (tscollection)

Purpose

Horizontal concatenation for `tscollection` objects

Syntax

```
tsc = horzcat(tsc1,tsc2,...)
```

Description

`tsc = horzcat(tsc1,tsc2,...)` performs horizontal concatenation for `tscollection` objects:

```
tsc = [tsc1 tsc2 ...]
```

This operation combines multiple `tscollection` objects, which must have the same time vectors, into one `tscollection` containing `timeseries` objects from all concatenated collections.

See Also

`tscollection`, `vertcat (tscollection)`

hostid

Purpose MATLAB server host identification number

Syntax

```
id = hostid
```

Description `id = hostid` usually returns a single element cell array containing the identifier as a string. UNIX systems may have more than one identifier. In this case, `hostid` returns a cell array with an identifier in each cell.

Purpose Convert HSV colormap to RGB colormap

Syntax

```
M = hsv2rgb(H)
rgb_image = hsv2rgb(hsv_image)
```

Description `M = hsv2rgb(H)` converts a hue-saturation-value (HSV) colormap to a red-green-blue (RGB) colormap. `H` is an m-by-3 matrix, where m is the number of colors in the colormap. The columns of `H` represent hue, saturation, and value, respectively. `M` is an m-by-3 matrix. Its columns are intensities of red, green, and blue, respectively.

`rgb_image = hsv2rgb(hsv_image)` converts the HSV image to the equivalent RGB image. HSV is an m-by-n-by-3 image array whose three planes contain the hue, saturation, and value components for the image. RGB is returned as an m-by-n-by-3 image array whose three planes contain the red, green, and blue components for the image.

Remarks As `H(:,1)` varies from 0 to 1, the resulting color varies from red through yellow, green, cyan, blue, and magenta, and returns to red. When `H(:,2)` is 0, the colors are unsaturated (i.e., shades of gray). When `H(:,2)` is 1, the colors are fully saturated (i.e., they contain no white component). As `H(:,3)` varies from 0 to 1, the brightness increases.

The MATLAB `hsv` colormap uses `hsv2rgb([huesaturationvalue])` where `hue` is a linear ramp from 0 to 1, and `saturation` and `value` are all 1's.

See Also `brighten`, `colormap`, `rgb2hsv`

"Color Operations" on page 1-97 for related functions

hypot

Purpose Square root of sum of squares

Syntax

```
c = hypot(a,b)
```

Description

`c = hypot(a,b)` returns the element-wise result of the following equation, computed to avoid underflow and overflow:

```
c = sqrt(abs(a).^2 + abs(b).^2)
```

Inputs `a` and `b` must follow these rules:

- Both `a` and `b` must be single- or double-precision, floating-point arrays.
- The sizes of the `a` and `b` arrays must either be equal, or one a scalar and the other nonscalar. In the latter case, `hypot` expands the scalar input to match the size of the nonscalar input.
- If `a` or `b` is an empty array (0-by-N or N-by-0), the other must be the same size or a scalar. The result `c` is an empty array having the same size as the empty input(s).

`hypot` returns the following in output `c`, depending upon the types of inputs:

- If the inputs to `hypot` are complex (`w+xi` and `y+zi`), then the statement `c = hypot(w+xi,y+zi)` returns the *positive real* result

  ```
  c = sqrt(abs(w).^2+abs(x).^2+abs(y).^2+abs(z).^2)
  ```

- If `a` or `b` is `–Inf`, `hypot` returns `Inf`.
- If neither `a` nor `b` is `Inf`, but one or both inputs is `NaN`, `hypot` returns `NaN`.
- If all inputs are finite, the result is finite. The one exception is when both inputs are very near the value of the MATLAB constant `realmax`. The reason for this is that the equation `c =`

hypot(realmax,realmax) is theoretically sqrt(2)*realmax, which overflows to Inf.

Examples

Example 1

To illustrate the difference between using the hypot function and coding the basic hypot equation in M-code, create an anonymous function that performs the same function as hypot, but without the consideration to underflow and overflow that hypot offers:

```
myhypot = @(a,b)sqrt(abs(a).^2+abs(b).^2);
```

Find the upper limit at which your coded function returns a useful value. You can see that this test function reaches its maximum at about 1e154, returning an infinite result at that point:

```
myhypot(1e153,1e153)
ans =
    1.4142e+153

myhypot(1e154,1e154)
ans =
   Inf
```

Do the same using the hypot function, and observe that hypot operates on values up to about 1e308, which is approximately equal to the value for realmax on your computer (the largest double-precision floating-point number you can represent on a particular computer):

```
hypot(1e308,1e308)
ans =
  1.4142e+308

hypot(1e309,1e309)
ans =
   Inf
```

Example 2

`hypot(a,a)` theoretically returns `sqrt(2)*abs(a)`, as shown in this example:

```
x = 1.271161e308;

y = x * sqrt(2)
y =
  1.7977e+308

y = hypot(x,x)
y =
  1.7977e+308
```

Algorithm

`hypot` 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

`sqrt`, `abs`, `norm`

Purpose

Imaginary unit

Syntax

```
i
a+bi
x+i*y
```

Description

As the basic imaginary unit `sqrt(-1)`, `i` is used to enter complex numbers. Since `i` is a function, it can be overridden and used as a variable. This permits you to use `i` as an index in `for` loops, etc.

If desired, use the character `i` without a multiplication sign as a suffix in forming a complex numerical constant.

You can also use the character `j` as the imaginary unit.

Examples

```
Z = 2+3i
Z = x+i*y
Z = r*exp(i*theta)
```

See Also

`conj`, `imag`, `j`, `real`

idealfilter (timeseries)

Purpose

Apply ideal (noncausal) filter to `timeseries` object

Syntax

```
ts2 = idealfilter(ts1,Interval,FilterType)
ts2 = idealfilter(ts1,Interval,FilterType,Index)
```

Description

`ts2 = idealfilter(ts1,Interval,FilterType)` applies an ideal filter of `FilterType` `'pass'` or `'notch'` to one or more frequency intervals specified by `Interval` for the `timeseries` object `ts1`. You specify several frequency intervals as an `n`-by-2 array of start and end frequencies, where `n` represents the number of intervals.

`ts2 = idealfilter(ts1,Interval,FilterType,Index)` applies an ideal filter and uses the optional `Index` integer array to specify the columns or rows to filter. When `ts.IsTimeFirst` is set to `true`, `Index` specifies one or more data columns. When `ts.IsTimeFirst` is set to `false`, Index specifies one or more data rows.

Remarks

When to Use the Ideal Filter

You use the ideal *notch* filter when you want to remove variations in a specific frequency range. Alternatively, you use the ideal *pass* filter to allow only the variations in a specific frequency range.

These filters are ideal in the sense that they are not realizable; an ideal filter is noncausal and the ends of the filter amplitude are perfectly flat in the frequency domain.

Requirement for Uniform Samples in Time

If the time-series data is sampled nonuniformly, filtering resamples this data on a uniform time vector.

Interpolation of NaN Values

All `NaN`s in the time series are interpolated before filtering using the interpolation method you assigned to the `timeseries` object.

Examples

You will apply an ideal notch filter to the data in `count.dat`.

1 Load the matrix `count` into the workspace.

```
load count.dat;
```

2 Create a `timeseries` object based on this matrix. The time vector ranges from 1 to 24 seconds in 1-second intervals.

```
count1=timeseries(count(:,1),1:24);
```

3 Enter the frequency interval in hertz.

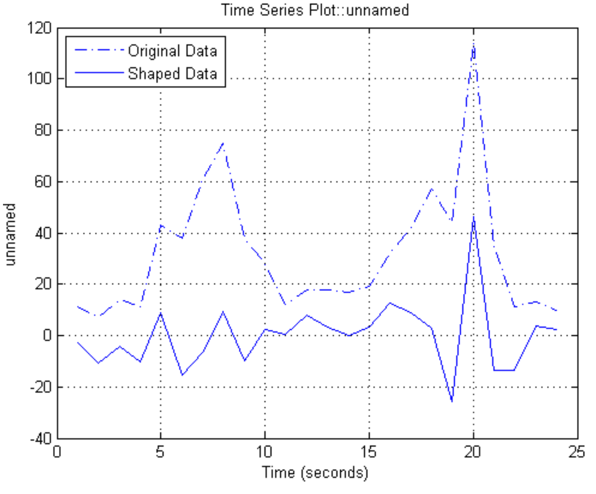
```
interval=[0.08 0.2];
```

4 Call the filter function:

```
idealfilter_count = idealfilter(count1,interval,'notch')
```

5 Compare the original data and the shaped data with an overlaid plot of the two curves.

```
plot(count1,'-.'), grid on, hold on
plot(filter_count,'-')
legend('Original Data','Shaped Data',2)
```



See Also

`filter (timeseries)`, `timeseries`

Purpose

Integer division with rounding option

Syntax

```
C = idivide(A, B, opt)
C = idivide(A, B)
C = idivide(A, B, 'fix')
C = idivide(A, B, 'round')
C = idivide(A, B, 'floor')
C = idivide(A, B, 'ceil')
```

Description

`C = idivide(A, B, opt)` is the same as `A./B` for integer classes except that fractional quotients are rounded to integers using the optional rounding mode specified by `opt`. The default rounding mode is `'fix'`. Inputs `A` and `B` must be real and must have the same dimensions unless one is a scalar. At least one of the arguments `A` and `B` must belong to an integer class, and the other must belong to the same integer class or be a scalar double. The result `C` belongs to the integer class.

`C = idivide(A, B)` is the same as `A./B` except that fractional quotients are rounded toward zero to the nearest integers.

`C = idivide(A, B, 'fix')` is the same as the syntax shown immediately above.

`C = idivide(A, B, 'round')` is the same as `A./B` for integer classes. Fractional quotients are rounded to the nearest integers.

`C = idivide(A, B, 'floor')` is the same as `A./B` except that fractional quotients are rounded toward negative infinity to the nearest integers.

`C = idivide(A, B, 'ceil')` is the same as `A./B` except that the fractional quotients are rounded toward infinity to the nearest integers.

Examples

```
a = int32([-2 2]);
b = int32(3);

idivide(a,b)             % Returns [0 0]
idivide(a,b,'floor')     % Returns [-1 0]
idivide(a,b,'ceil')      % Returns [0 1]
```

```
idivide(a,b,'round')     % Returns [-1 1]
```

See Also `ldivide`, `rdivide`, `mldivide`, `mrdivide`

Purpose

Execute statements if condition is true

Syntax

`if expression, statements, end`

Description

`if expression, statements, end` evaluates *expression* and, if the evaluation yields logical `1` (`true`) or a nonzero result, executes one or more MATLAB commands denoted here as *statements*.

expression is a MATLAB expression, usually consisting of variables or smaller expressions joined by relational operators (e.g., `count < limit`), or logical functions (e.g., `isreal(A)`). Simple expressions can be combined by logical operators (`&&`, `||`, `~`) into compound expressions such as the following. MATLAB evaluates compound expressions from left to right, adhering to operator precedence rules.

```
(count < limit) && ((height - offset) >= 0)
```

Nested `if` statements must each be paired with a matching `end`.

The `if` function can be used alone or with the `else` and `elseif` functions. When using `elseif` and/or `else` within an `if` statement, the general form of the statement is

```
if expression1
    statements1
elseif expression2
    statements2
else
    statements3
end
```

See "Program Control Statements" in the MATLAB Programming documentation for more information on controlling the flow of your program code.

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 `if (A < B)` is true only if each element of matrix `A` is less than its corresponding element in matrix `B`. See Example 2, 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)   if (A && B)                2)   if (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 `if` on an empty array treats the array as `false`. There are some conditions however under which `if` evaluates as `true` on an empty array. Two examples of this, where `A` is equal to `[]`, are

```
if all(A), do_something, end
if 1|A, do_something, end
```

The latter expression is `true` because of short-circuiting, which causes MATLAB to ignore the right side operand of an OR statement whenever the left side evaluates to `true`.

Short-Circuiting Behavior

When used in the context of an `if` or `while` 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 if Statement

In this example, if both of the conditions are satisfied, then the student passes the course.

```
if ((attendance >= 0.90) && (grade_average >= 60))
   pass = 1;
end;
```

Example 2 - Nonscalar Expression

Given matrices `A` and `B`,

```
A =                     B =
     1     0                 1     1
     2     3                 3     4
```

Expression	Evaluates As	Because
`A < B`	`false`	A(1,1) is not less than B(1,1).
`A < (B + 1)`	`true`	Every element of A is less than that same element of B with 1 added.

Expression	Evaluates As	Because
`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

`else`, `elseif`, `end`, `for`, `while`, `switch`, `break`, `return`, `relational operators`, logical operators (`elementwise` and `short-circuit`),

Purpose

Inverse discrete Fourier transform

Syntax

```
y = ifft(X)
y = ifft(X,n)
y = ifft(X,[],dim)
y = ifft(X,n,dim)
y = ifft(..., 'symmetric')
y = ifft(..., 'nonsymmetric')
```

Description

`y = ifft(X)` returns the inverse discrete Fourier transform (DFT) of vector `X`, computed with a fast Fourier transform (FFT) algorithm. If `X` is a matrix, `ifft` returns the inverse DFT of each column of the matrix.

`ifft` tests `X` to see whether vectors in `X` along the active dimension are *conjugate symmetric*. If so, the computation is faster and the output is real. An `N`-element vector `x` is conjugate symmetric if `x(i) = conj(x(mod(N-i+1,N)+1))` for each element of `x`.

If `X` is a multidimensional array, `ifft` operates on the first non-singleton dimension.

`y = ifft(X,n)` returns the `n`-point inverse DFT of vector `X`.

`y = ifft(X,[],dim)` and `y = ifft(X,n,dim)` return the inverse DFT of `X` across the dimension `dim`.

`y = ifft(..., 'symmetric')` causes `ifft` to treat `X` as conjugate symmetric along the active dimension. This option is useful when `X` is not exactly conjugate symmetric, merely because of round-off error.

`y = ifft(..., 'nonsymmetric')` is the same as calling `ifft(...)` without the argument `'nonsymmetric'`.

For any `X`, `ifft(fft(X))` equals `X` to within roundoff error.

Algorithm

The algorithm for `ifft(X)` is the same as the algorithm for `fft(X)`, except for a sign change and a scale factor of `n = length(X)`. As for `fft`, the execution time for `ifft` depends on the length of the transform. It is fastest for powers of two. It is almost as fast for lengths that have only small prime factors. It is typically several times slower for lengths that are prime or which have large prime factors.

Note You might be able to increase the speed of `ifft` using the utility function `fftw`, which controls how MATLAB optimizes the algorithm used to compute an FFT of a particular size and dimension.

Data Type Support

`ifft` supports inputs of data types `double` and `single`. If you call `ifft` with the syntax `y = ifft(X, ...)`, the output `y` has the same data type as the input `X`.

See Also

`fft`, `fft2`, `ifft2`, `ifftn`, `ifftshift`, `fftw`, `ifft2`, `ifftn`

`dftmtx` and `freqz`, in the Signal Processing Toolbox

Purpose

2-D inverse discrete Fourier transform

Syntax

```
Y = ifft2(X)
Y = ifft2(X,m,n)
y = ifft2(..., 'symmetric')
y = ifft2(..., 'nonsymmetric')
```

Description

`Y = ifft2(X)` returns the two-dimensional inverse discrete Fourier transform (DFT) of `X`, computed with a fast Fourier transform (FFT) algorithm. The result `Y` is the same size as `X`.

`ifft2` tests `X` to see whether it is *conjugate symmetric*. If so, the computation is faster and the output is real. An `M`-by-`N` matrix `X` is conjugate symmetric if `X(i,j) = conj(X(mod(M-i+1, M) + 1, mod(N-j+1, N) + 1))` for each element of `X`.

`Y = ifft2(X,m,n)` returns the `m`-by-`n` inverse fast Fourier transform of matrix `X`.

`y = ifft2(..., 'symmetric')` causes `ifft2` to treat `X` as conjugate symmetric. This option is useful when `X` is not exactly conjugate symmetric, merely because of round-off error.

`y = ifft2(..., 'nonsymmetric')` is the same as calling `ifft2(...)` without the argument `'nonsymmetric'`.

For any `X`, `ifft2(fft2(X))` equals `X` to within roundoff error.

Algorithm

The algorithm for `ifft2(X)` is the same as the algorithm for `fft2(X)`, except for a sign change and scale factors of `[m,n] = size(X)`. The execution time for `ifft2` depends on the length of the transform. It is fastest for powers of two. It is almost as fast for lengths that have only small prime factors. It is typically several times slower for lengths that are prime or which have large prime factors.

Note You might be able to increase the speed of `ifft2` using the utility function `fftw`, which controls how MATLAB optimizes the algorithm used to compute an FFT of a particular size and dimension.

Data Type Support

`ifft2` supports inputs of data types `double` and `single`. If you call `ifft2` with the syntax `y = ifft2(X, ...)`, the output `y` has the same data type as the input `X`.

See Also

`dftmtx` and `freqz` in the Signal Processing Toolbox, and:

`fft2`, `fftw`, `fftshift`, `ifft`, `ifftn`, `ifftshift`

Purpose

N-D inverse discrete Fourier transform

Syntax

```
Y = ifftn(X)
Y = ifftn(X,siz)
y = ifftn(..., 'symmetric')
y = ifftn(..., 'nonsymmetric')
```

Description

`Y = ifftn(X)` returns the n-dimensional inverse discrete Fourier transform (DFT) of `X`, computed with a multidimensional fast Fourier transform (FFT) algorithm. The result `Y` is the same size as `X`.

`ifftn` tests `X` to see whether it is *conjugate symmetric*. If so, the computation is faster and the output is real. An `N1`-by-`N2`-by- ... `Nk` array `X` is conjugate symmetric if

```
X(i1,i2, ...,ik) = conj(X(mod(N1-i1+1,N1)+1, mod(N2-i2+1,N2)+1,
... mod(Nk-ik+1,Nk)+1))
```

for each element of `X`.

`Y = ifftn(X,siz)` pads `X` with zeros, or truncates `X`, to create a multidimensional array of size `siz` before performing the inverse transform. The size of the result `Y` is `siz`.

`y = ifftn(..., 'symmetric')` causes `ifftn` to treat `X` as conjugate symmetric. This option is useful when `X` is not exactly conjugate symmetric, merely because of round-off error.

`y = ifftn(..., 'nonsymmetric')` is the same as calling `ifftn(...)` without the argument `'nonsymmetric'`.

Remarks

For any `X`, `ifftn(fftn(X))` equals `X` within roundoff error.

Algorithm

`ifftn(X)` is equivalent to

```
Y = X;
for p = 1:length(size(X))
    Y = ifft(Y,[],p);
end
```

This computes in-place the one-dimensional inverse DFT along each dimension of `X`.

The execution time for `ifftn` depends on the length of the transform. It is fastest for powers of two. It is almost as fast for lengths that have only small prime factors. It is typically several times slower for lengths that are prime or which have large prime factors.

Note You might be able to increase the speed of `ifftn` using the utility function `fftw`, which controls how MATLAB optimizes the algorithm used to compute an FFT of a particular size and dimension.

Data Type Support

`ifftn` supports inputs of data types `double` and `single`. If you call `ifftn` with the syntax `y = ifftn(X, ...)`, the output `y` has the same data type as the input `X`.

See Also

`fftn`, `fftw`, `ifft`, `ifft2`, `ifftshift`

Purpose

Inverse FFT shift

Syntax

```
ifftshift(X)
ifftshift(X,dim)
```

Description

`ifftshift(X)` swaps the left and right halves of the vector `X`. For matrices, `ifftshift(X)` swaps the first quadrant with the third and the second quadrant with the fourth. If `X` is a multidimensional array, `ifftshift(X)` swaps "half-spaces" of `X` along each dimension.

`ifftshift(X,dim)` applies the `ifftshift` operation along the dimension `dim`.

Note `ifftshift` undoes the results of `fftshift`. If the matrix `X` contains an odd number of elements, `ifftshift(fftshift(X))` must be done to obtain the original `X`. Simply performing `fftshift(X)` twice will not produce `X`.

See Also

`fft`, `fft2`, `fftn`, `fftshift`

Purpose

Sparse incomplete LU factorization

Syntax

```
ilu(A,setup)
[L,U] = ilu(A,setup)
[L,U,P] = ilu(A,setup)
```

Description

`ilu` produces a unit lower triangular matrix, an upper triangular matrix, and a permutation matrix.

`ilu(A,setup)` computes the incomplete LU factorization of `A`. `setup` is an input structure with up to five setup options. The fields must be named exactly as shown in the table below. You can include any number of these fields in the structure and define them in any order. Any additional fields are ignored.

Field Name	Description
`type`	Type of factorization. Values for `type` include: • `'nofill'`—Performs ILU factorization with `0` level of fill in, known as ILU(0). With `type` set to `'nofill'`, only the `milu` setup option is used; all other fields are ignored. • `'crout'`—Performs the Crout version of ILU factorization, known as ILUC. With `type` set to `'crout'`, only the `droptol` and `milu` setup options are used; all other fields are ignored. • `'ilutp'` (default)—Performs ILU factorization with threshold and pivoting. If `type` is not specified, the ILU factorization with pivoting ILUTP is performed. Pivoting is never performed with `type` set to `'nofill'` or `'crout'`.

Field Name	Description

droptol	Drop tolerance of the incomplete LU factorization. droptol is a non-negative scalar. The default value is 0, which produces the complete LU factorization.
	
	The nonzero entries of U satisfy
	
	`abs(U(i,j)) >= droptol*norm((A:,j)),`
	
	with the exception of the diagonal entries, which are retained regardless of satisfying the criterion. The entries of L are tested against the local drop tolerance before being scaled by the pivot, so for nonzeros in L
	
	`abs(L(i,j)) >= droptol*norm(A(:,j))/U(j,j).`

milu	Modified incomplete LU factorization. Values for milu include: • 'row'—Produces the row-sum modified incomplete LU factorization. Entries from the newly-formed column of the factors are subtracted from the diagonal of the upper triangular factor, U, preserving column sums. That is, A*e = L*U*e, where e is the vector of ones. • 'col'—Produces the column-sum modified incomplete LU factorization. Entries from the newly-formed column of the factors are subtracted from the diagonal of the upper triangular factor, U, preserving column sums. That is, e'*A = e'*L*U. • 'off' (default)—No modified incomplete LU factorization is produced.

Field Name	Description
udiag	If udiag is 1, any zeros on the diagonal of the upper triangular factor are replaced by the local drop tolerance. The default is 0.
thresh	Pivot threshold between 0 (forces diagonal pivoting) and 1, the default, which always chooses the maximum magnitude entry in the column to be the pivot.

`ilu(A,setup)` returns `L+U-speye(size(A))`, where `L` is a unit lower triangular matrix and `U` is an upper triangular matrix.

`[L,U] = ilu(A,setup)` returns a unit lower triangular matrix in `L` and an upper triangular matrix in `U`.

`[L,U,P] = ilu(A,setup)` returns a unit lower triangular matrix in `L`, an upper triangular matrix in `U`, and a permutation matrix in `P`.

Remarks

These incomplete factorizations may be useful as preconditioners for a system of linear equations being solved by iterative methods such as BICG (BiConjugate Gradients), GMRES (Generalized Minimum Residual Method).

Limitations

`ilu` works on sparse square matrices only.

Examples

Start with a sparse matrix and compute the LU factorization.

```
A = gallery('neumann', 1600) + speye(1600);
setup.type = 'crout';
setup.milu = 'row';
setup.droptol = 0.1;
[L,U] = ilu(A,setup);
e = ones(size(A,2),1);
norm(A*e-L*U*e)

ans =
```

```
    1.4251e-014
```

This shows that A and L*U, where L and U are given by the modified Crout ILU, have the same row-sum.

Start with a sparse matrix and compute the LU factorization.

```
A = gallery('neumann', 1600) + speye(1600);
setup.type = 'nofill';
nnz(A)
ans =

        7840

nnz(lu(A))
ans =

      126478

nnz(ilu(A,setup))
ans =

        7840
```

This shows that A has 7840 nonzeros, the complete LU factorization has 126478 nonzeros, and the incomplete LU factorization, with 0 level of fill-in, has 7840 nonzeros, the same amount as A.

See Also

bicg, cholinc,gmres,luinc

References

[1] Saad, Yousef, *Iterative Methods for Sparse Linear Systems*, PWS Publishing Company, 1996, Chapter 10 - Preconditioning Techniques.

im2frame

Purpose

Convert image to movie frame

Syntax

```
f = im2frame(X,map)
f = im2frame(X)
```

Description

`f = im2frame(X,map)` converts the indexed image `X` and associated colormap `map` into a movie frame `f`. If `X` is a truecolor (m-by-n-by-3) image, then `map` is optional and has no effect.

Typical usage:

```
M(1) = im2frame(X1,map);
M(2) = im2frame(X2,map);
 ...
M(n) = im2frame(Xn,map);
movie(M)
```

`f = im2frame(X)` converts the indexed image `X` into a movie frame `f` using the current colormap if `X` contains an indexed image.

See Also

`frame2im`, `movie`

"Bit-Mapped Images" on page 1-91 for related functions

Purpose

Convert image to Java image

Syntax

```
jimage = im2java(I)
jimage = im2java(X,MAP)
jimage = im2java(RGB)
```

Description

To work with a MATLAB image in the Java environment, you must convert the image from its MATLAB representation into an instance of the Java image class, `java.awt.Image`.

`jimage = im2java(I)` converts the intensity image `I` to an instance of the Java image class, `java.awt.Image`.

`jimage = im2java(X,MAP)` converts the indexed image `X`, with colormap `MAP`, to an instance of the Java image class, `java.awt.Image`.

`jimage = im2java(RGB)` converts the RGB image `RGB` to an instance of the Java image class, `java.awt.Image`.

Class Support

The input image can be of class `uint8`, `uint16`, or `double`.

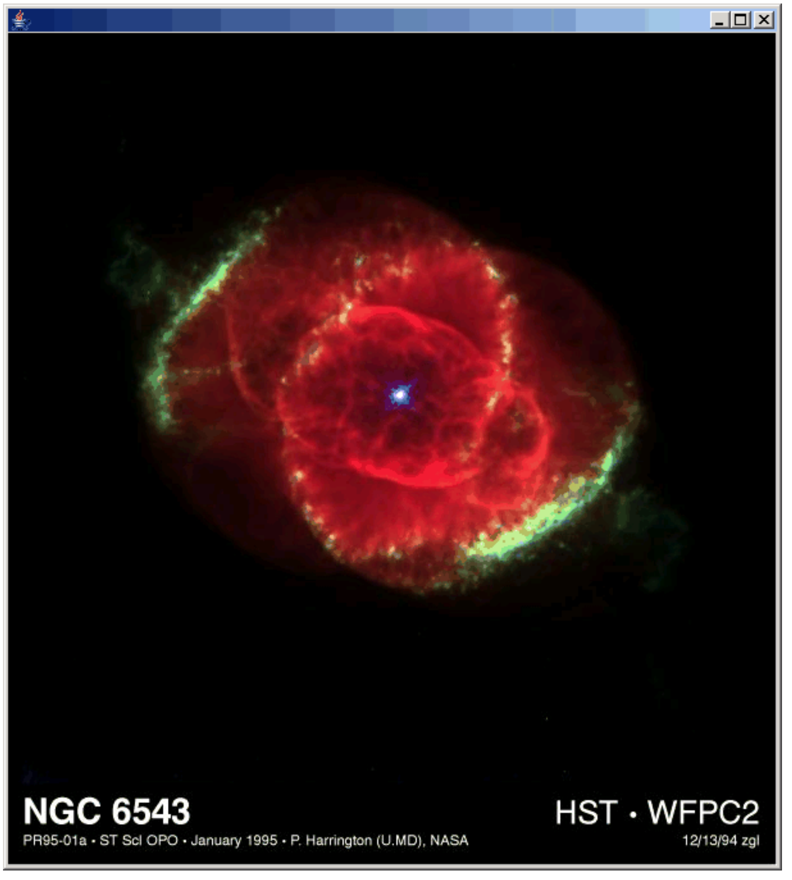
Note Java requires `uint8` data to create an instance of the Java image class, `java.awt.Image`. If the input image is of class `uint8`, `jimage` contains the same `uint8` data. If the input image is of class `double` or `uint16`, `im2java` makes an equivalent image of class `uint8`, rescaling or offsetting the data as necessary, and then converts this `uint8` representation to an instance of the Java image class, `java.awt.Image`.

Example

This example reads an image into the MATLAB workspace and then uses `im2java` to convert it into an instance of the Java image class.

```
I = imread('ngc6543a.jpg');
javaImage = im2java(I);
frame = javax.swing.JFrame;
icon = javax.swing.ImageIcon(javaImage);
label = javax.swing.JLabel(icon);
```

```
frame.getContentPane.add(label);
frame.pack
frame.show
```



See Also "Bit-Mapped Images" on page 1-91 for related functions

Purpose Imaginary part of complex number

Syntax

```
Y = imag(Z)
```

Description `Y = imag(Z)` returns the imaginary part of the elements of array `Z`.

Examples

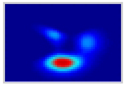
```
imag(2+3i)

ans =

     3
```

See Also `conj`, `i`, `j`, `real`

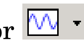
image

Purpose

Display image object



GUI Alternatives

To plot a selected matrix as an image use the Plot Selector  in the Workspace Browser, or use the Figure Palette Plot Catalog. Manipulate image characteristics 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

```
image(C)
image(x,y,C)
image(x,y,C,'PropertyName',PropertyValue,...)
image('PropertyName',PropertyValue,...)
handle = image(...)
```

Description

`image` creates an image graphics object by interpreting each element in a matrix as an index into the figure's colormap or directly as RGB values, depending on the data specified.

The `image` function has two forms:

- A high-level function that calls `newplot` to determine where to draw the graphics objects and sets the following axes properties:
  - `XLim` and `YLim` to enclose the image
  - `Layer` to `top` to place the image in front of the tick marks and grid lines
  - `YDir` to `reverse`
  - `View` to `[0 90]`

- A low-level function that adds the image to the current axes without calling `newplot`. The low-level function argument list can contain only property name/property value pairs.

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).

`image(C)` displays matrix `C` as an image. Each element of `C` specifies the color of a rectangular segment in the image.

`image(x,y,C)`, where `x` and `y` are two-element vectors, specifies the range of the *x*- and *y*-axis labels, but produces the same image as `image(C)`. This can be useful, for example, if you want the axis tick labels to correspond to real physical dimensions represented by the image.

`image(x,y,C,'`*`PropertyName`*`',PropertyValue,...)` is a high-level function that also specifies property name/property value pairs. This syntax calls `newplot` before drawing the image.

`image('`*`PropertyName`*`',PropertyValue,...)` is the low-level syntax of the `image` function. It specifies only property name/property value pairs as input arguments.

`handle = image(...)` returns the handle of the image object it creates. You can obtain the handle with all forms of the `image` function.

Remarks

Image data can be either indexed or true color. An indexed image stores colors as an array of indices into the figure colormap. A true color image does not use a colormap; instead, the color values for each pixel are stored directly as RGB triplets. In MATLAB, the `CData` property of a truecolor image object is a three-dimensional (`m`-by-`n`-by-3) array. This array consists of three `m`-by-`n` matrices (representing the red, green, and blue color planes) concatenated along the third dimension.

The `imread` function reads image data into MATLAB arrays from graphics files in various standard formats, such as TIFF. You can write MATLAB image data to graphics files using the `imwrite` function.

imread and imwrite both support a variety of graphics file formats and compression schemes.

When you read image data into MATLAB using imread, the data is usually stored as an array of 8-bit integers. However, imread also supports reading 16-bit-per-pixel data from TIFF and PNG files. These are more efficient storage methods than the double-precision (64-bit) floating-point numbers that MATLAB typically uses. However, it is necessary for MATLAB to interpret 8-bit and 16-bit image data differently from 64-bit data. This table summarizes these differences.

You cannot interactively pan or zoom outside the *x*-limits or *y*-limits of an image, unless the axes limits are already been set outside the bounds of the image, in which case there is no such restriction. If other objects (such as lineseries) occupy the axes and extend beyond the bounds of the image, you can pan or zoom to the bounds of the other objects, but no further.

Image Type	Double-Precision Data (double Array)	8-Bit Data (uint8 Array) 16-Bit Data (uint16 Array)
Indexed (colormap)	Image is stored as a two-dimensional (m-by-n) array of integers in the range [1, length(colormap)]; colormap is an m-by-3 array of floating-point values in the range [0, 1].	Image is stored as a two-dimensional (m-by-n) array of integers in the range [0, 255] (uint8) or [0, 65535] (uint16); colormap is an m-by-3 array of floating-point values in the range [0, 1].
True color (RGB)	Image is stored as a three-dimensional (m-by-n-by-3) array of floating-point values in the range [0, 1].	Image is stored as a three-dimensional (m-by-n-by-3) array of integers in the range [0, 255] (uint8) or [0, 65535] (uint16).

Indexed Images

In an indexed image of class `double`, the value 1 points to the first row in the colormap, the value 2 points to the second row, and so on. In a `uint8` or `uint16` indexed image, there is an offset; the value 0 points to the first row in the colormap, the value 1 points to the second row, and so on.

If you want to convert a `uint8` or `uint16` indexed image to `double`, you need to add 1 to the result. For example,

```
X64 = double(X8) + 1;
```

or

```
X64 = double(X16) + 1;
```

To convert from `double` to `uint8` or `uint16`, you need to first subtract 1, and then use `round` to ensure all the values are integers.

```
X8 = uint8(round(X64 - 1));
```

or

```
X16 = uint16(round(X64 - 1));
```

When you write an indexed image using `imwrite`, MATLAB automatically converts the values if necessary.

Colormaps

Colormaps in MATLAB are always `m`-by-3 arrays of double-precision floating-point numbers in the range [0, 1]. In most graphics file formats, colormaps are stored as integers, but MATLAB does not support colormaps with integer values. `imread` and `imwrite` automatically convert colormap values when reading and writing files.

True Color Images

In a true color image of class `double`, the data values are floating-point numbers in the range [0, 1]. In a true color image of class `uint8`, the data values are integers in the range [0, 255], and for true color images of class `uint16` the data values are integers in the range [0, 65535].

If you want to convert a true color image from one data type to the other, you must rescale the data. For example, this statement converts a `uint8` true color image to `double`.

```
RGB64 = double(RGB8)/255;
```

or for `uint16` images,

```
RGB64 = double(RGB16)/65535;
```

This statement converts a `double` true color image to `uint8`:

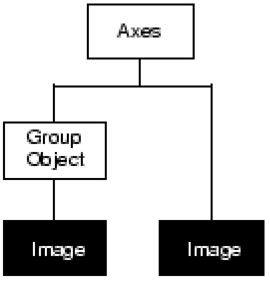
```
RGB8 = uint8(round(RGB64*255));
```

or to obtain `uint16` images, type

```
RGB16 = uint16(round(RGB64*65535));
```

When you write a true color image using `imwrite`, MATLAB automatically converts the values if necessary.

Object Hierarchy



Setting Default Properties

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

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

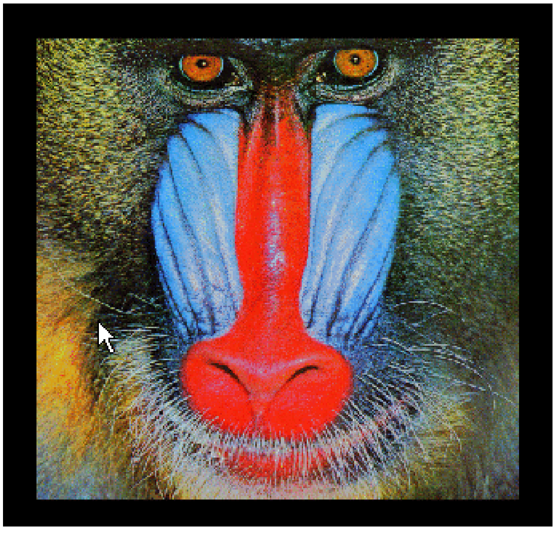
where *Property* is the name of the image property and `PropertyValue` is the value you are specifying. Use `set` and `get` to access image properties.

Example

Example 1

Load a mat-file containing a photograph of a colorful primate. Display the indexed image using its associated colormap.

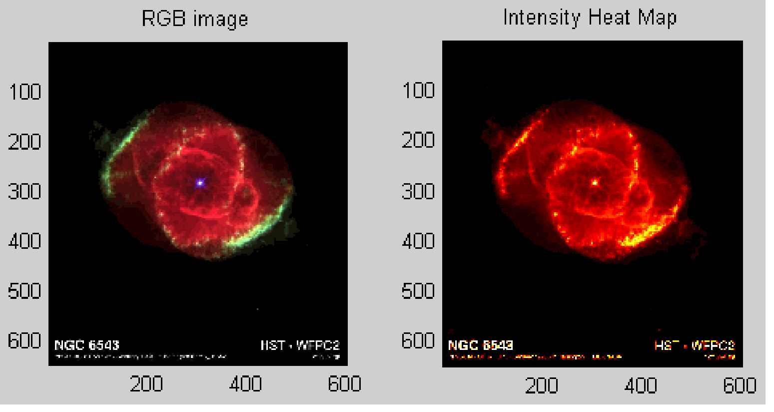
```
load mandrill
figure('color','k')
image(X)
colormap(map)
axis off          % Remove axis ticks and numbers
axis image        % Set aspect ratio to obtain square pixels
```



Example 2

Load a JPEG image file of the Cat's Eye Nebula from the Hubble Space Telescope (image courtesy NASA). Display the original image using its RGB color values (left) as a subplot. Create a linked subplot (same size and scale) to display the transformed intensity image as a heat map (right).

```
figure
ax(1) = subplot(1,2,1);
rgb = imread('ngc6543a.jpg');
image(rgb); title('RGB image')
ax(2) = subplot(122);
im = mean(rgb,3);
image(im); title('Intensity Heat Map')
colormap(hot(256))
linkaxes(ax,'xy')
axis(ax,'image')
```



See Also

`imagesc`, `imfinfo`, `imread`, `imwrite`, `colormap`, `pcolor`, `newplot`, `surface`

"Displaying Bit-Mapped Images"

"Bit-Mapped Images" on page 1-91 for related functions

Image Properties for property descriptions

Purpose

Define image 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.

Image Properties

This section lists property names along with the types of values each property accepts.

`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 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. 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).

`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
- 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`

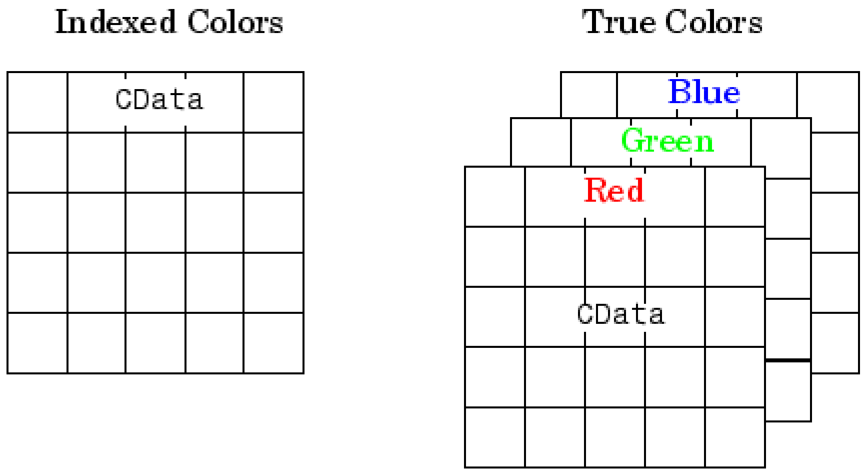
matrix or m-by-n-by-3 array

The image data. A matrix or 3-D array of values specifying the color of each rectangular area defining the image. `image(C)` assigns the values of `C` to `CData`. MATLAB determines the coloring of the image in one of three ways:

- Using the elements of `CData` as indices into the current colormap (the default) (`CDataMapping` set to `direct`)
- Scaling the elements of `CData` to range between the values `min(get(gca,'CLim'))` and `max(get(gca,'CLim'))` (`CDataMapping` set to `scaled`)
- Interpreting the elements of `CData` directly as RGB values (true color specification)

Note that the behavior of `NaN`s in image `CData` is not defined. See the image `AlphaData` property for information on using transparency with images.

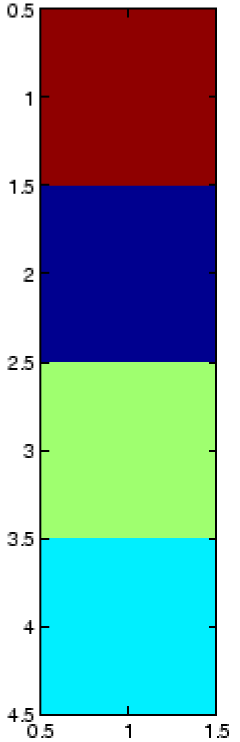
A true color specification for `CData` requires an m-by-n-by-3 array of RGB values. The first page contains the red component, the second page the green component, and the third page the blue component of each element in the image. RGB values range from 0 to 1. The following picture illustrates the relative dimensions of `CData` for the two color models.



If CData has only one row or column, the height or width respectively is always one data unit and is centered about the first YData or XData element respectively. For example, using a 4-by-1 matrix of random data,

```
C = rand(4,1);
image(C,'CDataMapping','scaled')
axis image
```

produces



`CDataMapping`

`scaled | {direct}`

Direct or scaled indexed colors. This property determines whether MATLAB interprets the values in `CData` as indices into the figure colormap (the default) or scales the values according to the values of the axes `CLim` property.

When `CDataMapping` is `direct`, the values of `CData` should be in the range 1 to `length(get(gcf,'Colormap'))`. If you use true color specification for `CData`, this property has no effect.

`Children`

handles

The empty matrix; image objects have no children.

`Clipping`
`on | off`

Clipping mode. By default, MATLAB clips images to the axes rectangle. If you set `Clipping` to `off`, the image can be displayed outside the axes rectangle. For example, if you create an image, set `hold` to `on`, freeze axis scaling (with `axis manual`), and then create a larger image, it extends beyond the axis limits.

`CreateFcn`
string or function handle

Callback routine executed during object creation. This property defines a callback routine that executes when MATLAB creates an image object. You must define this property as a default value for images or in a call to the `image` function to create a new image object. For example, the statement

```
set(0,'DefaultImageCreateFcn','axis image')
```

defines a default value on the root level that sets the aspect ratio and the axis limits so the image has square pixels. MATLAB executes this routine after setting all image properties. Setting this property on an existing image 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.

`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.

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.

`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 graphics object. For image objects, `Type` is always '`image`'.

`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`
`[1 size(CData,2)]` by default

Control placement of image along x-axis. A vector specifying the locations of the centers of the elements `CData(1,1)` and `CData(m,n)`, where `CData` has a size of `m`-by-`n`. Element `CData(1,1)` is centered over the coordinate defined by the first elements in `XData` and `YData`. Element `CData(m,n)` is centered over the coordinate defined by the last elements in `XData` and `YData`. The centers of the remaining elements of `CData` are evenly distributed between those two points.

The width of each `CData` element is determined by the expression

```
(XData(2)-XData(1))/(size(CData,2)-1)
```

You can also specify a single value for `XData`. In this case, `image` centers the first element at this coordinate and centers each following element one unit apart.

`YData`
`[1 size(CData,1)]` by default

Control placement of image along y-axis. A vector specifying the locations of the centers of the elements `CData(1,1)` and `CData(m,n)`, where `CData` has a size of `m`-by-`n`. Element

`CData(1,1)` is centered over the coordinate defined by the first elements in `XData` and `YData`. Element `CData(m,n)` is centered over the coordinate defined by the last elements in `XData` and `YData`. The centers of the remaining elements of `CData` are evenly distributed between those two points.

The height of each `CData` element is determined by the expression

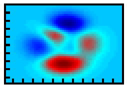
```
(YData(2)-YData(1))/(size(CData,1)-1)
```

You can also specify a single value for `YData`. In this case, `image` centers the first element at this coordinate and centers each following element one unit apart.

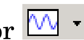
imagesc

Purpose

Scale data and display image object



GUI Alternatives

To plot a selected matrix as an image use the Plot Selector  in the Workspace Browser, or use the Figure Palette Plot Catalog. Manipulate image characteristics 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

```
imagesc(C)
imagesc(x,y,C)
imagesc(...,clims)
h = imagesc(...)
```

Description

The `imagesc` function scales image data to the full range of the current colormap and displays the image. (See “Examples” on page 2-1607 for an illustration.)

`imagesc(C)` displays `C` as an image. Each element of `C` corresponds to a rectangular area in the image. The values of the elements of `C` are indices into the current colormap that determine the color of each patch.

`imagesc(x,y,C)` displays `C` as an image and specifies the bounds of the *x*- and *y*-axis with vectors `x` and `y`.

`imagesc(...,clims)` normalizes the values in `C` to the range specified by `clims` and displays `C` as an image. `clims` is a two-element vector that limits the range of data values in `C`. These values map to the full range of values in the current colormap.

`h = imagesc(...)` returns the handle for an image graphics object.

Remarks

x and y do not affect the elements in C; they only affect the annotation of the axes. If length(x) > 2 or length(y) > 2, imagesc ignores all except the first and last elements of the respective vector.

imagesc creates an image with CDataMapping set to scaled, and sets the axes CLim property to the value passed in clims.

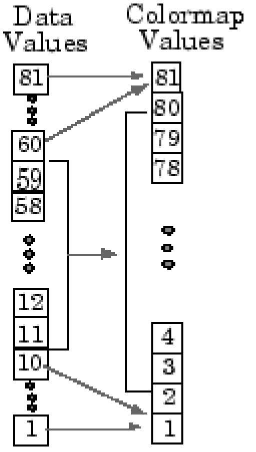
You cannot interactively pan or zoom outside the *x*-limits or *y*-limits of an image.

Examples

You can expand midrange color resolution by mapping low values to the first color and high values to the last color in the colormap by specifying color value limits (clims). If the size of the current colormap is 81-by-3, the statements

```
clims = [ 10 60 ]
imagesc(C,clims)
```

map the data values in C to the colormap as shown in this illustration and the code that follows:

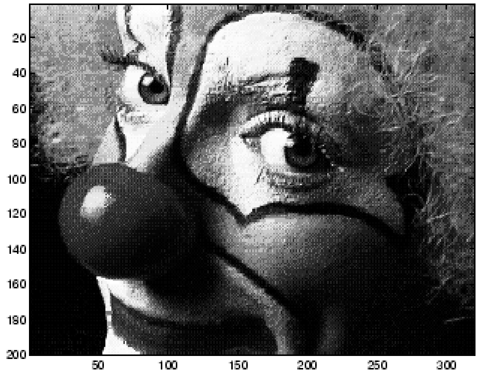


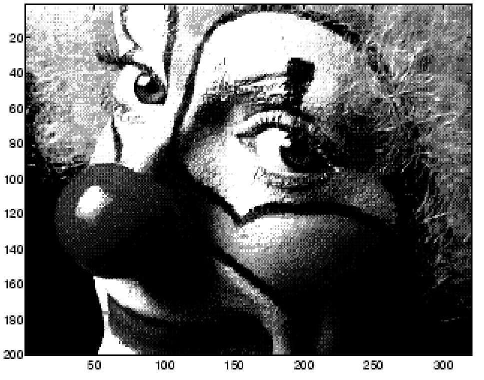
In this example, the left image maps to the gray colormap using the statements

```
load clown
imagesc(X)
colormap(gray)
```

The right image has values between 10 and 60 scaled to the full range of the gray colormap using the statements

```
load clown
clims = [10 60];
imagesc(X,clims)
colormap(gray)
```





See Also

`image`, `imfinfo`, `imread`, `imwrite`, `colorbar`, `colormap`, `pcolor`, `surface`, `surf`

"Bit-Mapped Images" on page 1-91 for related functions

Purpose

Information about graphics file

Syntax

```
info = imfinfo(filename,fmt)
info = imfinfo(filename)
info = imfino(URL,...)
```

Description

`info = imfinfo(filename,`*`fmt`*`)` returns a structure, `info`, whose fields contain information about an image in a graphics file. `filename` is a string that specifies the name of the graphics file, and *`fmt`* is a string that specifies the format of the file. The file must be in the current directory or in a directory on the MATLAB path. If `imfinfo` cannot find a file named `filename`, it looks for a file named `filename.`*`fmt`*. The possible values for *`fmt`* are contained in the MATLAB file format registry. To view of list of these formats, run the `imformats` command.

If `filename` is a TIFF, HDF, ICO, GIF, or CUR file containing more than one image, `info` is a structure array with one element for each image in the file. For example, `info(3)` would contain information about the third image in the file.

`info = imfinfo(filename)` attempts to infer the format of the file from its contents.

`info = imfino(URL,...)` reads the image from the specified Internet `URL`. The URL must include the protocol type (e.g., `http://`)

Information Returned

The set of fields in `info` depends on the individual file and its format. However, the first nine fields are always the same. This table lists these common fields, in the order they appear in the structure, and describes their values.

Field	Value
`Filename`	A string containing the name of the file; if the file is not in the current directory, the string contains the full pathname of the file.

Field	Value
`FileModDate`	A string containing the date when the file was last modified
`FileSize`	An integer indicating the size of the file in bytes
`Format`	A string containing the file format, as specified by *`fmt`*; for JPEG and TIFF files, the three-letter variant is returned.
`FormatVersion`	A string or number describing the version of the format
`Width`	An integer indicating the width of the image in pixels
`Height`	An integer indicating the height of the image in pixels
`BitDepth`	An integer indicating the number of bits per pixel
`ColorType`	A string indicating the type of image; either `'truecolor'` for a truecolor RGB image, `'grayscale'` for a grayscale intensity image, or `'indexed'` for an indexed image

Example

```
info = imfinfo('canoe.tif')

info =

             Filename: [1x76 char]
          FileModDate: '04-Dec-2000 13:57:55'
             FileSize: 69708
               Format: 'tif'
        FormatVersion: []
                Width: 346
               Height: 207
             BitDepth: 8
            ColorType: 'indexed'
```

```
              FormatSignature: [73 73 42 0]
                    ByteOrder: 'little-endian'
               NewSubFileType: 0
                BitsPerSample: 8
                  Compression: 'PackBits'
    PhotometricInterpretation: 'RGB Palette'
                 StripOffsets: [9x1 double]
              SamplesPerPixel: 1
                 RowsPerStrip: 23
              StripByteCounts: [9x1 double]
                  XResolution: 72
                  YResolution: 72
               ResolutionUnit: 'Inch'
                     Colormap: [256x3 double]
          PlanarConfiguration: 'Chunky'
                    TileWidth: []
                   TileLength: []
                  TileOffsets: []
               TileByteCounts: []
                  Orientation: 1
                    FillOrder: 1
             GrayResponseUnit: 0.0100
               MaxSampleValue: 255
               MinSampleValue: 0
                 Thresholding: 1
```

See Also

imformats, imread, imwrite

"Bit-Mapped Images" on page 1-91 for related functions

imformats

Purpose

Manage image file format registry

Syntax

```
imformats
formats = imformats
formats = imformats('fmt')
formats = imformats(format_struct)
formats = imformats('factory')
```

Description

`imformats` displays a table of information listing all the values in the MATLAB file format registry. This registry determines which file formats are supported by the `imfinfo`, `imread`, and `imwrite` functions.

`formats = imformats` returns a structure containing all the values in the MATLAB file format registry. The following tables lists the fields in the order they appear in the structure.

Field	Value
`ext`	A cell array of strings that specify filename extensions that are valid for this format
`isa`	A string specifying the name of the function that determines if a file is a certain format. This can also be a function handle.
`info`	A string specifying the name of the function that reads information about a file. This can also be a function handle.
`read`	A string specifying the name of the function that reads image data in a file. This can also be a function handle.
`write`	A string specifying the name of the function that writes MATLAB data to a file. This can also be a function handle.
`alpha`	Returns `1` if the format has an alpha channel, `0` otherwise
`description`	A text description of the file format

Note The values for the `isa`, `info`, `read`, and `write` fields must be functions on the MATLAB search path or function handles.

`formats = imformats('fmt')` searches the known formats in the MATLAB file format registry for the format associated with the filename extension `'fmt'`. If found, `imformats` returns a structure containing the characteristics and function names associated with the format. Otherwise, it returns an empty structure.

`formats = imformats(format_struct)` sets the MATLAB file format registry to the values in `format_struct`. The output structure, `formats`, contains the new registry settings.

Caution Using `imformats` to specify values in the MATLAB file format registry can result in the inability to load any image files. To return the file format registry to a working state, use `imformats` with the `'factory'` setting.

`formats = imformats('factory')` resets the MATLAB file format registry to the default format registry values. This removes any user-specified settings.

Changes to the format registry do not persist between MATLAB sessions. To have a format always available when you start MATLAB, add the appropriate `imformats` command to the MATLAB startup file, `startup.m`, located in `$MATLAB/toolbox/local` on UNIX systems, or `$MATLAB\toolbox\local` on Windows systems.

Example

```
formats = imformats;
formats(1)

ans =

              ext: {'bmp'}
```

```
         isa: @isbmp
        info: @imbmpinfo
        read: @readbmp
       write: @writebmp
       alpha: 0
 description: 'Windows Bitmap (BMP)'
```

See Also

`fileformats`, `imfinfo`, `imread`, `imwrite`, `path`

"Bit-Mapped Images" on page 1-91 for related functions

Purpose

Add package or class to current Java import list

Syntax

```
import package_name.*
import class_name
import cls_or_pkg_name1 cls_or_pkg_name2...
import
L = import
```

Description

`import package_name.*` adds all the classes in *package_name* to the current import list. Note that *package_name* must be followed by `.*`.

`import class_name` adds a single class to the current import list. Note that *class_name* must be fully qualified (that is, it must include the package name).

`import cls_or_pkg_name1 cls_or_pkg_name2...` adds all named classes and packages to the current import list. Note that each class name must be fully qualified, and each package name must be followed by `.*`.

`import` with no input arguments displays the current import list, without adding to it.

`L = import` with no input arguments returns a cell array of strings containing the current import list, without adding to it.

The `import` command operates exclusively on the import list of the function from which it is invoked. When invoked at the command prompt, `import` uses the import list for the MATLAB command environment. If `import` is used in a script invoked from a function, it affects the import list of the function. If `import` is used in a script that is invoked from the command prompt, it affects the import list for the command environment.

The import list of a function is persistent across calls to that function and is only cleared when the function is cleared.

To clear the current import list, use the following command.

```
clear import
```

This command may only be invoked at the command prompt. Attempting to use `clear import` within a function results in an error.

Remarks

The only reason for using `import` is to allow your code to refer to each imported class with the immediate class name only, rather than with the fully qualified class name. `import` is particularly useful in streamlining calls to constructors, where most references to Java classes occur.

Examples

This example shows importing and using the single class, `java.lang.String`, and two complete packages, `java.util` and `java.awt`.

```
import java.lang.String
import java.util.* java.awt.*
f = Frame;               % Create java.awt.Frame object
s = String('hello');     % Create java.lang.String object
methods Enumeration      % List java.util.Enumeration methods
```

See Also

`clear`, `importdata`

Purpose

Load data from disk file

Syntax

```
importdata(filename)
A = importdata(filename)
A = importdata(filename,delimiter)
A = importdata(filename,delimiter,headerline)
[A D] = importdata(...)
[A D H] = importdata(...)
[...] = importdata('-pastespecial', ...)
```

Description

`importdata(filename)` loads data from `filename` into the workspace. The `filename` input is a string enclosed in single quotes.

`A = importdata(filename)` loads data from `filename` into structure `A`.

`A = importdata(filename,delimiter)` loads data from `filename` using `delimiter` as the column separator. The `delimiter` argument must be a string enclosed in single quotes. Use `'\t'` for tab. When importing from an ASCII file, `delimiter` only separates numeric data.

`A = importdata(filename,delimiter,headerline)` where `headerline` is a number that indicates on which line of the file the header text is located, loads data from line `headerline+1` to the end of the file.

`[A D] = importdata(...)` returns the output structure in `A`, and the delimiter character in `D`.

`[A D H] = importdata(...)` returns the output structure in `A`, the delimiter character in `D`, and the line number of the header in `H`.

`[...]  = importdata('`**`-pastespecial`**`', ...)` loads data from your computer's paste buffer rather than from a file.

Remarks

`importdata` looks at the file extension to determine which helper function to use. If it can recognize the file extension, `importdata` calls the appropriate helper function, specifying the maximum number of output arguments. If it cannot recognize the file extension, `importdata` calls `finfo` to determine which helper function to use. If no helper function is defined for this file extension, importdata treats the file as delimited text. importdata removes from the result empty outputs returned from the helper function.

Examples

Example 1 — A Simple Import

Import data from file ding.wav:

```
s = importdata('ding.wav')
s =

   data: [11554x1 double]
     fs: 22050
```

Example 2 — Importing with Delimiter and Header

Use importdata to read in a text file. The third input argument is colheaders, which is the number of lines that belong to the header:

```
type 'myfile.txt'

 Day1  Day2  Day3  Day4  Day5  Day6  Day7
95.01 76.21 61.54 40.57  5.79 20.28  1.53
23.11 45.65 79.19 93.55 35.29 19.87 74.68
60.68  1.85 92.18 91.69 81.32 60.38 44.51
48.60 82.14 73.82 41.03  0.99 27.22 93.18
89.13 44.47 17.63 89.36 13.89 19.88 46.60
```

Import from the file, specifying the space character as the delimiter and 1 row for the column header. Assign the output to variable M:

```
M = importdata('myfile.txt', ' ', 1);
```

Print out columns 3 and 5, including the header for those columns:

```
for k=3:2:5
   M.colheaders(1,k)
   M.data(:,k)
   disp ' '
end
```

```
ans =
    'Day3'
ans =
   61.5400
   79.1900
   92.1800
   73.8200
   17.6300

ans =
    'Day5'
ans =
    5.7900
   35.2900
   81.3200
    0.9900
   13.8900
```

See Also

`load`

imread

Purpose

Read image from graphics file

Syntax

```
A = imread(filename, fmt)
[X, map] = imread(...)
[...]  = imread(filename)
[...]  = imread(URL,...)
[...]  = imread(..., idx)  CUR or ICO
[A, map, alpha] = imread(...)  CUR or ICO
[...]  = imread(..., idx)  GIF
[...]  = imread(..., 'frames', idx)  GIF
[...]  = imread(..., ref)  HDF4
[...]  = imread(...,'BackgroundColor',BG) PNG
[A, map, alpha] = imread(...)  PNG
[...]  = imread(..., idx)  TIFF
[...]  = imread(..., 'PixelRegion', {ROWS, COLS})  TIFF
```

Description

`A = imread(filename, fmt)` reads a grayscale or color image from the file specified by the string `filename`. If the file is not in the current directory, or in a directory on the MATLAB path, specify the full pathname.

The text string *fmt* specifies the format of the file by its standard file extension. For example, specify `'gif'` for Graphics Interchange Format files. To see a list of supported formats, with their file extensions, use the `imformats` function. If `imread` cannot find a file named `filename`, it looks for a file named `filename.fmt`.

The return value `A` is an array containing the image data. If the file contains a grayscale image, `A` is an M-by-N array. If the file contains a truecolor image, `A` is an M-by-N-by-3 array. For TIFF files containing color images that use the CMYK color space, `A` is an M-by-N-by-4 array. See TIFF in the Format-Specific Information section for more information.

The class of `A` depends on the bits-per-sample of the image data, rounded to the next byte boundary. For example, `imread` returns 24-bit color data as an array of `uint8` data because the sample size for each color component is 8 bits. See "Remarks" on page 2-1621 for a discussion of bitdepths, and see "Format-Specific Information" on page 2-1621 for more detail about supported bitdepths and sample sizes for a particular format.

`[X, map] = imread(...)` reads the indexed image in `filename` into `X` and its associated colormap into `map`. Colormap values in the image file are automatically rescaled into the range `[0,1]`.

`[...]  = imread(filename)` attempts to infer the format of the file from its content.

`[...]  = imread(URL,...)` reads the image from an Internet URL. The `URL` must include the protocol type (e.g., `http://`).

See the format-specific sections for additional syntaxes.

Remarks

Bitdepth is the number of bits used to represent each image pixel. Bitdepth is calculated by multiplying the bits-per-sample with the samples-per-pixel. Thus, a format that uses 8-bits for each color component (or sample) and three samples per pixel has a bitdepth of 24. Sometimes the sample size associated with a bitdepth can be ambiguous: does a 48-bit bitdepth represent six 8-bit samples, four 12-bit samples, or three 16-bit samples? The following format-specific sections provide sample size information to avoid this ambiguity.

Format-Specific Information

The following sections provide information about the support for specific formats, listed in alphabetical order by format name. These sections include information about format-specific syntaxes, if they exist. The following is a list of links to the various sections.

BMP — Windows Bitmap

The following table lists the supported bitdepths, compression, and output classes for BMP data.

Supported Bitdepths	No Compression	RLE Compression	Output Class	Notes
1-bit	x	–	logical	
4-bit	x	x	`uint8`	
8-bit	x	x	`uint8`	
16-bit	x	–	`uint8`	1 sample/pixel
24-bit	x	–	`uint8`	3 samples/pixel
32-bit	x	–	`uint8`	3 samples/pixel (1 byte padding)

CUR — Cursor File

The following table lists the supported bitdepths, compression, and output classes for Cursor files and Icon files.

Supported Bitdepths	No Compression	Compression	Output Class
1-bit	x	–	logical
4-bit	x	–	`uint8`
8-bit	x	–	`uint8`

The following are format-specific syntaxes for Cursor files and Icon files.

`[...] = imread(..., idx)` `CUR or ICO` reads in one image from a multi-image icon or cursor file. `idx` is an integer value that specifies the order that the image appears in the file. For example, if `idx` is `3`, `imread` reads the third image in the file. If you omit this argument, `imread` reads the first image in the file.

`[A, map, alpha] = imread(...)` `CUR or ICO` returns the AND mask for the resource, which can be used to determine the transparency information. For cursor files, this mask may contain the only useful data.

Note By default, Microsoft Windows cursors are 32-by-32 pixels. MATLAB pointers must be 16-by-16. You will probably need to scale your image. If you have Image Processing Toolbox, you can use the `imresize` function.

GIF — Graphics Interchange Format

The following table lists the supported bitdepths, compression, and output classes for GIF files.

Supported Bitdepths	No Compression	Compression	Output Class
1-bit	x	–	logical
2-bit to 8-bit	x	–	`uint8`

The following are format-specific syntaxes for GIF files.

`[...] = imread(..., idx)` GIF reads in one or more frames from a multiframe (i.e., animated) GIF file. `idx` must be an integer scalar or vector of integer values. For example, if `idx` is `3`, `imread` reads the third image in the file. If `idx` is `1:5`, `imread` returns only the first five frames.

`[...] = imread(..., 'frames', idx)` GIF is the same as the syntax above except that `idx` can be `'all'`. In this case, all the frames are read and returned in the order that they appear in the file.

Note Because of the way that GIF files are structured, all the frames must be read when a particular frame is requested. Consequently, it is much faster to specify a vector of frames or `'all'` for `idx` than to call `imread` in a loop when reading multiple frames from the same GIF file.

HDF4 — Hierarchical Data Format

The following table lists the supported bitdepths, compression, and output classes for HDF4 files.

Supported Bitdepths	Raster Image with colormap	Raster image without colormap	Output Class	Notes
8-bit	x	x	`uint8`	
24-bit	–	–	`uint8`	3 samples/pixel

The following are format-specific syntaxes for HDF4 files.

`[...] = imread(..., ref)` HDF4 reads in one image from a multi-image HDF4 file. `ref` is an integer value that specifies the reference number used to identify the image. For example, if `ref` is `12`, `imread` reads the image whose reference number is 12. (Note that in an HDF4 file the reference numbers do not necessarily correspond to the order of the images in the file. You can use `imfinfo` to match image order with reference number.) If you omit this argument, `imread` reads the first image in the file.

ICO — Icon File

See CUR – Cursor File

JPEG — Joint Photographic Experts Group

`imread` can read any baseline JPEG image as well as JPEG images with some commonly used extensions. The following table lists the supported bitdepths, compression, and output classes for JPEG files.

Supported Bitdepths	Lossy Compression	Lossless Compression	Output Class	Notes
8-bit	x	x	`uint8`	Grayscale or RGB
12-bit	x	x	`uint16`	Grayscale
16-bit	–	x	`uint16`	Grayscale
36-bit	x	x	`uint16`	RGB Three 12-bit samples/pixel

PBM — Portable Bitmap

The following table lists the supported bitdepths, compression, and output classes for PBM files.

Supported Bitdepths	Raw Binary	ASCII (Plain) Encoded	Output Class
1-bit	x	x	logical

PCX — Windows Paintbrush

The following table lists the supported bitdepths, compression, and output classes for PCX files.

Supported Bitdepths	Output Class	Notes
1-bit	`logical`	Grayscale only
8-bit	`uint8`	Grayscale or indexed
24-bit	`uint8`	RGB Three 8-bit samples/pixel

PGM — Portable Graymap

The following table lists the supported bitdepths, compression, and output classes for PGM files.

Supported Bitdepths	Raw Binary	ASCII (Plain) Encoded	Output Class
Up to 16-bit	x	–	`uint8`
Arbitrary	–	x	

PNG — Portable Network Graphics

The following table lists the supported bitdepths, compression, and output classes for PNG data.

Supported Bitdepths	Output Class	Notes
1-bit	`logical`	Grayscale
2-bit	`uint8`	Grayscale
4-bit	`uint8`	Grayscale
8-bit	`uint8`	Grayscale or Indexed
16-bit	`uint16`	Grayscale or Indexed

Supported Bitdepths	Output Class	Notes
24-bit	uint8	RGB Three 8-bit samples/pixel.
48-bit	uint16	RGB Three 16-bit samples/pixel.

The following are format-specific syntaxes for PNG files.

`[...] = imread(...,'BackgroundColor',BG)` PNG composites any transparent pixels in the input image against the color specified in `BG`. If `BG` is `'none'`, then no compositing is performed. If the input image is indexed, `BG` must be an integer in the range `[1,P]` where `P` is the colormap length. If the input image is grayscale, `BG` should be an integer in the range `[0,1]`. If the input image is RGB, `BG` should be a three-element vector whose values are in the range `[0,1]`. The string `'BackgroundColor'` may be abbreviated.

`[A, map, alpha] = imread(...)` PNG returns the alpha channel if one is present; otherwise `alpha` is `[]`. Note that `map` may be empty if the file contains a grayscale or truecolor image.

If the `alpha` output argument is specified, `BG` defaults to `'none'`, if not specified by the user. Otherwise, if the PNG file contains a background color chunk, that color is used as the default value for `BG`. If `alpha` is not used and the file does not contain a background color chunk, then the default value for `BG` is `1` for indexed images; `0` for grayscale images; and `[0 0 0]` for truecolor images.

PPM — Portable Pixmap

The following table lists the supported bitdepths, compression, and output classes for PPM files.

Supported Bitdepths	Raw Binary	ASCII (Plain) Encoded	Output Class
Up to 16-bit	x	–	uint8
Arbitrary	–	x	

RAS — Sun Raster

The following table lists the supported bitdepths, compression, and output classes for RAS files.

Supported Bitdepths	Output Class	Notes
1-bit	logical	Bitmap
8-bit	uint8	Indexed
24-bit	uint8	RGB Three 8-bit samples/pixel
32-bit	uint8	RGB with Alpha Four 8-bit samples/pixel

TIFF — Tagged Image File Format

The following table lists the supported bitdepths, compression, and output classes for TIFF files.

Supported	Compression			Color Spaces				Output	
Bitdepths	None	Packbits	CCITT	RGB	ICCLAB	CIELAB	CMYK	Class	Notes
1-bit	x	x	x	–	–	–	–	logical	
8-bit	x	x	–	–	–	–	–	uint8	
12-bit	–	–	–	–	–	–	–	uint16	Grayscale or Indexed
16-bit	–	–	–	x	–	–	–	uint16	Grayscale or Indexed

Supported	Compression			Color Spaces				Output	
Bitdepths	None	Packbits	CCITT	RGB	ICCLAB	CIELAB	CMYK	Class	Notes
24-bit	x	x	–	x	x	x	–	uint8	3 samples/pixel
32-bit	–	–	–	–	–	–	x	uint8	4 samples/pixel
36-bit	–	–	–	x	–	–	–	uint16	3 samples/pixel
48-bit	–	–	–	x	x	x	–	uint16	3 samples/pixel
64-bit	–	–	–	–	–	–	x	double	4 samples/pixel

The following are format-specific syntaxes for TIFF files.

`imread` also supports 8-bit integral and 32-bit floating-point tiled TIFF images, with any compression and color space combination listed above, and 32-bit IEEE floating-point images.

`[...] = imread(..., idx)` reads in one image from a multi-image TIFF file. `idx` is an integer value that specifies the order in which the image appears in the file. For example, if `idx` is `3`, `imread` reads the third image in the file. If you omit this argument, `imread` reads the first image in the file.

For TIFF files, `imread` can read color data represented in the RGB, CIELAB, or ICCLAB color spaces. To determine which color space is used, look at the value of the `PhotometricInterpretation` field returned by `imfinfo`. Note, however, that if a file contains CIELAB color data, `imread` converts it to ICCLAB before bringing it into the MATLAB workspace. 8- or 16-bit TIFF CIELAB-encoded values use a mixture of signed and unsigned data types that cannot be represented as a single MATLAB array.

`[...] = imread(..., 'PixelRegion', {ROWS, COLS})` returns the subimage specified by the boundaries in `ROWS` and `COLS`. For tiled TIFF images, `imread` reads only the tiles that encompass the region specified by `ROWS` and `COLS`, improving memory efficiency and performance. `ROWS` and `COLS` must be either two or three element vectors. If two elements are provided, they denote the 1-based indices `[START STOP]`. If three elements are provided, the indices `[START INCREMENT STOP]` allow image downsampling.

XWD — X Window Dump

The following table lists the supported bitdepths, compression, and output classes for XWD files.

Supported Bitdepths	ZPixmaps	XYBitmaps	XYPixmaps	Output Class
1-bit	x	–	x	`logical`
8-bit	x	–	–	`uint8`

Class Support

For most image file formats, `imread` uses 8 or fewer bits per color plane to store image pixels. The following table lists the class of the returned array for the data types used by the file formats.

Data Type Used in File	Class of Array Returned by imread
1-bit per pixel	`logical`
2- to 8-bits per color plane	`uint8`
9- to 16-bit per pixel	`uint16` (`BMP`, `JPEG`, `PNG`, and `TIFF`) For the 16-bit BMP packed format (5-6-5), MATLAB returns `uint8`

Note For indexed images, `imread` always reads the colormap into an array of class `double`, even though the image array itself may be of class `uint8` or `uint16`.

Examples

This example reads the sixth image in a TIFF file.

```
[X,map] = imread('your_image.tif',6);
```

This example reads the fourth image in an HDF4 file.

```
info = imfinfo('your_hdf_file.hdf');
[X,map] = imread('your_hdf_file.hdf',info(4).Reference);
```

This example reads a 24-bit PNG image and sets any of its fully transparent (alpha channel) pixels to red.

```
bg = [255 0 0];
A = imread('your_image.png','BackgroundColor',bg);
```

This example returns the alpha channel (if any) of a PNG image.

```
[A,map,alpha] = imread('your_image.png');
```

This example reads an ICO image, applies a transparency mask, and then displays the image.

```
[a,b,c] = imread('your_icon.ico');
% Augment colormap for background color (white).
b2 = [b; 1 1 1];
% Create new image for display.
d = ones(size(a)) * (length(b2) - 1);
% Use the AND mask to mix the background and
% foreground data on the new image
d(c == 0) = a(c == 0);
% Display new image
image(uint8(d)), colormap(b2)
```

See Also

`double`, `fread`, `image`, `imfinfo`, `imformats`, `imwrite`, `uint8`, `uint16`

"Bit-Mapped Images" on page 1-91 for related functions

Purpose

Write image to graphics file

Syntax

```
imwrite(A,filename,fmt)
imwrite(X,map,filename,fmt)
imwrite(...,filename)
imwrite(...,Param1,Val1,Param2,Val2...)
```

Description

`imwrite(A,filename,fmt)` writes the image `A` to the file specified by `filename` in the format specified by `fmt`.

`A` can be an M-by-N (grayscale image) or M-by-N-by-3 (truecolor image) array. `A` cannot be an empty array. If the format specified is TIFF, `imwrite` can also accept an M-by-N-by-4 array containing color data that uses the CMYK color space. For information about the class of the input array and the output image, see "Class Support" on page 2-1645.

`filename` is a string that specifies the name of the output file.

`fmt` can be any of the text strings listed in the table in "Supported Formats" on page 2-1634. This list of supported formats is determined by the MATLAB image file format registry. See `imformats` for more information about this registry.

`imwrite(X,map,filename,fmt)` writes the indexed image in `X` and its associated colormap `map` to `filename` in the format specified by `fmt`. If `X` is of class `uint8` or `uint16`, `imwrite` writes the actual values in the array to the file. If `X` is of class `double`, the `imwrite` function offsets the values in the array before writing, using `uint8(X 1)`. The `map` parameter must be a valid MATLAB colormap. Note that most image file formats do not support colormaps with more than 256 entries.

`imwrite(...,filename)` writes the image to `filename`, inferring the format to use from the filename's extension. The extension must be one of the values for `fmt`, listed in "Supported Formats" on page 2-1634.

`imwrite(...,Param1,Val1,Param2,Val2...)` specifies parameters that control various characteristics of the output file for HDF, JPEG, PBM, PGM, PNG, PPM, and TIFF files. For example, if you are writing a JPEG file, you can specify the quality of the output image. For the lists of parameters available for each format, see "Format-Specific Parameters" on page 2-1636.

Supported Formats

This table summarizes the types of images that `imwrite` can write. The MATLAB file format registry determines which file formats are supported. See `imformats` for more information about this registry. Note that, for certain formats, `imwrite` may take additional parameters, described in "Format-Specific Parameters" on page 2-1636.

Format	Full Name	Variants
`'bmp'`	Windows Bitmap (BMP)	1-bit, 8-bit, and 24-bit uncompressed images
`'gif'`	Graphics Interchange Format (GIF)	8-bit images
`'hdf'`	Hierarchical Data Format (HDF4)	8-bit raster image data sets, with or without associated colormap, 24-bit raster image data sets; uncompressed or with RLE or JPEG compression
`'jpg'` or `'jpeg'`	Joint Photographic Experts Group (JPEG)	8-bit, 12-bit, and 16-bit Baseline JPEG images **Note** Indexed images are converted to RGB before writing out JPEG files, because the JPEG format does not support indexed images.
`pbm`	Portable Bitmap (PBM)	Any 1-bit PBM image, ASCII (plain) or raw (binary) encoding

Format	Full Name	Variants
'pcx'	Windows Paintbrush (PCX)	8-bit images
'pgm'	Portable Graymap (PGM)	Any standard PGM image; ASCII (plain) encoded with arbitrary color depth; raw (binary) encoded with up to 16 bits per gray value
'png'	Portable Network Graphics (PNG)	1-bit, 2-bit, 4-bit, 8-bit, and 16-bit grayscale images; 8-bit and 16-bit grayscale images with alpha channels; 1-bit, 2-bit, 4-bit, and 8-bit indexed images; 24-bit and 48-bit truecolor images; 24-bit and 48-bit truecolor images with alpha channels
'pnm'	Portable Anymap (PNM)	Any of the PPM/PGM/PBM formats, chosen automatically
'ppm'	Portable Pixmap (PPM)	Any standard PPM image. ASCII (plain) encoded with arbitrary color depth; raw (binary) encoded with up to 16 bits per color component
'ras'	Sun Raster (RAS)	Any RAS image, including 1-bit bitmap, 8-bit indexed, 24-bit truecolor and 32-bit truecolor with alpha

Format	Full Name	Variants
'tif' or 'tiff'	Tagged Image File Format (TIFF)	Baseline TIFF images, including 1-bit, 8-bit, 16-bit, and 24-bit uncompressed images; 1-bit, 8-bit, 16-bit, and 24-bit images with packbits compression; 1-bit images with CCITT 1D, Group 3, and Group 4 compression; CIELAB, ICCLAB, and CMYK images
'xwd'	X Windows Dump (XWD)	8-bit ZPixmaps

Format-Specific Parameters

The following tables list parameters that can be used with specific file formats.

GIF-Specific Parameters

This table describes the available parameters for GIF files.

Parameter	Values
'BackgroundColor'	A scalar integer. This value specifies which index in the colormap should be treated as the transparent color for the image and is used for certain disposal methods in animated GIFs. If X is uint8 or logical, then indexing starts at 0. If X is double, then indexing starts at 1.
'Comment'	A string or cell array of strings containing a comment to be added to the image. For a cell array of strings, a carriage return is added after each row.
'DelayTime'	A scalar value between 0 and 655 inclusive, that specifies the delay in seconds before displaying the next image.
'DisposalMethod'	One of the following strings, which sets the disposal method of an animated GIF: 'leaveInPlace', 'restoreBG', 'restorePrevious', or 'doNotSpecify'.

Parameter	Values
'LoopCount'	A finite integer between 0 and 65535 or the value Inf (the default) which specifies the number of times to repeat the animation. By default, the animation loops continuously. For a value of 0, the animation will be played once. For a value of 1, the animation will be played twice, etc.
'TransparentColor'	A scalar integer. This value specifies which index in the colormap should be treated as the transparent color for the image. If X is uint8 or logical, then indexing starts at 0. If X is double, then indexing starts at 1.
'WriteMode'	One of these strings: 'overwrite' (the default) or 'append'. In append mode, a single frame is added to the existing file.

HDF4-Specific Parameters

This table describes the available parameters for HDF4 files.

Parameter	Values
'Compression'	One of these strings: 'none' (the default) 'jpeg'(valid only for grayscale and RGB images) 'rle' (valid only for grayscale and indexed images)

Parameter	Values
'Quality'	A number between 0 and 100; this parameter applies only if 'Compression' is 'jpeg'. Higher numbers mean higher *quality* (less image degradation due to compression), but the resulting file size is larger. The default value is 75.
'WriteMode'	One of these strings: 'overwrite' (the default) 'append'

JPEG-Specific Parameters

This table describes the available parameters for JPEG files.

Parameter	Values	Default
'Bitdepth'	A scalar value indicating desired bitdepth; for grayscale images this can be 8, 12, or 16; for color images this can be 8 or 12.	8 (grayscale) and 8 bit per plane for color images
'Comment'	A column vector cell array of strings or a character matrix. Each row of input is written out as a comment in the JPEG file.	Empty
'Mode'	Specifies the type of compression used; value can be either of these strings: 'lossy' or 'lossless'	'lossy'
'Quality'	A number between 0 and 100; higher numbers mean higher quality (less image degradation due to compression), but the resulting file size is larger.	75

PBM-, PGM-, and PPM-Specific Parameters

This table describes the available parameters for PBM, PGM, and PPM files.

Parameter	Values	Default
'Encoding'	One of these strings: 'ASCII' for plain encoding 'rawbits' for binary encoding	'rawbits'
'MaxValue'	A scalar indicating the maximum gray or color value. Available only for PGM and PPM files. For PBM files, this value is always 1.	Default is 65535 if image array is 'uint16'; 255 otherwise.

PNG-Specific Parameters

The following table lists the available parameters for PNG files, in alphabetical order. In addition to these PNG parameters, you can use any parameter name that satisfies the PNG specification for keywords; that is, uses only printable characters, contains 80 or fewer characters, and no contains no leading or trailing spaces. The value corresponding to these user-specified parameters must be a string that contains no control characters other than linefeed.

Parameter	Values
`'Alpha'`	A matrix specifying the transparency of each pixel individually. The row and column dimensions must be the same as the data array; they can be `uint8`, `uint16`, or `double`, in which case the values should be in the range [0,1].
`'Author'`	A string
`'Background'`	The value specifies background color to be used when compositing transparent pixels. For indexed images: an integer in the range [1,`P`], where `P` is the colormap length. For grayscale images: a scalar in the range [0,1]. For truecolor images: a three-element vector in the range [0,1].
`'bitdepth'`	A scalar value indicating desired bit depth. For grayscale images this can be 1, 2, 4, 8, or 16. For grayscale images with an alpha channel this can be 8 or 16. For indexed images this can be 1, 2, 4, or 8. For truecolor images with or without an alpha channel this can be 8 or 16. By default, `imwrite` uses 8 bits per pixel, if image is double or `uint8`; 16 bits per pixel if image is `uint16`; 1 bit per pixel if image is `logical`.

Parameter	Values
'Chromaticities'	An eight-element vector [wx wy rx ry gx gy bx by] that specifies the reference white point and the primary chromaticities
'Comment'	A string
'Copyright'	A string
'CreationTime'	A string
'Description'	A string
'Disclaimer'	A string
'Gamma'	A nonnegative scalar indicating the file gamma
'ImageModTime'	A MATLAB serial date number (see the datenum function) or a string convertible to a date vector via the datevec function. Values should be in Coordinated Universal Time (UTC).
'InterlaceType'	Either 'none' (the default) or 'adam7'
'ResolutionUnit'	Either 'unknown' or 'meter'
'SignificantBits'	A scalar or vector indicating how many bits in the data array should be regarded as significant; values must be in the range [1,BitDepth]. For indexed images: a three-element vector. For grayscale images: a scalar. For grayscale images with an alpha channel: a two-element vector. For truecolor images: a three-element vector. For truecolor images with an alpha channel: a four-element vector.
'Software'	A string
'Source'	A string

Parameter	Values
'Transparency'	This value is used to indicate transparency information only when no alpha channel is used. Set to the value that indicates which pixels should be considered transparent. (If the image uses a colormap, this value represents an index number to the colormap.) For indexed images: a Q-element vector in the range [0,1], where Q is no larger than the colormap length and each value indicates the transparency associated with the corresponding colormap entry. In most cases, Q = 1. For grayscale images: a scalar in the range [0,1]. The value indicates the grayscale color to be considered transparent. For truecolor images: a three-element vector in the range [0,1]. The value indicates the truecolor color to be considered transparent. **Note** You cannot specify 'Transparency' and 'Alpha' at the same time.
'Warning'	A string
'XResolution'	A scalar indicating the number of pixels/unit in the horizontal direction
'YResolution'	A scalar indicating the number of pixels/unit in the vertical direction

RAS-Specific Parameters

This table describes the available parameters for RAS files.

Parameter	Values	Default
'Alpha'	A matrix specifying the transparency of each pixel individually; the row and column dimensions must be the same as the data array; can be uint8, uint16, or double. Can only be used with truecolor images.	Empty matrix ([])
'Type'	One of these strings: 'standard' (uncompressed, b-g-r color order with truecolor images) 'rgb' (like 'standard', but uses r-g-b color order for truecolor images) 'rle' (run-length encoding of 1-bit and 8-bit images)	'standard'

TIFF-Specific Parameters

This table describes the available parameters for TIFF files.

Parameter	Values	Default
'ColorSpace'	Specifies one of the following color spaces used to represent the color data. 'rgb' 'cielab' 'icclab' See for more information about this parameter.	'rgb'
'Compression'	One of these strings: 'none', 'packbits', 'ccitt', 'fax3', or 'fax4' The 'ccitt', 'fax3', and 'fax4' compression schemes are valid for binary images only.	'ccitt' for binary images; 'packbits' for nonbinary images
'Description'	Any string; fills in the ImageDescription field returned by imfinfo	Empty

Parameter	Values	Default
'Resolution'	A two-element vector containing the XResolution and YResolution, or a scalar indicating both resolutions	72
'WriteMode'	One of these strings: 'overwrite' 'append'	'overwrite'

L*a*b* Color Data

For TIFF files only, imwrite can write a color image that uses the *L*a*b** color space. The 1976 CIE *L*a*b** specification defines numeric values that represent luminance (*L**) and chrominance (*a** and *b**) information.

To store *L*a*b** color data in a TIFF file, the values must be encoded to fit into either 8-bit or 16-bit storage. imwrite can store *L*a*b** color data in a TIFF file using these encodings:

- 8-bit and 16-bit encodings defined by the TIFF specification, called the CIELAB encodings
- 8-bit and 16-bit encodings defined by the International Color Consortium, called ICCLAB encodings

The output class and encoding used by imwrite to store color data depends on the class of the input array and the value you specify for the TIFF-specific ColorSpace parameter. The following table explains these options. (The 8-bit and 16-bit CIELAB encodings cannot be input arrays because they use a mixture of signed and unsigned values and cannot be represented as a single MATLAB array.)

Input Class and Encoding	ColorSpace Parameter Value	Output Class and Encoding
8-bit ICCLAB [1]	'icclab'	8-bit ICCLAB
	'cielab'	8-bit CIELAB
16-bit ICCLAB [2]	'icclab'	16-bit ICCLAB

Input Class and Encoding	ColorSpace Parameter Value	Output Class and Encoding
	'cielab'	16-bit CIELAB
Double-precision 1976 CIE $L^*a^*b^*$ values [3]	'icclab'	8-bit ICCLAB
	'cielab'	8-bit CIELAB

[1] 8-bit ICCLAB represents values as integers in the range [0 255]. L^* values are multiplied by `255/100`; `128` is added to both the a^* and b^* values.

[2] 16-bit ICCLAB multiplies L^* values by `65280/100` and represents the values as integers in the range [0, 65280]. `32768` is added to both the a^* and b^* values, which are represented as integers in the range [0,65535].

[3] L^* is in the dynamic range [0, 100]. a^* and b^* can take any value. Setting a* and b^* to 0 (zero) produces a neutral color (gray).

Class Support

The input array `A` can be of class `logical`, `uint8`, `uint16`, or `double`. Indexed images (`X`) can be of class `uint8`, `uint16`, or `double`; the associated colormap, `map`, must be of class `double`. Input values must be full (non-sparse).

The class of the image written to the file depends on the format specified. For most formats, if the input array is of class `uint8`, `imwrite` outputs the data as 8-bit values. If the input array is of class `uint16` and the format supports 16-bit data (JPEG, PNG, and TIFF), `imwrite` outputs the data as 16-bit values. If the format does not support 16-bit values, `imwrite` issues an error. Several formats, such as JPEG and PNG, support a parameter that lets you specify the bit depth of the output data.

If the input array is of class `double`, and the image is a grayscale or RGB color image, `imwrite` assumes the dynamic range is [0,1] and automatically scales the data by 255 before writing it to the file as 8-bit values.

If the input array is of class `double`, and the image is an indexed image, `imwrite` converts the indices to zero-based indices by subtracting 1 from each element, and then writes the data as `uint8`.

If the input array is of class `logical`, `imwrite` assumes the data is a binary image and writes it to the file with a bit depth of 1, if the format allows it. BMP, PNG, or TIFF formats accept binary images as input arrays.

Example

This example appends an indexed image `X` and its colormap `map` to an existing uncompressed multipage HDF4 file.

```
imwrite(X,map,'your_hdf_file.hdf','Compression','none',...
'WriteMode','append')
```

See Also

`fwrite`, `getframe`, `imfinfo`, `imformats`, `imread`

"Bit-Mapped Images" on page 1-91 for related functions

Purpose

Convert indexed image to RGB image

Syntax

```
RGB = ind2rgb(X,map)
```

Description

`RGB = ind2rgb(X,map)` converts the matrix `X` and corresponding colormap `map` to RGB (truecolor) format.

Class Support

`X` can be of class `uint8`, `uint16`, or `double`. RGB is an m-by-n-by-3 array of class `double`.

See Also

`image`

"Bit-Mapped Images" on page 1-91 for related functions

ind2sub

Purpose Subscripts from linear index

Syntax

```
[I,J] = ind2sub(siz,IND)
[I1,I2,I3,...,In] = ind2sub(siz,IND)
```

Description The `ind2sub` command determines the equivalent subscript values corresponding to a single index into an array.

`[I,J] = ind2sub(siz,IND)` returns the matrices `I` and `J` containing the equivalent row and column subscripts corresponding to each linear index in the matrix `IND` for a matrix of size `siz`. `siz` is a 2-element vector, where `siz(1)` is the number of rows and `siz(2)` is the number of columns.

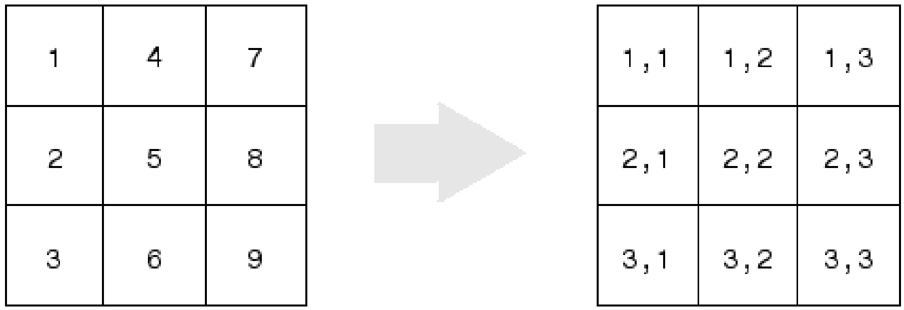
Note For matrices, `[I,J] = ind2sub(size(A),find(A>5))` returns the same values as `[I,J] = find(A>5)`.

`[I1,I2,I3,...,In] = ind2sub(siz,IND)` returns `n` subscript arrays `I1,I2,...,In` containing the equivalent multidimensional array subscripts equivalent to `IND` for an array of size `siz`. `siz` is an `n`-element vector that specifies the size of each array dimension.

Examples

Example 1 — Two-Dimensional Matrices

The mapping from linear indexes to subscript equivalents for a 3-by-3 matrix is

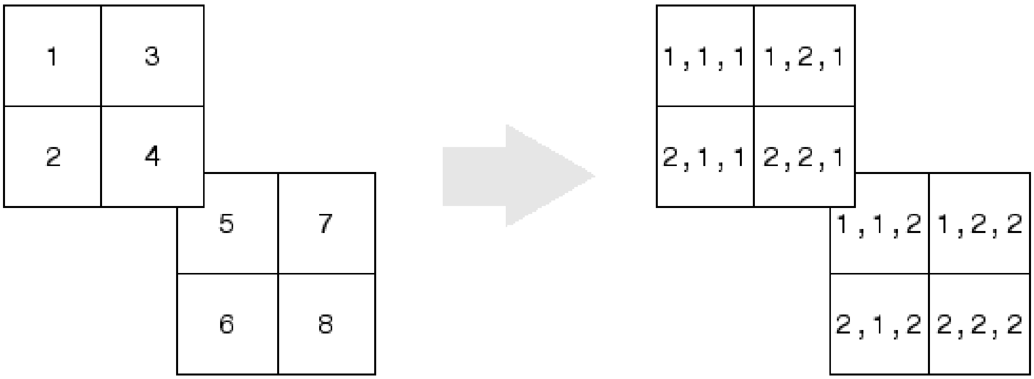


This code determines the row and column subscripts in a 3-by-3 matrix, of elements with linear indices 3, 4, 5, 6.

```
IND = [3 4 5 6]
s = [3,3];
[I,J] = ind2sub(s,IND)

I =
     3     1     2     3

J =
     1     2     2     2
```

Example 2 — Three-Dimensional Matrices

The mapping from linear indexes to subscript equivalents for a 2-by-2-by-2 array is



This code determines the subscript equivalents in a 2-by-2-by-2 array, of elements whose linear indices 3, 4, 5, 6 are specified in the `IND` matrix.

```
IND = [3 4;5 6];
s = [2,2,2];
[I,J,K] = ind2sub(s,IND)

I =
     1     2
     1     2

J =
     2     2
     1     1

K =
     1     1
     2     2
```

Example 3 — Effects of Returning Fewer Outputs

When calling `ind2sub` for an N-dimensional matrix, you would typically supply N output arguments in the call: one for each dimension of the matrix. This example shows what happens when you return three, two, and one output when calling `ind2sub` on a 3-dimensional matrix.

The matrix is 2-by-2-by-2 and the linear indices are 1 through 8:

```
dims = [2 2 2];
indices = [1 2 3 4 5 6 7 8];
```

The 3-output call to ind2sub returns the expected subscripts for the 2-by-2-by-2 matrix:

```
[rowsub colsub pagsub] = ind2sub(dims, indices)
rowsub =
     1     2     1     2     1     2     1     2
colsub =
     1     1     2     2     1     1     2     2
pagsub =
     1     1     1     1     2     2     2     2
```

If you specify only two outputs (row and column), ind2sub still returns a subscript for each specified index, but drops the third dimension from the matrix, returning subscripts for a 2-dimensional, 2-by-4 matrix instead:

```
[rowsub colsub] = ind2sub(dims, indices)
rowsub =
     1     2     1     2     1     2     1     2
colsub =
     1     1     2     2     3     3     4     4
```

If you specify one output (row), ind2sub drops both the second and third dimensions from the matrix, and returns subscripts for a 1-dimensional, 1-by-8 matrix instead:

```
[rowsub] = ind2sub(dims, indices)
rowsub =
     1     2     3     4     5     6     7     8
```

See Also

find, size, sub2ind

Inf

Purpose

Infinity

Syntax

```
Inf
Inf('double')
Inf('single')
Inf(n)
Inf(m,n)
Inf(m,n,p,...)
Inf(...,classname)
```

Description

`Inf` returns the IEEE arithmetic representation for positive infinity. Infinity results from operations like division by zero and overflow, which lead to results too large to represent as conventional floating-point values.

`Inf('double')` is the same as `Inf` with no inputs.

`Inf('single')` is the single precision representation of `Inf`.

`Inf(n)` is an `n`-by-`n` matrix of `Inf`s.

`Inf(m,n)` or `inf([m,n])` is an `m`-by-`n` matrix of `Inf`s.

`Inf(m,n,p,...)` or `Inf([m,n,p,...])` is an `m`-by-`n`-by-`p`-by-... array of `Inf`s.

Note The size inputs `m`, `n`, `p`, `...` should be nonnegative integers. Negative integers are treated as 0.

`Inf(...,classname)` is an array of `Inf`s of class specified by `classname`. `classname` must be either `'single'` or `'double'`.

Examples

`1/0`, `1.e1000`, `2^2000`, and `exp(1000)` all produce `Inf`.

`log(0)` produces `-Inf`.

`Inf-Inf` and `Inf/Inf` both produce `NaN` (Not-a-Number).

See Also `isinf`, `NaN`

inferiorto

Purpose Establish inferior class relationship

Syntax

```
inferiorto('class1', 'class2', ...)
```

Description The `inferiorto` function establishes a hierarchy that determines the order in which MATLAB calls object methods.

`inferiorto('class1', 'class2', ...)` invoked within a class constructor method (say `myclass.m`) indicates that `myclass`'s method should not be invoked if a function is called with an object of class `myclass` and one or more objects of class `class1`, `class2`, and so on.

Remarks Suppose `A` is of class `'class_a'`, `B` is of class `'class_b'` and `C` is of class `'class_c'`. Also suppose the constructor `class_c.m` contains the statement `inferiorto('class_a')`. Then `e = fun(a, c)` or `e = fun(c, a)` invokes `class_a/fun`.

If a function is called with two objects having an unspecified relationship, the two objects are considered to have equal precedence, and the leftmost object's method is called. So `fun(b, c)` calls `class_b/fun`, while `fun(c, b)` calls `class_c/fun`.

See Also `superiorto`

Purpose Information about contacting The MathWorks

Syntax

```
info
```

Description `info` displays in the Command Window, information about contacting The MathWorks.

See Also `help`, `version`

inline

Purpose

Construct inline object

Syntax

```
inline(expr)
inline(expr,arg1,arg2,...)
inline(expr,n)
```

Description

`inline(expr)` constructs an inline function object from the MATLAB expression contained in the string `expr`. The input argument to the inline function is automatically determined by searching `expr` for an isolated lower case alphabetic character, other than `i` or `j`, that is not part of a word formed from several alphabetic characters. If no such character exists, `x` is used. If the character is not unique, the one closest to `x` is used. If two characters are found, the one later in the alphabet is chosen.

`inline(expr,arg1,arg2,...)` constructs an inline function whose input arguments are specified by the strings `arg1`, `arg2`,.... Multicharacter symbol names may be used.

`inline(expr,n)` where `n` is a scalar, constructs an inline function whose input arguments are `x`, `P1`, `P2`, ...

Remarks

Three commands related to `inline` allow you to examine an inline function object and determine how it was created.

`char(fun)` converts the inline function into a character array. This is identical to `formula(fun)`.

`argnames(fun)` returns the names of the input arguments of the inline object `fun` as a cell array of strings.

`formula(fun)` returns the formula for the inline object `fun`.

A fourth command `vectorize(fun)` inserts a `.` before any `^`, `*` or `/`' in the formula for `fun`. The result is a vectorized version of the inline function.

Examples

Example 1

This example creates a simple inline function to square a number.

```
g = inline('t^2')
g =

     Inline function:
     g(t) = t^2
```

You can convert the result to a string using the `char` function.

```
char(g)

ans =

t^2
```

Example 2

This example creates an inline function to represent the formula $f = 3\sin(2x^2)$. The resulting inline function can be evaluated with the `argnames` and `formula` functions.

```
f = inline('3*sin(2*x.^2)')

f =
     Inline function:
     f(x) = 3*sin(2*x.^2)

argnames(f)

ans =
    'x'

formula(f)
ans =

3*sin(2*x.^2)
```

Example 3

This call to `inline` defines the function `f` to be dependent on two variables, `alpha` and `x`:

```
f = inline('sin(alpha*x)')

f =
     Inline function:
     f(alpha,x) = sin(alpha*x)
```

If `inline` does not return the desired function variables or if the function variables are in the wrong order, you can specify the desired variables explicitly with the `inline` argument list.

```
g = inline('sin(alpha*x)','x','alpha')

g =

     Inline function:
     g(x,alpha) = sin(alpha*x)
```

Purpose

Names of M-files, MEX-files, Java classes in memory

Syntax

```
M = inmem
[M, X] = inmem
[M, X, J] = inmem
[...] = inmem('-completenames')
```

Description

`M = inmem` returns a cell array of strings containing the names of the M-files that are currently loaded.

`[M, X] = inmem` returns an additional cell array `X` containing the names of the MEX-files that are currently loaded.

`[M, X, J] = inmem` also returns a cell array `J` containing the names of the Java classes that are currently loaded.

`[...]  = inmem('-completenames')` returns not only the names of the currently loaded M- and MEX-files, but the path and filename extension for each as well. No additional information is returned for loaded Java classes.

Examples

Example 1

This example lists the M-files that are required to run `erf`.

```
clear all;        % Clear the workspace
erf(0.5);

M = inmem
M =
   'erf'
```

Example 2

Generate a plot, and then find the M- and MEX-files that had been loaded to perform this operation:

```
clear all
surf(peaks)
```

```
[m x] = inmem('-completenames');

m(1:5)
ans =
    'F:\matlab\toolbox\matlab\ops\ismember.m'
    'F:\matlab\toolbox\matlab\datatypes\@opaque\double.m'
    'F:\matlab\toolbox\matlab\datatypes\isfield.m'
    'F:\matlab\toolbox\matlab\graphics\gcf.m'
    'F:\matlab\toolbox\matlab\elmat\meshgrid.m'

x(1:end)
ans =
    'F:\matlab\toolbox\matlab\graph2d\private\lineseriesmex.dll'
```

See Also

`clear`

Purpose

Points inside polygonal region

Syntax

```
IN = inpolygon(X,Y,xv,yv)
[IN ON] = inpolygon(X,Y,xv,yv)
```

Description

`IN = inpolygon(X,Y,xv,yv)` returns a matrix `IN` the same size as `X` and `Y`. Each element of `IN` is assigned the value 1 or 0 depending on whether the point `(X(p,q),Y(p,q))` is inside the polygonal region whose vertices are specified by the vectors `xv` and `yv`. In particular:

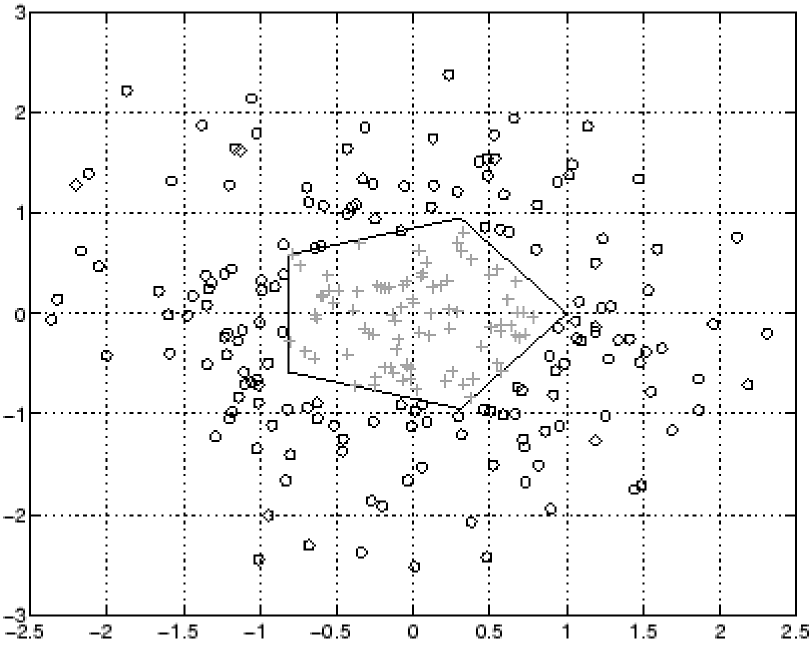
`IN(p,q) = 1`	If `(X(p,q),Y(p,q))` is inside the polygonal region or on the polygon boundary
`IN(p,q) = 0`	If `(X(p,q),Y(p,q))` is outside the polygonal region

`[IN ON] = inpolygon(X,Y,xv,yv)` returns a second matrix `ON` the same size as `X` and `Y`. Each element of `ON` is assigned the value 1 or 0 depending on whether the point `(X(p,q),Y(p,q))` is on the boundary of the polygonal region whose vertices are specified by the vectors `xv` and `yv`. In particular:

`ON(p,q) = 1`	If `(X(p,q),Y(p,q))` is on the polygon boundary
`ON(p,q) = 0`	If `(X(p,q),Y(p,q))` is inside or outside the polygon boundary

Examples

```
L = linspace(0,2.*pi,6); xv = cos(L)';yv = sin(L)';
xv = [xv ; xv(1)]; yv = [yv ; yv(1)];
x = randn(250,1); y = randn(250,1);
in = inpolygon(x,y,xv,yv);
plot(xv,yv,x(in),y(in),'r+',x(~in),y(~in),'bo')
```


3
2
1
0
−1
−2
−3
−2.5
−2
−1.5
−1
−0.5
0
0.5
1
1.5
2
2.5

Purpose

Request user input

Syntax

```
user_entry = input('prompt')
user_entry = input('prompt', 's')
```

Description

The response to the `input` prompt can be any MATLAB expression, which is evaluated using the variables in the current workspace.

`user_entry = input('prompt')` displays *`prompt`* as a prompt on the screen, waits for input from the keyboard, and returns the value entered in `user_entry`.

`user_entry = input('prompt', 's')` returns the entered string as a text variable rather than as a variable name or numerical value.

Remarks

If you press the **Return** key without entering anything, `input` returns an empty matrix.

The text string for the prompt can contain one or more `'\n'` characters. The `'\n'` means to skip to the next line. This allows the prompt string to span several lines. To display just a backslash, use `'\\'`.

If you enter an invalid expression at the prompt, MATLAB displays the relevant error message and then prompts you again to enter input.

Examples

Press **Return** to select a default value by detecting an empty matrix:

```
reply = input('Do you want more? Y/N [Y]: ', 's');
if isempty(reply)
    reply = 'Y';
end
```

See Also

`keyboard`, `menu`, `ginput`, `uicontrol`

Purpose

Create and open input dialog box

Syntax

```
answer = inputdlg(prompt)
answer = inputdlg(prompt,dlg_title)
answer = inputdlg(prompt,dlg_title,num_lines)
answer = inputdlg(prompt,dlg_title,num_lines,defAns)
answer = inputdlg(prompt,dlg_title,num_lines,defAns,options)
```

Description

`answer = inputdlg(prompt)` creates a modal dialog box and returns user input for multiple prompts in the cell array. `prompt` is a cell array containing prompt strings.

Note A modal dialog box prevents the user from interacting with other windows before responding. For more information, see `WindowStyle` in the MATLAB Figure Properties.

Note `inputdlg` uses the `uiwait` function to suspend execution until the user responds.

`answer = inputdlg(prompt,dlg_title)` `dlg_title` specifies a title for the dialog box.

`answer = inputdlg(prompt,dlg_title,num_lines)` `num_lines` specifies the number of lines for each user-entered value. `num_lines` can be a scalar, column vector, or matrix.

- If `num_lines` is a scalar, it applies to all prompts.
- If `num_lines` is a column vector, each element specifies the number of lines of input for a prompt.
- If `num_lines` is a matrix, it should be size m-by-2, where `m` is the number of prompts on the dialog box. Each row refers to a prompt.

The first column specifies the number of lines of input for a prompt. The second column specifies the width of the field in characters.

`answer = inputdlg(prompt,dlg_title,num_lines,defAns)` `defAns` specifies the default value to display for each prompt. `defAns` must contain the same number of elements as `prompt` and all elements must be strings.

`answer = inputdlg(prompt,dlg_title,num_lines,defAns,options)` If `options` is the string `'on'`, the dialog is made resizable in the horizontal direction. If options is a structure, the fields shown in the following table are recognized:

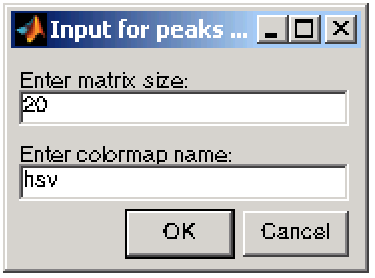
Field	Description
`Resize`	Can be `'on'` or `'off'` (default). If `'on'`, the window is resizable horizontally.
`WindowStyle`	Can be either `'normal'` or `'modal'` (default).
`Interpreter`	Can be either `'none'` (default) or `'tex'`. If the value is `'tex'`, the prompt strings are rendered using LaTeX.

Example

Example 1

Create a dialog box to input an integer and colormap name. Allow one line for each value.

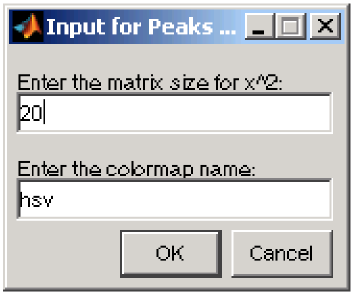
```
prompt = {'Enter matrix size:','Enter colormap name:'};
dlg_title = 'Input for peaks function';
num_lines = 1;
def = {'20','hsv'};
answer = inputdlg(prompt,dlg_title,num_lines,def);
```



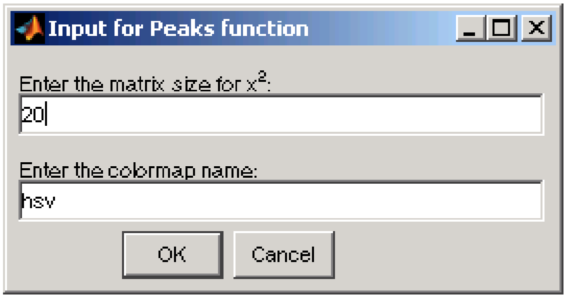
Example 2

Create a dialog box using the default options. Then use the options to make it resizable and not modal, and to interpret the text using LaTeX.

```
prompt={'Enter the matrix size for x^2:',...
        'Enter the colormap name:'};
name='Input for Peaks function';
numlines=1;
defaultanswer={'20','hsv'};
answer=inputdlg(prompt,name,numlines,defaultanswer);
```




```
options.Resize='on';
options.WindowStyle='normal';
options.Interpreter='tex';

answer=inputdlg(prompt,name,numlines,defaultanswer,options);
```



See Also

dialog, errordlg, helpdlg, listdlg, msgbox, questdlg, warndlg

figure, uiwait, uiresume

"Predefined Dialog Boxes" on page 1-103 for related functions

inputname

Purpose

Variable name of function input

Syntax

`inputname(argnum)`

Description

This command can be used only inside the body of a function.

`inputname(argnum)` returns the workspace variable name corresponding to the argument number *argnum*. If the input argument has no name (for example, if it is an expression instead of a variable), the `inputname` command returns the empty string (`''`).

Examples

Suppose the function `myfun.m` is defined as

```
function c = myfun(a,b)
disp(sprintf('First calling variable is "%s".', inputname(1))
```

Then

```
x = 5;  y = 3;  myfun(x,y)
```

produces

```
First calling variable is "x".
```

But

```
myfun(pi+1, pi-1)
```

produces

```
First calling variable is "".
```

See Also

`nargin`, `nargout`, `nargchk`

Purpose Construct input parser object

Syntax `p = inputParser`

Description `p = inputParser` constructs an empty `inputParser` object. Use this utility object to parse and validate input arguments to the functions that you develop. The input parser object follows handle semantics; that is, methods called on it affect the original object, not a copy of it.

MATLAB configures `inputParser` objects to recognize an input schema. Use any of the following methods to create the schema for parsing a particular function.

For more information on the `inputParser` class, see "Parsing Inputs with inputParser" in the MATLAB Programming documentation.

Methods

Method	Description
`addOptional`	Add an optional argument to the schema
`addParamValue`	Add a parameter-value pair argument to the schema
`addRequired`	Add a required argument to the schema
`createCopy`	Create a copy of the `inputParser` object
`parse`	Parse and validate the named inputs

Properties

Property	Description
`CaseSensitivity`	Enable or disable case-sensitive matching of argument names
`FunctionName`	Function name to be included in error messages
`KeepUnmatched`	Enable or disable errors on unmatched arguments

Property	Description
`Parameters`	Names of arguments defined in `inputParser` schema
`Results`	Names and values of arguments passed in function call that are in the schema for this function
`StructExpand`	Enable or disable passing arguments in a structure
`Unmatched`	Names and values of arguments passed in function call that are not in the schema for this function
`UsingDefaults`	Names of arguments not passed in function call that are given default values

Property Descriptions

Properties of the `inputParser` class are described below.

CaseSensitivity

Purpose — Enable or disable case sensitive matching of argument names

`p.CaseSensitivity = TF` enables or disables case-sensitivity when matching entries in the argument list with argument names in the schema. Set `CaseSensitivity` to logical `1` (`true`) to enable case-sensitive matching, or to logical `0` (`false`) to disable it. By default, case-sensitive matching is disabled.

FunctionName

Purpose — Function name to be included in error messages

`p.FunctionName = name` stores a function `name` that is to be included in error messages that might be thrown in the process of validating input arguments to the function. The `name` input is a string containing the name of the function for which you are parsing inputs with `inputParser`.

KeepUnmatched

Purpose — Enable or disable errors on unmatched arguments

`p.KeepUnmatched = TF` controls whether MATLAB throws an error when the function being called is passed an argument that has not been defined in the `inputParser` schema for this file. When this property is set to logical 1 (`true`), MATLAB does not throw an error, but instead stores the names and values of unmatched arguments in the `Unmatched` property of object p. When `KeepUnmatched` is set to logical 0 (false), MATLAB does throw an error whenever this condition is encountered and the `Unmatched` property is not affected.

Parameters

Purpose — Names of arguments defined in `inputParser` schema

`c = p.Parameters` is a cell array of strings containing the names of those arguments currently defined in the schema for the object. Each row of the `Parameters` cell array is a string containing the full name of a known argument.

Results

Purpose — Names and values of arguments passed in function call that are in the schema for this function

`arglist = p.Results` is a structure containing the results of the most recent parse of the input argument list. Each argument passed to the function is represented by a field in the `Results` structure, and the value of that argument is represented by the value of that field.

StructExpand

Purpose — Enable or disable passing arguments in a structure

`p.StructExpand = TF`, when set to logical 1 (`true`), tells MATLAB to accept a structure as an input in place of individual parameter-value arguments. If `StructExpand` is set to logical 0 (`false`), a structure is treated as a regular, single input.

Unmatched

Purpose — Names and values of arguments passed in function call that are not in the schema for this function

`c = p.Unmatched` is a structure array containing the names and values of all arguments passed in a call to the function that are not included in the schema for the function. `Unmatched` only contains this list of the `KeepUnmatched` property is set to true. If `KeepUnmatched` is set to `false`, MATLAB throws an error when unmatched arguments are passed in the function call. The `Unmatched` structure has the same format as the `Results` property of the `inputParser` class.

UsingDefaults

Purpose — Names of arguments not passed in function call that are given default values

`defaults = p.UsingDefaults` is a cell array of strings containing the names of those arguments that were not passed in the call to this function and consequently are set to their default values.

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 `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('\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

addRequired(inputParser), addOptional(inputParser), addParamValue(inputParser), parse(inputParser), createCopy(inputParser), varargin, nargchk, nargin

Purpose Open Property Inspector

Syntax

```
inspect
inspect(h)
inspect([h1,h2,...])
```

Description

`inspect` creates a separate Property Inspector window to enable the display and modification of the properties of any object you select in the figure window or Layout Editor. If no object is selected, the Property Inspector is blank.

`inspect(h)` creates a Property Inspector window for the object whose handle is `h`.

`inspect([h1,h2,...])` displays properties that objects `h1` and `h2` have in common, or a blank window if there are no such properties; any number of objects can be inspected and edited in this way (for example, handles returned by the `bar` command).

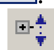
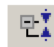
The Property Inspector has the following behaviors:

- Only one Property Inspector window is active at any given time; when you inspect a new object, its properties replace those of the object last inspected.
- When the Property Inspector is open and plot edit mode is on, clicking any object in the figure window displays the properties of that object (or set of objects) in the Property Inspector.
- When you select and inspect two or more objects of different types, the Property Inspector only shows the properties that all objects have in common.
- To change the value of any property, click on the property name shown at the left side of the window, and then enter the new value in the field at the right.

The Property Inspector provides two different views:

- List view — properties are ordered alphabetically (default); this is the only view available for annotation objects.
- Group view — properties are grouped under classified headings (Handle Graphics objects only)

To view alphabetically, click the “AZ” Icon  in the Property Inspector toolbar. To see properties in groups, click

the “++” icon. When properties are grouped, the “-” and “+” icons are enabled; click  to expand all categories and click  to collapse all categories. You can also expand and collapse individual categories by clicking on the “+” next to the category name. Some properties expand and collapse

---

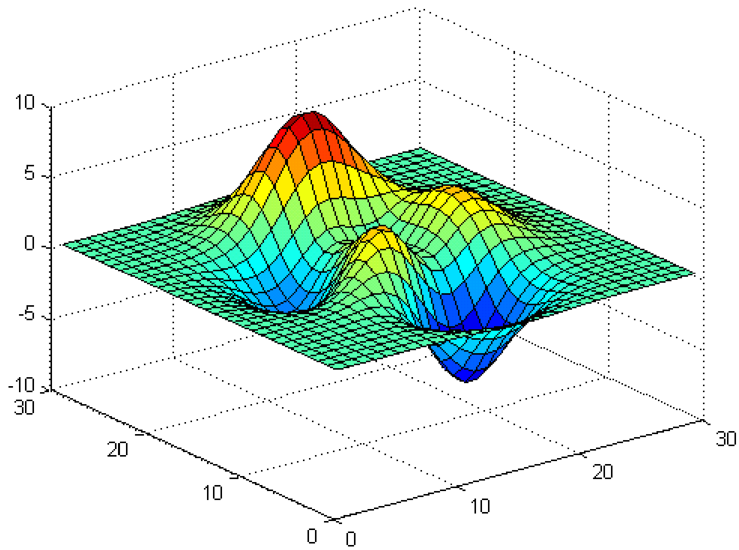
Notes The Property Inspector displays most, but not all, properties of Handle Graphics objects. For example, the `parent` and `children` of HG objects are not shown.
`inspect h` displays a Property Inspector window that enables modification of the string `'h'`, not the object whose handle is `h`.
If you modify properties at the MATLAB command line, you must refresh the Property Inspector window to see the change reflected there. Refresh the Property Inspector by reinvoking `inspect` on the object.

Examples

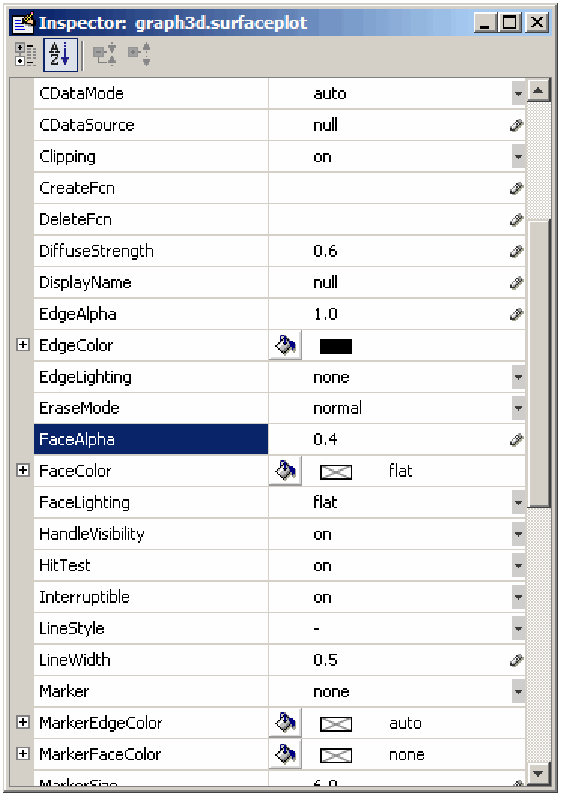
Example 1

Create a surface mesh plot and view its properties with the Property Inspector:

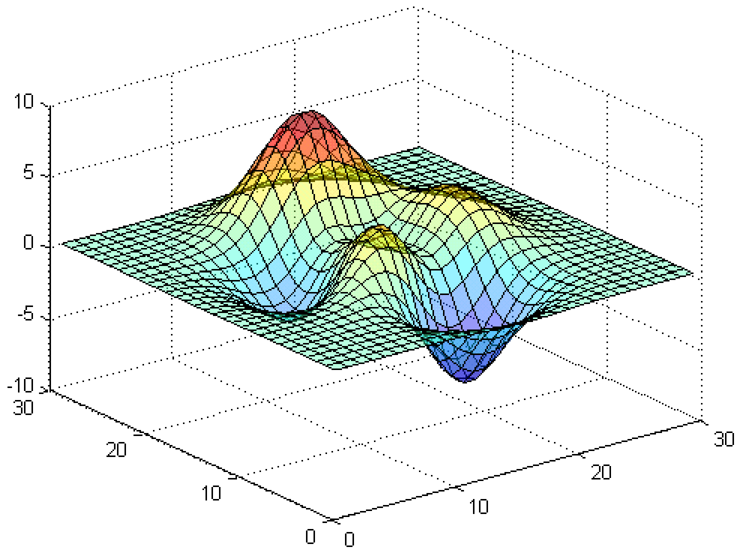
```
Z = peaks(30);
h = surf(Z)
inspect(h)
```



Use the Property Inspector to change the `FaceAlpha` property from `1.0` to `0.4` (equivalent to the command `set(h,'FaceAlpha',0.4)`). `FaceAlpha` controls the tranparency of patch faces.



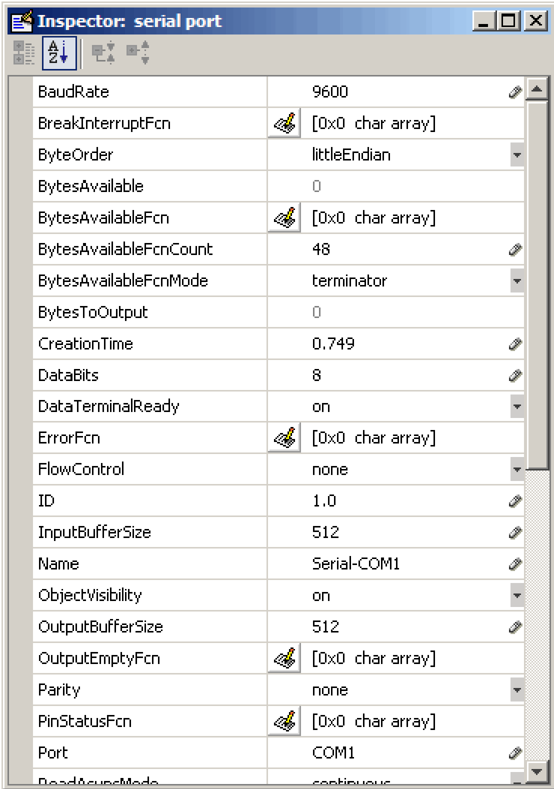
When you press **Enter** or click a different field, the `FaceAlpha` property of the surface object is updated:



Example 2

Create a serial port object for `COM1` and use the Property Inspector to peruse its properties:

```
s = serial('COM1');
inspect(s)
```



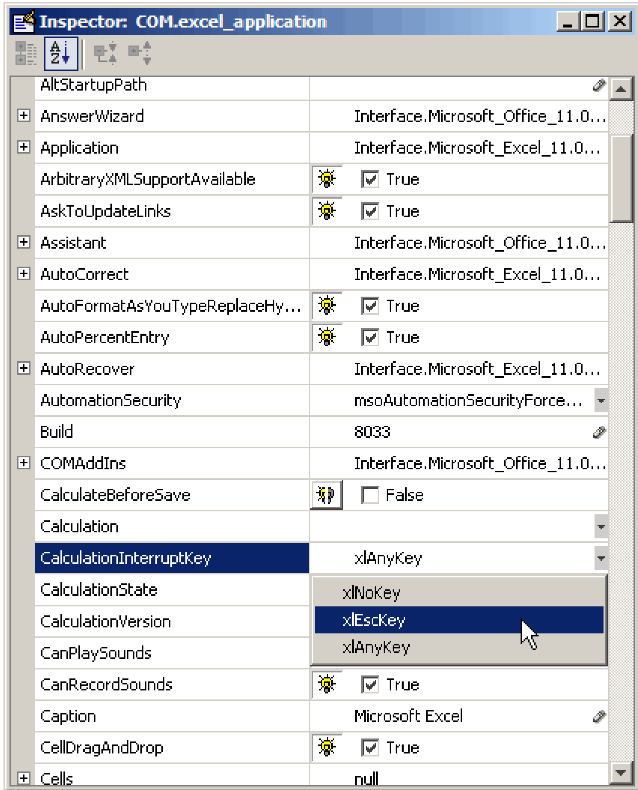
Because COM objects do not define property groupings, only the alphabetical list view of their properties is available.

Example 3

Create a COM Excel server and open a Property Inspector window with `inspect`:

```
h = actxserver('excel.application');
inspect(h)
```

Scroll down until you see the `CalculationInterruptKey` property, which by default is `xlAnyKey`. Click on the down-arrow in the right margin of the property inspector and select `xlEscKey` from the drop-down menu, as shown below:



Check this field in the MATLAB command window using `get` to confirm that it has changed:

```
get(h,'CalculationInterruptKey')

ans =
xlEscKey
```

See Also

`get`, `set`, `isprop`, `guide`, `addproperty`, `deleteproperty`

instrcallback

Purpose

Event information when event occurs

Syntax

```
instrcallback(obj,event)
```

Arguments

obj	An serial port object.
event	The event that caused the callback to execute.

Description

`instrcallback(obj,event)` displays a message that contains the event type, the time the event occurred, and the name of the serial port object that caused the event to occur.

For error events, the error message is also displayed. For pin status events, the pin that changed value and its value are also displayed.

Remarks

You should use `instrcallback` as a template from which you create callback functions that suit your specific application needs.

Example

The following example creates the serial port objects `s`, and configures `s` to execute `instrcallback` when an output-empty event occurs. The event occurs after the `*IDN?` command is written to the instrument.

```
s = serial('COM1');
set(s,'OutputEmptyFcn',@instrcallback)
fopen(s)
fprintf(s,'*IDN?','async')
```

The resulting display from `instrcallback` is shown below.

```
OutputEmpty event occurred at 08:37:49 for the object:
Serial-COM1.
```

Read the identification information from the input buffer and end the serial port session.

```
idn = fscanf(s);
fclose(s)
```

```
delete(s)
clear s
```

instrfind

Purpose

Read serial port objects from memory to MATLAB workspace

Syntax

```
out = instrfind
out = instrfind('PropertyName',PropertyValue,...)
out = instrfind(S)
out = instrfind(obj,'PropertyName',PropertyValue,...)
```

Arguments

`'PropertyName'`	A property name for `obj`.
`PropertyValue`	A property value supported by *`PropertyName`*.
`S`	A structure of property names and property values.
`obj`	A serial port object, or an array of serial port objects.
`out`	An array of serial port objects.

Description

`out = instrfind` returns all valid serial port objects as an array to `out`.

`out = instrfind('PropertyName',PropertyValue,...)` returns an array of serial port objects whose property names and property values match those specified.

`out = instrfind(S)` returns an array of serial port objects whose property names and property values match those defined in the structure `S`. The field names of `S` are the property names, while the field values are the associated property values.

`out = instrfind(obj,'PropertyName',PropertyValue,...)` restricts the search for matching property name/property value pairs to the serial port objects listed in `obj`.

Remarks

Refer to “Displaying Property Names and Property Values” for a list of serial port object properties that you can use with `instrfind`.

You must specify property values using the same format as the `get` function returns. For example, if `get` returns the `Name` property value as `MyObject`, `instrfind` will not find an object with a `Name` property value of `myobject`. However, this is not the case for properties that have a finite set of string values. For example, `instrfind` will find an object with a `Parity` property value of `Even` or `even`.

You can use property name/property value string pairs, structures, and cell array pairs in the same call to `instrfind`.

Example

Suppose you create the following two serial port objects.

```
s1 = serial('COM1');
s2 = serial('COM2');
set(s2,'BaudRate',4800)
fopen([s1 s2])
```

You can use `instrfind` to return serial port objects based on property values.

```
out1 = instrfind('Port','COM1');
out2 = instrfind({'Port','BaudRate'},{'COM2',4800});
```

You can also use `instrfind` to return cleared serial port objects to the MATLAB workspace.

```
clear s1 s2
newobjs = instrfind

   Instrument Object Array
   Index:   Type:        Status:     Name:
   1        serial       open        Serial-COM1
   2        serial       open        Serial-COM2
```

To close both `s1` and `s2`

```
fclose(newobjs)
```

See Also

Functions

`clear`, `get`

instrfindall

Purpose

Find visible and hidden serial port objects

Syntax

```
out = instrfindall
out = instrfindall('P1',V1,...)
out = instrfindall(s)
out = instrfindall(objs,'P1',V1,...)
```

Arguments

`'P1'`	Name of a serial port object property.
`V1`	Value allowed for corresponding *P1*.
`s`	A structure of property names and property values.
`objs`	An array of serial port objects.
`out`	An array of returned serial port objects.

Description

`out = instrfindall` finds all serial port objects, regardless of the value of the objects' `ObjectVisibility` property. The object or objects are returned to `out`.

`out = instrfindall('P1',V1,...)` returns an array, `out`, of serial port objects whose property names and corresponding property values match those specified as arguments.

`out = instrfindall(s)` returns an array, `out`, of serial port objects whose property names and corresponding property values match those specified in the structure `s`, where the field names correspond to property names and the field values correspond to the current value of the respective property.

`out = instrfindall(objs,'P1',V1,...)` restricts the search for objects with matching property name/value pairs to the serial port objects listed in `objs`.

Note that you can use string property name/property value pairs, structures, and cell array property name/property value pairs in the same call to `instrfindall`.

Remarks

instrfindall differs from instrfind in that it finds objects whose ObjectVisibility property is set to off.

Property values are case sensitive. You must specify property values using the same format as that returned by the get function. For example, if get returns the Name property value as 'MyObject', instrfindall will not find an object with a Name property value of 'myobject'. However, this is not the case for properties that have a finite set of string values. For example, instrfindall will find an object with a Parity property value of 'Even' or 'even'.

Examples

Suppose you create the following serial port objects:

```
s1 = serial('COM1');
s2 = serial('COM2');
set(s2,'ObjectVisibility','off')
```

Because object s2 has its ObjectVisibility set to 'off', it is not visible to commands like instrfind:

```
instrfind

   Serial Port Object : Serial-COM1
```

However, instrfindall finds all objects regardless of the value of ObjectVisibility:

```
instrfindall

 Instrument Object Array
 Index:   Type:          Status:     Name:
 1        serial         closed      Serial-COM1
 2        serial         closed      Serial-COM2
```

The following statements use instrfindall to return objects with specific property settings, which are passed as cell arrays:

```
props = {'PrimaryAddress','SecondaryAddress};
vals = {2,0};
```

```
obj = instrfindall(props,vals);
```

You can use `instrfindall` as an argument when you want to apply the command to all objects, visible and invisible. For example, the following statement makes all objects visible:

```
set(instrfindall,'ObjectVisibility','on')
```

See Also

Functions

`get`, `instrfind`

Properties

`ObjectVisibility`

Purpose

Convert integer to string

Syntax

```
str = int2str(N)
```

Description

`str = int2str(N)` converts an integer to a string with integer format. The input `N` can be a single integer or a vector or matrix of integers. Noninteger inputs are rounded before conversion.

Examples

`int2str(2+3)` is the string `'5'`.

One way to label a plot is

```
title(['case number ' int2str(n)])
```

For matrix or vector inputs, `int2str` returns a string matrix:

```
int2str(eye(3))

ans =

1  0  0
0  1  0
0  0  1
```

See Also

`fprintf`, `num2str`, `sprintf`

int8, int16, int32, int64

Purpose

Convert to signed integer

Syntax

```
I = int8(X)
I = int16(X)
I = int32(X)
I = int64(X)
```

Description

`I = int*(X)` converts the elements of array `X` into signed integers. `X` can be any numeric object (such as a `double`). The results of an `int*` operation are shown in the next table.

Operation	Output Range	Output Type	Bytes per Element	Output Class
`int8`	-128 to 127	Signed 8-bit integer	1	`int8`
`int16`	-32,768 to 32,767	Signed 16-bit integer	2	`int16`
`int32`	-2,147,483,648 to 2,147,483,647	Signed 32-bit integer	4	`int32`
`int64`	-9,223,372,036,854,775,808 to 9,223,372,036,854,775,807	Signed 64-bit integer	8	`int64`

`double` and `single` values are rounded to the nearest `int*` 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,

```
int16(40000)
ans =
   32767
```

If X is already a signed integer of the same class, then int* has no effect.

You can define or overload your own methods for int* (as you can for any object) by placing the appropriately named method in an @int* 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 int16). 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.

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 int64 array initialized to zero, type

```
I = zeros(100, 100, 'int64');
```

An easy way to find the range for any MATLAB integer type is to use the intmin and intmax functions as shown here for int32:

```
intmin('int32')                  intmax('int32')
ans =                            ans =
   -2147483648                      2147483647
```

See Also

double, single, uint8, uint16, uint32, uint64, intmax, intmin

interfaces

Purpose

List custom interfaces to COM server

Syntax

```
C = h.interfaces
C = interfaces(h)
```

Description

`C = h.interfaces` returns cell array of strings `C` listing all custom interfaces implemented by the component in a specific COM server. The server is designated by input argument, `h`, which is the handle returned by the `actxcontrol` or `actxserver` function when creating that server.

`C = interfaces(h)` is an alternate syntax for the same operation.

Note `interfaces` only lists the custom interfaces; it does not return any interfaces. Use the `invoke` function to return a handle to a specific custom interface.

Examples

Once you have created a COM server, you can query the server component to see if any custom interfaces are implemented. Use the `interfaces` function to return a list of all available custom interfaces:

```
h = actxserver('mytestenv.calculator')
h =
   COM.mytestenv.calculator

customlist = h.interfaces
customlist =
   ICalc1
   ICalc2
   ICalc3
```

To get a handle to the custom interface you want, use the `invoke` function, specifying the handle returned by `actxcontrol` or `actxserver` and also the name of the custom interface:

```
c1 = h.invoke('ICalc1')
c1 =
```

```
Interface.Calc_1.0_Type_Library.ICalc_Interface
```

You can now use this handle with most of the COM client functions to access the properties and methods of the object through the selected custom interface. For example, to list the properties available through the `ICalc1` interface, use

```
c1.get
     background: 'Blue'
         height: 10
          width: 0
```

To list the methods, use

```
c1.invoke
   Add = double Add(handle, double, double)
   Divide = double Divide(handle, double, double)
   Multiply = double Multiply(handle, double, double)
   Subtract = double Subtract(handle, double, double)
```

Add and multiply numbers using the `Add` and `Multiply` methods of the custom object `c1`:

```
sum = c1.Add(4, 7)
sum =
    11

prod = c1.Multiply(4, 7)
prod =
    28
```

See Also

`actxcontrol`, `actxserver`, `invoke`, `get`

interp1

Purpose

1-D data interpolation (table lookup)

Syntax

```
yi = interp1(x,Y,xi)
yi = interp1(Y,xi)
yi = interp1(x,Y,xi,method)
yi = interp1(x,Y,xi,method,'extrap')
yi = interp1(x,Y,xi,method,extrapval)
pp = interp1(x,Y,method,'pp')
```

Description

`yi = interp1(x,Y,xi)` interpolates to find `yi`, the values of the underlying function `Y` at the points in the vector or array `xi`. `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 `Y` is expanded to have the same length as `x`. `xi` can be a scalar, a vector, or a multidimensional array, and `yi` has the same size as `xi`.
- If `Y` is an array that is not a vector, the size of `Y` must have the form `[n,d1,d2,...,dk]`, where `n` is the length of `x`. The interpolation is performed for each `d1`-by-`d2`-by-...-`dk` value in `Y`. The sizes of `xi` and `yi` are related as follows:
  - If `xi` is a scalar or vector, `size(yi)` equals `[length(xi), d1, d2, ..., dk]`.
  - If `xi` is an array of size `[m1,m2,...,mj]`, `yi` has size `[m1,m2,...,mj,d1,d2,...,dk]`.

`yi = interp1(Y,xi)` assumes that `x = 1:N`, where `N` is the length of `Y` for vector `Y`, or `size(Y,1)` for matrix `Y`.

`yi = interp1(x,Y,xi,method)` interpolates using alternative methods:

'nearest'	Nearest neighbor interpolation
'linear'	Linear interpolation (default)

'spline'	Cubic spline interpolation
'pchip'	Piecewise cubic Hermite interpolation
'cubic'	(Same as 'pchip')
'v5cubic'	Cubic interpolation used in MATLAB 5. This method does not extrapolate. Also, if x is not equally spaced, 'spline' is used/

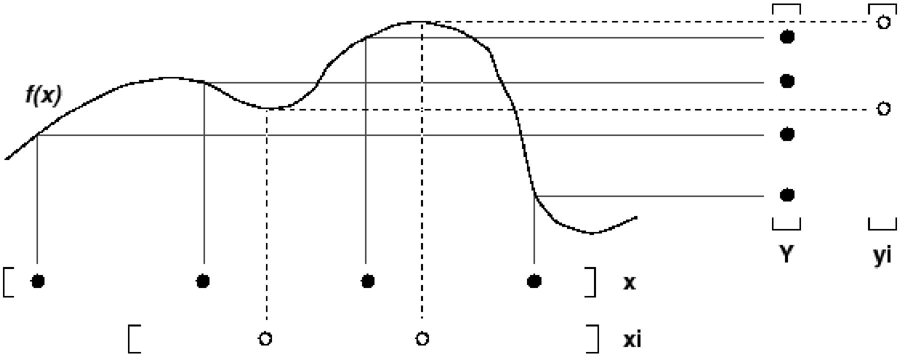
For the 'nearest', 'linear', and 'v5cubic' methods, interp1(x,Y,xi,method) returns NaN for any element of xi that is outside the interval spanned by x. For all other methods, interp1 performs extrapolation for out of range values.

yi = interp1(x,Y,xi,method,'extrap') uses the specified method to perform extrapolation for out of range values.

yi = interp1(x,Y,xi,method,extrapval) returns the scalar extrapval for out of range values. NaN and 0 are often used for extrapval.

pp = interp1(x,Y,method,'pp') uses the specified method to generate the piecewise polynomial form (ppform) of Y. You can use any of the methods in the preceding table, except for 'v5cubic'. pp can then be evaluated via ppval. ppval(pp,xi) is the same as interp1(x,Y,xi,method,'extrap').

The interp1 command interpolates between data points. It finds values at intermediate points, of a one-dimensional function $f(x)$ that underlies the data. This function is shown below, along with the relationship between vectors x, Y, xi, and yi.



Interpolation is the same operation as *table lookup*. Described in table lookup terms, the *table* is `[x,Y]` and `interp1` *looks up* the elements of `xi` in `x`, and, based upon their locations, returns values `yi` interpolated within the elements of `Y`.

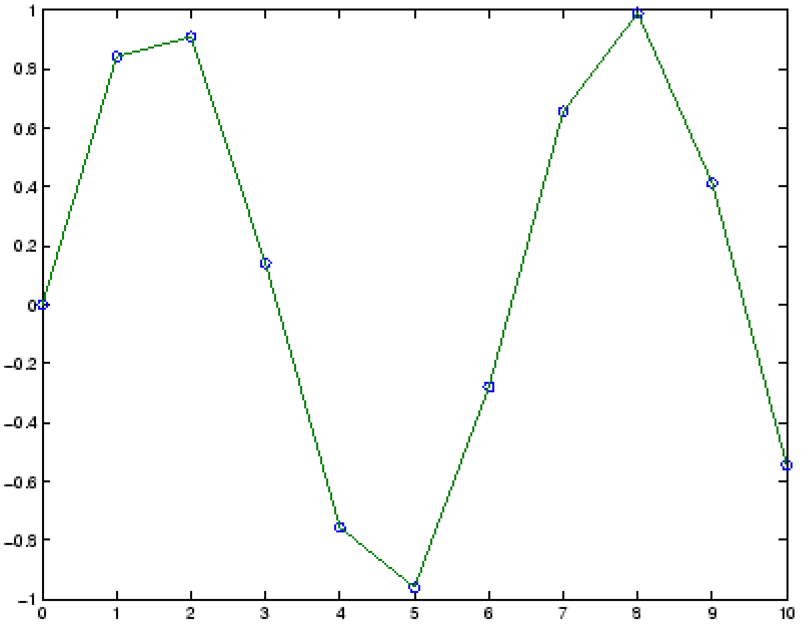
Note `interp1q` is quicker than `interp1` on non-uniformly spaced data because it does no input checking. For `interp1q` to work properly, `x` must be a monotonically increasing column vector and `Y` must be a column vector or matrix with `length(X)` rows. Type `help interp1q` at the command line for more information.

Examples

Example 1

Generate a coarse sine curve and interpolate over a finer abscissa.

```
x = 0:10;
y = sin(x);
xi = 0:.25:10;
yi = interp1(x,y,xi);
plot(x,y,'o',xi,yi)
```



Example 2

The following multidimensional example creates 2-by-2 matrices of interpolated function values, one matrix for each of the three functions x^2, x^3, and x^4.

```
x = [1:10]'; y = [ x.^2, x.^3, x.^4 ];
xi = [1.5, 1.75; 7.5, 7.75];
yi = interp1(x,y,xi);
```

The result `yi` has size 2-by-2-by-3.

```
size(yi)

ans =

     2     2     3
```

Example 3

Here are two vectors representing the census years from 1900 to 1990 and the corresponding United States population in millions of people.

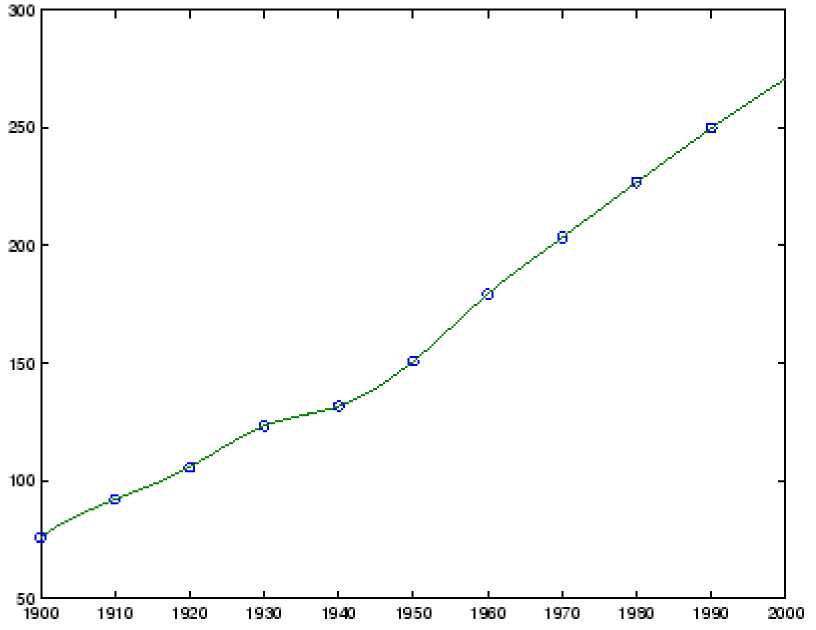
```
t = 1900:10:1990;
p = [75.995  91.972  105.711  123.203  131.669...
     150.697  179.323  203.212  226.505  249.633];
```

The expression `interp1(t,p,1975)` interpolates within the census data to estimate the population in 1975. The result is

```
ans =
    214.8585
```

Now interpolate within the data at every year from 1900 to 2000, and plot the result.

```
x = 1900:1:2000;
y = interp1(t,p,x,'spline');
plot(t,p,'o',x,y)
```



Sometimes it is more convenient to think of interpolation in table lookup terms, where the data are stored in a single table. If a portion of the census data is stored in a single 5-by-2 table,

```
tab =
    1950    150.697
    1960    179.323
    1970    203.212
    1980    226.505
    1990    249.633
```

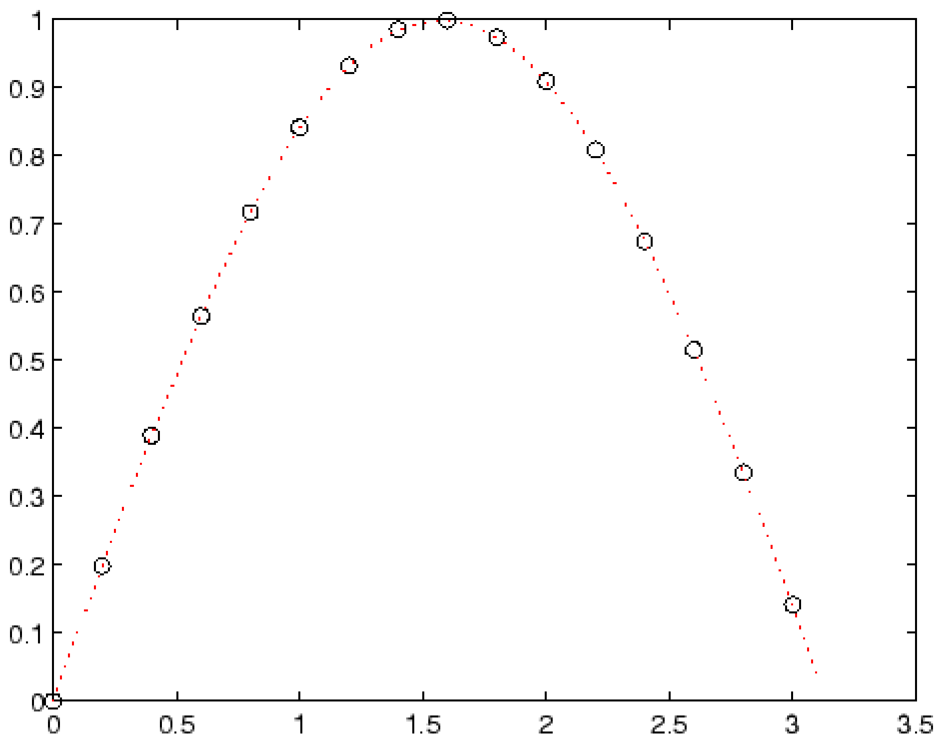
then the population in 1975, obtained by table lookup within the matrix `tab`, is

```
p = interp1(tab(:,1),tab(:,2),1975)
p =
    214.8585
```

Example 4

The following example uses the 'cubic' method to generate the piecewise polynomial form (ppform) of Y, and then evaluates the result using ppval.

```
x = 0:.2:pi; y = sin(x);
pp = interp1(x,y,'cubic','pp');
xi = 0:.1:pi;
yi = ppval(pp,xi);
plot(x,y,'ko'), hold on, plot(xi,yi,'r:'), hold off
```



Algorithm

The interp1 command is a MATLAB M-file. The 'nearest' and 'linear' methods have straightforward implementations.

For the 'spline' method, interp1 calls a function spline that uses the functions ppval, mkpp, and unmkpp. These routines form a small suite of functions for working with piecewise polynomials. spline uses them to perform the cubic spline interpolation. For access to more advanced features, see the spline reference page, the M-file help for these functions, and the Spline Toolbox.

For the 'pchip' and 'cubic' methods, interp1 calls a function pchip that performs piecewise cubic interpolation within the vectors x and y. This method preserves monotonicity and the shape of the data. See the pchip reference page for more information.

Interpolating Complex Data

For Real x and Complex Y. For interp1(x,Y,...) where x is real and Y is complex, you can use any interp1 method except for 'pchip'. The shape-preserving aspect of the 'pchip' algorithm involves the signs of the slopes between the data points. Because there is no notion of sign with complex data, it is impossible to talk about whether a function is increasing or decreasing. Consequently, the 'pchip' algorithm does not generalize to complex data.

The 'spline' method is often a good choice because piecewise cubic splines are derived purely from smoothness conditions. The second derivative of the interpolant must be continuous across the interpolating points. This does not involve any notion of sign or shape and so generalizes to complex data.

For Complex x. For interp1(x,Y,...) where x is complex and Y is either real or complex, use the two-dimensional interpolation routine interp2(REAL(x), IMAG(x),Y,...) instead.

See Also

interp1q, interpft, interp2, interp3, interpn, pchip, spline

References

[1] de Boor, C., *A Practical Guide to Splines*, Springer-Verlag, 1978.

interp1q

Purpose Quick 1-D linear interpolation

Syntax `yi = interp1q(x,Y,xi)`

Description `yi = interp1q(x,Y,xi)` returns the value of the 1-D function `Y` at the points of column vector `xi` using linear interpolation. The vector `x` specifies the coordinates of the underlying interval. The length of output `yi` is equal to the length of `xi`.

`interp1q` is quicker than `interp1` on non-uniformly spaced data because it does no input checking.

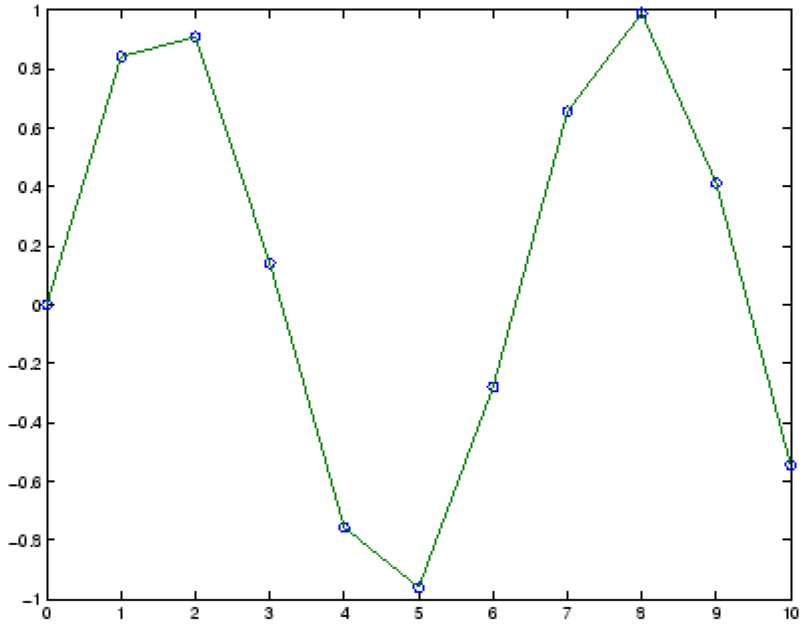
For `interp1q` to work properly,

- `x` must be a monotonically increasing column vector.
- `Y` must be a column vector or matrix with `length(x)` rows.
- `xi` must be a column vector

`interp1q` returns NaN for any values of `xi` that lie outside the coordinates in `x`. If `Y` is a matrix, then the interpolation is performed for each column of `Y`, in which case `yi` is `length(xi)-by-size(Y,2)`.

Example Generate a coarse sine curve and interpolate over a finer abscissa.

```
x = 0:10';
y = sin(x);
xi = (0:.25:10)';
yi = interp1q(x,y,xi);
plot(x,y,'o',xi,yi)
```



See Also `interp1`, `interp2`, `interp3`, `interpn`

interp2

Purpose

2-D data interpolation (table lookup)

Syntax

```
ZI = interp2(X,Y,Z,XI,YI)
ZI = interp2(Z,XI,YI)
ZI = interp2(Z,ntimes)
ZI = interp2(X,Y,Z,XI,YI,method)
ZI = interp2(...,method, extrapval)
```

Description

`ZI = interp2(X,Y,Z,XI,YI)` returns matrix `ZI` containing elements corresponding to the elements of `XI` and `YI` and determined by interpolation within the two-dimensional function specified by matrices `X`, `Y`, and `Z`. `X` and `Y` must be monotonic, and have the same format ("plaid") as if they were produced by `meshgrid`. Matrices `X` and `Y` specify the points at which the data `Z` is given. Out of range values are returned as `NaN`s.

`XI` and `YI` can be matrices, in which case `interp2` returns the values of `Z` corresponding to the points `(XI(i,j),YI(i,j))`. Alternatively, you can pass in the row and column vectors `xi` and `yi`, respectively. In this case, `interp2` interprets these vectors as if you issued the command `meshgrid(xi,yi)`.

`ZI = interp2(Z,XI,YI)` assumes that `X = 1:n` and `Y = 1:m`, where `[m,n] = size(Z)`.

`ZI = interp2(Z,ntimes)` expands `Z` by interleaving interpolates between every element, working recursively for `ntimes`. `interp2(Z)` is the same as `interp2(Z,1)`.

`ZI = interp2(X,Y,Z,XI,YI,method)` specifies an alternative interpolation method:

'nearest'	Nearest neighbor interpolation
'linear'	Linear interpolation (default)

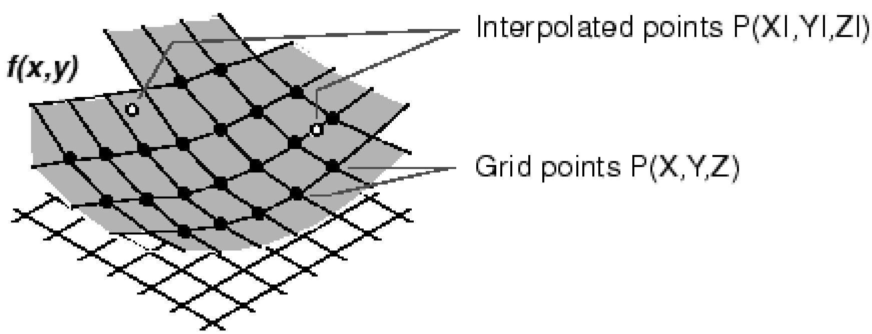
'spline'	Cubic spline interpolation
'cubic'	Cubic interpolation, as long as data is uniformly-spaced. Otherwise, this method is the same as 'spline'.

All interpolation methods require that X and Y be monotonic, and have the same format ("plaid") as if they were produced by meshgrid. If you provide two monotonic vectors, interp2 changes them to a plaid internally. Variable spacing is handled by mapping the given values in X, Y, XI, and YI to an equally spaced domain before interpolating. For faster interpolation when X and Y are equally spaced and monotonic, use the methods '*linear', '*cubic', '*spline', or '*nearest'.

ZI = interp2(...,method, extrapval) specifies a method and a scalar value for ZI outside of the domain created by X and Y. Thus, ZI equals extrapval for any value of YI or XI that is not spanned by Y or X respectively. A method must be specified to use extrapval. The default method is 'linear'.

Remarks

The interp2 command interpolates between data points. It finds values of a two-dimensional function $f(x, y)$ underlying the data at intermediate points.



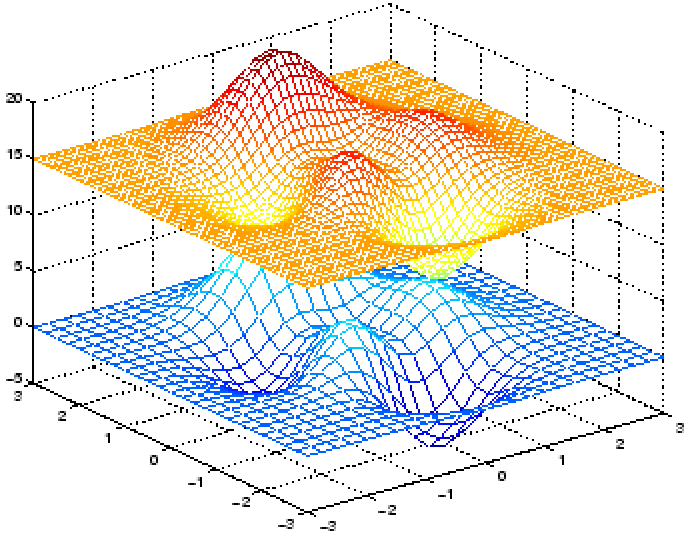
Interpolation is the same operation as table lookup. Described in table lookup terms, the table is tab = [NaN,Y;X,Z] and interp2 looks up the elements of XI in X, YI in Y, and, based upon their location, returns values ZI interpolated within the elements of Z.

Examples

Example 1

Interpolate the peaks function over a finer grid.

```
[X,Y] = meshgrid(-3:.25:3);
Z = peaks(X,Y);
[XI,YI] = meshgrid(-3:.125:3);
ZI = interp2(X,Y,Z,XI,YI);
mesh(X,Y,Z), hold, mesh(XI,YI,ZI+15)
hold off
axis([-3 3 -3 3 -5 20])
```



Example 2

Given this set of employee data,

```
years = 1950:10:1990;
service = 10:10:30;
```

```
wage = [150.697 199.592 187.625
179.323 195.072 250.287
203.212 179.092 322.767
226.505 153.706 426.730
249.633 120.281 598.243];
```

it is possible to interpolate to find the wage earned in 1975 by an employee with 15 years' service:

```
w = interp2(service,years,wage,15,1975)
w =
  190.6287
```

See Also

griddata, interp1, interp1q, interp3, interpn, meshgrid

Purpose

3-D data interpolation (table lookup)

Syntax

```
VI = interp3(X,Y,Z,V,XI,YI,ZI)
VI = interp3(V,XI,YI,ZI)
VI = interp3(V,ntimes)
VI = interp3(...,method)
VI = interp3(...,method,extrapval)
```

Description

`VI = interp3(X,Y,Z,V,XI,YI,ZI)` interpolates to find `VI`, the values of the underlying three-dimensional function `V` at the points in arrays `XI`, `YI` and `ZI`. `XI`,`YI`, `ZI` must be arrays of the same size, or vectors. Vector arguments that are not the same size, and have mixed orientations (i.e. with both row and column vectors) are passed through `meshgrid` to create the `Y1`, `Y2`, `Y3` arrays. Arrays `X`, `Y`, and `Z` specify the points at which the data `V` is given. Out of range values are returned as `NaN`.

`VI = interp3(V,XI,YI,ZI)` assumes `X=1:N`, `Y=1:M`, `Z=1:P` where `[M,N,P]=size(V)`.

`VI = interp3(V,ntimes)` expands `V` by interleaving interpolates between every element, working recursively for `ntimes` iterations. The command `interp3(V)` is the same as `interp3(V,1)`.

`VI = interp3(...,method)` specifies alternative methods:

'nearest'	Nearest neighbor interpolation
'linear'	Linear interpolation (default)
'spline'	Cubic spline interpolation
'cubic'	Cubic interpolation, as long as data is uniformly-spaced. Otherwise, this method is the same as `'spline'`.

`VI = interp3(...,method,extrapval)` specifies a method and a value for `VI` outside of the domain created by `X`, `Y` and `Z`. Thus, `VI` equals `extrapval` for any value of `XI`, `YI` or `ZI` that is not spanned by `X`, `Y`, and `Z`, respectively. You must specify a method to use `extrapval`. The default method is `'linear'`.

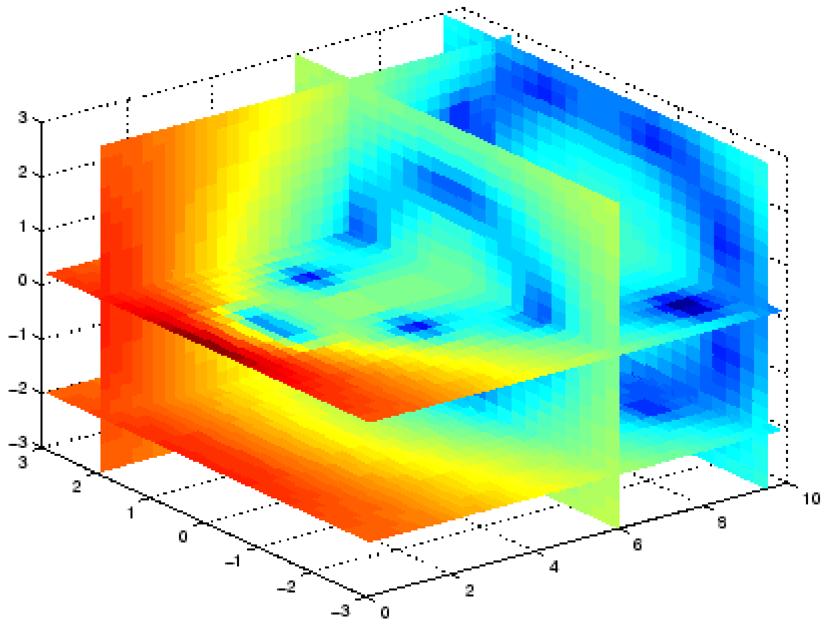
Discussion

All the interpolation methods require that X,Y and Z be monotonic and have the same format ("plaid") as if they were created using meshgrid. X, Y, and Z can be non-uniformly spaced. For faster interpolation when X, Y, and Z are equally spaced and monotonic, use the methods '*linear', '*cubic', or '*nearest'.

Examples

To generate a coarse approximation of flow and interpolate over a finer mesh:

```
[x,y,z,v] = flow(10);
[xi,yi,zi] = meshgrid(.1:.25:10, -3:.25:3, -3:.25:3);
vi = interp3(x,y,z,v,xi,yi,zi); % vi is 25-by-40-by-25
slice(xi,yi,zi,vi,[6 9.5],2,[-2 .2]), shading flat
```



See Also

interp1, interp1q, interp2, interpn, meshgrid

interpft

Purpose

1-D interpolation using FFT method

Syntax

```
y = interpft(x,n)
y = interpft(x,n,dim)
```

Description

`y = interpft(x,n)` returns the vector `y` that contains the value of the periodic function `x` resampled to `n` equally spaced points.

If `length(x) = m`, and `x` has sample interval `dx`, then the new sample interval for `y` is `dy = dx*m/n`. Note that `n` cannot be smaller than `m`.

If `X` is a matrix, `interpft` operates on the columns of `X`, returning a matrix `Y` with the same number of columns as `X`, but with `n` rows.

`y = interpft(x,n,dim)` operates along the specified dimension.

Algorithm

The `interpft` command uses the FFT method. The original vector `x` is transformed to the Fourier domain using `fft` and then transformed back with more points.

Examples

Interpolate a triangle-like signal using an interpolation factor of 5. First, set up signal to be interpolated:

```
y = [0 .5 1 1.5 2 1.5 1 .5 0 -.5 -1 -1.5 -2 -1.5 -1 -.5 0];
N = length(y);
```

Perform the interpolation:

```
L = 5;
M = N*L;
x = 0:L:L*N-1;
xi = 0:M-1;
yi = interpft(y,M);
plot(x,y,'o',xi,yi,'*')
legend('Original data','Interpolated data')
```

See Also

`interp1`

Purpose

N-D data interpolation (table lookup)

Syntax

```
VI = interpn(X1,X2,X3,...,V,Y1,Y2,Y3,...)
VI = interpn(V,Y1,Y2,Y3,...)
VI = interpn(V,ntimes)
VI = interpn(...,method)
VI = interpn(...,method,extrapval)
```

Description

`VI = interpn(X1,X2,X3,...,V,Y1,Y2,Y3,...)` interpolates to find `VI`, the values of the underlying multidimensional function `V` at the points in the arrays `Y1`, `Y2`, `Y3`, etc. For an n-dimensional array `V`, `interpn` is called with `2*N+1` arguments. Arrays `X1`, `X2`, `X3`, etc. specify the points at which the data `V` is given. Out of range values are returned as `NaN`s. `Y1`, `Y2`, `Y3`, etc. must be arrays of the same size, or vectors. Vector arguments that are not the same size, and have mixed orientations (i.e. with both row and column vectors) are passed through `ndgrid` to create the `Y1`, `Y2`, `Y3`, etc. arrays. `interpn` works for all n-dimensional arrays with 2 or more dimensions.

`VI = interpn(V,Y1,Y2,Y3,...)` interpolates as above, assuming `X1 = 1:size(V,1)`, `X2 = 1:size(V,2)`, `X3 = 1:size(V,3)`, etc.

`VI = interpn(V,ntimes)` expands `V` by interleaving interpolates between each element, working recursively for `ntimes` iterations. `interpn(V)` is the same as `interpn(V,1)`.

`VI = interpn(...,method)` specifies alternative methods:

'nearest'	Nearest neighbor interpolation
'linear'	Linear interpolation (default)
'spline'	Cubic spline interpolation
'cubic'	Cubic interpolation, as long as data is uniformly-spaced. Otherwise, this method is the same as `'spline'`.

`VI = interpn(...,method,extrapval)` specifies a method and a value for `VI` outside of the domain created by `X1`, `X2`, `...`. Thus, `VI` equals `extrapval` for any value of `Y1`, `Y2`,... that is not spanned by `X1`, `X2`,... respectively. You must specify a method to use `extrapval`. The default method is `'linear'`.

`interpn` requires that `X1`, `X2`, `X3`, ... be monotonic and plaid (as if they were created using `ndgrid`). `X1`, `X2`, `X3`, and so on can be non-uniformly spaced.

Discussion

All the interpolation methods require that `X1`,`X2`, `X3` ... be monotonic and have the same format ("plaid") as if they were created using `ndgrid`. `X1`,`X2`,`X3`,... and `Y1`, `Y2`, `Y3`, etc. can be non-uniformly spaced. For faster interpolation when `X1`, `X2`, `X3`, etc. are equally spaced and monotonic, use the methods '`*linear`', '`*cubic`', or '`*nearest`'.

Examples

Start by defining an anonymous function to compute $f = te^{-x^2-y^2-z^2}$:

```
f = @(x,y,z,t) t.*exp(-x.^2 - y.^2 - z.^2);
```

Build the lookup table by evaluating the function `f` on a grid constructed by `ndgrid`:

```
[x,y,z,t] = ndgrid(-1:0.2:1,-1:0.2:1,-1:0.2:1,0:2:10);
v = f(x,y,z,t);
```

Now construct a finer grid:

```
[xi,yi,zi,ti] = ndgrid(-1:0.05:1,-1:0.08:1,-1:0.05:1, ...
                       0:0.5:10);
```

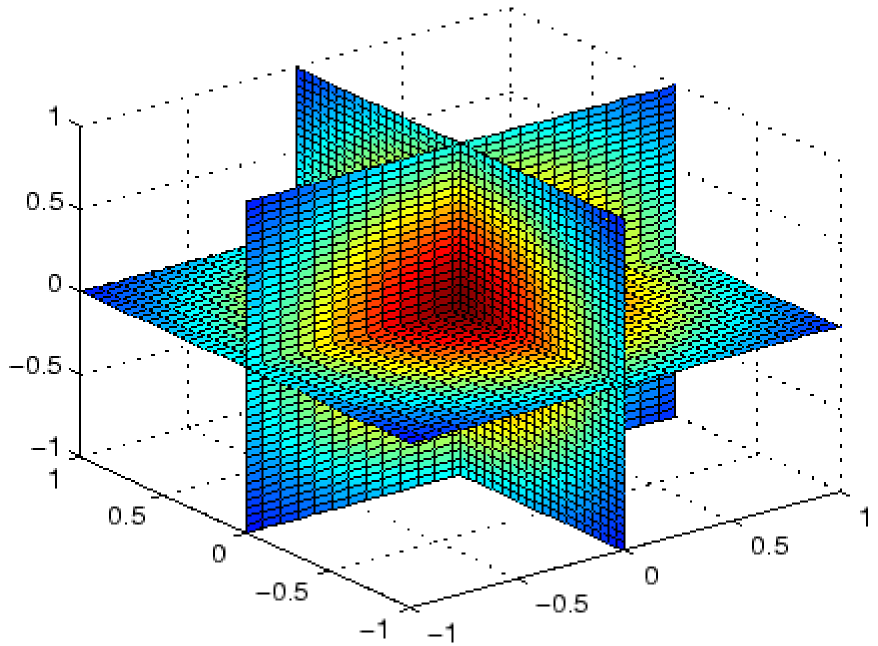
Compute the spline interpolation at `xi`, `yi`, `zi`, and `ti`:

```
vi = interpn(x,y,z,t,v,xi,yi,zi,ti,'spline');
```

Plot the interpolated function, and then create a movie from the plot:

```
nframes = size(ti, 4);
for j = 1:nframes
   slice(yi(:,:,:,j), xi(:,:,:,j), zi(:,:,:,j), ...
```

```
        vi(:,:,:,j),0,0,0);
    caxis([0 10]);
    M(j) = getframe;
end
movie(M);
```



See Also interp1, interp2, interp3, ndgrid

interpstreamspeed

Purpose

Interpolate stream-line vertices from flow speed

Syntax

```
interpstreamspeed(X,Y,Z,U,V,W,vertices)
interpstreamspeed(U,V,W,vertices)
interpstreamspeed(X,Y,Z,speed,vertices)
interpstreamspeed(speed,vertices)
interpstreamspeed(X,Y,U,V,vertices)
interpstreamspeed(U,V,vertices)
interpstreamspeed(X,Y,speed,vertices)
interpstreamspeed(speed,vertices)
interpstreamspeed(...,sf)
vertsout = interpstreamspeed(...)
```

Description

`interpstreamspeed(X,Y,Z,U,V,W,vertices)` interpolates streamline vertices based on the magnitude of the 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 (as if produced by `meshgrid`).

`interpstreamspeed(U,V,W,vertices)` 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)`.

`interpstreamspeed(X,Y,Z,speed,vertices)` uses the 3-D array `speed` for the speed of the vector field.

`interpstreamspeed(speed,vertices)` 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(speed)`.

`interpstreamspeed(X,Y,U,V,vertices)` interpolates streamline vertices based on the magnitude of the vector 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`).

`interpstreamspeed(U,V,vertices)` assumes `X` and `Y` are determined by the expression

```
[X Y] = meshgrid(1:n,1:m)
```

where `[M N]=size(U)`.

`interpstreamspeed(X,Y,speed,vertices)` uses the 2-D array `speed` for the speed of the vector field.

`interpstreamspeed(speed,vertices)` assumes `X` and `Y` are determined by the expression

```
[X Y] = meshgrid(1:n,1:m)
```

where `[M,N]= size(speed)`.

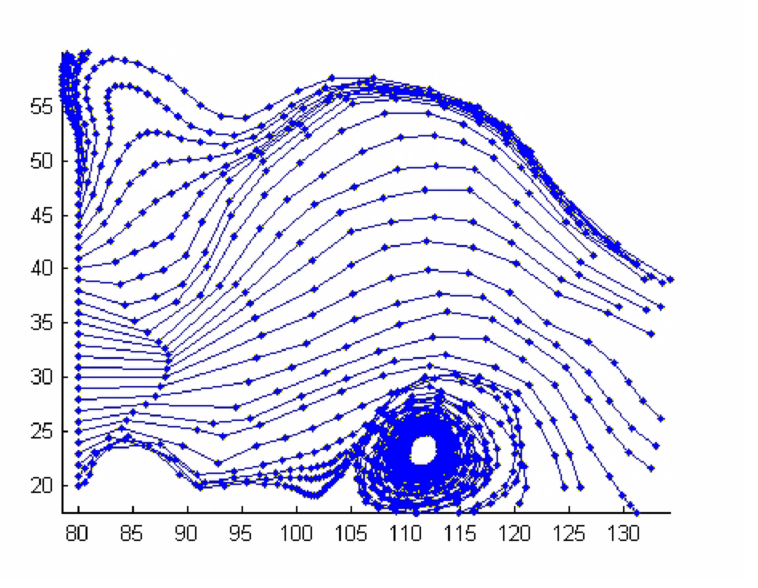
`interpstreamspeed(...,sf)` uses `sf` to scale the magnitude of the vector data and therefore controls the number of interpolated vertices. For example, if `sf` is 3, then `interpstreamspeed` creates only one-third of the vertices.

`vertsout = interpstreamspeed(...)` returns a cell array of vertex arrays.

Examples

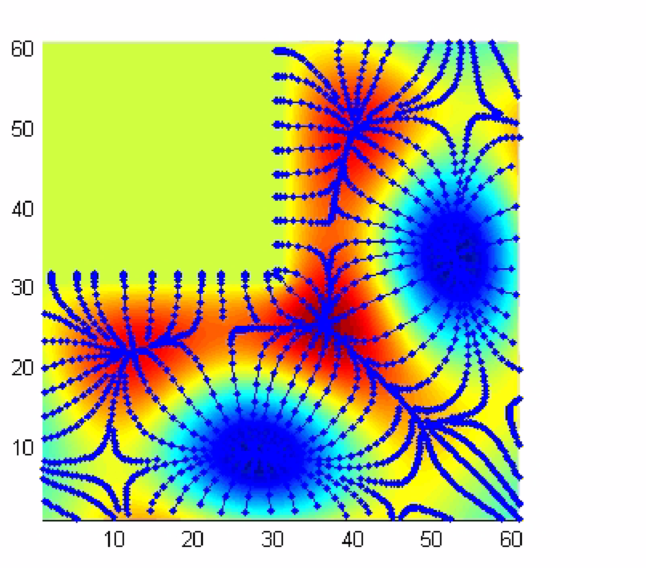
This example draws streamlines using the vertices returned by `interpstreamspeed`. Dot markers indicate the location of each vertex. This example enables you to visualize the relative speeds of the flow data. Streamlines having widely spaced vertices indicate faster flow; those with closely spaced vertices indicate slower flow.

```
load wind
[sx sy sz] = meshgrid(80,20:1:55,5);
verts = stream3(x,y,z,u,v,w,sx,sy,sz);
iverts = interpstreamspeed(x,y,z,u,v,w,verts,.2);
sl = streamline(iverts);
set(sl,'Marker','.')
axis tight; view(2); daspect([1 1 1])
```



This example plots streamlines whose vertex spacing indicates the value of the gradient along the streamline.

```
z = membrane(6,30);
[u v] = gradient(z);
[verts averts] = streamslice(u,v);
iverts = interpstreamspeed(u,v,verts,15);
sl = streamline(iverts);
set(sl,'Marker','.')
hold on; pcolor(z); shading interp
axis tight; view(2); daspect([1 1 1])
```



See Also

`stream2`, `stream3`, `streamline`, `streamslice`, `streamparticles`

"Volume Visualization" on page 1-101 for related functions

Purpose

Find set intersection of two vectors

Syntax

```
c = intersect(A, B)
c = intersect(A, B, 'rows')
[c, ia, ib] = intersect(a, b)
```

Description

`c = intersect(A, B)` returns the values common to both `A` and `B`. In set theoretic terms, this is `A`[[INTERSECT]] 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 = intersect(A, B, 'rows')` when `A` and `B` are matrices with the same number of columns returns the rows common to both `A` and `B`.

`[c, ia, ib] = intersect(a, b)` also returns column index vectors `ia` and `ib` such that `c = a(ia)` and `c = b(ib)` (or `c = a(ia,:)` and `c = b(ib,:)`).

Remarks

Because NaN is considered to be not equal to itself, it is never included in the result `c`.

Examples

```
A = [1 2 3 6]; B = [1 2 3 4 6 10 20];
[c, ia, ib] = intersect(A, B);
disp([c; ia; ib])
     1     2     3     6
     1     2     3     4
     1     2     3     5
```

See Also

`ismember`, `issorted`, `setdiff`, `setxor`, `union`, `unique`

Purpose

Largest value of specified integer type

Syntax

```
v = intmax
v = intmax('classname')
```

Description

`v = intmax` is the largest positive value that can be represented in MATLAB with a 32-bit integer. Any value larger than the value returned by `intmax` saturates to the `intmax` value when cast to a 32-bit integer.

`v = intmax('classname')` is the largest positive value in the integer class `classname`. Valid values for the string `classname` are

'int8'	'int16'	'int32'	'int64'
'uint8'	'uint16'	'uint32'	'uint64'

`intmax('int32')` is the same as `intmax` with no arguments.

Examples

Find the maximum value for a 64-bit signed integer:

```
v = intmax('int64')
v =
  9223372036854775807
```

Convert this value to a 32-bit signed integer:

```
x = int32(v)
x =
  2147483647
```

Compare the result with the default value returned by `intmax`:

```
isequal(x, intmax)
ans =
     1
```

See Also

`intmin`, `realmax`, `realmin`, `int8`, `uint8`, `isa`, `class`

intmin

Purpose

Smallest value of specified integer type

Syntax

```
v = intmin
v = intmin('classname')
```

Description

`v = intmin` is the smallest value that can be represented in MATLAB with a 32-bit integer. Any value smaller than the value returned by `intmin` saturates to the `intmin` value when cast to a 32-bit integer.

`v = intmin('classname')` is the smallest positive value in the integer class `classname`. Valid values for the string `classname` are

'int8'	'int16'	'int32'	'int64'
'uint8'	'uint16'	'uint32'	'uint64'

`intmin('int32')` is the same as `intmin` with no arguments.

Examples

Find the minimum value for a 64-bit signed integer:

```
v = intmin('int64')
v =
 -9223372036854775808
```

Convert this value to a 32-bit signed integer:

```
x = int32(v)
x =
  2147483647
```

Compare the result with the default value returned by `intmin`:

```
isequal(x, intmin)
ans =
     1
```

See Also

`intmax`, `realmin`, `realmax`, `int8`, `uint8`, `isa`, `class`

Purpose

Control state of integer warnings

Syntax

```
intwarning('action')
s = intwarning('action')
intwarning(s)
sOld = intwarning(sNew)
```

Description

MATLAB has four types of integer warnings. The `intwarning` function enables, disables, or returns information on these warnings:

- `MATLAB:intConvertNaN` — Warning on an attempt to convert NaN (Not a Number) to an integer. The result of the operation is zero.
- `MATLAB:intConvertNonIntVal` — Warning on an attempt to convert a non-integer value to an integer. The result is that the input value is rounded to the nearest integer for that class.
- `MATLAB:intConvertOverflow` — Warning on overflow when attempting to convert from a numeric class to an integer class. The result is the maximum value for the target class.
- `MATLAB:intMathOverflow` — Warning on overflow when attempting an integer arithmetic operation. The result is the maximum value for the class of the input value. MATLAB also issues this warning when NaN is computed (e.g., `int8(0)/0`).

`intwarning('`*`action`*`')` sets or displays the state of integer warnings in MATLAB according to the string, *`action`*. There are three possible actions, as shown here. The default state is `'off'`.

Action	Description
`off`	Disable the display of integer warnings
`on`	Enable the display of integer warnings
`query`	Display the state of all integer warnings

`s = intwarning('`*`action`*`')` sets the state of integer warnings in MATLAB according to the string *`action`*, and then returns the previous state in a 4-by-1 structure array, `s`. The return structure array has two fields: `identifier` and `state`.

`intwarning(s)` sets the state of integer warnings in MATLAB according to the `identifier` and `state` fields in structure array `s`.

`sOld = intwarning(sNew)` sets the state of integer warnings in MATLAB according to `sNew`, and then returns the previous state in `sOld`.

Remarks

Caution Enabling the `MATLAB:intMathOverflow` warning slows down integer arithmetic. It is recommended that you enable this particular warning only when you need to diagnose unusual behavior in your code, and disable it during normal program operation. The other integer warnings listed here do not affect program performance.

Examples

General Usage

Examples of the four types of integer warnings are shown here:

- **MATLAB:intConvertNaN**

Attempt to convert NaN (Not a Number) to an unsigned integer:

```
uint8(NaN);
Warning: NaN converted to uint8(0).
```

- **MATLAB:intConvertNonIntVal**

Attempt to convert a floating point number to an unsigned integer:

```
uint8(2.7);
Warning: Conversion rounded non-integer floating point
   value to nearest uint8 value.
```

- **MATLAB:intConvertOverflow**

Attempt to convert a large unsigned integer to a signed integer, where the operation overflows:

```
int8(uint8(200));
Warning: Out of range value converted to intmin('int8')
   or intmax('int8').
```

- **MATLAB:intMathOverflow**

Attempt an integer arithmetic operation that overflows:

```
intmax('uint8') + 5;
Warning: Out of range value or NaN computed in
integer arithmetic.
```

Example 1

Check the initial state of integer warnings:

```
intwarning('query')
The state of warning 'MATLAB:intConvertNaN' is 'off'.
The state of warning 'MATLAB:intConvertNonIntVal' is 'off'.
The state of warning 'MATLAB:intConvertOverflow' is 'off'.
The state of warning 'MATLAB:intMathOverflow' is 'off'.
```

Convert a floating point value to an 8-bit unsigned integer. MATLAB does the conversion, but that requires rounding the resulting value. Because all integer warnings have been disabled, no warning is displayed:

```
uint8(2.7)
ans =
    3
```

Store this state in structure array `iwState`:

```
iwState = intwarning('query');
```

Change the state of the `ConvertNonIntVal` warning to `'on'` by first setting the state to `'on'` in the `iwState` structure array, and then loading iwState back into the internal integer warning settings for your MATLAB session:

```
maxintwarn = 4;

for k = 1:maxintwarn
   if strcmp(iwState(k).identifier, ...
             'MATLAB:intConvertNonIntVal')
      iwState(k).state = 'on';
      intwarning(iwState);
   end
end
```

Verify that the state of ConvertNonIntVal has changed:

```
intwarning('query')
The state of warning 'MATLAB:intConvertNaN' is 'off'.
The state of warning 'MATLAB:intConvertNonIntVal' is 'on'.
The state of warning 'MATLAB:intConvertOverflow' is 'off'.
The state of warning 'MATLAB:intMathOverflow' is 'off'.
```

Now repeat the conversion from floating point to integer. This time MATLAB displays the warning:

```
uint8(2.7)
Warning: Conversion rounded non-integer floating point
   value to nearest uint8 value.
ans =
    3
```

See Also

warning, lastwarn

Purpose

Matrix inverse

Syntax

```
Y = inv(X)
```

Description

`Y = inv(X)` returns the inverse of the square matrix `X`. A warning message is printed if `X` is badly scaled or nearly singular.

In practice, it is seldom necessary to form the explicit inverse of a matrix. A frequent misuse of `inv` arises when solving the system of linear equations $Ax = b$. One way to solve this is with `x = inv(A)*b`. A better way, from both an execution time and numerical accuracy standpoint, is to use the matrix division operator `x = A\b`. This produces the solution using Gaussian elimination, without forming the inverse. See `\` and `/` for further information.

Examples

Here is an example demonstrating the difference between solving a linear system by inverting the matrix with `inv(A)*b` and solving it directly with `A\b`. A random matrix `A` of order 500 is constructed so that its condition number, `cond(A)`, is `1.e10`, and its norm, `norm(A)`, is `1`. The exact solution `x` is a random vector of length 500 and the right-hand side is `b = A*x`. Thus the system of linear equations is badly conditioned, but consistent.

On a 300 MHz, laptop computer the statements

```
n = 500;
Q = orth(randn(n,n));
d = logspace(0,-10,n);
A = Q*diag(d)*Q';
x = randn(n,1);
b = A*x;
tic, y = inv(A)*b; toc
err = norm(y-x)
res = norm(A*y-b)
```

produce

```
elapsed_time =
```

```
    1.4320
err =
    7.3260e-006
res =
    4.7511e-007
```

while the statements

```
tic, z = A\b, toc
err = norm(z-x)
res = norm(A*z-b)
```

produce

```
elapsed_time =
    0.6410
err =
    7.1209e-006
res =
    4.4509e-015
```

It takes almost two and one half times as long to compute the solution with `y = inv(A)*b` as with `z = A\b`. Both produce computed solutions with about the same error, `1.e-6`, reflecting the condition number of the matrix. But the size of the residuals, obtained by plugging the computed solution back into the original equations, differs by several orders of magnitude. The direct solution produces residuals on the order of the machine accuracy, even though the system is badly conditioned.

The behavior of this example is typical. Using `A\b` instead of `inv(A)*b` is two to three times as fast and produces residuals on the order of machine accuracy, relative to the magnitude of the data.

Algorithm

Inputs of Type Double

For inputs of type `double`, `inv` uses the following LAPACK routines to compute the matrix inverse:

Matrix	Routine
Real	DLANGE, DGETRF, DGECON, DGETRI
Complex	ZLANGE, ZGETRF, ZGECON, ZGETRI

Inputs of Type Single

For inputs of type `single`, `inv` uses the following LAPACK routines to compute the matrix inverse:

Matrix	Routine
Real	SLANGE, SGETRF, SGECON, SGETRI
Complex	CLANGE, CGETRF, CGECON, CGETRI

See Also

`det`, `lu`, `rref`

The arithmetic operators `\`, `/`

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.

invhilb

Purpose

Inverse of Hilbert matrix

Syntax

```
H = invhilb(n)
```

Description

`H = invhilb(n)` generates the exact inverse of the exact Hilbert matrix for `n` less than about 15. For larger `n`, `invhilb(n)` generates an approximation to the inverse Hilbert matrix.

Limitations

The exact inverse of the exact Hilbert matrix is a matrix whose elements are large integers. These integers may be represented as floating-point numbers without roundoff error as long as the order of the matrix, `n`, is less than 15.

Comparing `invhilb(n)` with `inv(hilb(n))` involves the effects of two or three sets of roundoff errors:

- The errors caused by representing `hilb(n)`
- The errors in the matrix inversion process
- The errors, if any, in representing `invhilb(n)`

It turns out that the first of these, which involves representing fractions like 1/3 and 1/5 in floating-point, is the most significant.

Examples

`invhilb(4)` is

```
  16   -120    240   -140
-120   1200  -2700   1680
 240  -2700   6480  -4200
-140   1680  -4200   2800
```

See Also

`hilb`

References

[1] Forsythe, G. E. and C. B. Moler, *Computer Solution of Linear Algebraic Systems*, Prentice-Hall, 1967, Chapter 19.

Purpose Invoke method on object or interface, or display methods

Syntax

```
S = h.invoke
S = h.invoke('methodname')
S = h.invoke('methodname', arg1, arg2, ...)
S = h.invoke('custominterfacename')
S = invoke(h, ...)
```

Description

`S = h.invoke` returns structure array `S` containing a list of all methods supported by the object or interface, `h`, along with the prototypes for these methods.

`S = h.invoke('methodname')` invokes the method specified in the string `methodname`, and returns an output value, if any, in `v`. The data type of the return value is dependent upon the specific method being invoked and is determined by the specific control or server.

`S = h.invoke('methodname', arg1, arg2, ...)` invokes the method specified in the string `methodname` with input arguments `arg1`, `arg2`, etc.

`S = h.invoke('custominterfacename')` returns an `Interface` object that serves as a handle to a custom interface implemented by the COM component. The `h` argument is a handle to the COM object. The `custominterfacename` argument is a quoted string returned by the `interfaces` function.

`S = invoke(h, ...)` is an alternate syntax for the same operation.

Remarks

If the method returns a COM interface, then `invoke` returns a new MATLAB COM object that represents the interface returned. See "Handling COM Data in MATLAB" in the External Interfaces documentation for a description of how MATLAB converts COM data types.

Examples

Example 1 — Invoking a Method

Create an `mwsamp` control and invoke its `Redraw` method:

```
f = figure ('position', [100 200 200 200]);
h = actxcontrol ('mwsamp.mwsampctrl.1', [0 0 200 200], f);

h.Radius = 100;
h.invoke('Redraw');
```

Here is a simpler way to use `invoke`. Just call the method directly, passing the handle, and any arguments:

```
h.Redraw;
```

Call `invoke` with only the handle argument to display a list of all `mwsamp` methods:

```
h.invoke
ans =
   AboutBox = void AboutBox(handle)
   Beep = void Beep(handle)
   FireClickEvent = void FireClickEvent(handle)
              .
              .
            etc.
```

Example 2 — Getting a Custom Interface

Once you have created a COM server, you can query the server component to see if any custom interfaces are implemented. Use the `interfaces` function to return a list of all available custom interfaces:

```
h = actxserver('mytestenv.calculator')
h =
   COM.mytestenv.calculator

customlist = h.interfaces
customlist =
   ICalc1
   ICalc2
   ICalc3
```

To get a handle to the custom interface you want, use the invoke function, specifying the handle returned by actxcontrol or actxserver and also the name of the custom interface:

```
c1 = h.invoke('ICalc1')
c1 =
   Interface.Calc_1.0_Type_Library.ICalc_Interface
```

You can now use this handle with most of the COM client functions to access the properties and methods of the object through the selected custom interface.

See Also

methods, ismethod, interfaces

ipermute

Purpose

Inverse permute dimensions of N-D array

Syntax

```
A = ipermute(B,order)
```

Description

`A = ipermute(B,order)` is the inverse of `permute`. `ipermute` rearranges the dimensions of `B` so that `permute(A,order)` will produce `B`. `B` has the same values as `A` but the order of the subscripts needed to access any particular element are 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

Consider the 2-by-2-by-3 array `a`:

```
a = cat(3,eye(2),2*eye(2),3*eye(2))

a(:,:,1) =                a(:,:,2) =
     1     0                   2     0
     0     1                   0     2

a(:,:,3) =
     3     0
     0     3
```

Permuting and inverse permuting `a` in the same fashion restores the array to its original form:

```
B = permute(a,[3 2 1]);
C = ipermute(B,[3 2 1]);
isequal(a,C)
ans=

   1
```

See Also

`permute`

Purpose

Interquartile range of `timeseries` data

Syntax

```
ts_iqr = iqr(ts)
iqr(ts,'PropertyName1',PropertyValue1,...)
```

Description

`ts_iqr = iqr(ts)` returns the interquartile range of `ts.Data`. When `ts.Data` is a vector, ts_iqr is the difference between the 75th and the 25th percentiles of the `ts.Data` values. When `ts.Data` is a matrix, ts_iqr is a row vector containing the interquartile range 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, `iqr` always operates along the first nonsingleton dimension of `ts.Data`.

`iqr(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

Create a time series with a missing value, represented by `NaN`.

```
ts = timeseries([3.0 NaN 5 6.1 8], 1:5);
```

Calculate the interquartile range of `ts.Data` after removing the missing value from the calculation.

```
iqr(ts,'MissingData','remove')
```

```
ans =

    3.0500
```

See Also timeseries

Purpose Detect state

Description These functions detect the state of MATLAB entities:

`isa`	Detect object of given MATLAB class or Java class
`isappdata`	Determine if object has specific application-defined data
`iscell`	Determine if input is cell array
`iscellstr`	Determine if input is cell array of strings
`ischar`	Determine if input is character array
`iscom`	Determine if input is Component Object Model (COM) object
`isdir`	Determine if input is directory
`isempty`	Determine if input is empty array
`isequal`	Determine if arrays are numerically equal
`isequalwithequalnans`	Determine if arrays are numerically equal, treating `NaN`s as equal
`isevent`	Determine if input is object event
`isfield`	Determine if input is MATLAB structure array field
`isfinite`	Detect finite elements of array
`isfloat`	Determine if input is floating-point array
`isglobal`	Determine if input is global variable
`ishandle`	Detect valid graphics object handles
`ishold`	Determine if graphics hold state is on
`isinf`	Detect infinite elements of array
`isinteger`	Determine if input is integer array
`isinterface`	Determine if input is Component Object Model (COM) interface

isjava	Determine if input is Java object
iskeyword	Determine if input is MATLAB keyword
isletter	Detect elements that are alphabetic letters
islogical	Determine if input is logical array
ismember	Detect members of specific set
ismethod	Determine if input is object method
isnan	Detect elements of array that are not a number (NaN)
isnumeric	Determine if input is numeric array
isobject	Determine if input is MATLAB OOPs object
ispc	Determine if PC (Windows) version of MATLAB
isprime	Detect prime elements of array
isprop	Determine if input is object property
isreal	Determine if all array elements are real numbers
isscalar	Determine if input is scalar
issorted	Determine if set elements are in sorted order
isspace	Detect space characters in array
issparse	Determine if input is sparse array
isstrprop	Determine if string is of specified category
isstruct	Determine if input is MATLAB structure array
isstudent	Determine if Student Version of MATLAB
isunix	Determine if UNIX version of MATLAB
isvarname	Determine if input is valid variable name
isvector	Determine if input is vector

See Also

isa

Purpose

Determine whether input is object of given class

Syntax

```
K = isa(obj, 'class_name')
```

Description

`K = isa(obj, 'class_name')` returns logical `1` (`true`) if `obj` is of class (or a subclass of) *`class_name`*, and logical `0` (`false`) otherwise.

The argument `obj` is a MATLAB object or a Java object. The argument *`class_name`* is the name of a MATLAB (predefined or user-defined) or a Java class. Predefined MATLAB classes include

`logical`	Logical array of `true` and `false` values
`char`	Characters array
`numeric`	Integer or floating-point array
`integer`	Signed or unsigned integer array
`int8`	8-bit signed integer array
`uint8`	8-bit unsigned integer array
`int16`	16-bit signed integer array
`uint16`	16-bit unsigned integer array
`int32`	32-bit signed integer array
`uint32`	32-bit unsigned integer array
`int64`	64-bit signed integer array
`uint64`	64-bit unsigned integer array
`float`	Single- or double-precision floating-point array
`single`	Single-precision floating-point array
`double`	Double-precision floating-point array
`cell`	Cell array
`struct`	Structure array

function_handle	Function handle
'*class_name*'	Custom MATLAB object class or Java class

To check for a sparse array, use issparse. To check for a complex array, use ~isreal.

Examples

```
isa(rand(3,4),'double')
ans =
     1
```

The following example creates an instance of the user-defined MATLAB class named polynom. The isa function identifies the object as being of the polynom class.

```
polynom_obj = polynom([1 0 -2 -5]);
isa(polynom_obj, 'polynom')
ans =
      1
```

See Also

class, is*

Purpose True if application-defined data exists

Syntax

```
isappdata(h,name)
```

Description `isappdata(h,name)` returns `1` if application-defined data with the specified `name` exists on the object specified by handle `h`, and returns `0` otherwise.

See Also `getappdata`, `rmappdata`, `setappdata`

Purpose Determine whether input is cell array

Syntax

```
tf = iscell(A)
```

Description `tf = iscell(A)` returns logical `1` (`true`) if `A` is a cell array and logical `0` (`false`) otherwise.

Examples

```
A{1,1} = [1 4 3; 0 5 8; 7 2 9];
A{1,2} = 'Anne Smith';
A{2,1} = 3+7i;
A{2,2} = -pi:pi/10:pi;

iscell(A)

ans =

     1
```

See Also `cell`, `iscellstr`, `isstruct`, `isnumeric`, `islogical`, `isobject`, `isa`, `is*`

Purpose

Determine whether input is cell array of strings

Syntax

```
tf = iscellstr(A)
```

Description

`tf = iscellstr(A)` returns logical `1` (`true`) if `A` is a cell array of strings and logical `0` (`false`) otherwise. A cell array of strings is a cell array where every element is a character array.

Examples

```
A{1,1} = 'Thomas Lee';
A{1,2} = 'Marketing';
A{2,1} = 'Allison Jones';
A{2,2} = 'Development';

iscellstr(A)

ans =

     1
```

See Also

`cellstr`, `iscell`, `isstrprop`, `strings`, `char`, `isstruct`, `isa`, `is*`

ischar

Purpose Determine whether item is character array

Syntax

```
tf = ischar(A)
```

Description

`tf = ischar(A)` returns logical `1` (`true`) if `A` is a character array and logical `0` (`false`) otherwise.

Examples

Given the following cell array,

```
C{1,1} = magic(3);          % double array
C{1,2} = 'John Doe';        % char array
C{1,3} = 2 + 4i             % complex double

C =

    [3x3 double]    'John Doe'    [2.0000+ 4.0000i]
```

`ischar` shows that only `C{1,2}` is a character array.

```
for k = 1:3
x(k) = ischar(C{1,k});
end

x

x =

     0     1     0
```

See Also

`char`, `strings`, `isletter`, `isspace`, `isstrprop`, `iscellstr`, `isnumeric`, `isa`, `is*`

Purpose Is input COM object

Syntax

```
tf = h.iscom
tf = iscom(h)
```

Description

`tf = h.iscom` returns logical `1` (`true`) if the input handle, `h`, is a COM or ActiveX object. Otherwise, `iscom` returns logical `0` (`false`) .

`tf = iscom(h)` is an alternate syntax for the same operation.

Examples

Create a COM server running Microsoft Excel. The `actxserver` function returns a handle `h` to the server object. Testing this handle with `iscom` returns `true`:

```
h = actxserver('excel.application');

h.iscom
ans =
   1
```

Create an interface to `workbooks`, returning handle `w`. Testing this handle with `iscom` returns `false`:

```
w = h.get('workbooks');

w.iscom
ans =
   0
```

See Also

`isinterface`

isdir

Purpose Determine whether input is a directory

Syntax

```
tf = isdir('A')
```

Description `tf = isdir('A')` returns logical `1` (`true`) if `A` is a directory and logical `0` (`false`) otherwise.

Examples Type

```
tf=isdir('mymfiles/results')
```

and MATLAB returns

```
tf =
 1
```

indicating that `mymfiles/results` is a directory.

See Also `dir`, `is*`

Purpose

Determine whether array is empty

Syntax

```
TF = isempty(A)
```

Description

`TF = isempty(A)` returns logical 1 (`true`) if `A` is an empty array and logical 0 (`false`) otherwise. An empty array has at least one dimension of size zero, for example, 0-by-0 or 0-by-5.

Examples

```
B = rand(2,2,2);
B(:,:,:) = [];

isempty(B)

ans = 1
```

See Also

`is*`

isempty (timeseries)

Purpose Determine whether `timeseries` object is empty

Syntax `isempty(ts)`

Description `isempty(ts)` returns a logical value for `timeseries` object `ts`, as follows:

- `1` — When `ts` contains no data samples or `ts.Data` is empty.
- `0` — When `ts` contains data samples

See Also `length (timeseries)`, `size (timeseries)`, `timeseries`, `tsprops`

Purpose Determine whether `tscollection` object is empty

Syntax

```
isempty(tsc)
```

Description `isempty(tsc)` returns a logical value for `tscollection` object `tsc`, as follows:

- `1` — When `tsc` contains neither `timeseries` members nor a time vector
- `0` — When `tsc` contains either `timeseries` members or a time vector

See Also `length (tscollection)`, `size (tscollection)`, `timeseries`, `tscollection`

isequal

Purpose

Test arrays for equality

Syntax

```
tf = isequal(A, B, ...)
```

Description

`tf = isequal(A, B, ...)` returns logical `1` (`true`) if the input arrays have the same contents, and logical `0` (`false`) otherwise. Nonempty arrays must be of the same data type and size.

Remarks

When comparing structures, the order in which the fields of the structures were created is not important. As long as the structures contain the same fields, with corresponding fields set to equal values, `isequal` considers the structures to be equal. See Example 2, below.

When comparing numeric values, `isequal` does not consider the data type used to store the values in determining whether they are equal. See Example 3, below.

`NaN`s (Not a Number), by definition, are not equal. Therefore, arrays that contain `NaN` elements are not equal, and `isequal` returns zero when comparing such arrays. See Example 4, below. Use the `isequalwithequalnans` function when you want to test for equality with `NaN`s treated as equal.

`isequal` recursively compares the contents of cell arrays and structures. If all the elements of a cell array or structure are numerically equal, `isequal` returns logical `1`.

Examples

Example 1

Given

```
A =                 B =                 C =
    1     0             1     0             1     0
    0     1             0     1             0     0
```

`isequal(A,B,C)` returns `0`, and `isequal(A,B)` returns `1`.

Example 2

When comparing structures with `isequal`, the order in which the fields of the structures were created is not important:

```
A.f1 = 25;    A.f2 = 50
A =
    f1: 25
    f2: 50

B.f2 = 50;    B.f1 = 25
B =
    f2: 50
    f1: 25

isequal(A, B)
ans =
     1
```

Example 3

When comparing numeric values, the data types used to store the values are not important:

```
A = [25 50];   B = [int8(25) int8(50)];

isequal(A, B)
ans =
     1
```

Example 4

Arrays that contain `NaN` (Not a Number) elements cannot be equal, since `NaN`s, by definition, are not equal:

```
A = [32 8 -29 NaN 0 5.7];
B = A;

isequal(A, B)
ans =
```

```
0
```

See Also

`isequalwithequalnans`, `strcmp`, `isa`, `is*`, `relational operators`

Purpose Test arrays for equality, treating NaNs as equal

Syntax

```
tf = isequalwithequalnans(A, B, ...)
```

Description `tf = isequalwithequalnans(A, B, ...)` returns logical `1` (`true`) if the input arrays are the same type and size and hold the same contents, and logical `0` (`false`) otherwise. `NaN` (Not a Number) values are considered to be equal to each other. Numeric data types and structure field order do not have to match.

Remarks `isequalwithequalnans` is the same as `isequal`, except `isequalwithequalnans` considers `NaN` (Not a Number) values to be equal, and `isequal` does not.

`isequalwithequalnans` recursively compares the contents of cell arrays and structures. If all the elements of a cell array or structure are numerically equal, `isequalwithequalnans` returns logical `1`.

Examples Arrays containing `NaN`s are handled differently by `isequal` and `isequalwithequalnans`. `isequal` does not consider `NaN`s to be equal, while `isequalwithequalnans` does.

```
A = [32 8 -29 NaN 0 5.7];
B = A;
isequal(A, B)
ans =
     0

isequalwithequalnans(A, B)
ans =
     1
```

The position of `NaN` elements in the array does matter. If they are not in the same position in the arrays being compared, then `isequalwithequalnans` returns zero.

```
A = [2 4 6 NaN 8];   B = [2 4 NaN 6 8];
```

```
isequalwithequalnans(A, B)
ans =
     0
```

See Also isequal, strcmp, isa, is*, relational operators

Purpose

Is input event

Syntax

```
tf = h.isevent('name')
tf = isevent(h, 'name')
```

Description

`tf = h.isevent('name')` returns logical `1` (`true`) if the specified `name` is an event that can be recognized and responded to by object `h`. Otherwise, `isevent` returns logical `0` (`false`).

`tf = isevent(h, 'name')` is an alternate syntax for the same operation.

Remarks

The string specified in the `name` argument is not case sensitive.

For COM control objects, `isevent` returns the same value regardless of whether the specified event is registered with the control or not. In order for the control to respond to the event, you must first register the event using either `actxcontrol` or `registerevent`.

Examples

Test an Event Example

Create an `mwsamp` control and test to see if `DblClick` is an event recognized by the control.

```
f = figure ('position', [100 200 200 200]);
h = actxcontrol ('mwsamp.mwsampctrl.2', [0 0 200 200], f);
h.isevent('DblClick')
```

MATLAB displays `ans = 1` (`true`), showing that `DblClick` is an event.

Test a Method Example

Try the same test on `Redraw`, which is one of the control's methods.

```
h.isevent('Redraw')
```

MATLAB displays `ans = 0` (`false`), showing that `Redraw` is not an event.

Test an Excel Workbook Example

Create an Excel Workbook object.

```
excel = actxserver('Excel.Application');
wbs = excel.Workbooks;
wb = wbs.Add;
```

Test the `Activate` event:

```
wb.isevent('Activate')
```

MATLAB displays `ans = 1` (`true`), showing that `Activate` is an event.

Test `Save` :

```
wb.isevent('Save')
```

MATLAB displays `ans = 0` (`false`), showing that `Save` is not an event; it is a method.

See Also

`events`, `eventlisteners`, `registerevent`, `unregisterevent`, `unregisterallevents`

Purpose

Determine whether input is structure array field

Syntax

```
tf = isfield(S, 'fieldname')
tf = isfield(S, C)
```

Description

`tf = isfield(S, 'fieldname')` examines structure `S` to see if it includes the field specified by the quoted string `'fieldname'`. Output `tf` is set to logical `1` (`true`) if `S` contains the field, or logical `0` (`false`) if not. If `S` is not a structure array, `isfield` returns `false`.

`tf = isfield(S, C)` examines structure `S` for multiple fieldnames as specified in cell array of strings `C`, and returns an array of logical values to indicate which of these fields are part of the structure. Elements of output array `tf` are set to a logical 1 (`true`) if the corresponding element of `C` holds a fieldname that belongs to structure `S`. Otherwise, logical 0 (`false`) is returned in that element. In other words, if structure `S` contains the field specified in `C{m,n}`, `isfield` returns a logical 1 (`true`) in `tf(m,n)`.

Note `isfield` returns `false` if the `field` or `fieldnames` input is empty.

Examples

Example 1 — Single Fieldname Syntax

Given the following MATLAB structure,

```
patient.name = 'John Doe';
patient.billing = 127.00;
patient.test = [79 75 73; 180 178 177.5; 220 210 205];
```

`isfield` identifies `billing` as a field of that structure.

```
isfield(patient,'billing')
ans =
     1
```

Example 2 — Multiple Fieldname Syntax

Check structure `S` for any of four possible fieldnames. Only the first is found, so the first element of the return value is set to `true`:

```
S = struct('one', 1, 'two', 2);

fields = isfield(S, {'two', 'pi', 'One', 3.14})
fields =
     1     0     0     0
```

See Also

`fieldnames`, `setfield`, `getfield`, `orderfields`, `rmfield`, `struct`, `isstruct`, `iscell`, `isa`, `is*`, dynamic field names

Purpose

Array elements that are finite

Syntax

```
TF = isfinite(A)
```

Description

`TF = isfinite(A)` returns an array the same size as `A` containing logical 1 (`true`) where the elements of the array `A` are finite and logical 0 (`false`) where they are infinite or `NaN`. For a complex number `z`, `isfinite(z)` returns `1` if both the real and imaginary parts of `z` are finite, and `0` if either the real or the imaginary part is infinite or `NaN`.

For any real `A`, exactly one of the three quantities `isfinite(A)`, `isinf(A)`, and `isnan(A)` is equal to one.

Examples

```
a = [-2  -1  0  1  2];

isfinite(1./a)
Warning: Divide by zero.

ans =
     1     1     0     1     1

isfinite(0./a)
Warning: Divide by zero.

ans =
     1     1     0     1     1
```

See Also

`isinf`, `isnan`, `is*`

Purpose Determine whether input is floating-point array

Syntax `isfloat(A)`

Description `isfloat(A)` returns a logical 1 (`true`) if A is a floating-point array and a logical 0 (`false`) otherwise. The only floating-point data types in MATLAB are `single` and `double`.

See Also `isa`, `isinteger`, `double`, `single`, `isnumeric`

Purpose

Determine whether input is global variable

Note Support for the `isglobal` function will be removed in a future release of MATLAB. See Remarks below.

Syntax

```
tf = isglobal(A)
```

Description

`tf = isglobal(A)` returns logical `1` (`true`) if `A` has been declared to be a global variable in the context from which `isglobal` is called, and logical `0` (`false`) otherwise.

Remarks

`isglobal` is most commonly used in conjunction with conditional global declaration. An alternate approach is to use a pair of variables, one local and one declared global.

Instead of using

```
if condition
   global x
end

x = some_value

if isglobal(x)
   do_something
end
```

You can use

```
global gx
if condition
   gx = some_value
else
   x = some_value
end
```

```
if condition
   do_something
end
```

If no other workaround is possible, you can replace the command

```
isglobal(variable)
```

with

```
~isempty(whos('global','variable'))
```

See Also

global, isvarname, isa, is*

Purpose Is object handle valid

Syntax `ishandle(h)`

Description `ishandle(h)` returns an array containing `1`'s where the elements of `h` are valid graphics handles and `0`'s where they are not.

See Also `findobj`, `gca`, `gcf`, `gco`, `set`

"Accessing Object Handles" for more information.

"Finding and Identifying Graphics Objects" on page 1-92 for related functions

ishold

Purpose Current hold state

Syntax

```
ishold
```

Description

`ishold` returns `1` if `hold` is `on`, and `0` if it is `off`. When `hold` is `on`, the current plot and most axis properties are held so that subsequent graphing commands add to the existing graph.

A state of `hold on` implies that both figure and axes `NextPlot` properties are set to `add`.

See Also

`hold`, `newplot`

"Controlling Graphics Output" for related information

"Axes Operations" on page 1-95 for related functions

Purpose Array elements that are infinite

Syntax

```
TF = isinf(A)
```

Description `TF = isinf(A)` returns an array the same size as `A` containing logical 1 (`true`) where the elements of `A` are `+Inf` or `-Inf` and logical 0 (`false`) where they are not. For a complex number `z`, `isinf(z)` returns `1` if either the real or imaginary part of `z` is infinite, and `0` if both the real and imaginary parts are finite or `NaN`.

For any real `A`, exactly one of the three quantities `isfinite(A)`, `isinf(A)`, and `isnan(A)` is equal to one.

Examples

```
a = [-2  -1  0  1  2]

isinf(1./a)
Warning: Divide by zero.

ans =
     0     0     1     0     0

isinf(0./a)
Warning: Divide by zero.

ans =
     0     0     0     0     0
```

See Also `isfinite`, `isnan`, `is*`

isinteger

Purpose Determine whether input is integer array

Syntax

Description `isinteger(A)` returns a logical 1 (`true`) if the array `A` has integer data type and a logical 0 (`false`) otherwise. The integer data types in MATLAB are

- `int8`
- `uint8`
- `int16`
- `uint16`
- `int32`
- `uint32`
- `int64`
- `uint64`

See Also `isa`, `isnumeric`, `isfloat`

Purpose

Is input COM interface

Syntax

```
tf = h.isinterface
tf = isinterface(h)
```

Description

`tf = h.isinterface` returns logical `1` (`true`) if the input handle, `h`, is a COM interface. Otherwise, `isinterface` returns logical `0` (`false`) .

`tf = isinterface(h)` is an alternate syntax for the same operation.

Examples

Create a COM server running Microsoft Excel. The `actxserver` function returns a handle `h` to the server object. Testing this handle with `isinterface` returns `false`:

```
h = actxserver('excel.application');

h.isinterface
ans =
   0
```

Create an interface to `workbooks`, returning handle `w`. Testing this handle with `isinterface` returns `true`:

```
w = h.get('workbooks');

w.isinterface
ans =
   1
```

See Also

`iscom`, `interfaces`, `get`

isjava

Purpose

Determine whether input is Java object

Syntax

```
tf = isjava(A)
```

Description

`tf = isjava(A)` returns logical `1` (`true`) if `A` is a Java object, and logical `0` (`false`) otherwise.

Examples

Create an instance of the Java Frame class and `isjava` indicates that it is a Java object.

```
frame = java.awt.Frame('Frame A');

isjava(frame)

ans =

     1
```

Note that, `isobject`, which tests for MATLAB objects, returns logical `0` (`false`).

```
isobject(frame)

ans =

     0
```

See Also

`isobject`, `javaArray`, `javaMethod`, `javaObject`, `isa`, `is*`

Purpose

Determine whether input is MATLAB keyword

Syntax

```
tf = iskeyword('str')
iskeyword str
iskeyword
```

Description

`tf = iskeyword('str')` returns logical `1` (`true`) if the string `str` is a keyword in the MATLAB language and logical `0` (`false`) otherwise.

`iskeyword str` uses the MATLAB command format.

`iskeyword` returns a list of all MATLAB keywords.

Examples

To test if the word `while` is a MATLAB keyword,

```
iskeyword while
ans =
     1
```

To obtain a list of all MATLAB keywords,

```
iskeyword
     'break'
     'case'
     'catch'
     'classdef'
     'continue'
     'else'
     'elseif'
     'end'
     'for'
     'function'
     'global'
     'if'
     'otherwise'
     'parfor'
     'persistent'
     'return'
```

```
'switch'
'try'
'while'
```

See Also isvarname, genvarname, is*

Purpose Array elements that are alphabetic letters

Syntax

```
tf = isletter('str')
```

Description `tf = isletter('str')` returns an array the same size as `str` containing logical `1` (`true`) where the elements of `str` are letters of the alphabet and logical `0` (`false`) where they are not.

Examples Find the letters in character array `s`.

```
s = 'A1,B2,C3';

isletter(s)
ans =
     1     0     0     1     0     0     1     0
```

See Also `ischar`, `isspace`, `isstrprop`, `iscellstr`, `isnumeric`, `char`, `strings`, `isa`, `is*`

islogical

Purpose Determine whether input is logical array

Syntax

```
tf = islogical(A)
```

Description `tf = islogical(A)` returns logical `1` (`true`) if `A` is a logical array and logical `0` (`false`) otherwise.

Examples Given the following cell array,

```
C{1,1} = pi;                 % double
C{1,2} = 1;                  % double
C{1,3} = ispc;               % logical
C{1,4} = magic(3)            % double array

C =
    [3.1416]    [1]    [1]    [3x3 double]
```

`islogical` shows that only `C{1,3}` is a logical array.

```
for k = 1:4
x(k) = islogical(C{1,k});
end

x
x =
     0     0     1     0
```

See Also `logical`, `isnumeric`, `ischar`, `isreal`, , logical operators (`elementwise` and `short-circuit`), `isa`, `is*`

Purpose

Determine whether running Macintosh OS X versions of MATLAB

Syntax

```
tf = ismac
```

Description

`tf = ismac` returns logical `1` (`true`) for the Macintosh OS X versions of MATLAB and logical `0` (`false`) otherwise.

See Also

`isunix`, `ispc`, `isstudent`, `is*`

ismember

Purpose Array elements that are members of set

Syntax

```
tf = ismember(A, S)
tf = ismember(A, S, 'rows')
[tf, loc] = ismember(A, S, ...)
```

Description

`tf = ismember(A, S)` returns a vector the same length as `A`, containing logical `1` (`true`) where the elements of `A` are in the set `S`, and logical `0` (`false`) elsewhere. In set theory terms, `k` is 1 where `A` ϵ `S`. Inputs `A` and `S` can be numeric or character arrays or cell arrays of strings.

`tf = ismember(A, S, 'rows')`, when `A` and `S` are matrices with the same number of columns, returns a vector containing `1` where the rows of `A` are also rows of `S` and `0` otherwise. You cannot use this syntax if `A` or `S` is a cell array of strings.

`[tf, loc] = ismember(A, S, ...)` returns index vector `loc` containing the highest index in `S` for each element in `A` that is a member of `S`. For those elements of `A` that do not occur in `S`, `ismember` returns `0`.

Remarks

Because NaN is considered to be not equal to anything, it is never a member of any set.

Examples

```
set = [0 2 4 6 8 10 12 14 16 18 20];
a = reshape(1:5, [5 1])

a =
     1
     2
     3
     4
     5

ismember(a, set)
ans =
 0
     1
```

```
      0
      1
      0
set = [5 2 4 2 8 10 12 2 16 18 20 3];
[tf, index] = ismember(a, set);

index
index =
      0
      8
     12
      3
      1
```

See Also

issorted, intersect, setdiff, setxor, union, unique, is*

ismethod

Purpose

Determine whether input is object method

Syntax

```
ismethod(h, 'name')
```

Description

`ismethod(h, 'name')` returns a logical `1` (`true`) if the specified `name` is a method that you can call on object `h`. Otherwise, `ismethod` returns logical `0` (`false`).

Examples

Create an Excel application and test to see if `SaveWorkspace` is a method of the object. `ismethod` returns `true`:

```
h = actxserver ('Excel.Application');

ismethod(h, 'SaveWorkspace')
ans =
     1
```

Try the same test on `UsableWidth`, which is a property. `ismethod` returns `false`:

```
ismethod(h, 'UsableWidth')
ans =
     0
```

See Also

`methods`, `methodsview`, `isprop`, `isevent`, `isobject`, `class`, `invoke`

Purpose Array elements that are NaN

Syntax

```
TF = isnan(A)
```

Description

`TF = isnan(A)` returns an array the same size as `A` containing logical 1 (`true`) where the elements of `A` are `NaN`s and logical 0 (`false`) where they are not. For a complex number `z`, `isnan(z)` returns `1` if either the real or imaginary part of `z` is `NaN`, and `0` if both the real and imaginary parts are finite or `Inf`.

For any real `A`, exactly one of the three quantities `isfinite(A)`, `isinf(A)`, and `isnan(A)` is equal to one.

Examples

```
a = [-2  -1  0  1  2]

isnan(1./a)
Warning: Divide by zero.

ans =
     0     0     0     0     0

isnan(0./a)
Warning: Divide by zero.

ans =
     0     0     1     0     0
```

See Also

`isfinite`, `isinf`, `is*`

isnumeric

Purpose

Determine whether input is numeric array

Syntax

```
tf = isnumeric(A)
```

Description

`tf = isnumeric(A)` returns logical `1` (`true`) if `A` is a numeric array and logical `0` (`false`) otherwise. For example, sparse arrays and double-precision arrays are numeric, while strings, cell arrays, and structure arrays and logicals are not.

Examples

Given the following cell array,

```
C{1,1} = pi;                  % double
C{1,2} = 'John Doe';          % char array
C{1,3} = 2 + 4i;              % complex double
C{1,4} = ispc;                % logical
C{1,5} = magic(3)             % double array

C =
   [3.1416] 'John Doe' [2.0000+ 4.0000i] [1][3x3 double]
```

`isnumeric` shows that all but `C{1,2}` and `C{1,4}` are numeric arrays.

```
for k = 1:5
x(k) = isnumeric(C{1,k});
end

x
x =
     1     0     1     0     1
```

See Also

`isstrprop`, `isnan`, `isreal`, `isprime`, `isfinite`, `isinf`, `isa`, `is*`

Purpose

Determine whether input is MATLAB OOPs object

Syntax

```
tf = isobject(A)
```

Description

`tf = isobject(A)` returns logical `1` (`true`) if `A` is a MATLAB object and logical `0` (`false`) otherwise.

Examples

Create an instance of the `polynom` class as defined in the section "Example — A Polynomial Class" in the MATLAB Programming documentation.

```
p = polynom([1 0 -2 -5])
p =
   x^3 - 2*x - 5
```

`isobject` indicates that `p` is a MATLAB object.

```
isobject(p)
ans =
     1
```

Note that `isjava`, which tests for Java objects in MATLAB, returns `false`.

```
isjava(p)
ans =
     0
```

See Also

`isjava`, `isstruct`, `iscell`, `ischar`, `isnumeric`, `islogical`, `ismethod`, `isprop`, `isevent`, `methods`, `class`, `isa`, is*

isocaps

Purpose

Compute isosurface end-cap geometry

Syntax

```
fvc = isocaps(X,Y,Z,V,isovalue)
fvc = isocaps(V,isovalue)
fvc = isocaps(...,'enclose')
fvc = isocaps(...,'whichplane')
[f,v,c] = isocaps(...)
isocaps(...)
```

Description

`fvc = isocaps(X,Y,Z,V,isovalue)` computes isosurface end-cap geometry for the volume data `V` at isosurface value `isovalue`. The arrays `X`, `Y`, and `Z` define the coordinates for the volume `V`.

The struct `fvc` contains the face, vertex, and color data for the end-caps and can be passed directly to the `patch` command.

`fvc = isocaps(V,isovalue)` 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)`.

`fvc = isocaps(...,'`*`enclose`*`')` specifies whether the end-caps enclose data values above or below the value specified in `isovalue`. The string *`enclose`* can be either `above` (default) or `below`.

`fvc = isocaps(...,'`*`whichplane`*`')` specifies on which planes to draw the end-caps. Possible values for *`whichplane`* are `all` (default), `xmin`, `xmax`, `ymin`, `ymax`, `zmin`, or `zmax`.

`[f,v,c] = isocaps(...)` returns the face, vertex, and color data for the end-caps in three arrays instead of the struct `fvc`.

`isocaps(...)` without output arguments draws a patch with the computed faces, vertices, and colors.

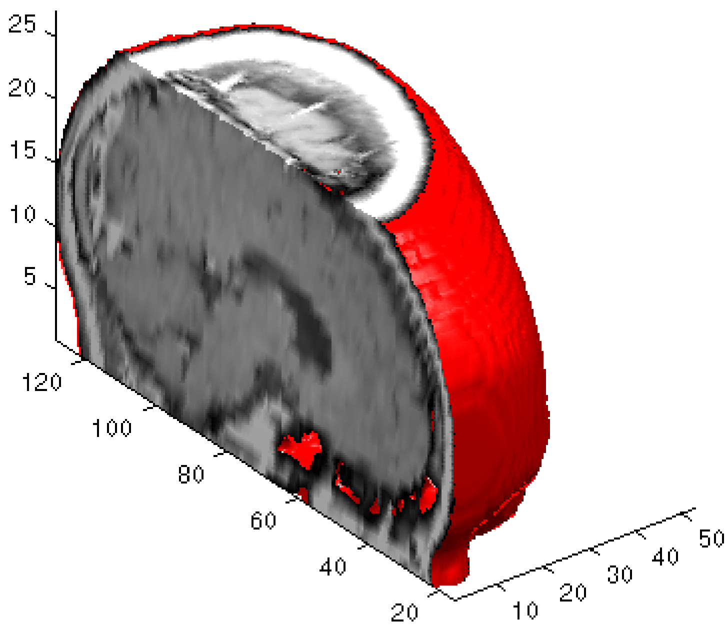
Examples

This example uses a data set that is a collection of MRI slices of a human skull. It illustrates the use of `isocaps` to draw the end-caps on this cutaway volume.

The red `isosurface` shows the outline of the volume (skull) and the end-caps show what is inside of the volume.

The patch created from the end-cap data (p2) uses interpolated face coloring, which means the gray colormap and the light sources determine how it is colored. The isosurface patch (p1) used a flat red face color, which is affected by the lights, but does not use the colormap.

```
load mri
D = squeeze(D);
D(:,1:60,:) = [];
p1 = patch(isosurface(D, 5),'FaceColor','red',...
 'EdgeColor','none');
p2 = patch(isocaps(D, 5),'FaceColor','interp',...
 'EdgeColor','none');
view(3); axis tight; daspect([1,1,.4])
colormap(gray(100))
camlight left; camlight; lighting gouraud
isonormals(D,p1)
```



See Also

`isosurface`, `isonormals`, `smooth3`, `subvolume`, `reducevolume`, `reducepatch`

“Isocaps Add Context to Visualizations” for more illustrations of isocaps

“Volume Visualization” on page 1-101 for related functions

Purpose

Calculate isosurface and patch colors

Syntax

```
nc = isocolors(X,Y,Z,C,vertices)
nc = isocolors(X,Y,Z,R,G,B,vertices)
nc = isocolors(C,vertices)
nc = isocolors(R,G,B,vertices)
nc = isocolors(...,PatchHandle)
isocolors(...,PatchHandle)
```

Description

`nc = isocolors(X,Y,Z,C,vertices)` computes the colors of isosurface (patch object) vertices (`vertices`) using color values `C`. Arrays `X`, `Y`, `Z` define the coordinates for the color data in `C` and must be monotonic vectors or 3-D plaid arrays (as if produced by `meshgrid`). The colors are returned in `nc`. `C` must be 3-D (index colors).

`nc = isocolors(X,Y,Z,R,G,B,vertices)` uses `R`, `G`, `B` as the red, green, and blue color arrays (true color).

`nc = isocolors(C,vertices)`, and `nc = isocolors(R,G,B,vertices)` assume `X`, `Y`, and `Z` are determined by the expression

```
[X Y Z] = meshgrid(1:n,1:m,1:p)
```

where `[m n p] = size(C)`.

`nc = isocolors(...,PatchHandle)` uses the vertices from the patch identified by `PatchHandle`.

`isocolors(...,PatchHandle)` sets the `FaceVertexCData` property of the patch specified by `PatchHandle` to the computed colors.

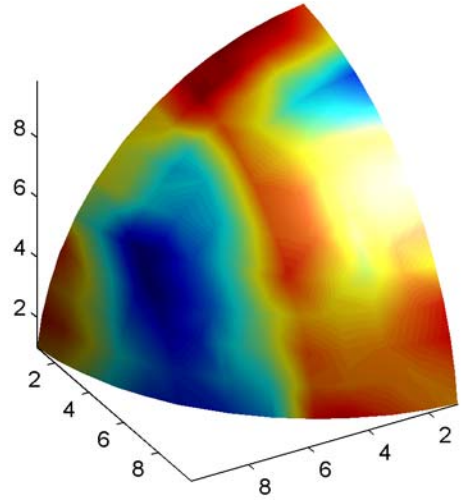
Examples

Indexed Color Data

This example displays an isosurface and colors it with random data using indexed color. (See “Interpolating in Indexed Color Versus Truecolor” for information on how patch objects interpret color data.)

```
[x y z] = meshgrid(1:20,1:20,1:20);
```

```
data = sqrt(x.^2 + y.^2 + z.^2);
cdata = smooth3(rand(size(data)),'box',7);
p = patch(isosurface(x,y,z,data,10));
isonormals(x,y,z,data,p);
isocolors(x,y,z,cdata,p);
set(p,'FaceColor','interp','EdgeColor','none')
view(150,30); daspect([1 1 1]);axis tight
camlight; lighting phong;
```

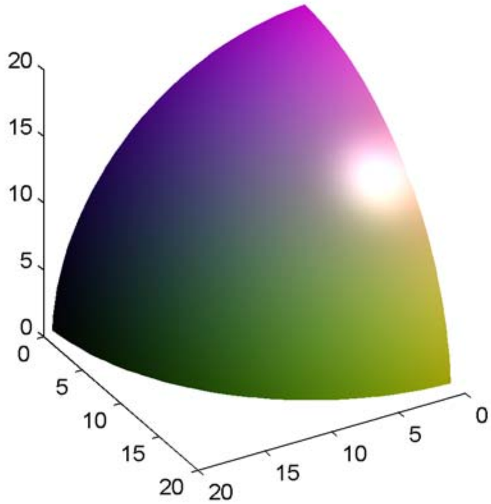


True Color Data

This example displays an isosurface and colors it with true color (RGB) data.

```
[x y z] = meshgrid(1:20,1:20,1:20);
data = sqrt(x.^2 + y.^2 + z.^2);
p = patch(isosurface(x,y,z,data,20));
isonormals(x,y,z,data,p);
[r g b] = meshgrid(20:-1:1,1:20,1:20);
```

```
isocolors(x,y,z,r/20,g/20,b/20,p);
set(p,'FaceColor','interp','EdgeColor','none')
view(150,30); daspect([1 1 1]);
camlight; lighting phong;
```

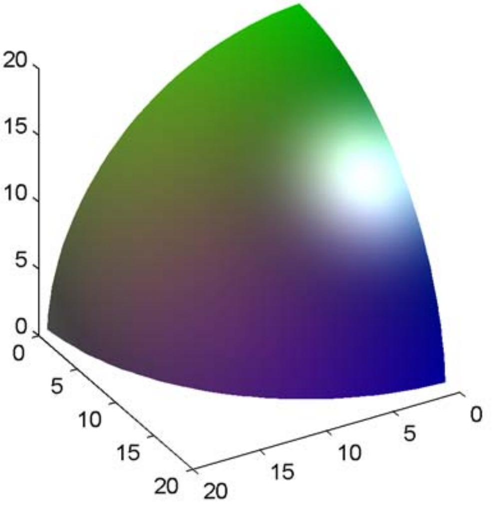


Modified True Color Data

This example uses `isocolors` to calculate the true color data using the isosurface's (patch object's) vertices, but then returns the color data in a variable (`c`) in order to modify the values. It then explicitly sets the isosurface's `FaceVertexCData` to the new data (`1-c`).

```
[x y z] = meshgrid(1:20,1:20,1:20);
data = sqrt(x.^2 + y.^2 + z.^2);
p = patch(isosurface(data,20));
isonormals(data,p);
[r g b] = meshgrid(20:-1:1,1:20,1:20);
c = isocolors(r/20,g/20,b/20,p);
set(p,'FaceVertexCData',1-c)
```

```
set(p,'FaceColor','interp','EdgeColor','none')
view(150,30); daspect([1 1 1]);
camlight; lighting phong;
```



See Also

`isosurface`, `isocaps`, `smooth3`, `subvolume`, `reducevolume`, `reducepatch`, `isonormals`

"Volume Visualization" on page 1-101 for related functions

Purpose

Compute normals of isosurface vertices

Syntax

```
n = isonormals(X,Y,Z,V,vertices)
n = isonormals(V,vertices)
n = isonormals(V,p) and n = isonormals(X,Y,Z,V,p)
n = isonormals(...,'negate')
isonormals(V,p) and isonormals(X,Y,Z,V,p)
```

Description

`n = isonormals(X,Y,Z,V,vertices)` computes the normals of the isosurface vertices from the vertex list, `vertices`, using the gradient of the data `V`. The arrays `X`, `Y`, and `Z` define the coordinates for the volume `V`. The computed normals are returned in `n`.

`n = isonormals(V,vertices)` 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)`.

`n = isonormals(V,p)` and `n = isonormals(X,Y,Z,V,p)` compute normals from the vertices of the patch identified by the handle `p`.

`n = isonormals(...,'negate')` negates (reverses the direction of) the normals.

`isonormals(V,p)` and `isonormals(X,Y,Z,V,p)` set the `VertexNormals` property of the patch identified by the handle `p` to the computed normals rather than returning the values.

Examples

This example compares the effect of different surface normals on the visual appearance of lit isosurfaces. In one case, the triangles used to draw the isosurface define the normals. In the other, the `isonormals` function uses the volume data to calculate the vertex normals based on the gradient of the data points. The latter approach generally produces a smoother-appearing isosurface.

Define a 3-D array of volume data (`cat`, `interp3`):

```
data = cat(3, [0 .2 0; 0 .3 0; 0 0 0], ...
              [.1 .2 0; 0 1 0; .2 .7 0],...
              [0 .4 .2; .2 .4 0;.1 .1 0]);
```

```
data = interp3(data,3,'cubic');
```

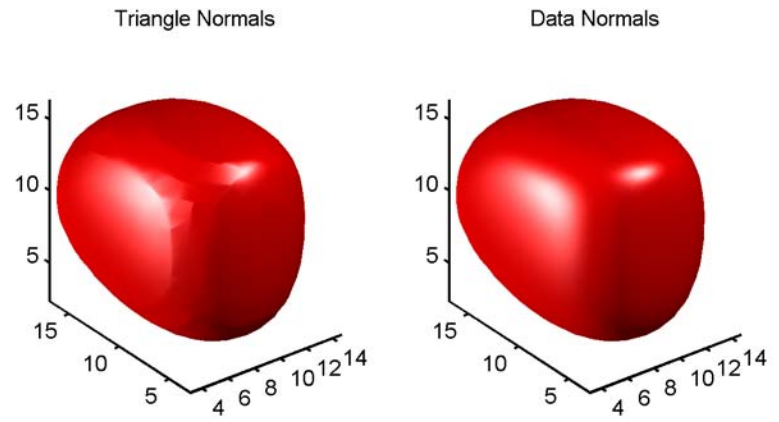
Draw an isosurface from the volume data and add lights. This isosurface uses triangle normals (`patch`, `isosurface`, `view`, `daspect`, `axis`, `camlight`, `lighting`, `title`):

```
subplot(1,2,1)
p1 = patch(isosurface(data,.5),...
'FaceColor','red','EdgeColor','none');
view(3); daspect([1,1,1]); axis tight
camlight; camlight(-80,-10); lighting phong;
title('Triangle Normals')
```

Draw the same lit isosurface using normals calculated from the volume data:

```
subplot(1,2,2)
p2 = patch(isosurface(data,.5),...
    'FaceColor','red','EdgeColor','none');
isonormals(data,p2)
view(3); daspect([1 1 1]); axis tight
camlight;  camlight(-80,-10); lighting phong;
title('Data Normals')
```

These isosurfaces illustrate the difference between triangle and data normals:



See Also

`interp3`, `isosurface`, `isocaps`, `smooth3`, `subvolume`, `reducevolume`, `reducepatch`

"Volume Visualization" on page 1-101 for related functions

isosurface

Purpose

Extract isosurface data from volume data

Syntax

```
fv = isosurface(X,Y,Z,V,isovalue)
fv = isosurface(V,isovalue)
fvc = isosurface(...,colors)
fv = isosurface(...,'noshare')
fv = isosurface(...,'verbose')
[f,v] = isosurface(...)
isosurface(...)
```

Description

`fv = isosurface(X,Y,Z,V,isovalue)` computes isosurface data from the volume data `V` at the isosurface value specified in `isovalue`. That is, the isosurface connects points that have the specified value much the way contour lines connect points of equal elevation.

The arrays `X`, `Y`, and `Z` define the coordinates for the volume `V`. The structure `fv` contains the faces and vertices of the isosurface, which you can pass directly to the `patch` command.

`fv = isosurface(V,isovalue)` 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)`.

`fvc = isosurface(...,colors)` interpolates the array `colors` onto the scalar field and returns the interpolated values in the `facevertexcdata` field of the `fvc` structure. The size of the `colors` array must be the same as `V`. The `colors` argument enables you to control the color mapping of the isosurface with data different from that used to calculate the isosurface (e.g., temperature data superimposed on a wind current isosurface).

`fv = isosurface(...,'noshare')` does not create shared vertices. This is faster, but produces a larger set of vertices.

`fv = isosurface(...,'verbose')` prints progress messages to the command window as the computation progresses.

`[f,v] = isosurface(...)` returns the faces and vertices in two arrays instead of a struct.

`isosurface(...)` with no output arguments creates a patch using the computed faces and vertices.

Special Case Behavior — isosurface Called with No Output Arguments

If there is no current axes and you call `isosurface` with without assigning output arguments, MATLAB creates a new axes, sets it to a 3-D view, and adds lighting to the isosurface graph.

Remarks

You can pass the `fv` structure created by `isosurface` directly to the `patch` command, but you cannot pass the individual faces and vertices arrays (`f`, `v`) to `patch` without specifying property names. For example,

```
patch(isosurface(X,Y,Z,V,isovalue))
```

or

```
[f,v] = isosurface(X,Y,Z,V,isovalue);
patch('Faces',f,'Vertices',v)
```

Examples

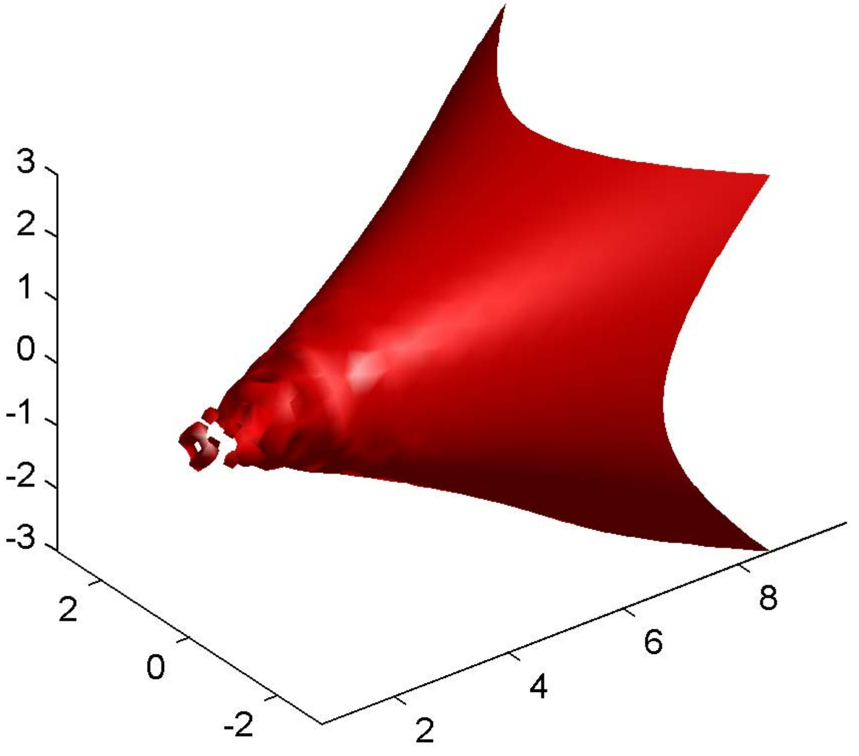
Example 1

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). The isosurface is drawn at the data value of -3. The statements that follow the `patch` command prepare the isosurface for lighting by

- Recalculating the isosurface normals based on the volume data (`isonormals`)
- Setting the face and edge color (`set`, `FaceColor`, `EdgeColor`)
- Specifying the view (`daspect`, `view`)
- Adding lights (`camlight`, `lighting`)

```
[x,y,z,v] = flow;
p = patch(isosurface(x,y,z,v,-3));
isonormals(x,y,z,v,p)
```

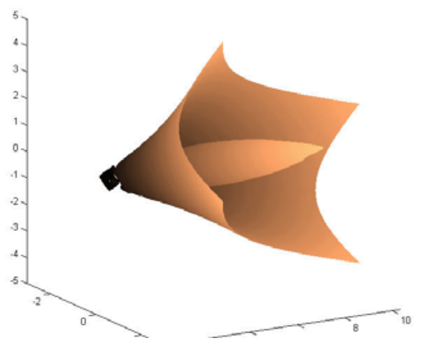
```
set(p,'FaceColor','red','EdgeColor','none');
daspect([1 1 1])
view(3); axis tight
camlight
lighting gouraud
```



Example 2

Visualize the same flow data as above, but color-code the surface to indicate magnitude along the X-axis. Use a sixth argument to `isosurface`, which provides a means to overlay another data set by coloring the resulting isosurface. The `colors` variable is a vector containing a scalar value for each vertex in the isosurface, to be portrayed with the current color map. In this case, it is one of the variables that define the surface, but it could be entirely independent. You can apply a different color scheme by changing the current figure color map.

```
[x,y,z,v] = flow;
[faces,verts,colors] = isosurface(x,y,z,v,-3,x);
patch('Vertices', verts, 'Faces', faces, ...
    'FaceVertexCData', colors, ...
    'FaceColor','interp', ...
    'edgecolor', 'interp');
view(30,-15);
axis vis3d;
colormap copper
```



See Also

`isonormals`, `shrinkfaces`, `smooth3`, `subvolume`

"Connecting Equal Values with Isosurfaces" for more examples

"Volume Visualization" on page 1-101 for related functions

Purpose

Determine whether PC (Windows) version of MATLAB

Syntax

```
tf = ispc
```

Description

`tf = ispc` returns logical `1` (`true`) for the PC version of MATLAB and logical `0` (`false`) otherwise.

See Also

`isunix`, `isstudent`, `is*`

Purpose

Test for existence of preference

Syntax

```
ispref('group','pref')
ispref('group')
ispref('group',{'pref1','pref2',...'prefn'})
```

Description

`ispref('group','pref')` returns `1` if the preference specified by `group` and `pref` exists, and `0` otherwise.

`ispref('group')` returns `1` if the GROUP exists, and `0` otherwise.

`ispref('group',{'pref1','pref2',...'prefn'})` returns a logical array the same length as the cell array of preference names, containing `1` where each preference exists, and `0` elsewhere.

Examples

```
addpref('mytoolbox','version','1.0')
ispref('mytoolbox','version')

ans =
     1.0
```

See Also

`addpref`, `getpref`, `rmpref`, `setpref`, `uigetpref`, `uisetpref`

isprime

Purpose

Array elements that are prime numbers

Syntax

`TF = isprime(A)`

Description

`TF = isprime(A)` returns an array the same size as `A` containing logical 1 (`true`) for the elements of `A` which are prime, and logical 0 (`false`) otherwise. `A` must contain only positive integers.

Examples

```
c = [2 3 0 6 10]

c =
     2     3     0     6    10

isprime(c)

ans =
     1     1     0     0     0
```

See Also

`is*`

Purpose

Determine whether input is object property

Syntax

```
isprop(h, 'name')
```

Description

`isprop(h, 'name')` returns logical `1` (`true`) if the specified `name` is a property you can use with object `h`. Otherwise, `isprop` returns logical `0` (`false`).

Examples

Create an Excel application and test to see if `UsableWidth` is a property of the object. `isprop` returns `true`:

```
h = actxserver ('Excel.Application');

isprop(h, 'UsableWidth')
ans =
     1
```

Try the same test on `SaveWorkspace`, which is a method, and `isprop` returns `false`:

```
isprop(h, 'SaveWorkspace')
ans =
     0
```

See Also

`get(COM)`, `inspect`, `addproperty`, `deleteproperty`, `ismethod`, `isevent`, `isobject`, `methods`, `class`

isreal

Purpose

Determine whether input is real array

Syntax

```
TF = isreal(A)
```

Description

`TF = isreal(A)` returns logical `0` (`false`) if any element of array `A` has an imaginary component, even if the value of that component is `0`. For `logical`, `char`, numeric, and function handle data types, `isreal` returns logical `1` (`true`) otherwise.

Note For `cell`, `struct`, and object data types, `isreal` also returns logical `0` (`false`).

`~isreal(x)` returns `true` for arrays that have at least one element with an imaginary component. The value of that component can be `0`.

Remarks

If `A` is real, `complex(A)` returns a complex number whose imaginary component is `0`, and `isreal(complex(A))` returns `false`. In contrast, the addition `A + 0i` returns the real value `A`, and `isreal(A + 0i)` returns `true`.

If `B` is real and `A = complex(B)`, then `A` is a complex matrix and `isreal(A)` returns `false`, while `A(m:n)` returns a real matrix and `isreal(A(m:n))` returns `true`.

Because MATLAB supports complex arithmetic, certain of its functions can introduce significant imaginary components during the course of calculations that appear to be limited to real numbers. Thus, you should use `isreal` with discretion.

Examples

Example 1

These examples use `isreal` to detect the presence or absence of imaginary numbers in an array. Let

```
x = magic(3);
y = complex(x);
```

`isreal(x)` returns `true` because no element of `x` has an imaginary component.

```
isreal(x)
ans =
     1
```

`isreal(y)` returns `false`, because every element of `x` has an imaginary component, even though the value of the imaginary components is `0`.

```
isreal(y)
ans =
     0
```

This expression detects strictly real arrays, i.e., elements with `0`-valued imaginary components are treated as real.

```
~any(imag(y(:)))
ans =
     1
```

Example 2

Given the following cell array,

```
C{1,1} = pi;                    % double
C{1,2} = 'John Doe';            % char array
C{1,3} = 2 + 4i;                % complex double
C{1,4} = ispc;                  % logical
C{1,5} = magic(3)               % double array
C{1,6} = complex(5,0)           % complex double

C =
  [3.1416]  'John Doe'  [2.0000+ 4.0000i]  [1]  [3x3 double]  [5]
```

`isreal` shows that all but `C{1,3}` and `C{1,6}` are real arrays.

```
for k = 1:6
x(k) = isreal(C{1,k});
end
```

```
x
x =
     1     1     0     1     1     0
```

See Also

`complex`, `isnumeric`, `isnan`, `isprime`, `isfinite`, `isinf`, `isa`, `is*`

Purpose

Determine whether input is scalar

Syntax

```
TF = isscalar(A)
```

Description

`TF = isscalar(A)` returns logical `1` (`true`) if `A` is a 1-by-1 matrix, and logical `0` (`false`) otherwise.

The `A` argument can be a structure or cell array. It also be a MATLAB object, as described in "Classes and Objects", as long as that object overloads the `size` function.

Examples

Test matrix `A` and one element of the matrix:

```
A = rand(5);

isscalar(A)
ans =
     0

isscalar(A(3,2))
ans =
     1
```

See Also

`isvector`, `isempty`, `isnumeric`, `islogical`, `ischar`, `isa`, `is*`

issorted

Purpose

Determine whether set elements are in sorted order

Syntax

```
TF = issorted(A)
TF = issorted(A, 'rows')
```

Description

`TF = issorted(A)` returns logical 1 (`true`) if the elements of `A` are in sorted order, and logical 0 (`false`) otherwise. Input `A` can be a vector or an N-by-1 or 1-by-N cell array of strings. `A` is considered to be sorted if `A` and the output of `sort(A)` are equal.

`TF = issorted(A, 'rows')` returns logical 1 (`true`) if the rows of two-dimensional matrix `A` are in sorted order, and logical 0 (`false`) otherwise. Matrix `A` is considered to be sorted if `A` and the output of `sortrows(A)` are equal.

Note Only the `issorted(A)` syntax supports `A` as a cell array of strings.

Remarks

For character arrays, `issorted` uses ASCII, rather than alphabetical, order.

You cannot use `issorted` on arrays of greater than two dimensions.

Examples

Example 1 — Using issorted on a vector

```
A = [5 12 33 39 78 90 95 107 128 131];

issorted(A)
ans =
     1
```

Example 2 — Using issorted on a matrix

```
A = magic(5)
A =
    17    24     1     8    15
    23     5     7    14    16
```

```
     4     6    13    20    22
    10    12    19    21     3
    11    18    25     2     9

issorted(A, 'rows')
ans =
     0

B = sortrows(A)
B =
     4     6    13    20    22
    10    12    19    21     3
    11    18    25     2     9
    17    24     1     8    15
    23     5     7    14    16

issorted(B)
ans =
     1
```

Example 3 — Using issorted on a cell array

```
x = {'one'; 'two'; 'three'; 'four'; 'five'};
issorted(x)
ans =
     0

y = sort(x)
y =
    'five'
    'four'
    'one'
    'three'
    'two'

issorted(y)
```

See Also sort, sortrows, ismember, unique, intersect, union, setdiff, setxor, is*

Purpose Array elements that are space characters

Syntax

```
tf = isspace('str')
```

Description `tf = isspace('str')` returns an array the same size as `'str'` containing logical `1` (`true`) where the elements of `str` are ASCII white spaces and logical `0` (`false`) where they are not. White spaces in ASCII are space, newline, carriage return, tab, vertical tab, or formfeed characters.

Examples

```
isspace('  Find spa ces ')
  Columns 1 through 13
     1   1   0   0   0   0   1   0   0   0   1   0   0
  Columns 14 through 15
     0   1
```

See Also `isletter`, `isstrprop`, `ischar`, `strings`, `isa`, `is*`

issparse

Purpose Determine whether input is sparse

Syntax

```
TF = issparse(S)
```

Description `TF = issparse(S)` returns logical 1 (`true`) if the storage class of `S` is sparse and logical 0 (`false`) otherwise.

See Also `is*`, `sparse`, `full`

Purpose

Determine whether input is character array

Note Use the `ischar` function in place of `isstr`. The `isstr` function will be removed in a future version of MATLAB.

See Also

`ischar`, `isa`, `is*`

isstrprop

Purpose

Determine whether string is of specified category

Syntax

```
tf = isstrprop('str', 'category')
```

Description

`tf = isstrprop('str', 'category')` returns a logical array the same size as `str` containing logical `1` (`true`) where the elements of `str` belong to the specified *`category`*, and logical `0` (`false`) where they do not.

The `str` input can be a character array, cell array, or any MATLAB numeric type. If `str` is a cell array, then the return value is a cell array of the same shape as `str`.

The *`category`* input can be any of the strings shown in the left column below:

Category	Description
`alpha`	`True` for those elements of `str` that are alphabetic
`alphanum`	`True` for those elements of `str` that are alphanumeric
`cntrl`	`True` for those elements of `str` that are control characters (for example, `char(0:20)`)
`digit`	`True` for those elements of `str` that are numeric digits

`graphic`	True for those elements of str that are graphic characters. These are all values that represent any characters except for the following:
	`unassigned, space, line separator,`
	`paragraph separator, control characters,`
	`Unicode format control characters,`
	`private user-defined characters,`
	`Unicode surrogate characters,`
	`Unicode other characters`

`lower`	`True` for those elements of `str` that are lowercase letters
`print`	`True` for those elements of `str` that are graphic characters, plus `char(32)`

Category	Description
punct	True for those elements of str that are punctuation characters
wspace	True for those elements of str that are white-space characters. This range includes the ANSI C definition of white space, {' ','\t','\n','\r','\v','\f'}.
upper	True for those elements of str that are uppercase letters
xdigit	True for those elements of str that are valid hexadecimal digits

Remarks

Numbers of type double are converted to int32 according to MATLAB rules of double-to-integer conversion. Numbers of type int64 and uint64 bigger than int32(inf) saturate to int32(inf).

MATLAB classifies the elements of the str input according to the Unicode definition of the specified category. If the numeric value of an element in the input array falls within the range that defines a Unicode character category, then this element is classified as being of that category. The set of Unicode character codes includes the set of ASCII character codes, but also covers a large number of languages beyond the scope of the ASCII set. The classification of characters is dependent on the global location of the platform on which MATLAB is installed.

Examples

Test for alphabetic characters in a string:

```
A = isstrprop('abc123def', 'alpha')
A =
   1  1  1  0  0  0  1  1  1
```

Test for numeric digits in a string:

```
A = isstrprop('abc123def', 'digit')
A =
   0  0  0  1  1  1  0  0  0
```

Test for hexadecimal digits in a string:

```
A = isstrprop('abcd1234efgh', 'xdigit')
A =
   1 1 1 1 1 1 1 1 1 1 0 0
```

Test for numeric digits in a character array:

```
A = isstrprop(char([97 98 99 49 50 51 101 102 103]), ...
              'digit')
A =
   0 0 0 1 1 1 0 0 0
```

Test for alphabetic characters in a two-dimensional cell array:

```
A = isstrprop({'abc123def';'456ghi789'}, 'alpha')
A =
   [1x9 logical]
   [1x9 logical]

A{:,:}
ans =
   1 1 1 0 0 0 1 1 1
   0 0 0 1 1 1 0 0 0
```

Test for white-space characters in a string:

```
A = isstrprop(sprintf('a bc\n'), 'wspace')
A =
   0 1 0 0 1
```

See Also

`strings`, `ischar`, `isletter`, `isspace`, `iscellstr`, `isnumeric`, `isa`, `is*`

Purpose

Determine whether input is structure array

Syntax

`tf = isstruct(A)`

Description

`tf = isstruct(A)` returns logical `1` (`true`) if `A` is a MATLAB structure and logical `0` (`false`) otherwise.

Examples

```
patient.name = 'John Doe';
patient.billing = 127.00;
patient.test = [79 75 73; 180 178 177.5; 220 210 205];

isstruct(patient)

ans =

     1
```

See Also

`struct`, `isfield`, `iscell`, `ischar`, `isobject`, `isnumeric`, `islogical`, `isa`, `is*`, dynamic field names

isstudent

Purpose Determine whether Student Version of MATLAB

Syntax `tf = isstudent`

Description `tf = isstudent` returns logical `1` (`true`) for the Student Version of MATLAB and logical `0` (`false`) for commercial versions.

See Also `ver`, `version`, `license`, `ispc`, `isunix`, `is*`

Purpose Determine whether UNIX version of MATLAB

Syntax `tf = isunix`

Description `tf = isunix` returns logical `1` (`true`) for the UNIX version of MATLAB and logical `0` (`false`) otherwise.

See Also `ispc`, `isstudent`, `is*`

isvalid (serial)

Purpose

Determine whether serial port objects are valid

Syntax

```
out = isvalid(obj)
```

Arguments

`obj`	A serial port object or array of serial port objects.
`out`	A logical array.

Description

`out = isvalid(obj)` returns the logical array `out`, which contains a `0` where the elements of `obj` are invalid serial port objects and a `1` where the elements of `obj` are valid serial port objects.

Remarks

`obj` becomes invalid after it is removed from memory with the `delete` function. Because you cannot connect an invalid serial port object to the device, you should remove it from the workspace with the `clear` command.

Example

Suppose you create the following two serial port objects.

```
s1 = serial('COM1');
s2 = serial('COM1');
```

`s2` becomes invalid after it is deleted.

```
delete(s2)
```

`isvalid` verifies that `s1` is valid and `s2` is invalid.

```
sarray = [s1 s2];
isvalid(sarray)
ans =
     1     0
```

See Also

Functions

`clear`, `delete`

Purpose Determine whether timer object is valid

Syntax

```
out = isvalid(obj)
```

Description

`out = isvalid(obj)` returns a logical array, `out`, that contains a `0` where the elements of `obj` are invalid timer objects and a `1` where the elements of `obj` are valid timer objects.

An invalid timer object is an object that has been deleted and cannot be reused. Use the `clear` command to remove an invalid timer object from the workspace.

Examples

Create a valid timer object.

```
t = timer;
out = isvalid(t)
out =

    1
```

Delete the timer object, making it invalid.

```
delete(t)
out1 = isvalid(t)
out1 =

    0
```

See Also

`timer`, `delete(timer)`

isvarname

Purpose

Determine whether input is valid variable name

Syntax

```
tf = isvarname 'str'
isvarname str
```

Description

`tf = isvarname 'str'` returns logical `1` (`true`) if the string `str` is a valid MATLAB variable name and logical `0` (`false`) otherwise. A valid variable name is a character string of letters, digits, and underscores, totaling not more than `namelengthmax` characters and beginning with a letter.

MATLAB keywords are not valid variable names. Type the command `iskeyword` with no input arguments to see a list of MATLAB keywords.

`isvarname str` uses the MATLAB command format.

Examples

This variable name is valid:

```
isvarname foo
ans =
   1
```

This one is not because it starts with a number:

```
isvarname 8th_column
ans =
   0
```

If you are building strings from various pieces, place the construction in parentheses.

```
d = date;

isvarname(['Monday_', d(1:2)])
ans =
   1
```

See Also

`genvarname`, `isglobal`, `iskeyword`, `namelengthmax`, `is*`

Purpose

Determine whether input is vector

Syntax

```
TF = isvector(A)
```

Description

`TF = isvector(A)` returns logical `1` (`true`) if `A` is a 1-by-`N` or `N`-by-1 vector where `N >= 0`, and logical `0` (`false`) otherwise.

The `A` argument can also be a MATLAB object, as described in "Classes and Objects", as long as that object overloads the `size` function.

Examples

Test matrix `A` and its row and column vectors:

```
A = rand(5);

isvector(A)
ans =
     0

isvector(A(3, :))
ans =
     1

isvector(A(:, 2))
ans =
     1
```

See Also

`isscalar`, `isempty`, `isnumeric`, `islogical`, `ischar`, `isa`, `is*`

Purpose

Imaginary unit

Syntax

```
j
x+yj
x+j*y
```

Description

Use the character `j` in place of the character `i`, if desired, as the imaginary unit.

As the basic imaginary unit `sqrt(-1)`, `j` is used to enter complex numbers. Since `j` is a function, it can be overridden and used as a variable. This permits you to use `j` as an index in `for` loops, etc.

It is possible to use the character `j` without a multiplication sign as a suffix in forming a numerical constant.

Examples

```
Z = 2+3j
Z = x+j*y
Z = r*exp(j*theta)
```

See Also

`conj`, `i`, `imag`, `real`

Purpose

Add entries to dynamic Java class path

Syntax

```
javaaddpath('dpath')
javaaddpath('dpath', '-end')
```

Description

`javaaddpath('dpath')` adds one or more directories or JAR files to the beginning of the current dynamic Java class path. `dpath` is a string or cell array of strings containing the directory or JAR file. (See the Remarks section for a description of static and dynamic Java paths.)

`javaaddpath('dpath', '-end')` adds one or more directories or files to the end of the current dynamic Java path.

Remarks

The Java path consists of two segments: a static path (read only at startup) and a dynamic path. MATLAB always searches the static path (defined in `classpath.txt`) before the dynamic path. Java classes on the static path should not have dependencies on classes on the dynamic path. Use `javaclasspath` to see the current static and dynamic Java paths.

Use the `clear java` command to reload the classes defined on the dynamic Java path. This is necessary if you add new Java classes or if you modify existing Java classes on the dynamic path.

Path Type	Description
Static	Loaded at the start of each MATLAB session from the file `classpath.txt`. The static Java path offers better Java class loading performance than the dynamic Java path. However, to modify the static Java path you need to edit the file `classpath.txt` and restart MATLAB.
Dynamic	Loaded at any time during a MATLAB session using the `javaclasspath` function. You can define the dynamic path (using `javaclasspath`), modify the path (using `javaaddpath` and `javarmpath`), and refresh the Java class definitions for all classes on the dynamic path (using `clear java`) without restarting MATLAB.

Examples

Create function to set initial dynamic Java class path:

```
function setdynpath
javaclasspath({
   'C:\Work\Java\ClassFiles', ...
   'C:\Work\JavaTest\curvefit.jar', ...
   'C:\Work\JavaTest\timer.jar', ...
   'C:\Work\JavaTest\patch.jar'});
% end of file
```

Call this function to set up your dynamic class path. Then, use the `javaclasspath` function with no arguments to display all current static and dynamic paths:

```
setdynpath;

javaclasspath

         STATIC JAVA PATH

   D:\Sys0\Java\util.jar
```

```
D:\Sys0\Java\widgets.jar
D:\Sys0\Java\beans.jar
          .
          .

    DYNAMIC JAVA PATH

C:\Work\Java\ClassFiles
C:\Work\JavaTest\curvefit.jar
C:\Work\JavaTest\timer.jar
C:\Work\JavaTest\patch.jar
```

At some later time, add the following two entries to the dynamic path. One entry specifies a directory and the other a Java Archive (JAR) file. When you add a directory to the path, MATLAB includes all files in that directory as part of the path:

```
javaaddpath({
   'C:\Work\Java\Curvefit\Test', ...
   'C:\Work\Java\mywidgets.jar'});
```

Use javaclasspath with just an output argument to return the dynamic path alone:

```
p = javaclasspath
p =
   'C:\Work\Java\ClassFiles'
   'C:\Work\JavaTest\curvefit.jar'
   'C:\Work\JavaTest\timer.jar'
   'C:\Work\JavaTest\patch.jar'
   'C:\Work\Java\Curvefit\Test'
   'C:\Work\Java\mywidgets.jar'
```

Create an instance of the mywidgets class that is defined on the dynamic path:

```
h = mywidgets.calendar;
```

If you modify one or more classes that are defined on the dynamic path, you need to clear the former definition for those classes from MATLAB memory. You can clear all dynamic Java class definitions from memory using,

```
clear java
```

If you then create a new instance of one of these classes, MATLAB uses the latest definition of the class to create the object.

Use `javarmpath` to remove a file or directory from the current dynamic class path:

```
javarmpath('C:\Work\Java\mywidgets.jar');
```

Other Examples

Add a JAR file from an internet URL to your dynamic Java path:

```
javaaddpath http://www.example.com/my.jar
```

Add the current directory with the following statement:

```
javaaddpath(pwd)
```

See Also

`javaclasspath`, `javarmpath`, `clear`

See "Bringing Java Classes and Methods into MATLAB" for more information.

Purpose

Construct Java array

Syntax

```
javaArray('package_name.class_name',x1,...,xn)
```

Description

`javaArray('package_name.class_name',x1,...,xn)` constructs an empty Java array capable of storing objects of Java class, '*class_name*'. The dimensions of the array are `x1` by `...` by `xn`. You must include the package name when specifying the class.

The array that you create with `javaArray` is equivalent to the array that you would create with the Java code

```
A = new class_name[x1]...[xn];
```

Examples

The following example constructs and populates a 4-by-5 array of `java.lang.Double` objects.

```
dblArray = javaArray ('java.lang.Double', 4, 5);
for m = 1:4
   for n = 1:5
   dblArray(m,n) = java.lang.Double((m*10) + n);
   end
end

dblArray

dblArray =
java.lang.Double[][]:
    [11]    [12]    [13]    [14]    [15]
    [21]    [22]    [23]    [24]    [25]
    [31]    [32]    [33]    [34]    [35]
    [41]    [42]    [43]    [44]    [45]
```

See Also

`javaObject`, `javaMethod`, `class`, `methodsview`, `isjava`

javachk

Purpose

Generate error message based on Java feature support

Syntax

```
javachk(feature)
javachk(feature, component)
```

Description

`javachk(feature)` returns a generic error message if the specified Java `feature` is not available in the current MATLAB session. If it is available, `javachk` returns an empty matrix. Possible `feature` arguments are shown in the following table.

Feature	Description
`'awt'`	Abstract Window Toolkit components[1] are available.
`'desktop'`	The MATLAB interactive desktop is running.
`'jvm'`	The Java Virtual Machine is running.
`'swing'`	Swing components[2] are available.

1. Java's GUI components in the Abstract Window Toolkit

2. Java's lightweight GUI components in the Java Foundation Classes

`javachk(feature, component)` works the same as the above syntax, except that the specified `component` is also named in the error message. (See the example below.)

Examples

The following M-file displays an error with the message `"CreateFrame is not supported on this platform."` when run in a MATLAB session in which the AWT's GUI components are not available. The second argument to `javachk` specifies the name of the M-file, which is then included in the error message generated by MATLAB.

```
javamsg = javachk('awt', mfilename);
if isempty(javamsg)
   myFrame = java.awt.Frame;
   myFrame.setVisible(1);
else
   error(javamsg);
end
```

See Also

usejava

Purpose

Set and get dynamic Java class path

Syntax

```
javaclasspath
javaclasspath(dpath)
dpath = javaclasspath
spath = javaclasspath('-static')
jpath = javaclasspath('-all')
javaclasspath(statusmsg)
```

Description

`javaclasspath` displays the static and dynamic segments of the Java path. (See the Remarks section, below, for a description of static and dynamic Java paths.)

`javaclasspath(dpath)` sets the dynamic Java path to one or more directory or file specifications given in `dpath`, where `dpath` can be a string or cell array of strings.

`dpath = javaclasspath` returns the dynamic segment of the Java path in cell array, `dpath`. If no dynamic paths are defined, `javaclasspath` returns an empty cell array.

`spath = javaclasspath('-static')` returns the static segment of the Java path in cell array, `spath`. No path information is displayed unless you specify an output variable. If no static paths are defined, `javaclasspath` returns an empty cell array.

`jpath = javaclasspath('-all')` returns the entire Java path in cell array, `jpath`. The returned cell array contains first the static segment of the path, and then the dynamic segment. No path information is displayed unless you specify an output variable. If no dynamic paths are defined, `javaclasspath` returns an empty cell array.

`javaclasspath(`*`statusmsg`*`)` enables or disables the display of status messages from the `javaclasspath`, `javaaddpath`, and `javarmpath` functions. Values for the *`statusmsg`* argument are

statusmsg	Description
`'-v1'`	Display status messages while loading the Java path from the file system
`'-v0'`	Do not display status messages. This is the default.

Remarks

The Java path consists of two segments: a static path and a dynamic path. MATLAB always searches the static path before the dynamic path. Java classes on the static path should not have dependencies on classes on the dynamic path.

Path Type	Description
Static	Loaded at the start of each MATLAB session from the file `classpath.txt`. The static Java path offers better Java class loading performance than the dynamic Java path. However, to modify the static Java path you need to edit the file `classpath.txt` and restart MATLAB.
Dynamic	Loaded at any time during a MATLAB session using the `javaclasspath` function. You can define the dynamic path (using `javaclasspath`), modify the path (using `javaaddpath` and `javarmpath`), and refresh the Java class definitions for all classes on the dynamic path (using `clear java`) without restarting MATLAB.

Examples

Create a function to set your initial dynamic Java class path:

```
function setdynpath
javaclasspath({
   'C:\Work\Java\ClassFiles', ...
   'C:\Work\JavaTest\curvefit.jar', ...
   'C:\Work\JavaTest\timer.jar', ...
   'C:\Work\JavaTest\patch.jar'});
%             end of file
```

Call this function to set up your dynamic class path. Then, use the `javaclasspath` function with no arguments to display all current static and dynamic paths:

```
setdynpath;

javaclasspath

       STATIC JAVA PATH

   D:\Sys0\Java\util.jar
   D:\Sys0\Java\widgets.jar
   D:\Sys0\Java\beans.jar
             .
             .

       DYNAMIC JAVA PATH

   C:\Work\Java\ClassFiles
   C:\Work\JavaTest\curvefit.jar
   C:\Work\JavaTest\timer.jar
   C:\Work\JavaTest\patch.jar
```

At some later time, add the following two entries to the dynamic path. One entry specifies a directory and the other a Java Archive (JAR) file. When you add a directory to the path, MATLAB includes all files in that directory as part of the path:

```
javaaddpath({
   'C:\Work\Java\Curvefit\Test', ...
   'C:\Work\Java\mywidgets.jar'});
```

Use `javaclasspath` with just an output argument to return the dynamic path alone:

```
p = javaclasspath
p =
```

```
'C:\Work\Java\ClassFiles'
'C:\Work\JavaTest\curvefit.jar'
'C:\Work\JavaTest\timer.jar'
'C:\Work\JavaTest\patch.jar'
'C:\Work\Java\Curvefit\Test'
'C:\Work\Java\mywidgets.jar'
```

Create an instance of the `mywidgets` class that is defined on the dynamic path:

```
h = mywidgets.calendar;
```

If, at some time, you modify one or more classes that are defined on the dynamic path, you will need to clear the former definition for those classes from MATLAB memory. You can clear all dynamic Java class definitions from memory using,

```
clear java
```

If you then create a new instance of one of these classes, MATLAB uses the latest definition of the class to create the object.

Use `javarmpath` to remove a file or directory from the current dynamic class path:

```
javarmpath('C:\Work\Java\mywidgets.jar');
```

See Also

`javaaddpath`, `javarmpath`, `clear`

javaMethod

Purpose

Invoke Java method

Syntax

```
javaMethod('method_name','class_name',x1,...,xn)
javaMethod('method_name',J,x1,...,xn)
```

Description

`javaMethod('method_name','class_name',x1,...,xn)` invokes the `static` method `method_name` in the class `class_name`, with the argument list that matches `x1,...,xn`.

`javaMethod('method_name',J,x1,...,xn)` invokes the nonstatic method `method_name` on the object J, with the argument list that matches `x1,...,xn`.

Remarks

Using the `javaMethod` function enables you to

- Use methods having names longer than 31 characters
- Specify the method you want to invoke at run-time, for example, as input from an application user

The `javaMethod` function enables you to use methods having names longer than 31 characters. This is the only way you can invoke such a method in MATLAB. For example:

```
javaMethod('DataDefinitionAndDataManipulationTransactions', T);
```

With `javaMethod`, you can also specify the method to be invoked at run-time. In this situation, your code calls `javaMethod` with a string variable in place of the method name argument. When you use `javaMethod` to invoke a static method, you can also use a string variable in place of the class name argument.

Note Typically, you do not need to use `javaMethod`. The default MATLAB syntax for invoking a Java method is somewhat simpler and is preferable for most applications. Use `javaMethod` primarily for the two cases described above.

Examples

To invoke the `static` Java method `isNaN` on class, `java.lang.Double`, use

```
javaMethod('isNaN','java.lang.Double',2.2)
```

The following example invokes the nonstatic method `setTitle`, where `frameObj` is a `java.awt.Frame` object.

```
frameObj = java.awt.Frame;
javaMethod('setTitle', frameObj, 'New Title');
```

See Also

`javaArray`, `javaObject`, `import`, `methods`, `isjava`

Purpose

Construct Java object

Syntax

```
javaObject('class_name',x1,...,xn)
```

Description

`javaObject('class_name',x1,...,xn)` invokes the Java constructor for class '`class_name`' with the argument list that matches `x1,...,xn`, to return a new object.

If there is no constructor that matches the class name and argument list passed to `javaObject`, an error occurs.

Remarks

Using the `javaObject` function enables you to

- Use classes having names with more than 31 consecutive characters
- Specify the class for an object at run-time, for example, as input from an application user

The default MATLAB constructor syntax requires that no segment of the input class name be longer than 31 characters. (A *name segment*, is any portion of the class name before, between, or after a period. For example, there are three segments in class, `java.lang.String`.) Any class name segment that exceeds 31 characters is truncated by MATLAB. In the rare case where you need to use a class name of this length, you must use `javaObject` to instantiate the class.

The `javaObject` function also allows you to specify the Java class for the object being constructed at run-time. In this situation, you call `javaObject` with a string variable in place of the class name argument.

```
class  = 'java.lang.String';
text = 'hello';
strObj = javaObject(class, text);
```

In the usual case, when the class to instantiate is known at development time, it is more convenient to use the MATLAB constructor syntax. For example, to create a `java.lang.String` object, you would use

```
strObj = java.lang.String('hello');
```

Note Typically, you will not need to use `javaObject`. The default MATLAB syntax for instantiating a Java class is somewhat simpler and is preferable for most applications. Use `javaObject` primarily for the two cases described above.

Examples

The following example constructs and returns a Java object of class `java.lang.String`:

```
strObj = javaObject('java.lang.String','hello')
```

See Also

`javaArray`, `javaMethod`, `import`, `methods`, `fieldnames`, `isjava`

javarmpath

Purpose

Remove entries from dynamic Java class path

Syntax

```
javarmpath('dpath')
javarmpath dpath1 dpath2 ... dpathN
javarmpath(v1, v2, ..., vN)
```

Description

`javarmpath('dpath')` removes a directory or file from the current dynamic Java path. `dpath` is a string containing the directory or file specification. (See the Remarks section, below, for a description of static and dynamic Java paths.)

`javarmpath dpath1 dpath2 ...  dpathN` removes those directories and files specified by `dpath1`, `dpath2`, `...`, `dpathN` from the dynamic Java path. Each input argument is a string containing a directory or file specification.

`javarmpath(v1, v2, ..., vN)` removes those directories and files specified by `v1`, `v2`, `...`, `vN` from the dynamic Java path. Each input argument is a variable to which a directory or file specification is assigned.

Remarks

The Java path consists of two segments: a static path and a dynamic path. MATLAB always searches the static path before the dynamic path. Java classes on the static path should not have dependencies on classes on the dynamic path.

Path Type	Description
Static	Loaded at the start of each MATLAB session from the file `classpath.txt`. The static Java path offers better Java class loading performance than the dynamic Java path. However, to modify the static Java path you need to edit the file `classpath.txt` and restart MATLAB.
Dynamic	Loaded at any time during a MATLAB session using the `javaclasspath` function. You can define the dynamic path (using `javaclasspath`), modify the path (using `javaaddpath` and `javarmpath`), and refresh the Java class definitions for all classes on the dynamic path (using `clear java`) without restarting MATLAB.

Examples

Create a function to set your initial dynamic Java class path:

```
function setdynpath
javaclasspath({
   'C:\Work\Java\ClassFiles', ...
   'C:\Work\JavaTest\curvefit.jar', ...
   'C:\Work\JavaTest\timer.jar', ...
   'C:\Work\JavaTest\patch.jar'});
% end of file
```

Call this function to set up your dynamic class path. Then, use the `javaclasspath` function with no arguments to display all current static and dynamic paths:

```
setdynpath;

javaclasspath

         STATIC JAVA PATH
```

```
D:\Sys0\Java\util.jar
D:\Sys0\Java\widgets.jar
D:\Sys0\Java\beans.jar
          .
          .

    DYNAMIC JAVA PATH

D:\Work\Java\ClassFiles
C:\Work\JavaTest\curvefit.jar
C:\Work\JavaTest\timer.jar
C:\Work\JavaTest\patch.jar
```

At some later time, add the following two entries to the dynamic path. One entry specifies a directory and the other a Java Archive (JAR) file. When you add a directory to the path, MATLAB includes all files in that directory as part of the path:

```
javaaddpath({
   'C:\Work\Java\Curvefit\Test', ...
   'C:\Work\Java\mywidgets.jar'});
```

Use `javaclasspath` with just an output argument to return the dynamic path alone:

```
p = javaclasspath
p =
   'C:\Work\Java\ClassFiles'
   'C:\Work\JavaTest\curvefit.jar'
   'C:\Work\JavaTest\timer.jar'
   'C:\Work\JavaTest\patch.jar'
   'C:\Work\Java\Curvefit\Test'
   'C:\Work\Java\mywidgets.jar'
```

Create an instance of the `mywidgets` class that is defined on the dynamic path:

```
h = mywidgets.calendar;
```

If, at some time, you modify one or more classes that are defined on the dynamic path, you will need to clear the former definition for those classes from MATLAB memory. You can clear all dynamic Java class definitions from memory using,

```
clear java
```

If you then create a new instance of one of these classes, MATLAB uses the latest definition of the class to create the object.

Use `javarmpath` to remove a file or directory from the current dynamic class path:

```
javarmpath('C:\Work\Java\mywidgets.jar');
```

See Also

`javaclasspath`, `javaaddpath`, `clear`

keyboard

Purpose Input from keyboard

Syntax

```
keyboard
```

Description

`keyboard` , when placed in an M-file, stops execution of the file and gives control to the keyboard. The special status is indicated by a `K` appearing before the prompt. You can examine or change variables; all MATLAB commands are valid. This keyboard mode is useful for debugging your M-files..

To terminate the keyboard mode, type the command

```
return
```

then press the **Return** key.

See Also `dbstop`, `input`, `quit`, `pause`, `return`

Purpose

Kronecker tensor product

Syntax

```
K = kron(X,Y)
```

Description

`K = kron(X,Y)` returns the Kronecker tensor product of `X` and `Y`. The result is a large array formed by taking all possible products between the elements of `X` and those of `Y`. If `X` is `m`-by-`n` and `Y` is `p`-by-`q`, then `kron(X,Y)` is `m*p`-by-`n*q`.

Examples

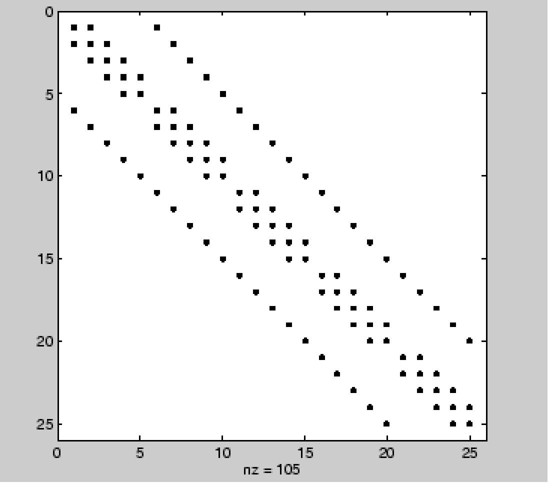
If `X` is 2-by-3, then `kron(X,Y)` is

```
[ X(1,1)*Y X(1,2)*Y X(1,3)*Y
  X(2,1)*Y X(2,2)*Y X(2,3)*Y ]
```

The matrix representation of the discrete Laplacian operator on a two-dimensional, `n`-by-`n` grid is a `n^2`-by-`n^2` sparse matrix. There are at most five nonzero elements in each row or column. The matrix can be generated as the Kronecker product of one-dimensional difference operators with these statements:

```
I = speye(n,n);
E = sparse(2:n,1:n-1,1,n,n);
D = E+E'-2*I;
A = kron(D,I)+kron(I,D);
```

Plotting this with the `spy` function for `n = 5` yields:



See Also `hankel`, `toeplitz`

Purpose

Last error message

Note `lasterr` has been replaced by `lasterror`, but will be maintained for backward compatibility.

Syntax

```
msgstr = lasterr
[msgstr, msgid] = lasterr
lasterr('new_msgstr')
lasterr('new_msgstr', 'new_msgid')
[msgstr, msgid] = lasterr('new_msgstr', 'new_msgid')
```

Description

`msgstr = lasterr` returns the last error message generated by MATLAB.

`[msgstr, msgid] = lasterr` returns the last error in `msgstr` and its message identifier in `msgid`. If the error was not defined with an identifier, `lasterr` returns an empty string for `msgid`. See "Message Identifiers" and "Using Message Identifiers with lasterror" in the MATLAB Programming documentation for more information on the `msgid` argument and how to use it.

`lasterr('new_msgstr')` sets the last error message to a new string, `new_msgstr`, so that subsequent invocations of `lasterr` return the new error message string. You can also set the last error to an empty string with `lasterr('')`.

`lasterr('new_msgstr', 'new_msgid')` sets the last error message and its identifier to new strings `new_msgstr` and `new_msgid`, respectively. Subsequent invocations of `lasterr` return the new error message and message identifier.

`[msgstr, msgid] = lasterr('new_msgstr', 'new_msgid')` returns the last error message and its identifier, also changing these values so that subsequent invocations of `lasterr` return the message and identifier strings specified by `new_msgstr` and `new_msgid` respectively.

Examples

Example 1

Here is a function that examines the `lasterr` string and displays its own message based on the error that last occurred. This example deals with two cases, each of which is an error that can result from a matrix multiply:

```
function matrix_multiply(A, B)
try
   A * B
catch
   errmsg = lasterr;
   if(strfind(errmsg, 'Inner matrix dimensions'))
      disp('** Wrong dimensions for matrix multiply')
   else
      if(strfind(errmsg, 'not defined for variables of class'))
         disp('** Both arguments must be double matrices')
      end
   end
end
```

If you call this function with matrices that are incompatible for matrix multiplication (e.g., the column dimension of `A` is not equal to the row dimension of `B`), MATLAB catches the error and uses `lasterr` to determine its source:

```
A = [1  2  3; 6  7  2; 0  -1  5];
B = [9  5  6; 0  4  9];

matrix_multiply(A, B)
** Wrong dimensions for matrix multiply
```

Example 2

Specify a message identifier and error message string with `error`:

```
error('MyToolbox:angleTooLarge', ...
      'The angle specified must be less than 90 degrees.');
```

In your error handling code, use `lasterr` to determine the message identifier and error message string for the failing operation:

```
[errmsg, msgid] = lasterr
errmsg =
   The angle specified must be less than 90 degrees.
msgid =
   MyToolbox:angleTooLarge
```

See Also

`error`, `lasterror`, `rethrow`, `warning`, `lastwarn`

Purpose Last error message and related information

Syntax

```
s = lasterror
s = lasterror(err)
s = lasterror('reset')
```

Description

`s = lasterror` returns a structure `s` containing information about the most recent error issued by MATLAB. The return structure contains the following fields:

Fieldname	Description
`message`	Character array containing the text of the error message.
`identifier`	Character array containing the message identifier of the error message. If the last error issued by MATLAB had no message identifier, then the `identifier` field is an empty character array.
`stack`	Structure providing information on the location of the error. The structure has fields `file`, `name`, and `line`, and is the same as the structure returned by the `dbstack` function. If `lasterror` returns no stack information, `stack` is a 0-by-1 structure having the same three fields.

Note The `lasterror` return structure might contain additional fields in future versions of MATLAB.

The fields of the structure returned in `stack` are

Fieldname	Description
file	Name of the file in which the function generating the error appears. This field is the empty string if there is no file.
name	Name of the function in which the error occurred. If this is the primary function of the M-file, and the function name differs from the M-file name, name is set to the M-file name.
line	M-file line number where the error occurred.

See "Message Identifiers" in the MATLAB Programming documentation for more information on the syntax and usage of message identifiers.

`s = lasterror(err)` sets the last error information to the error message and identifier specified in the structure `err`. Subsequent invocations of `lasterror` return this new error information. The optional return structure `s` contains information on the previous error.

`s = lasterror('reset')` sets the last error information to the default state. In this state, the `message` and `identifier` fields of the return structure are empty strings, and the `stack` field is a 0-by-1 structure.

Examples

Example 1

Save the following MATLAB code in an M-file called `average.m`:

```
function y = average(x)
% AVERAGE Mean of vector elements.
% AVERAGE(X), where X is a vector, is the mean of vector elements.
% Nonvector input results in an error.
check_inputs(x)
y = sum(x)/length(x);      % The actual computation

function check_inputs(x)
[m,n] = size(x);
if (~((m == 1) || (n == 1)) || (m == 1 && n == 1))
    error('AVG:NotAVector', 'Input must be a vector.')
```

```
end
```

Now run the function. Because this function requires vector input, passing a scalar value to it forces an error. The error occurs in subroutine `check_inputs`:

```
average(200)
??? Error using ==> average>check_inputs
Input must be a vector.

Error in ==> average at 5
check_inputs(x)
```

Get the three fields from `lasterror`:

```
err = lasterror
err =
       message: [1x61 char]
    identifier: 'AVG:NotAVector'
         stack: [2x1 struct]
```

Display the text of the error message:

```
msg = err.message
msg =
    Error using ==> average>check_inputs
    Input must be a vector.
```

Display the fields containing the `stack` information. `err.stack` is a 2-by-1 structure because it provides information on the failing subroutine `check_inputs` and also the outer, primary function `average`:

```
st1 = err.stack(1,1)
st1 =
    file: 'd:\matlab_test\average.m'
    name: 'check_inputs'
    line: 11
```

```
st2 = err.stack(2,1)
st2 =
    file: 'd:\matlab_test\average.m'
    name: 'average'
    line: 5
```

Note As a rule, the name of your primary function should be the same as the name of the M-file containing that function. If these names differ, MATLAB uses the M-file name in the `name` field of the `stack` structure.

Example 2

`lasterror` is often used in conjunction with the `rethrow` function in `try-catch` statements. For example,

```
try
   do_something
catch
   do_cleanup
   rethrow(lasterror)
end
```

See Also

`error`, `rethrow`, `try`, `catch`, `lastwarn`, `dbstack`

lastwarn

Purpose

Last warning message

Syntax

```
msgstr = lastwarn
[msgstr, msgid] = lastwarn
lastwarn('new_msgstr')
lastwarn('new_msgstr', 'new_msgid')
[msgstr, msgid] = lastwarn('new_msgstr', 'new_msgid')
```

Description

`msgstr = lastwarn` returns the last warning message generated by MATLAB.

`[msgstr, msgid] = lastwarn` returns the last warning in `msgstr` and its message identifier in `msgid`. If the warning was not defined with an identifier, `lastwarn` returns an empty string for `msgid`. See "Message Identifiers" and "Warning Control" in the MATLAB Programming documentation for more information on the `msgid` argument and how to use it.

`lastwarn('new_msgstr')` sets the last warning message to a new string, `new_msgstr`, so that subsequent invocations of `lastwarn` return the new warning message string. You can also set the last warning to an empty string with `lastwarn('')`.

`lastwarn('new_msgstr', 'new_msgid')` sets the last warning message and its identifier to new strings `new_msgstr` and `new_msgid`, respectively. Subsequent invocations of `lastwarn` return the new warning message and message identifier.

`[msgstr, msgid] = lastwarn('new_msgstr', 'new_msgid')` returns the last warning message and its identifier, also changing these values so that subsequent invocations of `lastwarn` return the message and identifier strings specified by `new_msgstr` and `new_msgid`, respectively.

Remarks

`lastwarn` does not return warnings that are reported during the parsing of MATLAB commands. (Warning messages that include the failing file name and line number are parse-time warnings.)

Examples

Specify a message identifier and warning message string with `warning`:

```
warning('MATLAB:divideByZero', 'Divide by zero');
```

Use `lastwarn` to determine the message identifier and error message string for the operation:

```
[warnmsg, msgid] = lastwarn
warnmsg =
   Divide by zero
msgid =
   MATLAB:divideByZero
```

See Also

`warning`, `error`, `lasterr`, `lasterror`

lcm

Purpose

Least common multiple

Syntax

```
L = lcm(A,B)
```

Description

`L = lcm(A,B)` returns the least common multiple of corresponding elements of arrays `A` and `B`. Inputs `A` and `B` must contain positive integer elements and must be the same size (or either can be scalar).

Examples

```
lcm(8,40)

ans =

    40
lcm(pascal(3),magic(3))

ans =
     8     1     6
     3    10    21
     4     9     6
```

See Also

`gcd`

Purpose

Block ldl' factorization for Hermitian indefinite matrices

Syntax

```
L = ldl(A)
[L,D] = ldl(A)
[L,D,P] = ldl(A)
[L,D,p] = ldl(A,'vector')
[U,D,P] = ldl(A,'upper')
[U,D,p] = ldl(A,'upper','vector')
```

Description

`L = ldl(A)` returns only the "psychologically lower triangular matrix" `L` as in the two-output form. The permutation information is lost, as is the block diagonal factor `D`. By default, `ldl` references only the diagonal and lower triangle of `A`, and assumes that the upper triangle is the complex conjugate transpose of the lower triangle. Therefore `[L,D,P] = ldl(TRIL(A))` and `[L,D,P] = ldl(A)`both return the exact same factors.

`[L,D] = ldl(A)` stores a block diagonal matrix `D` and a "psychologically lower triangular matrix" (i.e. a product of unit lower triangular and permutation matrices) in `L` such that `A = L*D*L'`. The block diagonal matrix `D` has 1-by-1 and 2-by-2 blocks on its diagonal.

`[L,D,P] = ldl(A)` returns unit lower triangular matrix `L`, block diagonal `D`, and permutation matrix `P` such that `P'*A*P = L*D*L'`. This is equivalent to `[L,D,P] = ldl(A,'matrix')`.

`[L,D,p] = ldl(A,'vector')` returns the permutation information as a vector, `p`, instead of a matrix. The `p` output is a row vector such that `A(p,p) = L*D*L'`.

`[U,D,P] = ldl(A,'upper')` references only the diagonal and upper triangle of `A` and assumes that the lower triangle is the complex conjugate transpose of the upper triangle. This syntax returns a unit upper triangular matrix `U` such that `P'*A*P = U'*D*U` (assuming that `A` is Hermitian, and not just upper triangular). Similarly, `[L,D,P] = ldl(A,'lower')` gives the default behavior.

`[U,D,p] = ldl(A,'upper','vector')` returns the permutation information as a vector, `p`, as does `[L,D,p] = ldl(A,'lower','vector')`. `A` must be a full matrix.

Examples

These examples illustrate the use of the various forms of the `ldl` function, including the one-, two-, and three-output form, and the use of the `vector` and `upper` options. The topics covered are

- "Example 1 — One-Output Form of ldl" on page 2-1850
- "Example 2 — Two-Output Form of ldl" on page 2-1851
- "Example 3 — Three Output Form of ldl" on page 2-1851
- "Example 4 — The Structure of D" on page 2-1852
- "Example 5 — Using the 'vector' Option" on page 2-1852
- "Example 6 — Using the 'upper' Option" on page 2-1853
- "Example 7 — linsolve and the Hermitian indefinite solver" on page 2-1853

Before running any of these examples, you will need to generate the following positive definite and indefinite Hermitian matrices:

```
A = full(delsq(numgrid('L', 10)));
rand('state', 0);
B = rand(10);
M = [eye(10) B; B' zeros(10)];
```

The structure of `M` here is very common in optimization and fluid-flow problems, and `M` is in fact indefinite. Note that the positive definite matrix `A` must be full, as `ldl` does not accept sparse arguments.

Example 1 — One-Output Form of ldl

The one-output form of `ldl` returns the psychologically unit lower-triangular matrix as above. Note that this is a different matrix from that which you would derive with the `lu` function, as `lu` just returns what comes from LAPACK. Although `ldl` is also implemented using LAPACK routines (ssytrf, dsytrf, chetrf, zhetrf), you must decipher the output in ways that are lost when only one output is returned:

```
Lm = ldl(M); Dm = Lm\(M/Lm');
fprintf(1, ...
'The error norm ||M - Lm*Dm*Lm''|| is %g\n', norm(M - Lm*Dm*Lm'));
```

You can apply the L output from this command to the input matrix to recover D (approximately).

Example 2 — Two-Output Form of ldl

The two-output form of ldl returns L and D such that A-(L*D*L') is small, L is "psychologically unit lower triangular" (i.e., a permuted unit lower triangular matrix), and D is a block 2-by-2 diagonal. Note also that, because A is positive definite, the diagonal of D is all positive:

```
[LA,DA] = ldl(A);
fprintf(1, ...
'The factorization error ||A - LA*DA*LA''|| is %g\n', ...
norm(A - LA*DA*LA'));
neginds = find(diag(DA) < 0)
```

Given a b, solve Ax=b using LA, DA:

```
bA = sum(A,2);
x = LA'\(DA\(LA\bA));
fprintf(...
'The absolute error norm ||x - ones(size(bA))|| is %g\n', ...
norm(x - ones(size(bA))));
```

Example 3 — Three Output Form of ldl

The three output form returns the permutation matrix as well, so that L is in fact unit lower triangular:

```
[Lm, Dm, Pm] = ldl(M);
fprintf(1, ...
'The error norm ||Pm''*M*Pm - Lm*Dm*Lm''|| is %g\n', ...
```

```
norm(Pm'*M*Pm - Lm*Dm*Lm'));
fprintf(1, ...
'The difference between Lm and tril(Lm) is %g\n', ...
norm(Lm - tril(Lm)));
```

Given b, solve Mx=b using Lm, Dm, and Pm:

```
bM = sum(M,2);
x = Pm*(Lm'\(Dm\(Lm\(Pm'*bM))));
fprintf(...
'The absolute error norm ||x - ones(size(b))|| is %g\n', ...
norm(x - ones(size(bM))));
```

Example 4 — The Structure of D

D is a block diagonal matrix with 1-by-1 blocks and 2-by-2 blocks. That makes it a special case of a tridiagonal matrix. When the input matrix is positive definite, D is almost always diagonal (depending on how definite the matrix is). When the matrix is indefinite however, D may be diagonal or it may express the block structure. For example, with A as above, DA is diagonal. But if you shift A just a bit, you end up with an indefinite matrix and then you can compute a D that has the block structure.

```
figure; spy(DA); title('Structure of D from ldl(A)');
[Las, Das] = ldl(A - 4*eye(size(A)));
figure; spy(Das);
title('Structure of D from ldl(A - 4*eye(size(A)))');
```

Example 5 — Using the 'vector' Option

Like the lu function, ldl accepts an argument that determines whether the function returns a permutation vector or permutation matrix. ldl returns the latter by default. When you select 'vector', the function executes faster and uses less memory. For this reason, specifying the 'vector' option is recommended. Another thing to note is that indexing is typically faster than multiplying for this kind of operation:

```
[Lm, Dm, pm] = ldl(M, 'vector');
fprintf(1, 'The error norm ||M(pm,pm) - Lm*Dm*Lm''|| is %g\n', ...
```

```
  norm(M(pm,pm) - Lm*Dm*Lm'));

% Solve a system with this kind of factorization.
clear x;
x(pm,:) = Lm'\(Dm\(Lm\(bM(pm,:))));
fprintf('The absolute error norm ||x - ones(size(b))|| is %g\n', ...
  norm(x - ones(size(bM))));
```

Example 6 — Using the 'upper' Option

Like the `chol` function, `ldl` accepts an argument that determines which triangle of the input matrix is referenced, and also whether `ldl` returns a lower (`L`) or upper (`L'`) triangular factor. For dense matrices, there are no real savings with using the upper triangular version instead of the lower triangular version:

```
Ml = tril(M);
[Lml, Dml, Pml] = ldl(Ml, 'lower'); % 'lower' is default behavior.
fprintf(1, ...
'The difference between Lml and Lm is %g\n', norm(Lml - Lm));
[Umu, Dmu, pmu] = ldl(triu(M), 'upper', 'vector');
fprintf(1, ...
'The difference between Umu and Lm'' is %g\n', norm(Umu - Lm'));

% Solve a system using this factorization.
clear x;
x(pm,:) = Umu\(Dmu\(Umu'\(bM(pmu,:))));
fprintf(...
'The absolute error norm ||x - ones(size(b))|| is %g\n', ...
norm(x - ones(size(bM))));
```

When specifying both the `'upper'` and `'vector'` options, `'upper'` must precede `'vector'` in the argument list.

Example 7 — linsolve and the Hermitian indefinite solver

When using the `linsolve` function, you may experience better performance by exploiting the knowledge that a system has a symmetric matrix. The matrices used in the examples above are a bit small to see this so, for this example, generate a larger matrix. The matrix here is symmetric positive definite, and below we will see that with each bit of knowledge about the matrix, there is a corresponding speedup. That is, the symmetric solver is faster than the general solver while the symmetric positive definite solver is faster than the symmetric solver:

```
Abig = full(delsq(numgrid('L', 30)));
bbig = sum(Abig, 2);
LSopts.POSDEF = false;
LSopts.SYM = false;
tic; linsolve(Abig, bbig, LSopts); toc;
LSopts.SYM = true;
tic; linsolve(Abig, bbig, LSopts); toc;
LSopts.POSDEF = true;
tic; linsolve(Abig, bbig, LSopts); toc;
```

Algorithm

`ldl` uses the LAPACK routines listed in the following table.

	Real	Complex
Double	DSYTRF	ZHETRF
Single	SSYTRN	CHETRF

See Also

`chol`, `lu`, `qr`

Purpose

Left or right array division

Syntax

```
ldivide(A,B)
A.\B
rdivide(A,B)
A./B
```

Description

`ldivide(A,B)` and the equivalent `A.\B` divides each entry of `B` by the corresponding entry of `A`. `A` and `B` must be arrays of the same size. A scalar value for either `A` or `B` is expanded to an array of the same size as the other.

`rdivide(A,B)` and the equivalent `A./B` divides each entry of `A` by the corresponding entry of `B`. `A` and `B` must be arrays of the same size. A scalar value for either `A` or `B` is expanded to an array of the same size as the other.

Example

```
A = [1 2 3;4 5 6];
B = ones(2, 3);
A.\B

ans =

    1.0000    0.5000    0.3333
    0.2500    0.2000    0.1667
```

See Also

Arithmetic Operators, `mldivide`, `mrdivide`

Purpose

Test for less than or equal to

Syntax

```
A <= B
le(A, B)
```

Description

`A <= B` compares each element of array `A` with the corresponding element of array `B`, and returns an array with elements set to logical 1 (`true`) where `A` is less than or equal to `B`, or set to logical 0 (`false`) where `A` is greater than `B`. Each input of the expression can be an array or a scalar value.

If both `A` and `B` are scalar (i.e., 1-by-1 matrices), then MATLAB returns a scalar value.

If both `A` and `B` are nonscalar arrays, then these arrays must have the same dimensions, and MATLAB returns an array of the same dimensions as `A` and `B`.

If one input is scalar and the other a nonscalar array, then the scalar input is treated as if it were an array having the same dimensions as the nonscalar input array. In other words, if input `A` is the number 100, and `B` is a 3-by-5 matrix, then `A` is treated as if it were a 3-by-5 matrix of elements, each set to 100. MATLAB returns an array of the same dimensions as the nonscalar input array.

`le(A, B)` is called for the syntax `A < =B` when either `A` or `B` is an object.

Examples

Create two 6-by-6 matrices, `A` and `B`, and locate those elements of `A` that are less than or equal to the corresponding elements of `B`:

```
A = magic(6);
B = repmat(3*magic(3), 2, 2);

A <= B
ans =
     0     1     1     0     0     0
     1     0     1     0     0     0
     0     1     1     0     1     0
     1     0     0     1     0     1
```

```
0     1     0     0     1     1
1     0     0     0     1     0
```

See Also

`lt`, `eq`, `ge`, `gt`, `ne`, Relational Operators

legend

Purpose

Graph legend for lines and patches

GUI Alternatives

Add a legend to a selected axes on a graph with the **Insert Legend** tool  on the figure toolbar, or use **Insert —> Legend** from the figure menu. Use the Property Editor to modify the position, font, and other properties of a legend. For details, see Using Plot Edit Mode in the MATLAB Graphics documentation.

Syntax

```
legend('string1','string2',...)
legend(h,'string1','string2',...)
legend(M)
legend(h,M)
legend(M,'parameter_name','parameter_value',...)
legend(h,M,'parameter_name','parameter_value',...)
legend(axes_handle,...)
legend('off'), legend(axes_handle,'off')
legend('toggle'), legend(axes_handle,'toggle')
legend('hide'), legend(axes_handle,'hide')
legend('show'), legend(axes_handle,'show')
legend('boxoff'), legend(axes_handle,'boxoff')
legend('boxon'), legend(axes_handle,'boxon')
legend_handle = legend(...)
legend
legend(legend_handle)
legend(...,'Location',location)
legend(...,'Orientation','orientation')
[legend_h,object_h,plot_h,text_strings] = legend(...)
legend(li_object,string1,string2,string3)
legend(li_objects,M)
legend('v6',M,...)
legend('v6',AX)
```

Description

`legend` places a legend on various types of graphs (line plots, bar graphs, pie charts, etc.). For each line plotted, the legend shows a sample of the line type, marker symbol, and color beside the text label you specify. When plotting filled areas (patch or surface objects), the legend contains a sample of the face color next to the text label.

The font size and font name for the legend strings match the axes `FontSize` and `FontName` properties.

`legend('string1','string2',...)` displays a legend in the current axes using the specified strings to label each set of data.

`legend(h,'string1','string2',...)` displays a legend on the plot containing the objects identified by the handles in the vector `h` and uses the specified strings to label the corresponding graphics object (line, barseries, etc.).

`legend(M)` adds a legend containing the rows of the matrix or cell array of strings `M` as labels. For matrices, this is the same as `legend(M(1,:),M(2,:),...)`.

`legend(h,M)` associates each row of the matrix or cell array of strings `M` with the corresponding graphics object (patch or line) in the vector of handles `h`.

`legend(M,'parameter_name','parameter_value',...)` and `legend(h,M,'parameter_name','parameter_value',...)` allow parameter/value pairs to be set when creating a legend (you can also assign them with `set` or with the Property Editor or Property Inspector). `M` must be a cell array of names. Legends inherit the properties of axes, although not all of them are relevant to legend objects.

`legend(axes_handle,...)` displays the legend for the axes specified by `axes_handle`.

`legend('off'), legend(axes_handle,'off')` removes the legend in the current axes or the axes specified by `axes_handle`.

`legend('toggle'), legend(axes_handle,'toggle')` toggles the legend on or off. If no legend exists for the current axes, one is created using default strings.

The *default string* for an object is the value of the object's `DisplayName` property, if you have defined a value for `DisplayName` (which you can do using the Property Editor or calling `set`). Otherwise, `legend` constructs a string of the form `data1`, `data2`, etc. Setting display names is useful when you are experimenting with legends and might forget how objects in a lineseries, for example, are ordered.

When you specify legend strings in a `legend` command, their respective `DisplayNames` are set to these strings. If you delete a legend and then create a new legend without specifying labels for it, the values of `DisplayName` are (re)used as label names. Naturally, the associated plot objects must have a `DisplayName` property for this to happen: all *`_series`* and *`_group`* plot objects have a `DisplayName` property; Handle Graphics primitives, such as `line` and `patch`, do not.

`legend('hide')`, `legend(axes_handle,'hide')` makes the legend in the current axes or the axes specified by `axes_handle` invisible.

`legend('show')`, `legend(axes_handle,'show')` makes the legend in the current axes or the axes specified by `axes_handle` visible.

`legend('boxoff')`, `legend(axes_handle,'boxoff')` removes the box from the legend in the current axes or the axes specified by `axes_handle`, and makes its background transparent.

`legend('boxon')`, `legend(axes_handle,'boxon')` adds a box with an opaque background to the legend in the current axes or the axes specified by `axes_handle`.

You can also type the above six commands using the syntax

```
legend keyword
```

If the keyword is not recognized, it is used as legend text, creating a legend or replacing the current legend.

`legend_handle = legend(...)` returns the handle to the legend on the current axes, or `[]` if no legend exists.

`legend` with no arguments refreshes all the legends in the current figure.

`legend(legend_handle)` refreshes the specified legend.

`legend(...,'Location',location)` uses *location* to determine where to place the legend. *location* can be either a 1-by-4 position vector ([left bottom width height]) or one of the following strings.

Specifier	Location in Axes
`North`	Inside plot box near top
`South`	Inside bottom
`East`	Inside right
`West`	Inside left
`NorthEast`	Inside top right (default)
`NorthWest`	Inside top left
`SouthEast`	Inside bottom right
`SouthWest`	Inside bottom left
`NorthOutside`	Outside plot box near top
`SouthOutside`	Outside bottom
`EastOutside`	Outside right
`WestOutside`	Outside left
`NorthEastOutside`	Outside top right
`NorthWestOutside`	Outside top left
`SouthEastOutside`	Outside bottom right
`SouthWestOutside`	Outside bottom left
`Best`	Least conflict with data in plot
`BestOutside`	Least unused space outside plot

If the legend text does not fit in the 1-by-4 position vector, the position vector is resized around the midpoint to fit the legend text given its font and size, making the legend taller or wider. The *location* string can be all lowercase and can be abbreviated by sentinel letter (e.g., N, NE, NEO, etc.). Using one of the `...Outside` values for *location* ensures that the legend does not overlap the plot, whereas overlaps can occur when you specify any of the other cardinal values. The *location* property applies to colorbars and legends, but not to axes.

Obsolete Location Values

The first column of the following table shows the now-obsolete specifiers for legend locations that were in use prior to Version 7, along with a description of the locations and their current equivalent syntaxes:

Obsolete Specifier	Location in Axes	Current Specifier
-1	Outside axes on right side	NorthEastOutside
0	Inside axes	Best
1	Upper right corner of axes	NorthEast
2	Upper left corner of axes	NorthWest
3	Lower left corner of axes	SouthWest
4	Lower right corner of axes	SouthEast

`legend(...,'Orientation','orientation')` creates a legend with the legend items arranged in the specified orientation. *orientation* can be `vertical` (the default) or `horizontal`.

`[legend_h,object_h,plot_h,text_strings] = legend(...)` returns

- `legend_h` — Handle of the legend axes
- `object_h` — Handles of the line, patch, and text graphics objects used in the legend
- `plot_h` — Handles of the lines and other objects used in the plot
- `text_strings` — Cell array of the text strings used in the legend

These handles enable you to modify the properties of the respective objects.

`legend(li_object,string1,string2,string3)` creates a legend for legendinfo objects `li_objects` with strings `string1`, etc.

`legend(li_objects,M)` creates a legend of legendinfo objects `li_objects`, where `M` is a string matrix or cell array of strings corresponding to the legendinfo objects.

Backward Compatibility

`legend('v6',M,...)`, for a cell array of strings `M`, creates a legend compatible with MATLAB 6.5 from the strings in `M` and any additional inputs.

`legend('v6',AX)`, for an axes handle `AX`, updates any Version 6 legends and returns the legend handle.

The following calls to `legend` are passed to the Version 6 legend mechanism to maintain backward compatibility:

```
legend('DeleteLegend')
legend('EditLegend',h)
legend('ShowLegendPlot',h)
legend('ResizeLegend')
legend('RestoreSize',hLegend)
legend('RecordSize',hPlot)
```

Remarks

`legend` associates strings with the objects in the axes in the same order that they are listed in the axes `Children` property. By default, the legend annotates the current axes.

MATLAB displays only one legend per axes. `legend` positions the legend based on a variety of factors, such as what objects the legend obscures.

The properties that legends do not share with axes are

- `Location`
- `Orientation`
- `EdgeColor`
- `TextColor`

- `Interpreter`
- `String`

You can specify `EdgeColor` and `TextColor` as RGB triplets or as `ColorSpecs`. You cannot set these colors to `'none'`. To hide the box surrounding a legend, set the `Box` property to `'off'`. To allow the background to show through the legend box, set the legend's `Color` property to `'none'`, for example,

```
set(legend_handle, 'Box', 'off')
set(legend_handle, 'Color', 'none')
```

This is similar to the effect of the command `legend boxoff`, except that `boxoff` also hides the legend's border.

You can use a legend's handle to set text properties for all the strings in a legend at once, rather than looping through each of them. See the last line of the example below, which demonstrates setting a legend's `Interpreter` property. See the documentation for Text Properties for additional details.

`legend` installs a figure `ResizeFcn` if there is not already a user-defined `ResizeFcn` assigned to the figure. This `ResizeFcn` attempts to keep the legend the same size.

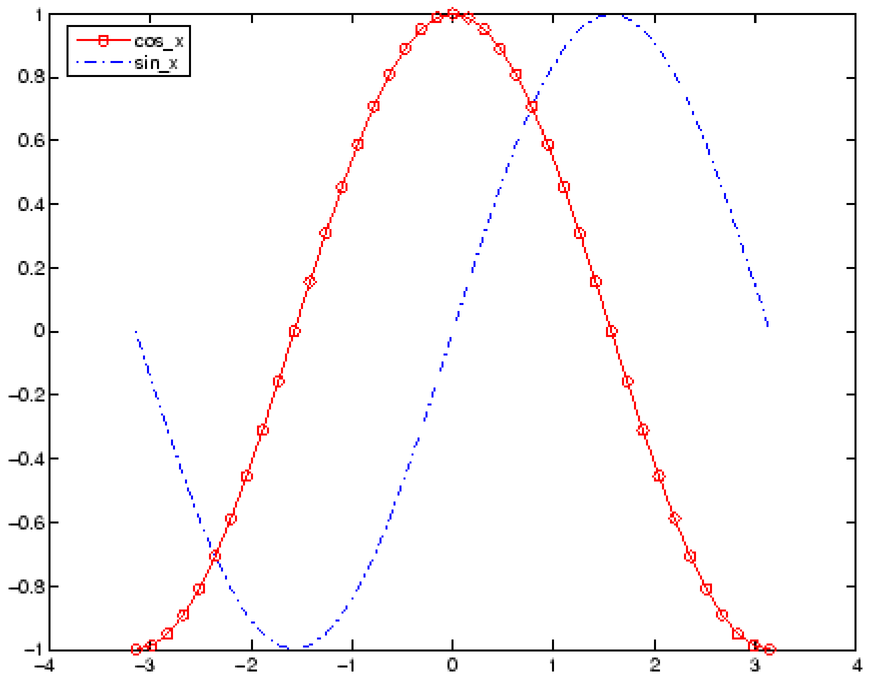
Moving the Legend

Move the legend by pressing the left mouse button while the cursor is over the legend and dragging the legend to a new location. Double-clicking a label allows you to edit the label.

Example

Add a legend to a graph showing a sine and cosine function:

```
x = -pi:pi/20:pi;
plot(x,cos(x),'-ro',x,sin(x),'-.b')
h = legend('cos_x','sin_x',2);
set(h,'Interpreter','none')
```



In this example, the `plot` command specifies a solid, red line (`'-r'`) for the cosine function and a dash-dot, blue line (`'-.b'`) for the sine function.

See Also

`LineSpec`, `plot`

"Adding a Legend to a Graph" for more information on using legends

"Annotating Plots" on page 1-86 for related functions

legendre

Purpose

Associated Legendre functions

Syntax

```
P = legendre(n,X)
S = legendre(n,X,'sch')
N = legendre(n,X,'norm')
```

Definitions

Associated Legendre Functions

The Legendre functions are defined by

$$P_n^m(x) = (-1)^m(1-x^2)^{m/2}\frac{d^m}{dx^m}P_n(x)$$

where

$$P_n(x)$$

is the Legendre polynomial of degree n.

$$P_n(x) = \frac{1}{2^n n!}\left[\frac{d^n}{dx^n}(x^2-1)^n\right]$$

Schmidt Seminormalized Associated Legendre Functions

The Schmidt seminormalized associated Legendre functions are related to the nonnormalized associated Legendre functions $P_n^m(x)$ by

$P_n(x)$ for $m = 0$

$S_n^m(x) = (-1)^m \sqrt{\frac{2(n-m)!}{(n+m)!}} P_n^m(x)$ for $m > 0$.

Fully Normalized Associated Legendre Functions

The fully normalized associated Legendre functions are normalized such that

$$\int_{-1}^{1} (N_n^m(x))^2 dx = 1$$

and are related to the unnormalized associated Legendre functions $P_n^m(x)$ by

$$N_n^m(x) = (-1)^m \sqrt{\frac{\left(n+\frac{1}{2}\right)(n-m)!}{(n+m)!}} P_n^m(x)$$

Description

`P = legendre(n,X)` computes the associated Legendre functions $P_n^m(x)$ of degree `n` and order `m = 0,1,...,n`, evaluated for each element of `X`. Argument `n` must be a scalar integer, and `X` must contain real values in the domain $-1 \le x \le 1$.

If `X` is a vector, then `P` is an `(n+1)`-by-`q` matrix, where `q = length(X)`. Each element `P(m+1,i)` corresponds to the associated Legendre function of degree `n` and order `m` evaluated at `X(i)`.

In general, the returned array `P` has one more dimension than `X`, and each element `P(m+1,i,j,k,...)` contains the associated Legendre function of degree `n` and order `m` evaluated at `X(i,j,k,...)`. Note that the first row of `P` is the Legendre polynomial evaluated at `X`, i.e., the case where `m` = 0.

`S = legendre(n,X,'sch')` computes the Schmidt seminormalized associated Legendre functions $S_n^m(x)$.

`N = legendre(n,X,'norm')` computes the fully normalized associated Legendre functions $N_n^m(x)$.

Examples

Example 1

The statement `legendre(2,0:0.1:0.2)` returns the matrix

	x = 0	x = 0.1	x = 0.2
m = 0	-0.5000	-0.4850	-0.4400
m = 1	0	-0.2985	-0.5879
m = 2	3.0000	2.9700	2.8800

Example 2

Given,

```
X = rand(2,4,5);
n = 2;
P = legendre(n,X)
```

then

```
size(P)
ans =
      3      2      4      5
```

and

```
P(:,1,2,3)
ans =
   -0.2475
   -1.1225
    2.4950
```

is the same as

```
legendre(n,X(1,2,3))
ans =
   -0.2475
   -1.1225
    2.4950
```

Algorithm

`legendre` uses a three-term backward recursion relationship in `m`. This recursion is on a version of the Schmidt seminormalized associated

Legendre functions $Q_n^m(x)$, which are complex spherical harmonics. These functions are related to the standard Abramowitz and Stegun [1] functions $P_n^m(x)$ by

$$P_n^m(x) = \sqrt{\frac{(n+m)!}{(n-m)!}}\, Q_n^m(x)$$

They are related to the Schmidt form given previously by

$$S_n^m(x) = Q_n^0(x) \text{ for } m = 0$$
$$S_n^m(x) = (-1)^m \sqrt{2}\, Q_n^m(x) \text{ for } m > 0$$

References

[1] Abramowitz, M. and I. A. Stegun, *Handbook of Mathematical Functions*, Dover Publications, 1965, Ch.8.

[2] Jacobs, J. A., *Geomagnetism*, Academic Press, 1987, Ch.4.

length

Purpose

Length of vector

Syntax

```
n = length(X)
```

Description

The statement `length(X)` is equivalent to `max(size(X))` for nonempty arrays and `0` for empty arrays.

`n = length(X)` returns the size of the longest dimension of `X`. If `X` is a vector, this is the same as its length.

Examples

```
x = ones(1,8);
n = length(x)

n =
     8
x = rand(2,10,3);
n = length(x)

n =
    10
```

See Also

`ndims`, `size`

length (serial)

Purpose Length of serial port object array

Syntax

```
length(obj)
```

Arguments

`obj`	A serial port object or an array of serial port objects.

Description

`length(obj)` returns the length of `obj`. It is equivalent to the command `max(size(obj))`.

See Also

Functions

`size`

length (timeseries)

Purpose Length of time vector

Syntax `length(ts)`

Description `length(ts)` returns an integer that represents the length of the time vector for the `timeseries` object `ts`. It returns `0` if `ts` is empty.

See Also `isempty (timeseries)`, `size (timeseries)`

Purpose Length of time vector

Syntax `length(tsc)`

Description `length(tsc)` returns an integer that represents the length of the time vector for the `tscollection` object `tsc`.

See Also `isempty (tscollection)`, `size (tscollection)`, `tscollection`

libfunctions

Purpose

Information on functions in external library

Syntax

```
m = libfunctions('libname')
m = libfunctions('libname', '-full')
libfunctions libname -full
```

Description

`m = libfunctions('libname')` returns the names of all functions defined in the external shared library, `libname`, that has been loaded into MATLAB with the `loadlibrary` function. The return value, `m`, is a cell array of strings.

If you used an alias when initially loading the library, then you must use that alias for the `libname` argument.

`m = libfunctions('libname', '-full')` returns a full description of the functions in the library, including function signatures. This includes duplicate function names with different signatures. The return value, `m`, is a cell array of strings.

`libfunctions libname -full` is the command format for this function.

Examples

List the functions in the MATLAB `libmx` library:

```
hfile = [matlabroot '\extern\include\matrix.h'];
loadlibrary('libmx', hfile)

libfunctions libmx

Methods for class lib.libmx:
mxAddField               mxGetFieldNumber  mxIsLogicalScalarTrue
mxArrayToString          mxGetImagData     mxIsNaN
mxCalcSingleSubscript    mxGetInf          mxIsNumeric
mxCalloc                 mxGetIr           mxIsObject
mxClearScalarDoubleFlag  mxGetJc           mxIsOpaque
mxCreateCellArray        mxGetLogicals     mxIsScalarDoubleFlagSet
       .                      .                  .
       .                      .                  .
```

To list the functions along with their signatures, use the **-full** switch with `libfunctions`:

```
libfunctions libmx -full

Methods for class lib.libmx:
[mxClassID, MATLAB array] mxGetClassID(MATLAB array)
[lib.pointer, MATLAB array] mxGetData(MATLAB array)
[MATLAB array, voidPtr] mxSetData(MATLAB array, voidPtr)
[uint8, MATLAB array] mxIsNumeric(MATLAB array)
[uint8, MATLAB array] mxIsCell(MATLAB array)
[lib.pointer, MATLAB array] mxGetPr(MATLAB array)
[MATLAB array, doublePtr] mxSetPr(MATLAB array, doublePtr)
         .
         .

unloadlibrary libmx
```

See Also

`loadlibrary`, `libfunctionsview`, `libpointer`, `libstruct`, `calllib`, `libisloaded`, `unloadlibrary`

libfunctionsview

Purpose

Create window displaying information on functions in external library

Syntax

```
libfunctionsview libname
libfunctionsview libname
```

Description

`libfunctionsview libname` displays the names of the functions in the external shared library, `libname`, that has been loaded into MATLAB with the `loadlibrary` function.

If you used an alias when initially loading the library, then you must use that alias for the `libname` argument.

MATLAB creates a new window in response to the `libfunctionsview` command. This window displays all of the functions defined in the specified library. For each of these functions, the following information is supplied:

- Data type returned by the function
- Name of the function
- Arguments passed to the function

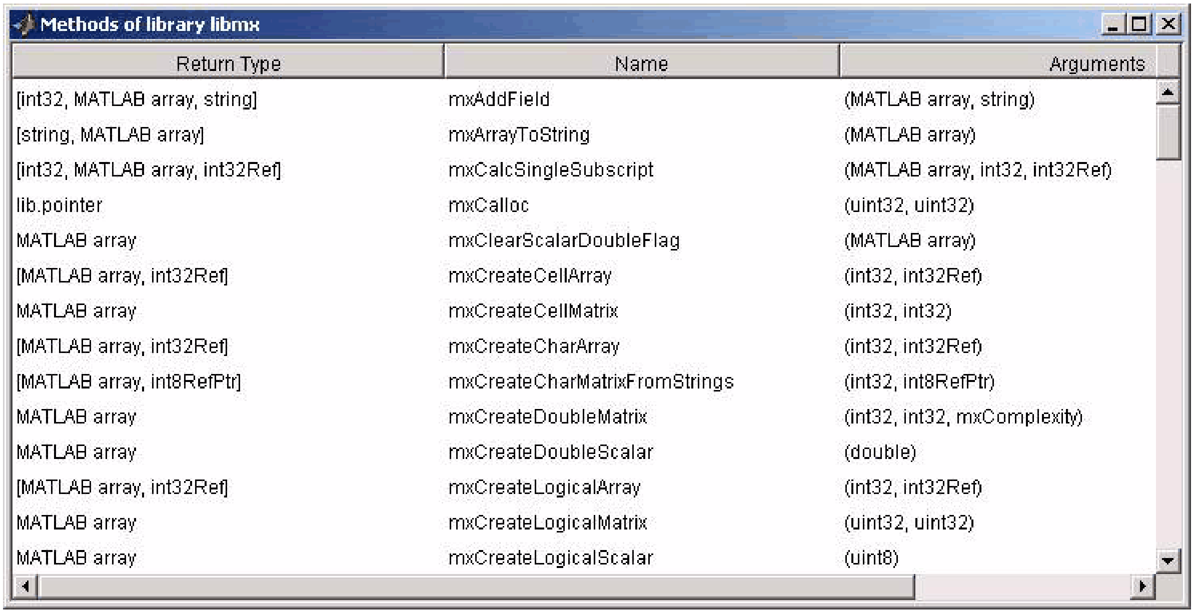
An additional column entitled "Inherited From" is displayed at the far right of the window. The information in this column is not useful for external libraries.

`libfunctionsview libname` is the command format for this function.

Examples

The following command opens the window shown below for the `libmx` library:

```
libfunctionsview libmx
```



Methods of library libmx

Return Type	Name	Arguments
[int32, MATLAB array, string]	mxAddField	(MATLAB array, string)
[string, MATLAB array]	mxArrayToString	(MATLAB array)
[int32, MATLAB array, int32Ref]	mxCalcSingleSubscript	(MATLAB array, int32, int32Ref)
lib.pointer	mxCalloc	(uint32, uint32)
MATLAB array	mxClearScalarDoubleFlag	(MATLAB array)
[MATLAB array, int32Ref]	mxCreateCellArray	(int32, int32Ref)
MATLAB array	mxCreateCellMatrix	(int32, int32)
[MATLAB array, int32Ref]	mxCreateCharArray	(int32, int32Ref)
[MATLAB array, int8RefPtr]	mxCreateCharMatrixFromStrings	(int32, int8RefPtr)
MATLAB array	mxCreateDoubleMatrix	(int32, int32, mxComplexity)
MATLAB array	mxCreateDoubleScalar	(double)
[MATLAB array, int32Ref]	mxCreateLogicalArray	(int32, int32Ref)
MATLAB array	mxCreateLogicalMatrix	(uint32, uint32)
MATLAB array	mxCreateLogicalScalar	(uint8)

See Also

`loadlibrary`, `libfunctions`, `libpointer`, `libstruct`, `calllib`, `libisloaded`, `unloadlibrary`

libisloaded

Purpose

Determine whether external library is loaded

Syntax

```
libisloaded('libname')
libisloaded libname
```

Description

`libisloaded('libname')` returns logical `1` (`true`) if the shared library `libname` is loaded and logical `0` (`false`) otherwise.

`libisloaded 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

Example 1

Load the `shrlibsample` library and check to see if the load was successful before calling one of its functions:

```
addpath([matlabroot '\extern\examples\shrlib'])
loadlibrary shrlibsample shrlibsample.h

if libisloaded('shrlibsample')
   x = calllib('shrlibsample', 'addDoubleRef', 1.78, 5.42, 13.3)
end
```

Since the library is successfully loaded, the call to `addDoubleRef` works as expected and returns

```
x =
    20.5000

unloadlibrary shrlibsample
```

Example 2

Load the same library, this time giving it an alias. If you use `libisloaded` with the library name, `shrlibsample`, it now returns `false`. Since you loaded the library using an alias, all further references to the library must also use that alias:

```
addpath([matlabroot '\extern\examples\shrlib'])
loadlibrary shrlibsample shrlibsample.h alias lib

libisloaded shrlibsample
ans =
     0

libisloaded lib
ans =
     1

unloadlibrary lib
```

See Also

loadlibrary, libfunctions, libfunctionsview, libpointer, libstruct, calllib, unloadlibrary

Purpose

Create pointer object for use with external libraries

Syntax

```
p = libpointer
p = libpointer('type')
p = libpointer('type',value)
```

Description

`p = libpointer` returns an empty (void) pointer.

`p = libpointer('type')` returns an empty pointer that contains a reference to the specified data `type`. This `type` can be any MATLAB numeric type, or a structure or enumerated type defined in an external library that has been loaded into MATLAB with the `loadlibrary` function. For valid `types`, see the table under "Primitive Types" in the MATLAB External Interfaces documentation.

`p = libpointer('type',value)` returns a pointer to the specified data `type` and initialized to the `value` supplied.

Examples

This example passes an `int16` pointer to a function that multiplies each value in a matrix by its index. The function `multiplyShort` is defined in the MATLAB sample shared library, `shrlibsample`.

Here is the C function:

```
void multiplyShort(short *x, int size)
{
    int i;
    for (i = 0; i < size; i++)
    *x++ *= i;
}
```

Load the `shrlibsample` library. Create the matrix, `v`, and also a pointer to it, `pv`:

```
addpath([matlabroot '\extern\examples\shrlib'])
loadlibrary shrlibsample shrlibsample.h

v = [4 6 8; 7 5 3];
```

```
pv = libpointer('int16Ptr', v);
get(pv, 'Value')
ans =
     4     6     8
     7     5     3
```

Now call the C function in the library, passing the pointer to `v`. If you were to pass a *copy* of `v`, the results would be lost once the function terminates. Passing a pointer to `v` enables you to get back the results:

```
calllib('shrlibsample', 'multiplyShort', pv, 6);
get(pv, 'Value')
ans =
     0    12    32
     7    15    15

unloadlibrary shrlibsample
```

Note In most cases, you can pass by value and MATLAB will automatically convert the argument to a pointer for you. See "Creating References" in the MATLAB External Interfaces documentation for more information.

See Also

`loadlibrary`, `libfunctions`, `libfunctionsview`, `libstruct`, `calllib`, `libisloaded`, `unloadlibrary`

libstruct

Purpose Construct structure as defined in external library

Syntax

```
s = libstruct('structtype')
s = libstruct('structtype',mlstruct)
```

Description

`s = libstruct('structtype')` returns a `libstruct` object `s` that is a MATLAB object designed to resemble a C structure of type specified by `structtype`. The structure type, `structtype`, is defined in an external library that must be loaded into MATLAB using the `loadlibrary` function.

Note Using this syntax, `s` is a `NULL` pointer. You, therefore, must ensure that any library function to which you pass `s` must be able to accept a `NULL` pointer as an argument.

`s = libstruct('structtype',mlstruct)` returns a `libstruct` object `s` with its fields initialized from MATLAB structure, `mlstruct`.

The `libstruct` function essentially creates a C-like structure that you can pass to functions in an external library. You can handle this structure in MATLAB as you would a true MATLAB structure.

What Data Types Are Available

To determine which MATLAB data types to use when passing arguments to library functions, see the output of `libfunctionsview` or `libfunctions -full`. These functions list all of the functions found in a particular library along with a specification of the data types required for each argument.

Examples

This example performs a simple addition of the fields of a structure. The function `addStructFields` is defined in the MATLAB sample shared library, `shrlibsample`.

Here is the C function:

```
double addStructFields(struct c_struct st)
```

```
{
    double t = st.p1 + st.p2 + st.p3;
    return t;
}
```

Start by loading the `shrlibsample` library and creating MATLAB structure, `sm`:

```
addpath([matlabroot '\extern\examples\shrlib'])
loadlibrary shrlibsample shrlibsample.h

sm.p1 = 476;   sm.p2 = -299;   sm.p3 = 1000;
```

Construct a `libstruct` object `sc` that uses the `c_struct` template:

```
sc = libstruct('c_struct', sm);

get(sc)
    p1: 476
    p2: -299
    p3: 1000
```

Now call the function, passing the `libstruct` object, `sc`:

```
calllib('shrlibsample', 'addStructFields', sc)
ans =
    1177
```

You must clear the `libstruct` object before unloading the library:

```
clear sc
unloadlibrary shrlibsample
```

Note In most cases, you can pass a MATLAB structure and MATLAB automatically converts the argument to a C structure. See "Structures" in the MATLAB External Interfaces documentation for more information.

See Also

`loadlibrary`, `libfunctions`, `libfunctionsview`, `libpointer`, `calllib`, `libisloaded`, `unloadlibrary`

Purpose

Return license number or perform licensing task

Syntax

```
license
license('inuse')
S = license('inuse')
S = license('inuse', feature)
license('test',feature)
license('test',feature,toggle)
result = license('checkout',feature)
```

Description

`license` returns the license number for this MATLAB. The return value is always a string but is not guaranteed to be a number. The following table lists text strings that `license` can return.

String	Description
`'demo'`	MATLAB is a demonstration version
`'student'`	MATLAB is the student version
`'unknown'`	License number cannot be determined

`license('inuse')` returns a list of licenses checked out in the current MATLAB session. In the list, products are listed alphabetically by their license feature names, i.e., the text string used to identify products in the `INCREMENT` lines in a License File (`license.dat`). Note that the feature names returned in the list contain only lower-case characters.

`S = license('inuse')` returns an array of structures, where each structure represents a checked-out license. The structures contains two fields: feature and user. The feature field contains the license feature name. The user field contains the username of the person who has the license checked out.

`S = license('inuse', feature)` checks if the product specified by the text string `feature` is checked out in the current MATLAB session. If the product is checked out, the `license` function returns the product name and the username of the person who has it checked out in the structure `S`. If the product is not currently checked out, the fields in the structure are empty.

The `feature` string must be a license feature name, spelled exactly as it appears in the `INCREMENT` lines in a License File. For example, the string `'Identification_Toolbox'` is the feature name for the System Identification Toolbox. The `feature` string is not case-sensitive and must not exceed 27 characters.

`license('test',feature)` tests if a license exists for the product specified by the text string `feature`. The `license` command returns `1` if the license exists and `0` if the license does not exist. The `feature` string identifies a product, as described in the previous syntax.

Note Testing for a license only confirms that the license exists. It does not confirm that the license can be checked out. For example, license will return 1 if a license exists, even if the license has expired or if a system administrator has excluded you from using the product in an options file.

`license('test',feature,toggle)` enables or disables testing of the product specified by the text string `feature`, depending on the value of `toggle`. The parameter `toggle` can have either of two values:

`'enable'`	The syntax `license('test',feature)` returns `1` if the product license exists and `0` if the product license does not exist.
`'disable'`	The syntax `license('test',feature)` always returns `0` (product license does not exist) for the specified product.

Note Disabling a test for a particular product can impact other tests for the existence of the license, not just tests performed using the `license` command.

`result = license('checkout',feature)` checks out a license for the product identified by the text string `feature`. The `license` command returns `1` if it could check out a license for the product and `0` if it could not check out a license for the product.

Examples

Get the license number for this MATLAB.

```
license
```

Get a list of licenses currently being used. Note that the products appear in alphabetical order by their license feature name in the list returned.

```
license('inuse')

image_toolbox
map_toolbox
matlab
```

Get a list of licenses in use with information about who is using the license.

```
S = license('inuse');

S(1)

ans =

    feature: 'image_toolbox'
       user: 'juser'
```

Determine if the license for MATLAB is currently in use.

```
S = license('inuse','MATLAB')

S =

    feature: 'matlab'
       user: 'jsmith'
```

Determine if a license exists for the Mapping Toolbox.

```
license('test','map_toolbox')

ans =

     1
```

Check out a license for the Control System Toolbox.

```
license('checkout','control_toolbox')

ans =

     1
```

Determine if the license for the Control System Toolbox is checked out.

```
license('inuse')

control_toolbox
image_toolbox
map_toolbox
matlab
```

See Also

isstudent

Purpose

Create light object

Syntax

```
light('PropertyName',propertyvalue,...)
handle = light(...)
```

Description

`light` creates a light object in the current axes. Lights affect only patch and surface objects.

`light('PropertyName',propertyvalue,...)` creates a light object using the specified values for the named properties. MATLAB parents the light to the current axes unless you specify another axes with the `Parent` property.

`handle = light(...)` returns the handle of the light object created.

Remarks

You cannot see a light object *per se*, but you can see the effects of the light source on patch and surface objects. You can also specify an axes-wide ambient light color that illuminates these objects. However, ambient light is visible only when at least one light object is present and visible in the axes.

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).

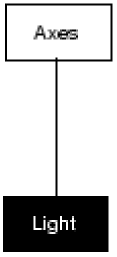
See also the patch and surface `AmbientStrength`, `DiffuseStrength`, `SpecularStrength`, `SpecularExponent`, `SpecularColorReflectance`, and `VertexNormals` properties. Also see the `lighting` and `material` commands.

Examples

Light the `peaks` surface plot with a light source located at infinity and oriented along the direction defined by the vector `[1 0 0]`, that is, along the *x*-axis.

```
h = surf(peaks);
set(h,'FaceLighting','phong','FaceColor','interp',...
      'AmbientStrength',0.5)
light('Position',[1 0 0],'Style','infinite');
```

Object Hierarchy



Setting Default Properties

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

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

where *Property* is the name of the light property and PropertyValue is the value you are specifying. Use set and get to access light properties.

See Also

lighting, material, patch, surface

"Lighting as a Visualization Tool" for more information about lighting

"Lighting" on page 1-100 for related functions

Light Properties for property descriptions

Purpose

Light 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".

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

Light Property Descriptions

This section lists property names along with the type of values each accepts.

`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

This property is not used on lights.

`Children`
handles

The empty matrix; light objects have no children.

`Clipping`
`on | off`

`Clipping` has no effect on light objects.

`Color`
`ColorSpec`

Color of light. This property defines the color of the light emanating from the light object. Define it as a three-element RGB vector or one of the MATLAB predefined names. See the `ColorSpec` reference page for more information.

`CreateFcn`

functional 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 light object. You must define this property as a default value for lights or in a call to the `light` function to create a new light object. For example, the following statement:

```
set(0,'DefaultLightCreateFcn',@light_create)
```

defines a default value for the line `CreateFcn` property on the root level that sets the current figure colormap to `gray` and uses a reddish light color whenever you create a light object.

```
function light_create(src,evnt)
% src - the object that is the source of the event
% evnt - empty for this property
 set(src,'Color',[.9 .2 .2])
 set(gcbf,'Colormap',gray)
end
```

MATLAB executes this function after setting all light properties. Setting this property on an existing light object has no effect. The function must define at least two input arguments (handle of light 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`

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

Delete light callback function. A callback function that executes when you delete the light 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.

`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`

This property is not used by light objects.

`Interruptible`
`{on} | off`

Callback routine interruption mode. Light object callback routines defined for the `DeleteFcn` property are not affected by the `Interruptible` property.

`Parent`
handle of parent axes

Parent of light object. This property contains the handle of the light object's parent. The parent of a light object is the `axes` object that contains it.

Note that light objects cannot be parented to hggroup or hgtransform objects.

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

`Position`
`[x,y,z]` in axes data units

Location of light object. This property specifies a vector defining the location of the light object. The vector is defined from the origin to the specified *x*-, *y*-, and *z*-coordinates. The placement of the light depends on the setting of the `Style` property:

- If the `Style` property is set to `local`, `Position` specifies the actual location of the light (which is then a point source that radiates from the location in all directions).
- If the `Style` property is set to `infinite`, `Position` specifies the direction from which the light shines in parallel rays.

`Selected`
`on | off`

This property is not used by light objects.

`SelectionHighlight`
`{on} | off`

This property is not used by light objects.

`Style`
`{infinite} | local`

Parallel or divergent light source. This property determines whether MATLAB places the light object at infinity, in which case the light rays are parallel, or at the location specified by the `Position` property, in which case the light rays diverge in all directions. See the `Position` property.

`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)

Type of graphics object. This property contains a string that identifies the class of graphics object. For light objects, `Type` is always `'light'`.

`UIContextMenu`
handle of a uicontextmenu object

This property is not used by light objects.

`UserData`
matrix

User-specified data. This property can be any data you want to associate with the light object. The light does not use this property, but you can access it using `set` and `get`.

`Visible`
`{on} | off`

Light visibility. While light objects themselves are not visible, you can see the light on patch and surface objects. When you set `Visible` to `off`, the light emanating from the source is not visible. There must be at least one light object in the axes whose `Visible` property is `on` for any lighting features to be enabled (including the axes `AmbientLightColor` and patch and surface `AmbientStrength`).

Purpose

Create or position `light` object in spherical coordinates

Syntax

```
lightangle(az,el)
light_handle = lightangle(az,el)
lightangle(light_handle,az,el)
[az,el] = lightangle(light_handle)
```

Description

`lightangle(az,el)` creates a light at the position specified by azimuth and elevation. `az` is the azimuthal (horizontal) rotation and `el` is the vertical elevation (both in degrees). The interpretation of azimuth and elevation is the same as that of the `view` command.

`light_handle = lightangle(az,el)` creates a light and returns the handle of the light in `light_handle`.

`lightangle(light_handle,az,el)` sets the position of the light specified by `light_handle`.

`[az,el] = lightangle(light_handle)` returns the azimuth and elevation of the light specified by `light_handle`.

Remarks

By default, when a light is created, its style is `infinite`. If the light handle passed in to `lightangle` refers to a local light, the distance between the light and the camera target is preserved as the position is changed.

Examples

```
surf(peaks)
axis vis3d
h = light;
for az = -50:10:50
 lightangle(h,az,30)
 drawnow
end
```

See Also

`light`, `camlight`, `view`

"Lighting as a Visualization Tool" for more information about lighting

"Lighting" on page 1-100 for related functions

Purpose Specify lighting algorithm

Syntax

```
lighting flat
lighting gouraud
lighting phong
lighting none
```

Description `lighting` selects the algorithm used to calculate the effects of `light` objects on all `surface` and `patch` objects in the current axes.

`lighting flat` selects flat lighting.

`lighting gouraud` selects gouraud lighting.

`lighting phong` selects phong lighting.

`lighting none` turns off lighting.

Remarks The `surf`, `mesh`, `pcolor`, `fill`, `fill3`, `surface`, and `patch` functions create graphics objects that are affected by light sources. The `lighting` command sets the `FaceLighting` and `EdgeLighting` properties of surfaces and patches appropriately for the graphics object.

See Also `light`, `material`, `patch`, `surface`

"Lighting as a Visualization Tool" for more information about lighting

"Lighting" on page 1-100 for related functions

Purpose Convert linear audio signal to mu-law

Syntax

```
mu = lin2mu(y)
```

Description `mu = lin2mu(y)` converts linear audio signal amplitudes in the range `-1 ≤ Y ≤ 1` to mu-law encoded “flints” in the range `0 ≤ u ≤ 255`.

See Also `auwrite`, `mu2lin`

Purpose Create line object

Syntax

```
line(X,Y)
line(X,Y,Z)
line(X,Y,Z,'PropertyName',propertyvalue,...)
line('XData',x,'YData',y,'ZData',z,...)
h = line(...)
```

Description

`line` creates a line object in the current axes. You can specify the color, width, line style, and marker type, as well as other characteristics.

The `line` function has two forms:

- Automatic color and line style cycling. When you specify matrix coordinate data using the informal syntax (i.e., the first three arguments are interpreted as the coordinates),

  ```
  line(X,Y,Z)
  ```

  MATLAB cycles through the axes `ColorOrder` and `LineStyleOrder` property values the way the `plot` function does. However, unlike `plot`, `line` does not call the `newplot` function.

- Purely low-level behavior. When you call `line` with only property name/property value pairs,

  ```
  line('XData',x,'YData',y,'ZData',z)
  ```

  MATLAB draws a line object in the current axes using the default line color (see the `colordef` function for information on color defaults). Note that you cannot specify matrix coordinate data with the low-level form of the `line` function.

`line(X,Y)` adds the line defined in vectors `X` and `Y` to the current axes. If `X` and `Y` are matrices of the same size, `line` draws one line per column.

`line(X,Y,Z)` creates lines in three-dimensional coordinates.

`line(X,Y,Z,'PropertyName',propertyvalue,...)` creates a line using the values for the property name/property value pairs specified and default values for all other properties.

See the `LineStyle` and `Marker` properties for a list of supported values.

`line('XData',x,'YData',y,'ZData',z,...)` creates a line in the current axes using the property values defined as arguments. This is the low-level form of the `line` function, which does not accept matrix coordinate data as the other informal forms described above.

`h = line(...)` returns a column vector of handles corresponding to each line object the function creates.

Remarks

In its informal form, the `line` function interprets the first three arguments (two for 2-D) as the `X`, `Y`, and `Z` coordinate data, allowing you to omit the property names. You must specify all other properties as name/value pairs. For example,

```
line(X,Y,Z,'Color','r','LineWidth',4)
```

The low-level form of the `line` function can have arguments that are only property name/property value pairs. For example,

```
line('XData',x,'YData',y,'ZData',z,'Color','r','LineWidth',4)
```

Line properties control various aspects of the line object and are described in the "Line Properties" section. You can also set and query property values after creating the line using `set` and `get`.

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).

Unlike high-level functions such as `plot`, `line` does not respect the settings of the figure and axes `NextPlot` properties. It simply adds line objects to the current axes. However, axes properties that are under automatic control, such as the axis limits, can change to accommodate the line within the current axes.

Connecting the dots

The coordinate data is interpreted as vectors of corresponding x, y, and z values:

```
X = [x(1) x(2) x(3)...x(n)]
Y = [y(1) x(2) y(3)...y(n)]
Z = [z(1) z(2) x(3)...z(n)]
```

where a point is determined by the corresponding vector elements:

```
p1(x(i),y(i),z(i))
```

For example, to draw a line from the point located at `x = .3` and `y = .4` and `z = 1` to the point located at `x = .7` and `y = .9` and `z = 1`, use the following data:

```
axis([0 1 0 1])
line([.3 .7],[.4 .9],[1 1],'Marker','.','LineStyle','-')
```

Examples

This example uses the `line` function to add a shadow to plotted data. First, plot some data and save the line's handle:

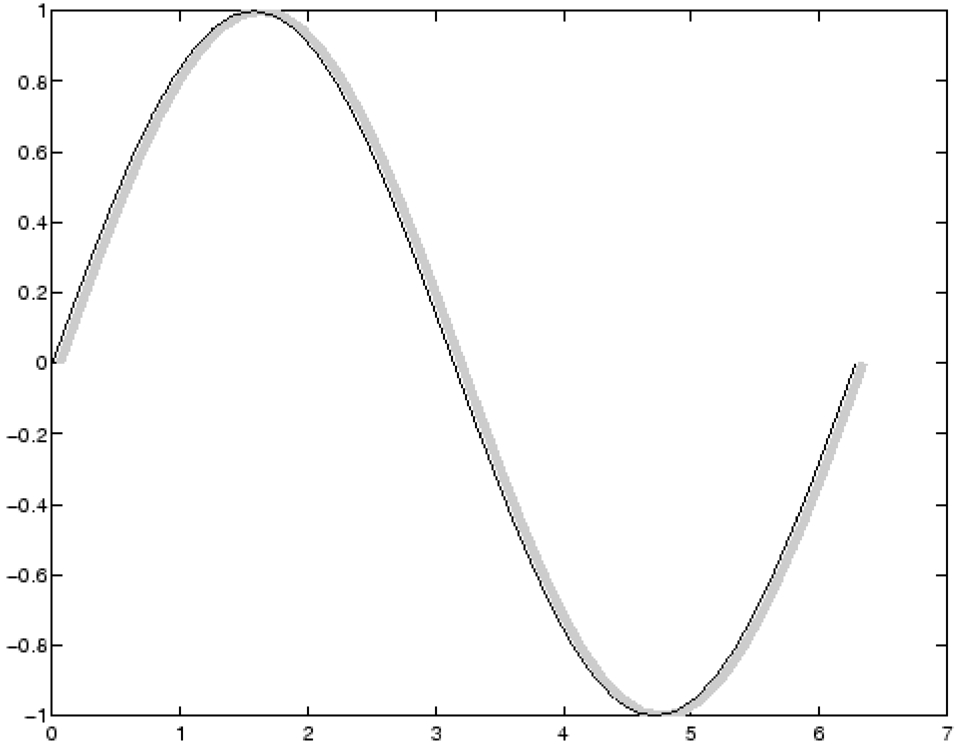
```
t = 0:pi/20:2*pi;
hline1 = plot(t,sin(t),'k');
```

Next, add a shadow by offsetting the *x*-coordinates. Make the shadow line light gray and wider than the default `LineWidth`:

```
hline2 = line(t+.06,sin(t),'LineWidth',4,'Color',[.8 .8 .8]);
```

Finally, pop the first line to the front:

```
set(gca,'Children',[hline1 hline2])
```



Drawing Lines Interactively

You can use the ginput function to select points from a figure. For example:

```
axis([0 1 0 1])
for n = 1:5
 [x(n),y(n)] = ginput(1);
end
line(x,y)
```

The for loop enables you to select five points and build the x and y arrays. Because line requires arrays of corresponding x and y coordinates, you can just pass these arrays to the line function.

Drawing with mouse motion

You can use the axes CurrentPoint property and the figure WindowButtonDownFcn and WindowButtonMotionFcn properties to select a point with a mouse click and draw a line to another point by dragging the mouse, like a simple drawing program. The following example illustrates a few useful techniques for doing this type of interactive drawing.

Click to view in editor — This example enables you to click and drag the cursor to draw lines.

Click to run example — Click the left mouse button in the axes and move the cursor, left-click to define the line end point, right-click to end drawing mode.

Input Argument Dimensions — Informal Form

This statement reuses the one-column matrix specified for ZData to produce two lines, each having four points.

```
line(rand(4,2),rand(4,2),rand(4,1))
```

If all the data has the same number of columns and one row each, MATLAB transposes the matrices to produce data for plotting. For example,

```
line(rand(1,4),rand(1,4),rand(1,4))
```

is changed to

```
line(rand(4,1),rand(4,1),rand(4,1))
```

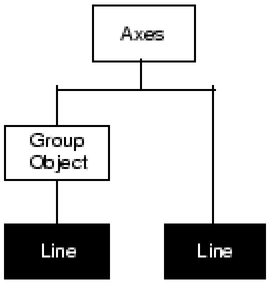
This also applies to the case when just one or two matrices have one row. For example, the statement

```
line(rand(2,4),rand(2,4),rand(1,4))
```

is equivalent to

```
line(rand(4,2),rand(4,2),rand(4,1))
```

Object Hierarchy



Setting Default Properties

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

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

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

See Also

`annotationaxes`, `newplot`, `plot`, `plot3`

"Object Creation Functions" on page 1-93 for related functions

Line Properties for property descriptions

Line Properties

Purpose

Line 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".

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

Line Property Descriptions

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

`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`

functional 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 line 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 line associated with the button down event and an event structure, which is empty for this property)

The following example shows how to access the callback object's handle as well as the handle of the figure that contains the object from the callback function.

```
function button_down(src,evnt)
% src - the object that is the source of the event
```

```
% evnt - empty for this property
   sel_typ = get(gcbf,'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 line 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; line objects have no children.

`Clipping`
`{on} | off`

Clipping mode. MATLAB clips lines to the axes plot box by default. If you set `Clipping` to `off`, lines are displayed outside the axes plot box. This can occur if you create a line, set `hold` to `on`, freeze axis scaling (set `axis` to `manual`), and then create a longer line.

`Color`

`ColorSpec`

Line color. 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.

`CreateFcn`

functional 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 line object. You must define this property as a default value for lines or in a call to the `line` function to create a new line object. For example, the statement

```
set(0,'DefaultLineCreateFcn',@line_create)
```

defines a default value for the line `CreateFcn` property on the root level that sets the axes `LineStyleOrder` whenever you create a line object. The callback function must be on your MATLAB path when you execute the above statement.

```
function line_create(src,evnt)
% src - the object that is the source of the event
% evnt - empty for this property
 axh = get(src,'Parent');
 set(axh,'LineStyleOrder','-.|--')
end
```

MATLAB executes this function after setting all line properties. Setting this property on an existing line object has no effect. The function must define at least two input arguments (handle of line 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`

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

Delete line callback function. A callback function that executes when you delete the line 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 line 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.

`EraseMode`
`{normal} | none | xor | background`

Erase mode. This property controls the technique MATLAB uses to draw and erase line 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 line 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 line 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 line. However, the line's color depends on the color of whatever is beneath it on the display.
- `background` — Erase the line 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 line, but lines 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 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.

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

`HitTest`
`{on} | off`

Selectable by mouse click. `HitTest` determines if the line 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 line. If `HitTest` is `off`, clicking the line selects the object below it (which may be the axes containing it).

`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.

`Interruptible`

`{on} | off`

Callback routine interruption mode. The `Interruptible` property controls whether a line 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. This property specifies the line style. Available line styles are shown in the table.

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

The width of the line object. 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 marks that display at data points. You can set values for the `Marker` property independently from the `LineStyle` property. Supported markers include those shown in the table.

Marker Specifier	Description
`'+'`	Plus sign
`'o'`	Circle

Marker Specifier	Description
`'*'`	Asterisk
`'.'`	Point
`'x'`	Cross
`'square'` or `'s'`	Square
`'diamond'` or `'d'`	Diamond
`'^'`	Upward-pointing triangle
`'v'`	Downward-pointing triangle
`'>'`	Right-pointing triangle
`'<'`	Left-pointing triangle
`'pentagram'` or `'p'`	Five-pointed star (pentagram)
`'hexagram'` or `'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 line's `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 the figure color, if the axes `Color` property is set to `none` (which is the factory default for axes).

`MarkerSize`
size in points

Marker size. A scalar specifying the size of the marker, in points. The default value for `MarkerSize` is six 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 axes, hggroup, or hgtransform

Parent of line object. This property contains the handle of the line object's parent. The parent of a line object is the axes that contains it. You can reparent line objects to other axes, hggroup, or hgtransform objects.

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 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 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 line objects, `Type` is always the string `'line'`.

`UIContextMenu`
handle of a uicontextmenu object

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

`UserData`
matrix

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

`Visible`
`{on} | off`

Line visibility. By default, all lines are visible. When set to `off`, the line is not visible, but still exists, and you can `get` and `set` its properties.

`XData`
vector of coordinates

X-coordinates. A vector of x-coordinates defining the line. `YData` and `ZData` must be the same length and have the same number of rows. (See “Examples” on page 2-1904.)

`YData`
vector of coordinates

Y-coordinates. A vector of y-coordinates defining the line. `XData` and `ZData` must be the same length and have the same number of rows.

`ZData`
vector of coordinates

Z-coordinates. A vector of z-coordinates defining the line. `XData` and `YData` must have the same number of rows.

Purpose

Define lineseries properties

Modifying Properties

You can set and query graphics object properties using the `set` and `get` commands or with the property editor (`propertyeditor`).

See "Plot Objects" for more information on lineseries objects.

Note that you cannot define default properties for lineseries objects.

Lineseries Property Descriptions

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

`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
- 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`
vector of handles

The empty matrix; line objects have no children.

`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

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

Label used by plot legends. The `legend` function, the figure's active legend, and the plot browser use this text when displaying labels for this object.

`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.

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`

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

Specifier String	Line Style
-.	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

Marker Specifier	Description
`^`	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`

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)

Class of graphics object. For lineseries objects, Type is always the string line.

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`
vector or matrix

The x-axis values for a graph. The *x*-axis values for graphs are specified by the `X` input argument. If `XData` is a vector, `length(XData)` must equal `length(YData)` and must be monotonic. If `XData` is a matrix, `size(XData)` must equal `size(YData)` and each column must be monotonic.

You can use `XData` to define meaningful coordinates for an underlying surface whose topography is being mapped. See "Setting the Axis Limits on Contour Plots" on page 2-623 for more 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.

`YData`
vector or matrix of coordinates

Y-coordinates. A vector of *y*-coordinates defining the values along the *y*-axis for the graph. `XData` and `ZData` must be the same length and have the same number of rows.

`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)

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

Line specification string syntax

GUI Alternative

To modify the style, width, and color of lines on a graph, use the Property Editor, one of the plotting tools . For details, see The Property Editor in the MATLAB Graphics documentation.

Description

This page describes how to specify the properties of lines used for plotting. MATLAB gives you control over these graphic characteristics:

- Line style
- Line width
- Color
- Marker type
- Marker size
- Marker face and edge coloring (for filled markers)

You indicate the line styles, marker types, and colors you want to display to MATLAB using *string specifiers*, detailed in the following tables:

Line Style Specifiers

Specifier	Line Style
-	Solid line (default)
--	Dashed line
:	Dotted line
-.	Dash-dot line

Marker Specifiers

Specifier	Marker Type
`+`	Plus sign
`o`	Circle
`*`	Asterisk
`.`	Point
`x`	Cross
`'square'` or `s`	Square
`'diamond'` or `d`	Diamond
`^`	Upward-pointing triangle
`v`	Downward-pointing triangle
`>`	Right-pointing triangle
`<`	Left-pointing triangle
`'pentagram'` or `p`	Five-pointed star (pentagram)
`'hexagram'` or `h`	Six-pointed star (hexagram)

Color Specifiers

Specifier	Color
`r`	Red
`g`	Green
`b`	Blue
`c`	Cyan
`m`	Magenta
`y`	Yellow

Specifier	Color
`k`	Black
`w`	White

All high-level plotting functions (except for the `ez...` family of function-plotting functions) accept a `LineSpec` argument that defines three components used to specify lines:

- Line style
- Marker symbol
- Color

For example,

```
plot(x,y,'-.or')
```

plots `y` versus `x` using a dash-dot line (`-.`), places circular markers (`o`) at the data points, and colors both line and marker red (`r`). Specify the components (in any order) as a quoted string after the data arguments. Note that linespecs are single strings, not property-value pairs.

Plotting Data Points with No Line

If you specify a marker, but not a line style, MATLAB plots only the markers. For example,

```
plot(x,y,'d')
```

Related Properties

When using the `plot` and `plot3` functions, you can also specify other characteristics of lines using graphics 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)

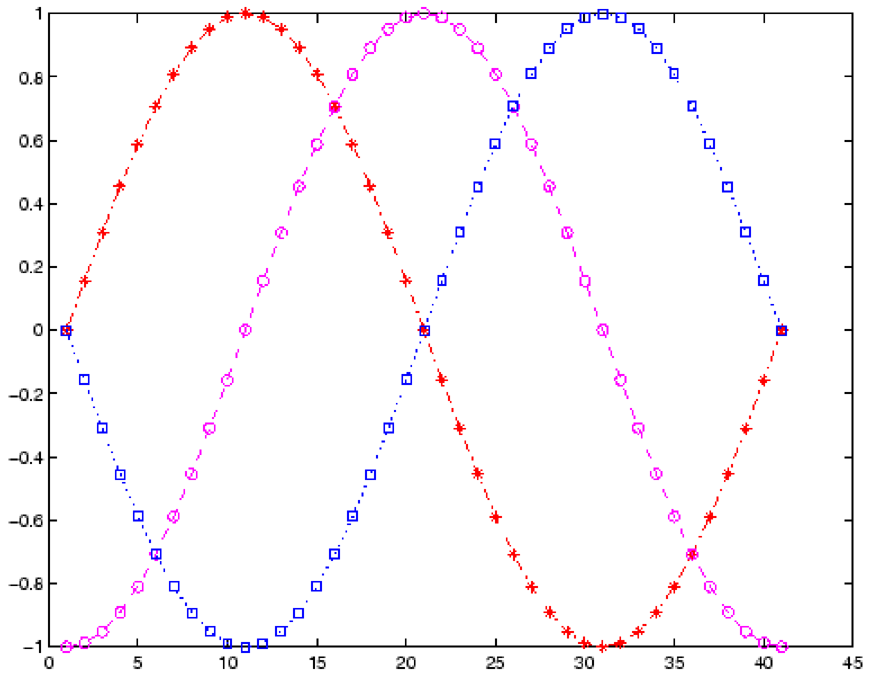
- `MarkerFaceColor` — Specifies the color of the face of filled markers
- `MarkerSize` — Specifies the size of the marker in points

In addition, you can specify the `LineStyle`, `Color`, and `Marker` properties instead of using the symbol string. This is useful if you want to specify a color that is not in the list by using RGB values. See Line Properties for details on these properties and `ColorSpec` for more information on color.

Examples

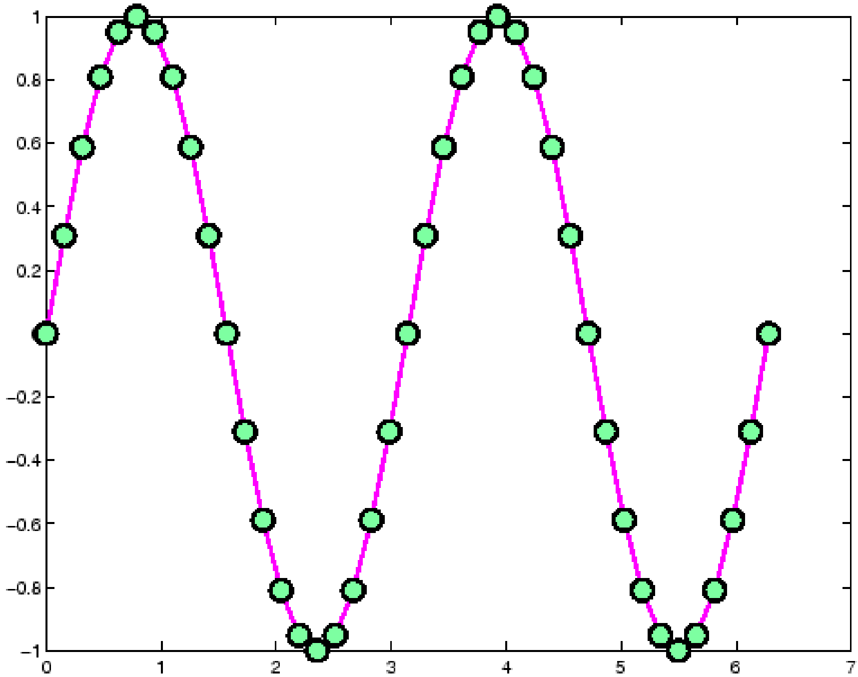
Plot the sine function over three different ranges using different line styles, colors, and markers.

```
t = 0:pi/20:2*pi;
plot(t,sin(t),'-.r*')
hold on
plot(t,sin(t-pi/2),'--mo')
plot(t,sin(t-pi),':bs')
hold off
```



Create a plot illustrating how to set line properties.

```
plot(t,sin(2*t),'-mo',...
                'LineWidth',2,...
                'MarkerEdgeColor','k',...
                'MarkerFaceColor',[.49 1 .63],...
                'MarkerSize',12)
```



See Also

`line`, `plot`, `patch`, `set`, `surface`, `axes` , `Line Properties`, `ColorSpec`

"Line Styles Used for Plotting — LineStyleOrder" for information about defining an order for applying linestyles

"Types of Plots Available in MATLAB" for functions that use linespecs

"Basic Plots and Graphs" on page 1-85 for related functions

Purpose

Synchronize limits of specified 2-D axes

Syntax

```
linkaxes(axes_handles)
linkaxes(axes_handles,'option')
```

Description

Use `linkaxes` to synchronize the individual axis limits across several figures or subplots within a figure. Calling `linkaxes` will make all input axes have identical limits. Linking axes is most useful when you want to zoom or pan in one subplot and display the same range of data in another subplot.

`linkaxes(axes_handles)` links the *x*- and *y*-axis limits of the axes specified in the vector `axes_handles`. You can link any number of existing plots or subplots.

`linkaxes(axes_handles,'option')` links the axes' `axes_handles` according to the specified option. The *`option`* argument can be one of the following strings:

`x`	Link *x*-axis only
`y`	Link *y*-axis only
`xy`	Link *x*-axis and *y*-axis
`off`	Remove linking

See the `linkprop` function for more advanced capabilities that allow linking object properties on any graphics object.

Remarks

The first axes provided to `linkaxes` determines the x-limits and y-limits for all axes linked. This can cause plots to partly or entirely disappear if their limits or scaling are very different. To override this behavior, after calling `linkaxes` specify the limits of the axes that you wish to control with the `set` command, as shown in Example 3, below.

Examples

You can use interactive zooming or panning (selected from the figure toolbar) to see the effect of axes linking. For example, pan in one graph and notice how the *x*-axis also changes in the other. The axes will respond in the same way to `zoom` and `pan` directives typed in the Command Window.

Example 1

This example creates two subplots and links the *x*-axis limits of the two axes:

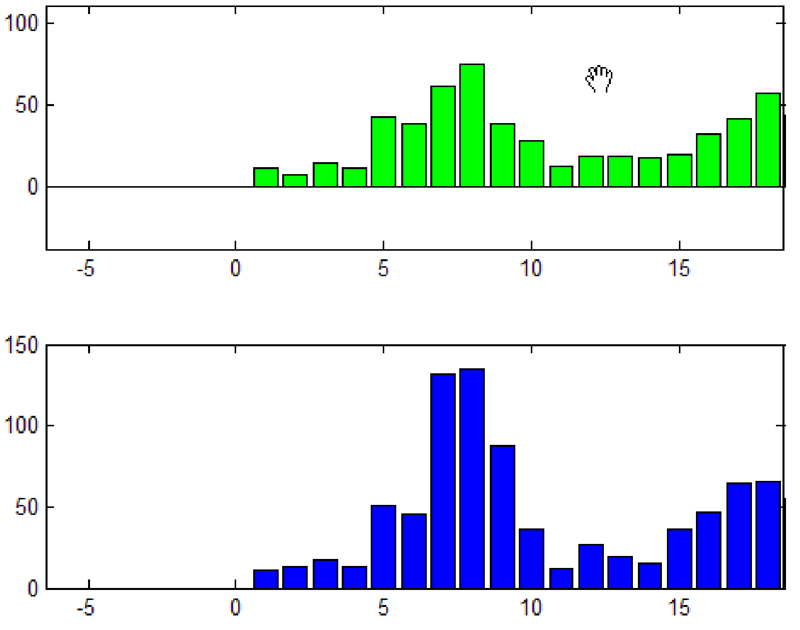
```
ax(1) = subplot(2,2,1);
plot(rand(1,10)*10,'Parent',ax(1));
ax(2) = subplot(2,2,2);
plot(rand(1,10)*100,'Parent',ax(2));
linkaxes(ax,'x');
```

Example 2

This example creates two figures and links the *x*-axis limits of the two axes. The illustration shows the effect of manually panning the top subplot:

```
load count.dat
figure; ax(1) = subplot(2,1,1);
h(1) = bar(ax(1),count(:,1),'g');
ax(2) = subplot(2,1,2);
h(2) = bar(ax(2),count(:,2),'b');
linkaxes(ax,'x');
```

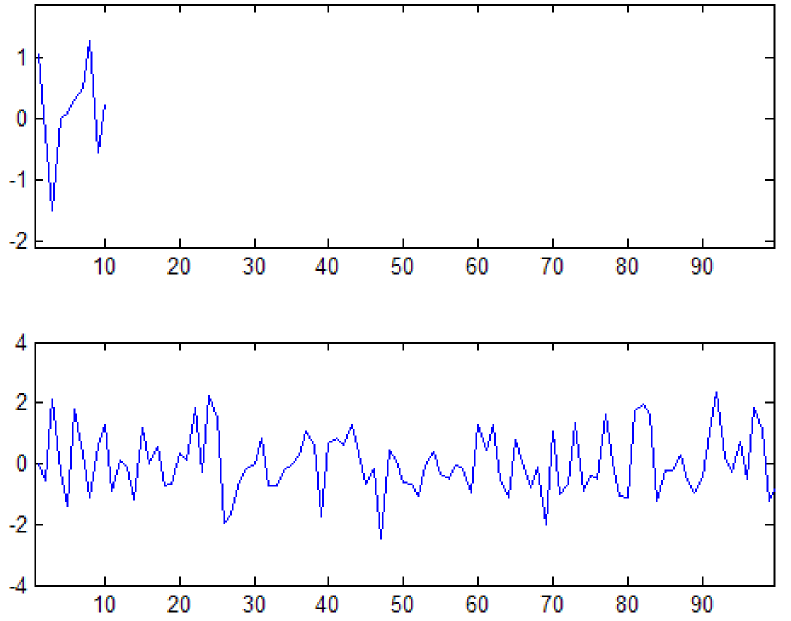
Choose the Pan tool (**Tools** ⇒ **Pan**) and drag the top axes. Both axes will pan in step in x, but only the top one pans in y.



Example 3

Create two subplots containing data having different ranges. The first axes handle passed to `linkaxes` determines the data range for all other linked axes. In this example, calling `set` for the lower axes overrides the *x*-limits established by the call to `linkaxes`:

```
a1 = subplot(2,1,1);
plot(randn(10,1));          % Plot 10 numbers on top
a2 = subplot(2,1,2);
plot(a2,randn(100,1))       % Plot 100 numbers below
linkaxes([a1 a2], 'x');     % Link the axes; subplot 2 now out of range
set(a2,'xlimmode','auto'); % Now both axes run from 1-100 in x
                            % You could also set(a2,'xlim',[1 100])
```



See Also `linkprop`, `zoom`, `pan`

Purpose

Keep same value for corresponding properties

Syntax

```
hlink = linkprop(obj_handles,'PropertyName')
hlink = linkprop(obj_handles,{'PropertyName1','PropertyName2',...})
```

Description

Use `linkprop` to maintain the same values for the corresponding properties of different objects.

`hlink = linkprop(obj_handles,'`*`PropertyName`*`')` maintains the same value for the property *`PropertyName`* on all objects whose handles appear in `obj_handles`. `linkprop` returns the link object in `hlink`. See "Link Object" on page 2-1947 for more information.

`hlink =`
`linkprop(obj_handles,{'`*`PropertyName1`*`','`*`PropertyName2`*`',...})` maintains the same respective values for all properties passed as a cell array on all objects whose handles appear in `obj_handles`.

Note that the linked properties of all linked objects are updated immediately when `linkprop` is called. The first object in the list (`obj_handles`) determines the property values for the rest of the objects.

Link Object

The mechanism to link the properties of different graphics objects is stored in the link object, which is returned by `linkprop`. Therefore, the link object must exist within the context where you want property linking to occur (such as in the base workspace if users are to interact with the objects from the command line or figure tools).

The following list describes ways to maintain a reference to the link object.

- Return the link object as an output argument from a function and keep it in the base workspace while interacting with the linked objects.
- Make the `hlink` variable global.

- Store the hlink variable in an object's UserData property or in application data. See the "Examples" on page 2-1948 section for an example that uses application data.

Modifying Link Object

If you want to change either the graphics objects or the properties that are linked, you need to use the link object methods designed for that purpose. These methods are functions that operate only on link objects. To use them, you must first create a link object using linkprop.

Method	Purpose
addtarget	Add specified graphics object to the link object's targets.
removetarget	Remove specified graphics object from the link object's targets.
addprop	Add specified property to the linked properties.
removeprop	Remove specified property from the linked properties.

Method Syntax

```
addtarget(hlink,obj_handles)
removetarget(hlink,obj_handles)
addprop(hlink,'PropertyName')
removeprop(hlink,'PropertyName')
```

Arguments

- hlink — Link object returned by linkprop
- obj_handles — One or more graphic object handles
- *PropertyName* — Name of a property common to all target objects

Examples

This example creates four isosurface graphs of fluid flow data, each displaying a different isovalue. The CameraPosition and CameraUpVector properties of each subplot axes are linked so that the user can rotate all subplots in unison.

After running the example, select **Rotate 3D** from the figure **Tools** menu and observe how all subplots rotate together.

Note If you are using the MATLAB help browser, you can run this example or open it in the MATLAB editor.

The property linking code is in step 3.

1 Define the data using the `flow` M-file and specify property values for the isosurface (which is a patch object).

```
function linkprop_example
[x y z v] = flow;
isoval = [-3 -1 0 1];
props.FaceColor = [0 0 .5];
props.EdgeColor = 'none';
props.AmbientStrength = 1;
props.FaceLighting = 'gouraud';
```

2 Create four subplot axes and add an isosurface graph to each one. Add a title and set viewing and lighting parameters using a local function (`set_view`). (`subplot`, `patch`, `isosurface`, `title`, `num2str`)

```
for k = 1:4
    h(k) = subplot(2,2,k);
    patch(isosurface(x,y,z,v,isoval(k)),props)
    title(h(k),['Isovalue = ',num2str(k)])
    set_view(h(k))
end
```

3 Link the `CameraPosition` and `CameraTarget` properties of all subplot axes. Since this example function will have completed execution when the user is rotating the subplots, the link object is stored in the first subplot axes application data. See `setappdata` for more information on using application data.

```
hlink = linkprop(h,{'CameraPosition','CameraUpVector'});
key = 'graphics_linkprop';
% Store link object on first subplot axes
setappdata(h(1),key,hlink);
```

4 The following local function contains viewing and lighting commands issued on each axes. It is called with the creation of each subplot (`view`, `axis`, `camlight`).

```
function set_view(ax)
% Set the view and add lighting
view(ax,3); axis(ax,'tight','equal')
camlight left; camlight right
% Make axes invisible and title visible
axis(ax,'off')
set(get(ax,'title'),'Visible','on')
```

Linking an Additional Property

Suppose you want to add the axes `PlotBoxAspectRatio` to the linked properties in the previous example. You can do this by modifying the link object that is stored in the first subplot axes' application data.

1 First click the first subplot axes to make it the current axes (since its handle was saved only within the creating function). Then get the link object's handle from application data (`getappdata`).

```
hlink = getappdata(gca,'graphics_linkprop');
```

2 Use the `addprop` method to add a new property to the link object.

```
addprop(hlink,'PlotBoxAspectRatio')
```

Since `hlink` is a reference to the link object (i.e., not a copy), `addprop` can change the object that is stored in application data.

See Also

`getappdata`, `linkaxes`, `setappdata`

Purpose

Solve linear system of equations

Syntax

```
X = linsolve(A,B)
X = linsolve(A,B,opts)
```

Description

`X = linsolve(A,B)` solves the linear system `A*X = B` using LU factorization with partial pivoting when A is square and QR factorization with column pivoting otherwise. The number of rows of `A` must equal the number of rows of `B`. If `A` is m-by-n and `B` is m-by-k, then `X` is n-by-k. `linsolve` returns a warning if `A` is square and ill conditioned or if it is not square and rank deficient.

`[X, R] = linsolve(A,B)` suppresses these warnings and returns `R`, which is the reciprocal of the condition number of `A` if `A` is square, or the rank of `A` if `A` is not square.

`X = linsolve(A,B,opts)` solves the linear system `A*X = B` or `A'*X = B`, using the solver that is most appropriate given the properties of the matrix `A`, which you specify in `opts`. For example, if `A` is upper triangular, you can set `opts.UT = true` to make `linsolve` use a solver designed for upper triangular matrices. If `A` has the properties in `opts`, `linsolve` is faster than `mldivide`, because `linsolve` does not perform any tests to verify that `A` has the specified properties.

Notes If `A` does not have the properties that you specify in `opts`, `linsolve` returns incorrect results and does not return an error message. If you are not sure whether `A` has the specified properties, use `mldivide` instead.
For small problems, there is no speed benefit in using `linsolve` on triangular matrices as opposed to using the `mldivide` function.

The `TRANSA` field of the `opts` structure specifies the form of the linear system you want to solve:

- If you set `opts.TRANSA = false`, `linsolve(A,B,opts)` solves `A*X = B`.

- If you set `opts.TRANSA = true`, `linsolve(A,B,opts)` solves `A'*X = B`.

The following table lists all the field of `opts` and their corresponding matrix properties. The values of the fields of `opts` must be `logical` and the default value for all fields is `false`.

Field Name	Matrix Property
LT	Lower triangular
UT	Upper triangular
UHESS	Upper Hessenberg
SYM	Real symmetric or complex Hermitian
POSDEF	Positive definite
RECT	General rectangular
TRANSA	Conjugate transpose — specifies whether the function solves `A*X = B` or `A'*X = B`

The following table lists all combinations of field values in `opts` that are valid for `linsolve`. A true/false entry indicates that `linsolve` accepts either true or false.

LT	UT	UHESS	SYM	POSDEF	RECT	TRANSA
true	false	false	false	false	true/false	true/false
false	true	false	false	false	true/false	true/false
false	false	true	false	false	false	true/false
false	false	false	true	true/false	false	true/false
false	false	false	false	false	true/false	true/false

Example

The following code solves the system `A'x = b` for an upper triangular matrix `A` using both `mldivide` and `linsolve`.

```
A = triu(rand(5,3)); x = [1 1 1 0 0]'; b = A'*x;
y1 = (A')\b
opts.UT = true; opts.TRANSA = true;
y2 = linsolve(A,b,opts)

y1 =

    1.0000
    1.0000
    1.0000
         0
         0


y2 =

    1.0000
    1.0000
    1.0000
         0
         0
```

Note If you are working with matrices having different properties, it is useful to create an options structure for each type of matrix, such as `opts_sym`. This way you do not need to change the fields whenever you solve a system with a different type of matrix `A`.

See Also

`mldivide`

Purpose

Generate linearly spaced vectors

Syntax

```
y = linspace(a,b)
y = linspace(a,b,n)
```

Description

The `linspace` function generates linearly spaced vectors. It is similar to the colon operator ":", but gives direct control over the number of points.

`y = linspace(a,b)` generates a row vector `y` of 100 points linearly spaced between and including `a` and `b`.

`y = linspace(a,b,n)` generates a row vector `y` of `n` points linearly spaced between and including `a` and `b`.

See Also

`logspace`

The colon operator `:`

Purpose

Create and open list-selection dialog box

Syntax

```
[Selection,ok] = listdlg('ListString',S)
```

Description

`[Selection,ok] = listdlg('ListString',S)` creates a modal dialog box that enables you to select one or more items from a list. `Selection` is a vector of indices of the selected strings (in single selection mode, its length is 1). `Selection` is `[]` when `ok` is 0. `ok` is 1 if you click the **OK** button, or 0 if you click the **Cancel** button or close the dialog box. Double-clicking on an item or pressing **Return** when multiple items are selected has the same effect as clicking the **OK** button. The dialog box has a **Select all** button (when in multiple selection mode) that enables you to select all list items.

Inputs are in parameter/value pairs:

Parameter	Description
`'ListString'`	Cell array of strings that specify the list box items.
`'SelectionMode'`	String indicating whether one or many items can be selected: `'single'` or `'multiple'` (the default).
`'ListSize'`	List box size in pixels, specified as a two-element vector `[width height]`. Default is `[160 300]`.
`'InitialValue'`	Vector of indices of the list box items that are initially selected. Default is 1, the first item.
`'Name'`	String for the dialog box's title. Default is ''.
`'PromptString'`	String matrix or cell array of strings that appears as text above the list box. Default is {}.
`'OKString'`	String for the OK button. Default is `'OK'`.
`'CancelString'`	String for the Cancel button. Default is '`Cancel`'.
`'uh'`	Uicontrol button height, in pixels. Default is 18.

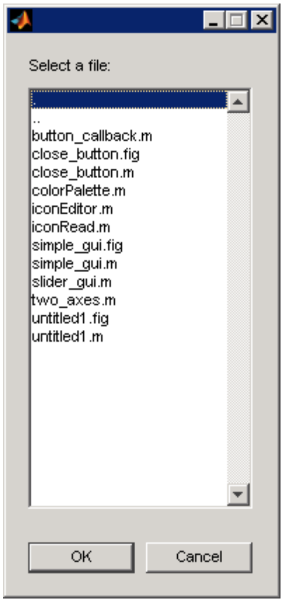
Parameter	Description
'fus'	Frame/uicontrol spacing, in pixels. Default is 8.
'ffs'	Frame/figure spacing, in pixels. Default is 8.

Note A modal dialog box prevents the user from interacting with other windows before responding. For more information, see `WindowStyle` in the MATLAB Figure Properties.

Example

This example displays a dialog box that enables the user to select a file from the current directory. The function returns a vector. Its first element is the index to the selected file; its second element is 0 if no selection is made, or 1 if a selection is made.

```
d = dir;
str = {d.name};
[s,v] = listdlg('PromptString','Select a file:',...
                'SelectionMode','single',...
                'ListString',str)
```



See Also

`dialog`, `errordlg`, `helpdlg`, `inputdlg`, `msgbox`, `questdlg`, `warndlg`

`dir`, `figure`, `uiwait`, `uiresume`

"Predefined Dialog Boxes" on page 1-103 for related functions

listfonts

Purpose

List available system fonts

Syntax

```
c = listfonts
c = listfonts(h)
```

Description

`c = listfonts` returns sorted list of available system fonts.

`c = listfonts(h)` returns sorted list of available system fonts and includes the `FontName` property of the object with handle `h`.

Examples

Example 1

This example returns a list of available system fonts similar in format to the one shown.

```
list = listfonts

list =
    'Agency FB'
    'Algerian'
    'Arial'
    ...
    'ZapfChancery'
    'ZapfDingbats'
    'ZWAdobeF'
```

Example 2

This example returns a list of available system fonts with the value of the`FontName` property, for the object with handle `h`, sorted into the list.

```
 h = uicontrol('Style','text','String','My Font','FontName','MyFont');
 list = listfonts(h)

list =
    'Agency FB'
    'Algerian'
    'Arial'
    ...
```

```
'MyFont'
...
'ZapfChancery'
'ZapfDingbats'
'ZWAdobeF'
```

See Also

`uisetfont`

Purpose

Load workspace variables from disk

Syntax

```
load
load filename
load filename X Y Z ...
load filename -regexp expr1 expr2 ...
load -ascii filename
load -mat filename
S = load('arg1', 'arg2', 'arg3', ...)
```

Description

`load` loads all the variables from the MAT-file `matlab.mat`, if it exists, or returns an error if the file doesn't exist.

`load filename` loads all the variables from the file specified by `filename`. `filename` is an unquoted string specifying a file name, and can also include a file extension and a full or `partial path` name. If `filename` has no extension, `load` looks for a file named `filename.mat` and treats it as a binary MAT-file. If `filename` has an extension other than `.mat`, `load` treats the file as ASCII data.

`load filename X Y Z ...` loads just the specified variables `X`, `Y`, `Z`, etc. from the MAT-file. The wildcard `'*'` loads variables that match a pattern (MAT-file only).

`load filename` **`-regexp`** `expr1 expr2 ...` loads those variables that match any of the "Regular Expressions" given by `expr1`, `expr1`, etc.

`load` **`-ascii`** `filename` forces `load` to treat the file as an ASCII file, regardless of file extension. If the file is not numeric text, `load` returns an error. Use `load -ascii` only on files that have been created with the `save -ascii` command.

`load` **`-mat`** `filename` forces `load` to treat the file as a MAT-file, regardless of file extension. If the file is not a MAT-file, `load` returns an error.

`S = load('arg1', 'arg2', 'arg3', ...)` calls `load` using MATLAB *function syntax*, (as opposed to the MATLAB *command syntax* that has been shown thus far). You can use function syntax with any form of the load command shown above, replacing arg1, arg2, etc. with the arguments shown. For example,

```
S = load('myfile.mat', '-regexp', '^Mon', '^Tue')
```

To specify a command line option, such as -mat, with the functional form, specify the option as a string argument, and include the hyphen. For example,

```
load('myfile.dat', '-mat')
```

Function syntax enables you to assign values returned by load to an output variable. You can also use function syntax when loading from a file having a name that contains space characters, or a filename that is stored in a variable.

If the file you are loading from is a MAT-file, then output S is a structure containing fields that match the variables retrieved. If the file contains ASCII data, then S is a double-precision array.

Remarks

For information on any of the following topics related to saving to MAT-files, see "Importing Data from MAT-Files" in the MATLAB Programming documentation:

- Previewing MAT-file contents
- Loading binary data
- Loading ASCII data

You can also use the Current Directory browser to view the contents of a MAT-file without loading it — see "Viewing and Making Changes to Directories".

MATLAB saves numeric data in MAT-files in the native byte format. The header of the MAT-file contains a 2-byte Endian Indicator that MATLAB uses to determine the byte format when loading the MAT-file. When MATLAB reads a MAT-file, it determines whether byte-swapping needs to be performed by the state of this indicator.

Examples

Example 1 — Loading From a Binary MAT-file

To see what is in the MAT-file prior to loading it, use `whos -file`:

```
whos -file mydata.mat
  Name             Size         Bytes  Class

  javArray        10x1                  java.lang.Double[][]
  spArray          5x5             84  double array (sparse)
  strArray         2x5            678  cell array
  x                3x2x2           96  double array
  y                4x5           1230  cell array
```

Clear the workspace and load it from MAT-file `mydata.mat`:

```
clear
load mydata

whos
  Name             Size         Bytes  Class

  javArray        10x1                 java.lang.Double[][]
  spArray          5x5            84  double array (sparse)
  strArray         2x5           678  cell array
  x                3x2x2          96  double array
  y                4x5          1230  cell array
```

Example 2 — Loading a List of Variables

You can use a comma-separated list to pass the names of those variables you want to load from a file. This example generates a comma-separated list from a cell array

In this example, the file name is stored in a variable, `saved_file`. You must call `load` using the function syntax of the command if you intend to reference the file name through a variable:

```
saved_file = 'myfile.mat';
saved_file = 'ptarray.mat';
whos('-file', saved_file)
```

```
  Name           Size                   Bytes  Class

  AName          1x24                      48  char array
  AVal           1x1                        8  double array
  BName          1x24                      48  char array
  BVal           1x1                        8  double array
  CVal           5x5                       84  double array (sparse)
  DArr           2x5                      678  cell array

filevariables = {'AName', 'BVal', 'DArr'};
load(saved_file, filevariables{:});
```

The second part of this example generates a comma-separated list from the name field of a structure array, and loads the first ten variables from the specified file:

```
saved_file = 'myfile.mat';
vars = whos('-file', saved_file);
load(saved_file, vars(1:10).name);
```

Example 3 — Loading From an ASCII File

Create several 4-column matrices and save them to an ASCII file:

```
a = magic(4);  b = ones(2, 4) * -5.7;  c = [8 6 4 2];
save -ascii mydata.dat
```

Clear the workspace and load it from the file `mydata.dat`. If the filename has an extension other than `.mat`, MATLAB assumes that it is ASCII:

```
clear
load mydata.dat
```

MATLAB loads all data from the ASCII file, merges it into a single matrix, and assigns the matrix to a variable named after the filename:

```
mydata
```

```
mydata =
   16.0000    2.0000    3.0000   13.0000
    5.0000   11.0000   10.0000    8.0000
    9.0000    7.0000    6.0000   12.0000
    4.0000   14.0000   15.0000    1.0000
   -5.7000   -5.7000   -5.7000   -5.7000
   -5.7000   -5.7000   -5.7000   -5.7000
    8.0000    6.0000    4.0000    2.0000
```

Example 4 — Using Regular Expressions

Using regular expressions, load from MAT-file `mydata.mat` those variables with names that begin with `Mon`, `Tue`, or `Wed`:

```
load('mydata', '-regexp', '^Mon|^Tue|^Wed');
```

Here is another way of doing the same thing. In this case, there are three separate expression arguments:

```
load('mydata', '-regexp', '^Mon', '^Tue', '^Wed');
```

See Also

`clear`, `fprintf`, `fscanf`, `partialpath`, `save`, `spconvert`, `who`

Purpose

Initialize control object from file

Syntax

```
h.load('filename')
load(h, 'filename')
```

Description

`h.load('filename')` initializes the COM object associated with the interface represented by the MATLAB COM object `h` from file specified in the string `filename`. The file must have been created previously by serializing an instance of the same control.

`load(h, 'filename')` is an alternate syntax for the same operation.

Note The COM `load` function is only supported for controls at this time.

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
ans =
      Label: 'Label'
     Radius: 20
```

See Also

`save`, `actxcontrol`, `actxserver`, `release`, `delete`

load (serial)

Purpose

Load serial port objects and variables into MATLAB workspace

Syntax

```
load filename
load filename obj1 obj2...
```

Arguments

`filename`	The MAT-file name.
`obj1 obj2...`	Serial port objects or arrays of serial port objects.
`out`	A structure containing the specified serial port objects.

Description

`load filename` returns all variables from the MAT-file specified by `filename` into the MATLAB workspace.

`load filename obj1 obj2...` returns the serial port objects specified by `obj1 obj2` ... from the MAT-file `filename` into the MATLAB workspace.

`out = load('filename','obj1','obj2',...)` returns the specified serial port objects from the MAT-file `filename` as a structure to `out` instead of directly loading them into the workspace. The field names in `out` match the names of the loaded serial port objects.

Remarks

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

Suppose you create the serial port objects `s1` and `s2`, configure a few properties for `s1`, and connect both objects to their instruments:

```
s1 = serial('COM1');
s2 = serial('COM2');
set(s1,'Parity','mark','DataBits',7);
fopen(s1);
fopen(s2);
```

Save s1 and s2 to the file MyObject.mat, and then load the objects back into the workspace:

```
save MyObject s1 s2;
load MyObject s1;
load MyObject s2;

get(s1, {'Parity', 'DataBits'})
ans =
    'mark'    [7]
get(s2, {'Parity', 'DataBits'})
ans =
    'none'    [8]
```

See Also

Functions

save

Properties

Status

Purpose Load external library into MATLAB

Syntax

```
loadlibrary('shrlib', 'hfile')
loadlibrary('shrlib', @protofile)
loadlibrary('shrlib', ..., 'options')
loadlibrary shrlib hfile options
```

Description

`loadlibrary('shrlib', 'hfile')` loads the functions defined in header file `hfile` and found in shared library `shrlib` into MATLAB. On Windows systems, `shrlib` refers to the name of a dynamic link library (`.dll`) file. On Linux systems, it refers to the name of a shared object (`.so`) file. See “File Extensions for Libraries” on page 2-1968 for more information.

`loadlibrary('shrlib', @protofile)` uses the prototype M-file `protofile` in place of a header file in loading the library `shrlib`. The string `@protofile` specifies a function handle to the prototype M-file. (See the description of “Prototype M-Files” on page 2-1970 below).

Note The MATLAB Generic Shared Library interface does not support library functions that have function pointer inputs.

File Extensions for Libraries

If you do not include a file extension with the `shrlib` argument, `loadlibrary` attempts to find the library with either the appropriate platform MEX-file extension or the appropriate platform library extension (usually `.dll` or `.so`). See `mex` for a list of extensions.

If you do not include a file extension with the second argument, and this argument is not a function handle, `loadlibrary` uses `.h` for the extension.

`loadlibrary('shrlib', ..., '`*`options`*`')` loads the library `shrlib` with one or more of the following *`options`*.

Option	Description

addheader hfileN	Loads the functions defined in the additional header file, hfileN. Note that each file specified by addheader must be referenced by a corresponding #include statement in the base header file.
	
	Specify the string hfileN as a filename without a file extension. MATLAB does not verify the existence of the header files and ignores any that are not needed.
	
	You can specify as many additional header files as you need using the syntax
	
	`loadlibrary shrlib hfile ...`
	`    addheader hfile1 ...`
	`    addheader hfile2 ...      % and so on`

alias name	Associates the specified alias name with the library. All subsequent calls to MATLAB functions that reference this library must use this alias until the library is unloaded.
includepath path	Specifies an additional path in which to look for included header files.
mfilename mfile	Generates a prototype M-file mfile in the current directory. You can use this file in place of a header file when loading the library. (See the description of "Prototype M-Files" on page 2-1970 below).

Only the **alias** option is available when loading using a prototype M-file.

If you have more than one library file of the same name, load the first using the library filename, and load the additional libraries using the **alias** option.

loadlibrary shrlib hfile *options* is the command format for this function.

Remarks

How to Use the addheader Option

The `addheader` option enables you to add functions for MATLAB to load from those listed in header files included in the base header file (with a `#include` statement). For example, if your library header file contains the statement:

```
#include header2.h
```

then to load the functions in `header2.h`, you need to use `addheader` in the call to `loadlibrary`:

```
loadlibrary libname libname.h addheader header2.h
```

You can use the `addheader` option with a header file that lists function prototypes for only the functions that are needed by your library, and thereby avoid loading functions that you do not define in your library. To do this, you might need to create a header file that contains a subset of the functions listed in large header file.

addheader Syntax

When using `addheader` to specify which functions to load, ensure that there are `#include` statements in the base header file for each additional header file in the `loadlibrary` call. For example, to use the following statement:

```
loadlibrary mylib mylib.h addheader header2.h
```

the file `mylib.h` must contain this statement:

```
#include header2.h
```

Prototype M-Files

When you use the **`mfilename`** option with `loadlibrary`, MATLAB generates an M-file called a prototype file. This file can then be used on subsequent calls to `loadlibrary` in place of a header file.

Like a header file, the prototype file supplies MATLAB with function prototype information for the library. You can make changes to the prototypes by editing this file and reloading the library.

Here are some reasons for using a prototype file, along with the changes you would need to make to the file:

- You want to make temporary changes to signatures of the library functions.

  Edit the prototype file, changing the `fcns.LHS` or `fcns.RHS` field for that function. This changes the types of arguments on the left hand side or right hand side, respectively.

- You want to rename some of the library functions.

  Edit the prototype file, defining the `fcns.alias` field for that function.

- You expect to use only a small percentage of the functions in the library you are loading.

  Edit the prototype file, commenting out the unused functions. This reduces the amount of memory required for the library.

- You need to specify a number of include files when loading a particular library.

  Specify the full list of include files (plus the **`mfilename`** option) in the first call to `loadlibrary`. This puts all the information from the include files into the prototype file. After that, specify just the prototype file.

Examples

Example 1

Use `loadlibrary` to load the MATLAB sample shared library, `shrlibsample`:

```
addpath([matlabroot '\extern\examples\shrlib'])
loadlibrary shrlibsample shrlibsample.h
```

Example 2

Load sample library `shrlibsample`, giving it an alias name of `lib`. Once you have set an alias, you need to use this name in all further interactions with the library for this session:

```
addpath([matlabroot '\extern\examples\shrlib'])
loadlibrary shrlibsample shrlibsample.h alias lib

libfunctionsview lib

str = 'This was a Mixed Case string';
calllib('lib', 'stringToUpper', str)
ans =
   THIS WAS A MIXED CASE STRING
unloadlibrary lib
```

Example 3

Load the library, specifying an additional path in which to search for included header files:

```
addpath([matlabroot '\extern\examples\shrlib'])
loadlibrary('shrlibsample','shrlibsample.h','includepath', ...
          fullfile(matlabroot , 'extern', 'include'));
```

Example 4

Load the `libmx` library and generate a prototype M-file containing the prototypes defined in header file `matrix.h`:

```
hfile = [matlabroot '\extern\include\matrix.h'];
loadlibrary('libmx', hfile, 'mfilename', 'mxproto')

dir mxproto.m
   mxproto.m
```

Edit the generated file `mxproto.m` and locate the function `'mxGetNumberOfDimensions'`. Give it an alias of `'mxGetDims'` by adding this text to the line before `fcnNum` is incremented:

```
fcns.alias{fcnNum}='mxGetDims';
```

Here is the new function prototype. The change is shown in bold:

```
fcns.name{fcnNum}='mxGetNumberOfDimensions';
fcns.calltype{fcnNum}='cdecl';
fcns.LHS{fcnNum}='int32';
fcns.RHS{fcnNum}={'MATLAB array'};
fcns.alias{fcnNum}='mxGetDims'; % Alias defined
fcnNum=fcnNum+1; % Increment fcnNum
```

Unload the library and then reload it using the prototype M-file.

```
unloadlibrary libmx

loadlibrary('libmx', @mxproto)
```

Now call `mxGetNumberOfDimensions` using the alias function name:

```
y = rand(4, 7, 2);

calllib('libmx', 'mxGetDims', y)
ans =
     3

unloadlibrary libmx
```

See Also

`libisloaded`, `unloadlibrary`, `libfunctions`, `libfunctionsview`, `libpointer`, `libstruct`, `calllib`

Purpose User-defined extension of `load` function for user objects

Syntax

```
b = loadobj(a)
```

Description

`b = loadobj(a)` extends the `load` function for user objects. When an object is loaded from a MAT-file, the `load` function calls the `loadobj` method for the object's class if it is defined. The `loadobj` method must have the calling syntax shown. The input argument `a` is the object as loaded from the MAT-file or a structure created by `load` if the object cannot be resolved, and the output argument `b` is the object that the `load` function loads into the workspace.

The following steps describe how an object is loaded from a MAT-file into the workspace:

1 The `load` function detects the object `a` in the MAT-file.

2 The `load` function looks in the current workspace for an object of the same class as the object `a`. If there isn't an object of the same class in the workspace, `load` calls the default constructor, registering an object of that class in the workspace. The default constructor is the constructor function called with no input arguments.

3 The `load` function checks to see if the structure of the object `a` matches the structure of the object registered in the workspace. If the objects match, `a` is loaded. If the objects don't match, `load` converts `a` to a structure variable and issues a warning if no `loadobj` method exists.

4 The `load` function calls the `loadobj` method for the object's class if it is defined. `load` passes the object `a` to the `loadobj` method as an input argument. Note that the format of the object `a` is dependent on the results of step 3 (object or structure). The output argument of `loadobj`, `b`, is loaded into the workspace in place of the object `a` and MATLAB issues no warning because the class' `loadobj` method is assumed to have converted the structure to a proper object conforming to the current class definition.

See "The loadobj Method" for an example of a `loadobj` method.

Remarks

`loadobj` can be overloaded only for user objects. `load` does not call `loadobj` for built-in data types (such as `double`).

`loadobj` is invoked separately for each object in the MAT-file. The `load` function recursively descends cell arrays and structures, applying the `loadobj` method to each object encountered.

A child object inherits the `loadobj` method of its parent class. First the child object's `loadobj` method is called, then the parents `loadobj` is called. Note that this behavior is different from that of the `saveobj` method, which is not inherited from its parent.

See Also

`load`, `save`, `saveobj`

log

Purpose

Natural logarithm

Syntax

```
Y = log(X)
```

Description

The `log` function operates element-wise on arrays. Its domain includes complex and negative numbers, which may lead to unexpected results if used unintentionally.

`Y = log(X)` returns the natural logarithm of the elements of `X`. For complex or negative z, where $z = x + y*i$, the complex logarithm is returned.

```
log(z) = log(abs(z)) + i*atan2(y,x)
```

Examples

The statement `abs(log(-1))` is a clever way to generate π.

```
ans =

    3.1416
```

See Also

`exp`, `log10`, `log2`, `logm`, `reallog`

Purpose Common (base 10) logarithm

Syntax

```
Y = log10(X)
```

Description The `log10` function operates element-by-element on arrays. Its domain includes complex numbers, which may lead to unexpected results if used unintentionally.

`Y = log10(X)` returns the base 10 logarithm of the elements of `X`.

Examples

```
log10(realmax) is 308.2547
```

and

```
log10(eps) is -15.6536
```

See Also `exp`, `log`, `log2`, `logm`

log1p

Purpose Compute `log(1+x)` accurately for small values of `x`

Syntax

```
y = log1p(x)
```

Description `y = log1p(x)` computes `log(1+x)`, compensating for the roundoff in `1+x`. `log1p(x)` is more accurate than `log(1+x)` for small values of x. For small `x`, `log1p(x)` is approximately `x`, whereas `log(1+x)` can be zero.

See Also `log`, `expm1`

Purpose

Base 2 logarithm and dissect floating-point numbers into exponent and mantissa

Syntax

```
Y = log2(X)
[F,E] = log2(X)
```

Description

`Y = log2(X)` computes the base 2 logarithm of the elements of `X`.

`[F,E] = log2(X)` returns arrays `F` and `E`. Argument `F` is an array of real values, usually in the range `0.5 <= abs(F) < 1`. For real `X`, `F` satisfies the equation: `X = F.*2.^E`. Argument `E` is an array of integers that, for real `X`, satisfy the equation: `X = F.*2.^E`.

Remarks

This function corresponds to the ANSI C function `frexp()` and the IEEE floating-point standard function `logb()`. Any zeros in `X` produce `F = 0` and `E = 0`.

Examples

For IEEE arithmetic, the statement `[F,E] = log2(X)` yields the values:

X	F	E
1	1/2	1
pi	pi/4	2
-3	-3/4	2
eps	1/2	-51
realmax	1-eps/2	1024
realmin	1/2	-1021

See Also

`log`, `pow2`

logical

Purpose

Convert numeric values to logical

Syntax

```
K = logical(A)
```

Description

`K = logical(A)` returns an array that can be used for logical indexing or logical tests.

`A(B)`, where `B` is a logical array that is the same size as `A`, returns the values of `A` at the indices where the real part of `B` is nonzero.

`A(B)`, where `B` is a logical array that is smaller than `A`, returns the values of column vector `A(:)` at the indices where the real part of column vector `B(:)` is nonzero.

Remarks

Most arithmetic operations remove the logicalness from an array. For example, adding zero to a logical array removes its logical characteristic. `A = +A` is the easiest way to convert a logical array, `A`, to a numeric double array.

Logical arrays are also created by the relational operators (==,<,>,~, etc.) and functions like `any`, `all`, `isnan`, `isinf`, and `isfinite`.

Examples

Given `A = [1 2 3; 4 5 6; 7 8 9]`, the statement `B = logical(eye(3))` returns a logical array

```
B =
    1    0    0
    0    1    0
    0    0    1
```

which can be used in logical indexing that returns `A`'s diagonal elements:

```
A(B)

ans =
      1
      5
      9
```

However, attempting to index into `A` using the *numeric* array `eye(3)` results in:

```
A(eye(3))
??? Subscript indices must either be real positive integers or
logicals.
```

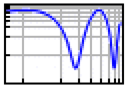
See Also

`islogical`, logical operators (elementwise and short-circuit),

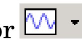
loglog

Purpose

Log-log scale 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

```
loglog(Y)
loglog(X1,Y1,...)
loglog(X1,Y1,LineSpec,...)
loglog(...,'PropertyName',PropertyValue,...)
h = loglog(...)
hlines = loglog('v6',...)
```

Description

`loglog(Y)` plots the columns of `Y` versus their index if `Y` contains real numbers. If `Y` contains complex numbers, `loglog(Y)` and `loglog(real(Y),imag(Y))` are equivalent. `loglog` ignores the imaginary component in all other uses of this function.

`loglog(X1,Y1,...)` plots all `Xn` versus `Yn` pairs. If only `Xn` or `Yn` is a matrix, `loglog` plots the vector argument versus the rows or columns of the matrix, depending on whether the vector's row or column dimension matches the matrix.

`loglog(X1,Y1,LineSpec,...)` plots all lines defined by the `Xn,Yn,LineSpec` triples, where `LineSpec` determines line type, marker symbol, and color of the plotted lines. You can mix `Xn,Yn,LineSpec` triples with `Xn,Yn` pairs, for example,

```
loglog(X1,Y1,X2,Y2,LineSpec,X3,Y3)
```

`loglog(...,'PropertyName',PropertyValue,...)` sets property values for all lineseries graphics objects created by `loglog`. See the `line` reference page for more information.

`h = loglog(...)` returns a column vector of handles to lineseries graphics objects, one handle per line.

Backward-Compatible Version

`hlines = loglog('v6',...)` returns the handles to line objects instead of lineseries objects.

Remarks

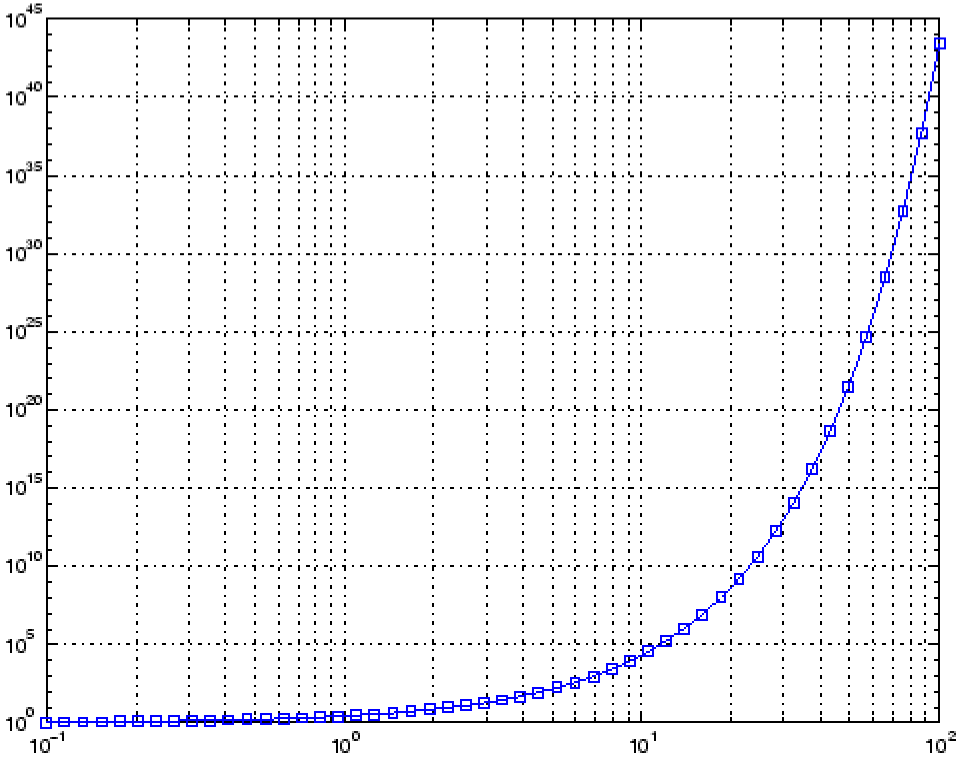
If you do not specify a color when plotting more than one line, `loglog` automatically cycles through the colors and line styles in the order specified by the current axes.

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 `loglog` plot with square markers.

```
x = logspace(-1,2);
loglog(x,exp(x),'-s')
grid on
```



See Also

`LineSpec`, `plot`, `semilogx`, `semilogy`

"Basic Plots and Graphs" on page 1-85 for related functions

Purpose

Matrix logarithm

Syntax

```
L = logm(A)
[L, exitflag] = logm(A)
```

Description

`L = logm(A)` is the principal matrix logarithm of A, the inverse of `expm(A)`. `L` is the unique logarithm for which every eigenvalue has imaginary part lying strictly between $-\pi$ and π. If `A` is singular or has any eigenvalues on the negative real axis, the principal logarithm is undefined. In this case, `logm` computes a non-principal logarithm and returns a warning message.

`[L, exitflag] = logm(A)` returns a scalar `exitflag` that describes the exit condition of `logm`:

- If `exitflag = 0`, the algorithm was successfully completed.
- If `exitflag = 1`, one or more Taylor series evaluations did not converge. However, the computed value of `L` might still be accurate.

The input `A` can have class `double` or `single`.

Remarks

If `A` is real symmetric or complex Hermitian, then so is `logm(A)`.

Some matrices, like `A = [0 1; 0 0]`, do not have any logarithms, real or complex, so `logm` cannot be expected to produce one.

Limitations

For most matrices:

```
logm(expm(A)) = A = expm(logm(A))
```

These identities may fail for some `A`. For example, if the computed eigenvalues of `A` include an exact zero, then `logm(A)` generates infinity. Or, if the elements of `A` are too large, `expm(A)` may overflow.

Examples

Suppose `A` is the 3-by-3 matrix

```
1     1     0
```

```
         0         0         2
         0         0        -1
```

and `Y = expm(A)` is

```
Y =
    2.7183    1.7183    1.0862
         0    1.0000    1.2642
         0         0    0.3679
```

Then `A = logm(Y)` produces the original matrix `A`.

```
Y =
    1.0000    1.0000    0.0000
         0         0    2.0000
         0         0   -1.0000
```

But `log(A)` involves taking the logarithm of zero, and so produces

```
ans =
    1.0000    0.5413    0.0826
      -Inf         0    0.2345
      -Inf      -Inf   -1.0000
```

Algorithm

The algorithm `logm` uses is described in [1].

See Also

`expm`, `funm`, `sqrtm`

References

[1] Davies, P. I. and N. J. Higham, "A Schur-Parlett algorithm for computing matrix functions," *SIAM J. Matrix Anal. Appl.*, Vol. 25, Number 2, pp. 464-485, 2003.

[2] Cheng, S. H., N. J. Higham, C. S. Kenney, and A. J. Laub, "Approximating the logarithm of a matrix to specified accuracy," *SIAM J. Matrix Anal. Appl.*, Vol. 22, Number 4, pp. 1112-1125, 2001.

[3] Higham, N. J., “Evaluating Pade approximants of the matrix logarithm,” *SIAM J. Matrix Anal. Appl.*, Vol. 22, Number 4, pp. 1126-1135, 2001.

[4] Golub, G. H. and C. F. Van Loan, *Matrix Computation*, Johns Hopkins University Press, 1983, p. 384.

[5] Moler, C. B. and C. F. Van Loan, “Nineteen Dubious Ways to Compute the Exponential of a Matrix,” *SIAM Review* 20, 1978, pp. 801-836.

Purpose

Generate logarithmically spaced vectors

Syntax

```
y = logspace(a,b)
y = logspace(a,b,n)
y = logspace(a,pi)
```

Description

The `logspace` function generates logarithmically spaced vectors. Especially useful for creating frequency vectors, it is a logarithmic equivalent of `linspace` and the ":" or colon operator.

`y = logspace(a,b)` generates a row vector `y` of 50 logarithmically spaced points between decades `10^a` and `10^b`.

`y = logspace(a,b,n)` generates `n` points between decades `10^a` and `10^b`.

`y = logspace(a,pi)` generates the points between `10^a` and `pi`, which is useful for digital signal processing where frequencies over this interval go around the unit circle.

Remarks

All the arguments to `logspace` must be scalars.

See Also

`linspace`

The colon operator `:`

Purpose Search for keyword in all help entries

Syntax

```
lookfor topic
lookfor topic -all
```

Description `lookfor topic` searches for the string `topic` in the first comment line (the H1 line) of the help text in all M-files found on the MATLAB search path. For all files in which a match occurs, `lookfor` displays the H1 line.

`lookfor topic -all` searches the entire first comment block of an M-file looking for `topic`.

Examples For example

```
lookfor inverse
```

finds at least a dozen matches, including H1 lines containing "inverse hyperbolic cosine," "two-dimensional inverse FFT," and "pseudoinverse." Contrast this with

```
which inverse
```

or

```
what inverse
```

These functions run more quickly, but probably fail to find anything because MATLAB does not have a function `inverse`.

In summary, `what` lists the functions in a given directory, `which` finds the directory containing a given function or file, and `lookfor` finds all functions in all directories that might have something to do with a given keyword.

Even more extensive than the `lookfor` function is the find feature in the Current Directory browser. It looks for all occurrences of a specified word in all the M-files in the current directory. For instructions, see the topic “Finding Files and Content Within Files” in the MATLAB Desktop Tools and Development Environment documentation.

See Also `dir`, `doc`, `filebrowser`, `findstr`, `help`, `helpdesk`, `helpwin`, `regexp`, `what`, `which`, `who`

Purpose Convert string to lowercase

Syntax

```
t = lower('str')
B = lower(A)
```

Description `t = lower('str')` returns the string formed by converting any uppercase characters in `str` to the corresponding lowercase characters and leaving all other characters unchanged.

`B = lower(A)` when `A` is a cell array of strings, returns a cell array the same size as `A` containing the result of applying `lower` to each string within `A`.

Examples `lower('MathWorks')` is `mathworks`.

Remarks Character sets supported:

- PC: Windows Latin-1
- Other: ISO Latin-1 (ISO 8859-1)

See Also `upper`

Purpose Directory contents on UNIX system

Syntax

```
ls
```

Description `ls` displays the results of the `ls` command on UNIX. On UNIX, `ls` returns a character row vector of filenames separated by tab and space characters. On Windows, `ls` returns an `m`-by-`n` character array of filenames, where `m` is the number of filenames and `n` is the number of characters in the longest filename found. Filenames shorter than `n` characters are padded with space characters.

On UNIX, you can pass any flags to `ls` that your operating system supports.

See Also `dir`

Purpose

Least-squares solution in presence of known covariance

Syntax

```
x = lscov(A,b)
x = lscov(A,b,w)
x = lscov(A,b,V)
x = lscov(A,b,V,alg)
[x,stdx] = lscov(...)
[x,stdx,mse] = lscov(...)
[x,stdx,mse,S] = lscov(...)
```

Description

`x = lscov(A,b)` returns the ordinary least squares solution to the linear system of equations `A*x = b`, i.e., `x` is the n-by-1 vector that minimizes the sum of squared errors `(b - A*x)'*(b - A*x)`, where `A` is m-by-n, and `b` is m-by-1. `b` can also be an m-by-k matrix, and `lscov` returns one solution for each column of `b`. When `rank(A) < n`, `lscov` sets the maximum possible number of elements of `x` to zero to obtain a "basic solution".

`x = lscov(A,b,w)`, where `w` is a vector length m of real positive weights, returns the weighted least squares solution to the linear system `A*x = b`, that is, `x` minimizes `(b - A*x)'*diag(w)*(b - A*x)`. `w` typically contains either counts or inverse variances.

`x = lscov(A,b,V)`, where `V` is an m-by-m real symmetric positive definite matrix, returns the generalized least squares solution to the linear system `A*x = b` with covariance matrix proportional to `V`, that is, `x` minimizes `(b - A*x)'*inv(V)*(b - A*x)`.

More generally, `V` can be positive semidefinite, and `lscov` returns `x` that minimizes `e'*e`, subject to `A*x + T*e = b`, where the minimization is over `x` and `e`, and `T*T' = V`. When `V` is semidefinite, this problem has a solution only if `b` is consistent with `A` and `V` (that is, `b` is in the column space of `[A T]`), otherwise `lscov` returns an error.

By default, `lscov` computes the Cholesky decomposition of `V` and, in effect, inverts that factor to transform the problem into ordinary least squares. However, if `lscov` determines that `V` is semidefinite, it uses an orthogonal decomposition algorithm that avoids inverting `V`.

`x = lscov(A,b,V,alg)` specifies the algorithm used to compute `x` when `V` is a matrix. `alg` can have the following values:

- `'chol'` uses the Cholesky decomposition of `V`.
- `'orth'` uses orthogonal decompositions, and is more appropriate when `V` is ill-conditioned or singular, but is computationally more expensive.

`[x,stdx] = lscov(...)` returns the estimated standard errors of `x`. When `A` is rank deficient, `stdx` contains zeros in the elements corresponding to the necessarily zero elements of `x`.

`[x,stdx,mse] = lscov(...)` returns the mean squared error.

`[x,stdx,mse,S] = lscov(...)` returns the estimated covariance matrix of `x`. When `A` is rank deficient, `S` contains zeros in the rows and columns corresponding to the necessarily zero elements of `x`. `lscov` cannot return `S` if it is called with multiple right-hand sides, that is, if `size(B,2) > 1`.

The standard formulas for these quantities, when `A` and `V` are full rank, are

- `x = inv(A'*inv(V)*A)*A'*inv(V)*B`
- `mse = B'*(inv(V) - inv(V)*A*inv(A'*inv(V)*A)*A'*inv(V))*B./(m-n)`
- `S = inv(A'*inv(V)*A)*mse`
- `stdx = sqrt(diag(S))`

However, `lscov` uses methods that are faster and more stable, and are applicable to rank deficient cases.

`lscov` assumes that the covariance matrix of `B` is known only up to a scale factor. `mse` is an estimate of that unknown scale factor, and `lscov` scales the outputs `S` and `stdx` appropriately. However, if `V` is known to be exactly the covariance matrix of `B`, then that scaling is unnecessary.

To get the appropriate estimates in this case, you should rescale S and stdx by 1/mse and sqrt(1/mse), respectively.

Algorithm

The vector x minimizes the quantity (A*x-b)'*inv(V)*(A*x-b). The classical linear algebra solution to this problem is

```
x = inv(A'*inv(V)*A)*A'*inv(V)*b
```

but the lscov function instead computes the QR decomposition of A and then modifies Q by V.

Examples

Example 1 — Computing Ordinary Least Squares

The MATLAB backslash operator (\) enables you to perform linear regression by computing ordinary least-squares (OLS) estimates of the regression coefficients. You can also use lscov to compute the same OLS estimates. By using lscov, you can also compute estimates of the standard errors for those coefficients, and an estimate of the standard deviation of the regression error term:

```
x1 = [.2 .5 .6 .8 1.0 1.1]';
x2 = [.1 .3 .4 .9 1.1 1.4]';
X = [ones(size(x1)) x1 x2];
y = [.17 .26 .28 .23 .27 .34]';

a = X\y
a =
    0.1203
    0.3284
   -0.1312

[b,se_b,mse] = lscov(X,y)
b =
    0.1203
    0.3284
   -0.1312
se_b =
    0.0643
```

```
    0.2267
    0.1488
mse =
    0.0015
```

Example 2 — Computing Weighted Least Squares

Use `lscov` to compute a weighted least-squares (WLS) fit by providing a vector of relative observation weights. For example, you might want to downweight the influence of an unreliable observation on the fit:

```
w = [1 1 1 1 1 .1]';

[bw,sew_b,msew] = lscov(X,y,w)
bw =
    0.1046
    0.4614
   -0.2621
sew_b =
    0.0309
    0.1152
    0.0814
msew =
  3.4741e-004
```

Example 3 — Computing General Least Squares

Use `lscov` to compute a general least-squares (GLS) fit by providing an observation covariance matrix. For example, your data may not be independent:

```
V = .2*ones(length(x1)) + .8*diag(ones(size(x1)));

[bg,sew_b,mseg] = lscov(X,y,V)
bg =
    0.1203
    0.3284
   -0.1312
sew_b =
```

```
    0.0672
    0.2267
    0.1488
mseg =
    0.0019
```

Example 4 — Estimating the Coefficient Covariance Matrix

Compute an estimate of the coefficient covariance matrix for either OLS, WLS, or GLS fits. The coefficient standard errors are equal to the square roots of the values on the diagonal of this covariance matrix:

```
[b,se_b,mse,S] = lscov(X,y);

S
S =
    0.0041   -0.0130    0.0075
   -0.0130    0.0514   -0.0328
    0.0075   -0.0328    0.0221

[se_b sqrt(diag(S))]
ans =
    0.0643    0.0643
    0.2267    0.2267
    0.1488    0.1488
```

See Also

`lsqnonneg`, `qr`

The arithmetic operator `\`

Reference

[1] Strang, G., *Introduction to Applied Mathematics*, Wellesley-Cambridge, 1986, p. 398.

Purpose Solve nonnegative least-squares constraints problem

Syntax

```
x = lsqnonneg(C,d)
x = lsqnonneg(C,d,x0)
x = lsqnonneg(C,d,x0,options)
[x,resnorm] = lsqnonneg(...)
[x,resnorm,residual] = lsqnonneg(...)
[x,resnorm,residual,exitflag] = lsqnonneg(...)
[x,resnorm,residual,exitflag,output] = lsqnonneg(...)
[x,resnorm,residual,exitflag,output,lambda] = lsqnonneg(...)
```

Description

`x = lsqnonneg(C,d)` returns the vector `x` that minimizes `norm(C*x-d)` subject to `x >= 0`. `C` and `d` must be real.

`x = lsqnonneg(C,d,x0)` uses `x0` as the starting point if all `x0 >= 0`; otherwise, the default is used. The default start point is the origin (the default is used when `x0==[ ]` or when only two input arguments are provided).

`x = lsqnonneg(C,d,x0,options)` minimizes with the optimization parameters specified in the structure `options`. You can define these parameters using the `optimset` function. `lsqnonneg` uses these `options` structure fields:

`Display`	Level of display. `'off'` displays no output; `'final'` displays just the final output; `'notify'` (default) displays output only if the function does not converge.
`TolX`	Termination tolerance on `x`.
`OutputFcn`	User-defined function that is called at each iteration. See “Output Function” in the Optimization Toolbox for more information.
`PlotFcns`	User-defined plot function that is called at each iteration. See “Plot Functions” in the Optimization Toolbox for more information.

`[x,resnorm] = lsqnonneg(...)` returns the value of the squared 2-norm of the residual: `norm(C*x-d)^2`.

`[x,resnorm,residual] = lsqnonneg(...)` returns the residual, `d-C*x`.

`[x,resnorm,residual,exitflag] = lsqnonneg(...)` returns a value `exitflag` that describes the exit condition of `lsqnonneg`:

>0	Indicates that the function converged to a solution `x`.
0	Indicates that the iteration count was exceeded. Increasing the tolerance (`TolX` parameter in `options`) may lead to a solution.

`[x,resnorm,residual,exitflag,output] = lsqnonneg(...)` returns a structure `output` that contains information about the operation:

`output.algorithm`	The algorithm used
`output.iterations`	The number of iterations taken

`[x,resnorm,residual,exitflag,output,lambda] = lsqnonneg(...)` returns the dual vector (Lagrange multipliers) `lambda`, where `lambda(i)<=0` when `x(i)` is (approximately) `0`, and `lambda(i)` is (approximately) `0` when `x(i)>0`.

Examples

Compare the unconstrained least squares solution to the `lsqnonneg` solution for a 4-by-2 problem:

```
C = [
    0.0372    0.2869
    0.6861    0.7071
    0.6233    0.6245
    0.6344    0.6170];
d = [
    0.8587
    0.1781
    0.0747
```

```
    0.8405];
[C\d lsqnonneg(C,d)] =
    -2.5627         0
     3.1108    0.6929
[norm(C*(C\d)-d) norm(C*lsqnonneg(C,d)-d)] =
     0.6674 0.9118
```

The solution from `lsqnonneg` does not fit as well (has a larger residual), as the least squares solution. However, the nonnegative least squares solution has no negative components.

Algorithm

`lsqnonneg` uses the algorithm described in [1]. The algorithm starts with a set of possible basis vectors and computes the associated dual vector `lambda`. It then selects the basis vector corresponding to the maximum value in `lambda` in order to swap out of the basis in exchange for another possible candidate. This continues until `lambda <= 0`.

See Also

The arithmetic operator `\`, `optimset`

References

[1] Lawson, C.L. and R.J. Hanson, *Solving Least Squares Problems*, Prentice-Hall, 1974, Chapter 23, p. 161.

Purpose

LSQR method

Syntax

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

Description

`x = lsqr(A,b)` attempts to solve the system of linear equations `A*x=b` for `x` if `A` is consistent, otherwise it attempts to solve the least squares solution `x` that minimizes `norm(b-A*x)`. The `m`-by-`n` coefficient matrix `A` need not be square but it should be large and sparse. The column vector `b` must have length `m`. `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.

"Parameterizing Functions Called by Function 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 `lsqr` converges, a message to that effect is displayed. If `lsqr` fails to converge after the maximum number of iterations or halts for any reason, a warning message is printed displaying the relative residual `norm(b-A*x)/norm(b)` and the iteration number at which the method stopped or failed.

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

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

lsqr(A,b,tol,maxit,M) and lsqr(A,b,tol,maxit,M1,M2) use n-by-n preconditioner M or M = M1*M2 and effectively solve the system A*inv(M)*y = b for y, where y = M*x. If M is [] then lsqr applies no preconditioner. M can be a function mfun such that mfun(x,'notransp') returns M\x and mfun(x,'transp') returns M'\x.

lsqr(A,b,tol,maxit,M1,M2,x0) specifies the n-by-1 initial guess. If x0 is [], then lsqr uses the default, an all zero vector.

[x,flag] = lsqr(A,b,tol,maxit,M1,M2,x0) also returns a convergence flag.

Flag	Convergence
0	lsqr converged to the desired tolerance tol within maxit iterations.
1	lsqr iterated maxit times but did not converge.
2	Preconditioner M was ill-conditioned.
3	lsqr stagnated. (Two consecutive iterates were the same.)
4	One of the scalar quantities calculated during lsqr 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 you specify the flag output.

[x,flag,relres] = lsqr(A,b,tol,maxit,M1,M2,x0) also returns an estimate of the relative residual norm(b-A*x)/norm(b). If flag is 0, relres <= tol.

[x,flag,relres,iter] = lsqr(A,b,tol,maxit,M1,M2,x0) also returns the iteration number at which x was computed, where 0 <= iter <= maxit.

`[x,flag,relres,iter,resvec] = lsqr(A,b,tol,maxit,M1,M2,x0)` also returns a vector of the residual norm estimates at each iteration, including `norm(b-A*x0)`.

`[x,flag,relres,iter,resvec,lsvec] = lsqr(A,b,tol,maxit,M1,M2,x0)` also returns a vector of estimates of the scaled normal equations residual at each iteration: `norm((A*inv(M))'*(B-A*X))/norm(A*inv(M),'fro')`. Note that the estimate of `norm(A*inv(M),'fro')` changes, and hopefully improves, at each iteration.

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 = lsqr(A,b,tol,maxit,M1,M2);
```

displays the following message:

```
lsqr converged at iteration 11 to a solution with relative
residual 3.5e-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_lsqr` that

- Calls `lsqr` with the function handle `@afun` as its first argument.
- Contains `afun` as a nested function, so that all variables in `run_lsqr` are available to `afun`.

The following shows the code for run_lsqr:

```
function x1 = run_lsqr
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 = lsqr(@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
```

When you enter

```
x1=run_lsqr;
```

MATLAB displays the message

```
lsqr converged at iteration 11 to a solution with relative
residual 3.5e-009
```

See Also

bicg, bicgstab, cgs, gmres, minres, norm, pcg, qmr, symmlq, function_handle (@)

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, "LSQR: An Algorithm for Sparse Linear Equations And Sparse Least Squares," *ACM Trans. Math. Soft.*, Vol.8, 1982, pp. 43-71.

Purpose

Test for less than

Syntax

```
A < B
lt(A, B)
```

Description

`A < B` compares each element of array `A` with the corresponding element of array `B`, and returns an array with elements set to logical 1 (`true`) where `A` is less than `B`, or set to logical 0 (`false`) where `A` is greater than or equal to `B`. Each input of the expression can be an array or a scalar value.

If both `A` and `B` are scalar (i.e., 1-by-1 matrices), then MATLAB returns a scalar value.

If both `A` and `B` are nonscalar arrays, then these arrays must have the same dimensions, and MATLAB returns an array of the same dimensions as `A` and `B`.

If one input is scalar and the other a nonscalar array, then the scalar input is treated as if it were an array having the same dimensions as the nonscalar input array. In other words, if input `A` is the number 100, and `B` is a 3-by-5 matrix, then `A` is treated as if it were a 3-by-5 matrix of elements, each set to 100. MATLAB returns an array of the same dimensions as the nonscalar input array.

`lt(A, B)` is called for the syntax `A < B` when either `A` or `B` is an object.

Examples

Create two 6-by-6 matrices, `A` and `B`, and locate those elements of `A` that are less than the corresponding elements of `B`:

```
A = magic(6);
B = repmat(3*magic(3), 2, 2);

A < B
ans =
     0     1     1     0     0     0
     1     0     1     0     0     0
     0     1     1     0     0     0
     1     0     0     1     0     1
```

```
     0     1     0     0     1     1
     1     0     0     0     1     0
```

See Also `gt`, `le`, `ge`, `ne`, `eq`, "Relational Operators" in the MATLAB Programming documentation

Purpose LU matrix factorization

Syntax

```
Y = lu(A)
[L,U] = lu(A)
[L,U,P] = lu(A)
[L,U,P,Q] = lu(A)
[L,U,P,Q,R] = lu(A)
[...] = lu(A,'vector')
[...] = lu(A,thresh)
[...] = lu(A,thresh,'vector')
```

Description

The `lu` function expresses a matrix `A` as the product of two essentially triangular matrices, one of them a permutation of a lower triangular matrix and the other an upper triangular matrix. The factorization is often called the *LU*, or sometimes the *LR*, factorization. `A` can be rectangular. For a full matrix `A`, `lu` uses the Linear Algebra Package (LAPACK) routines described in "Algorithm" on page 2-2014.

`Y = lu(A)` returns matrix `Y` that, for sparse `A`, contains the strictly lower triangular `L`, i.e., without its unit diagonal, and the upper triangular `U` as submatrices. That is, if `[L,U,P] = lu(A)`, then `Y = U+L-eye(size(A))`. For nonsparse `A`, `Y` is the output from the LAPACK `dgetrf` or `zgetrf` routine. The permutation matrix `P` is not returned.

`[L,U] = lu(A)` returns an upper triangular matrix in `U` and a permuted lower triangular matrix in `L` such that `A = L*U`. Return value `L` is a product of lower triangular and permutation matrices.

`[L,U,P] = lu(A)` returns an upper triangular matrix in `U`, a lower triangular matrix `L` with a unit diagonal, and a permutation matrix `P`, such that `L*U = P*A`. The statement `lu(A,'matrix')` returns identical output values.

`[L,U,P,Q] = lu(A)` for sparse nonempty `A`, returns a unit lower triangular matrix `L`, an upper triangular matrix `U`, a row permutation matrix `P`, and a column reordering matrix `Q`, so that `P*A*Q = L*U`. This syntax uses UMFPACK and is significantly more time and memory efficient than the other syntaxes, even when used with `colamd`. If `A` is empty or not sparse, lu displays an error message. The statement lu(A,'matrix') returns identical output values.

[L,U,P,Q,R] = lu(A) returns unit lower triangular matrix L, upper triangular matrix U, permutation matrices P and Q, and a diagonal scaling matrix R so that P*(R\A)*Q = L*U for sparse non-empty A. This uses UMFPACK as well. Typically, but not always, the row-scaling leads to a sparser and more stable factorization. Note that this factorization is the same as that used by sparse mldivide when UMFPACK is used. The statement lu(A,'matrix') returns identical output values.

[...] = lu(A,'vector') returns the permutation information in two row vectors p and q. You can specify from 1 to 5 outputs. Output p is defined as A(p,:)=L*U, output q is defined as A(p,q)=L*U, and output R is defined as R(:,p)\A(:,q)=L*U.

[...] = lu(A,thresh) controls pivoting in UMFPACK. This syntax applies to sparse matrices only. The thresh input is a one- or two-element vector of type single or double that defaults to [0.1, 0.001]. If A is a square matrix with a mostly symmetric structure and mostly nonzero diagonal, UMFPACK uses a symmetric pivoting strategy. For this strategy, the diagonal where

```
A(i,j) >= thresh(2) * max(abs(A(j:m,j)))
```

is selected. If the diagonal entry fails this test, a pivot entry below the diagonal is selected, using thresh(1). In this case, L has entries with absolute value 1/min(thresh) or less.

If A is not as described above, UMFPACK uses an asymmetric strategy. In this case, the sparsest row i where

```
A(i,j) >= thresh(1) * max(abs(A(j:m,j)))
```

is selected. A value of 1.0 results in conventional partial pivoting. Entries in L have an absolute value of 1/thresh(1) or less. The second element of the thresh input vector is not used when UMFPACK uses an asymmetric strategy.

Smaller values of `thresh(1)` and `thresh(2)` tend to lead to sparser LU factors, but the solution can become inaccurate. Larger values can lead to a more accurate solution (but not always), and usually an increase in the total work and memory usage. The statement `lu(A,thresh,'matrix')` returns identical output values.

`[...] = lu(A,thresh,'vector')` controls the pivoting strategy and also returns the permutation information in row vectors, as described above. The `thresh` input must precede `'vector'` in the input argument list.

Note In rare instances, incorrect factorization results in `P*A*Q` ≠ `L*U`. Increase `thresh`, to a maximum of `1.0` (regular partial pivoting), and try again.

Remarks

Most of the algorithms for computing LU factorization are variants of Gaussian elimination. The factorization is a key step in obtaining the inverse with `inv` and the determinant with `det`. It is also the basis for the linear equation solution or matrix division obtained with `\` and `/`.

Arguments

`A`	Rectangular matrix to be factored.
`thresh`	Pivot threshold for sparse matrices. Valid values are in the interval `[0,1]`. If you specify the fourth output `Q`, the default is `0.1`. Otherwise, the default is `1.0`.
`L`	Factor of `A`. Depending on the form of the function, `L` is either a unit lower triangular matrix, or else the product of a unit lower triangular matrix with `P'`.
`U`	Upper triangular matrix that is a factor of `A`.
`P`	Row permutation matrix satisfying the equation `L*U = P*A`, or `L*U = P*A*Q`. Used for numerical stability.

Q	Column permutation matrix satisfying the equation `P*A*Q = L*U`. Used to reduce fill-in in the sparse case.
R	Row-scaling matrix

Examples

Example 1

Start with

```
A = [ 1    2    3
      4    5    6
      7    8    0 ];
```

To see the LU factorization, call `lu` with two output arguments.

```
[L1,U] = lu(A)

L1 =
    0.1429    1.0000         0
    0.5714    0.5000    1.0000
    1.0000         0         0

U =
    7.0000    8.0000         0
         0    0.8571    3.0000
         0         0    4.5000
```

Notice that `L1` is a permutation of a lower triangular matrix: if you switch rows 2 and 3, and then switch rows 1 and 2, the resulting matrix is lower triangular and has `1`s on the diagonal. Notice also that `U` is upper triangular. To check that the factorization does its job, compute the product

```
L1*U
```

which returns the original `A`. The inverse of the example matrix, `X = inv(A)`, is actually computed from the inverses of the triangular factors

```
X = inv(U)*inv(L1)
```

Using three arguments on the left side to get the permutation matrix as well,

```
[L2,U,P] = lu(A)
```

returns a truly lower triangular L2, the same value of U, and the permutation matrix P.

```
L2 =

    1.0000         0         0
    0.1429    1.0000         0
    0.5714    0.5000    1.0000

U =
    7.0000    8.0000         0
         0    0.8571    3.0000
         0         0    4.5000

P =
    0    0    1
    1    0    0
    0    1    0
```

Note that L2 = P*L1.

```
P*L1

ans =

    1.0000         0         0
    0.1429    1.0000         0
    0.5714    0.5000    1.0000
```

To verify that L2*U is a permuted version of A, compute L2*U and subtract it from P*A:

```
P*A - L2*U

ans =
     0     0     0
     0     0     0
     0     0     0
```

In this case, `inv(U)*inv(L)` results in the permutation of `inv(A)` given by `inv(P)*inv(A)`.

The determinant of the example matrix is

```
d = det(A)

d =    27
```

It is computed from the determinants of the triangular factors

```
d = det(L)*det(U)
```

The solution to $Ax = b$ is obtained with matrix division

```
x = A\b
```

The solution is actually computed by solving two triangular systems

```
y = L\b
x = U\y
```

Example 2

The 1-norm of their difference is within roundoff error, indicating that `L*U = P*B*Q`.

Generate a 60-by-60 sparse adjacency matrix of the connectivity graph of the Buckminster-Fuller geodesic dome.

```
B = bucky;
```

Use the sparse matrix syntax with four outputs to get the row and column permutation matrices.

```
[L,U,P,Q] = lu(B);
```

Apply the permutation matrices to B, and subtract the product of the lower and upper triangular matrices.

```
Z = P*B*Q - L*U;
norm(Z,1)

ans =
  7.9936e-015
```

Example 3

This example illustrates the benefits of using the 'vector' option. Note how much memory is saved by using the lu(F,'vector') syntax.

```
rand('state',0);
F = rand(1000,1000);
g = sum(F,2);
[L,U,P] = lu(F);
[L,U,p] = lu(F,'vector');
whos P p

Name           Size              Bytes  Class      Attributes
P            1000x1000         8000000  double
p               1x1000            8000  double
```

The following two statements are equivalent. The first typically requires less time:

```
x = U\(L\(g(p,:)));
y = U\(L\(P*g));
```

Algorithm

For full matrices X, lu uses the LAPACK routines listed in the following table.

	Real	Complex
X double	DGETRF	ZGETRF
X single	SGETRF	CGETRF

For sparse X, with four outputs, lu uses UMFPACK routines. With three or fewer outputs, lu uses its own sparse matrix routines.

See Also

cond, det, inv, luinc, qr, rref

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.

[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.

Purpose Sparse incomplete LU factorization

Syntax

```
luinc(A,'0')
luinc(A,droptol)
luinc(A,options)
[L,U] = luinc(A,0)
[L,U] = luinc(A,options)
[L,U,P] = luinc(...)
```

Description

`luinc` produces a unit lower triangular matrix, an upper triangular matrix, and a permutation matrix.

`luinc(A,'0')` computes the incomplete LU factorization of level `0` of a square sparse matrix. The triangular factors have the same sparsity pattern as the permutation of the original sparse matrix `A`, and their product agrees with the permuted `A` over its sparsity pattern. `luinc(A,'0')` returns the strict lower triangular part of the factor and the upper triangular factor embedded within the same matrix. The permutation information is lost, but `nnz(luinc(A,'0')) = nnz(A)`, with the possible exception of some zeros due to cancellation.

`luinc(A,droptol)` computes the incomplete LU factorization of any sparse matrix using the drop tolerance specified by the non-negative scalar `droptol`. The result is an approximation of the complete LU factors returned by `lu(A)`. For increasingly smaller values of the drop tolerance, this approximation improves until the drop tolerance is `0`, at which time the complete LU factorization is produced, as in `lu(A)`.

As each column `j` of the triangular incomplete factors is being computed, the entries smaller in magnitude than the local drop tolerance (the product of the drop tolerance and the norm of the corresponding column of `A`)

```
droptol*norm(A(:,j))
```

are dropped from the appropriate factor.

The only exceptions to this dropping rule are the diagonal entries of the upper triangular factor, which are preserved to avoid a singular factor.

luinc(A,options) computes the factorization with up to four options. These options are specified by fields of the input structure options. The fields must be named exactly as shown in the table below. You can include any number of these fields in the structure and define them in any order. Any additional fields are ignored.

Field Name	Description
droptol	Drop tolerance of the incomplete factorization.
milu	If milu is 1, luinc produces the modified incomplete LU factorization that subtracts the dropped elements in any column from the diagonal element of the upper triangular factor. The default value is 0.
udiag	If udiag is 1, any zeros on the diagonal of the upper triangular factor are replaced by the local drop tolerance. The default is 0.
thresh	Pivot threshold between 0 (forces diagonal pivoting) and 1, the default, which always chooses the maximum magnitude entry in the column to be the pivot. thresh is described in greater detail in the lu reference page.

luinc(A,options) is the same as luinc(A,droptol) if options has droptol as its only field.

[L,U] = luinc(A,0) returns the product of permutation matrices and a unit lower triangular matrix in L and an upper triangular matrix in U. The exact sparsity patterns of L, U, and A are not comparable but the number of nonzeros is maintained with the possible exception of some zeros in L and U due to cancellation:

```
nnz(L)+nnz(U) = nnz(A)+n, where A is n-by-n.
```

The product L*U agrees with A over its sparsity pattern. (L*U).*spones(A)-A has entries of the order of eps.

`[L,U] = luinc(A,options)` returns a permutation of a unit lower triangular matrix in `L` and an upper triangular matrix in `U`. The product `L*U` is an approximation to `A`. `luinc(A,options)` returns the strict lower triangular part of the factor and the upper triangular factor embedded within the same matrix. The permutation information is lost.

`[L,U,P] = luinc(...)` returns a unit lower triangular matrix in `L`, an upper triangular matrix in `U`, and a permutation matrix in `P`.

`[L,U,P] = luinc(A,'0')` returns a unit lower triangular matrix in `L`, an upper triangular matrix in `U` and a permutation matrix in `P`. `L` has the same sparsity pattern as the lower triangle of permuted `A`

```
spones(L) = spones(tril(P*A))
```

with the possible exceptions of `1`s on the diagonal of `L` where `P*A` may be zero, and zeros in `L` due to cancellation where `P*A` may be nonzero. `U` has the same sparsity pattern as the upper triangle of `P*A`

```
spones(U) = spones(triu(P*A))
```

with the possible exceptions of zeros in `U` due to cancellation where `P*A` may be nonzero. The product `L*U` agrees within rounding error with the permuted matrix `P*A` over its sparsity pattern. `(L*U).*spones(P*A)-P*A` has entries of the order of `eps`.

`[L,U,P] = luinc(A,options)` returns a unit lower triangular matrix in `L`, an upper triangular matrix in `U`, and a permutation matrix in `P`. The nonzero entries of `U` satisfy

```
abs(U(i,j)) >= droptol*norm((A:,j)),
```

with the possible exception of the diagonal entries, which were retained despite not satisfying the criterion. The entries of `L` were tested against the local drop tolerance before being scaled by the pivot, so for nonzeros in `L`

```
abs(L(i,j)) >= droptol*norm(A(:,j))/U(j,j).
```

The product `L*U` is an approximation to the permuted `P*A`.

Remarks

These incomplete factorizations may be useful as preconditioners for solving large sparse systems of linear equations. The lower triangular factors all have `1`s along the main diagonal but a single `0` on the diagonal of the upper triangular factor makes it singular. The incomplete factorization with a drop tolerance prints a warning message if the upper triangular factor has zeros on the diagonal. Similarly, using the `udiag` option to replace a zero diagonal only gets rid of the symptoms of the problem but does not solve it. The preconditioner may not be singular, but it probably is not useful and a warning message is printed.

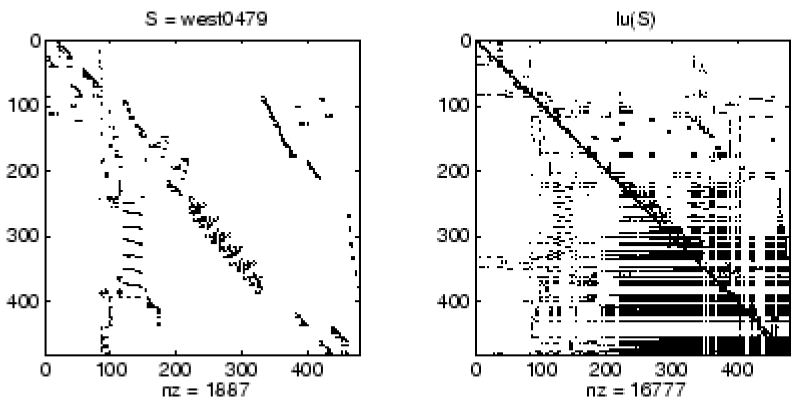
Limitations

`luinc(X,'0')` works on square matrices only.

Examples

Start with a sparse matrix and compute its LU factorization.

```
load west0479;
S = west0479;
LU = lu(S);
```

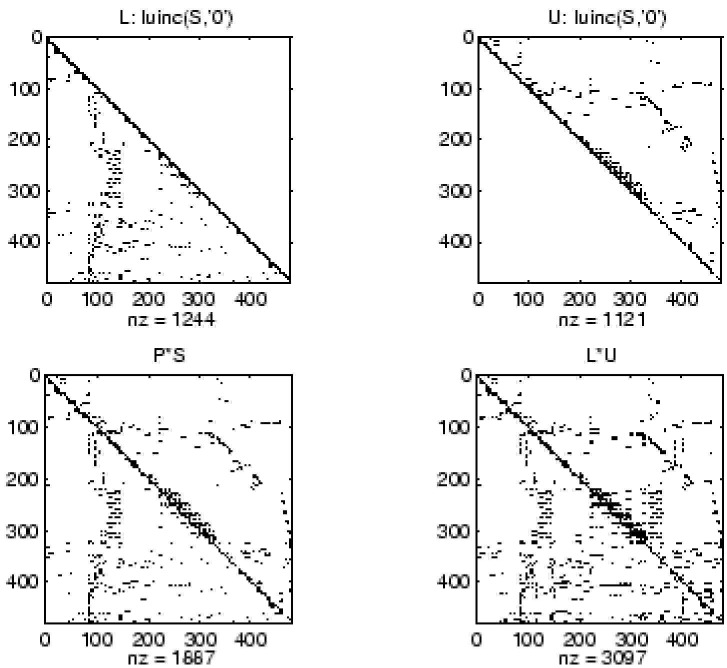


Compute the incomplete LU factorization of level 0.

```
[L,U,P] = luinc(S,'0');
D = (L*U).*spones(P*S)-P*S;
```

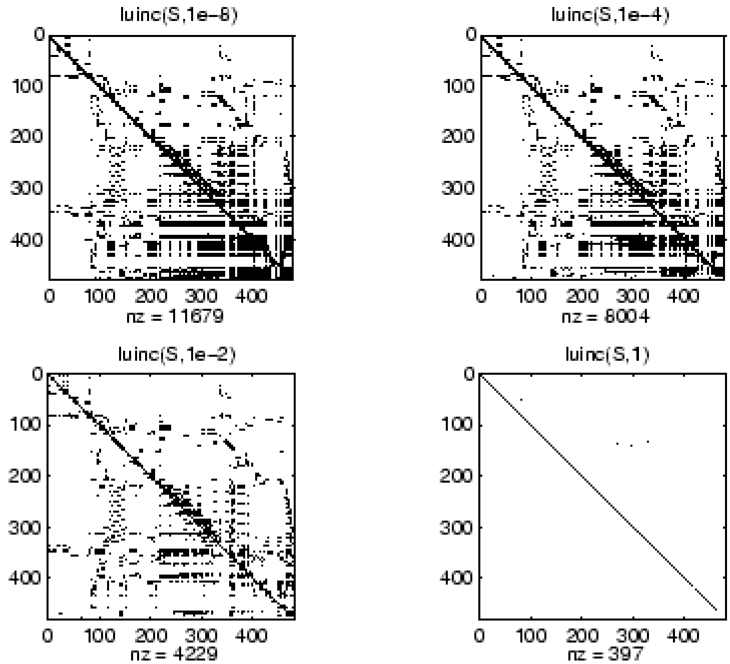
`spones(U)` and `spones(triu(P*S))` are identical.

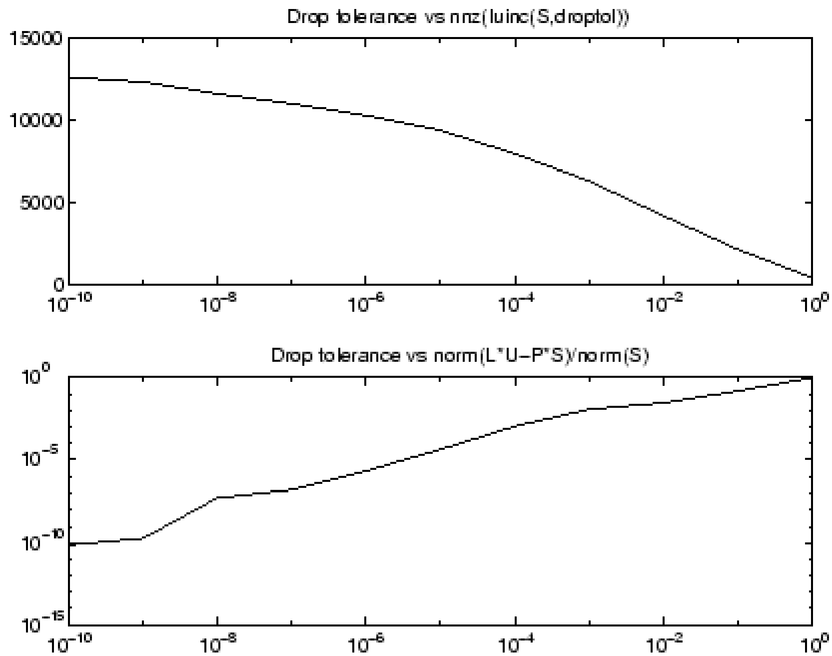
spones(L) and spones(tril(P*S)) disagree at 73 places on the diagonal, where L is 1 and P*S is 0, and also at position (206,113), where L is 0 due to cancellation, and P*S is -1. D has entries of the order of eps.




```
[IL0,IU0,IP0] = luinc(S,0);
[IL1,IU1,IP1] = luinc(S,1e-10);
                .
                .
                .
```

A drop tolerance of 0 produces the complete LU factorization. Increasing the drop tolerance increases the sparsity of the factors (decreases the number of nonzeros) but also increases the error in the factors, as seen in the plot of drop tolerance versus norm(L*U-P*S,1)/norm(S,1) in the second figure below.


luinc(S,1e-6)
nz = 11679
luinc(S,1e-4)
nz = 8004
luinc(S,1e-2)
nz = 4229
luinc(S,1)
nz = 397



Algorithm

`luinc(A,'0')` is based on the "KJI" variant of the LU factorization with partial pivoting. Updates are made only to positions which are nonzero in `A`.

`luinc(A,droptol)` and `luinc(A,options)` are based on the column-oriented `lu` for sparse matrices.

See Also

`bicg`, `cholinc`,`ilu`, `lu`

References

[1] Saad, Yousef, *Iterative Methods for Sparse Linear Systems*, PWS Publishing Company, 1996, Chapter 10 - Preconditioning Techniques.

Purpose Magic square

Syntax

```
M = magic(n)
```

Description `M = magic(n)` returns an `n`-by-`n` matrix constructed from the integers `1` through `n^2` with equal row and column sums. The order `n` must be a scalar greater than or equal to `3`.

Remarks A magic square, scaled by its magic sum, is doubly stochastic.

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 sum of the elements in each column is the same.

```
sum(M) =

    15     15     15
```

And the sum of the elements in each row, obtained by transposing twice, is the same.

```
sum(M')' =

    15
    15
    15
```

This is also a special magic square because the diagonal elements have the same sum.

```
sum(diag(M)) =

     15
```

The value of the characteristic sum for a magic square of order n is

```
sum(1:n^2)/n
```

which, when n = 3, is 15.

Algorithm

There are three different algorithms:

- n odd
- n even but not divisible by four
- n divisible by four

To make this apparent, type

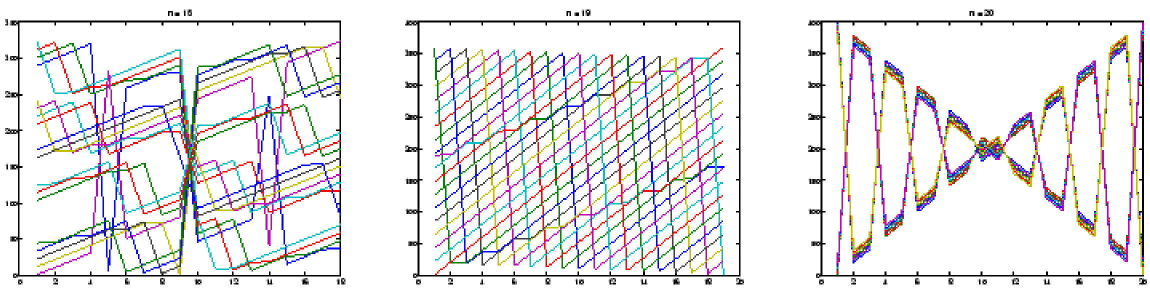
```
for n = 3:20
    A = magic(n);
    r(n) = rank(A);
end
```

For n odd, the rank of the magic square is n. For n divisible by 4, the rank is 3. For n even but not divisible by 4, the rank is n/2 + 2.

```
[(3:20)',r(3:20)']
ans =
     3     3
     4     3
     5     5
     6     5
     7     7
     8     3
     9     9
    10     7
    11    11
```

12	3
13	13
14	9
15	15
16	3
17	17
18	11
19	19
20	3

Plotting A for n = 18, 19, 20 shows the characteristic plot for each category.



Limitations

If you supply `n` less than `3`, `magic` returns either a nonmagic square, or else the degenerate magic squares `1` and `[]`.

See Also

`ones`, `rand`

makehgtform

Purpose

Create 4-by-4 transform matrix

Syntax

```
M = makehgtform
M = makehgtform('translate',[tx ty tz])
M = makehgtform('scale',s)
M = makehgtform('scale',[sx,sy,sz])
M = makehgtform('xrotate',t)
M = makehgtform('yrotate',t)
M = makehgtform('zrotate',t)
M = makehgtform('axisrotate',[ax,ay,az],t)
```

Description

Use `makehgtform` to create transform matrices for translation, scaling, and rotation of graphics objects. Apply the transform to graphics objects by assigning the transform to the `Matrix` property of a parent hgtransform object. See Examples for more information.

`M = makehgtform` returns an identity transform.

`M = makehgtform('translate',[tx ty tz])` or M = makehgtform('translate',tx,ty,tz) returns a transform that translates along the *x*-axis by `tx`, along the *y*-axis by `ty`, and along the *z*-axis by `tz`.

`M = makehgtform('scale',s)` returns a transform that scales uniformly along the *x*-, *y*-, and *z*-axes.

`M = makehgtform('scale',[sx,sy,sz])` returns a transform that scales along the *x*-axis by `sx`, along the *y*-axis by `sy`, and along the *z*-axis by `sz`.

`M = makehgtform('xrotate',t)` returns a transform that rotates around the *x*-axis by `t` radians.

`M = makehgtform('yrotate',t)` returns a transform that rotates around the *y*-axis by `t` radians.

`M = makehgtform('zrotate',t)` returns a transform that rotates around the *z*-axis by `t` radians.

`M = makehgtform('axisrotate',[ax,ay,az],t)` Rotate around axis `[ax ay az]` by `t` radians.

Note that you can specify multiple operations in one call to makehgtform and MATLAB returns a transform matrix that is the result of concatenating all specified operations. For example,

```
m = makehgtform('xrotate',pi/2,'yrotate',pi/2);
```

is the same as

```
m = makehgtform('xrotate',pi/2)*makehgtform('yrotate',pi/2);
```

See Also

hgtransform

mat2cell

Purpose Divide matrix into cell array of matrices

Syntax

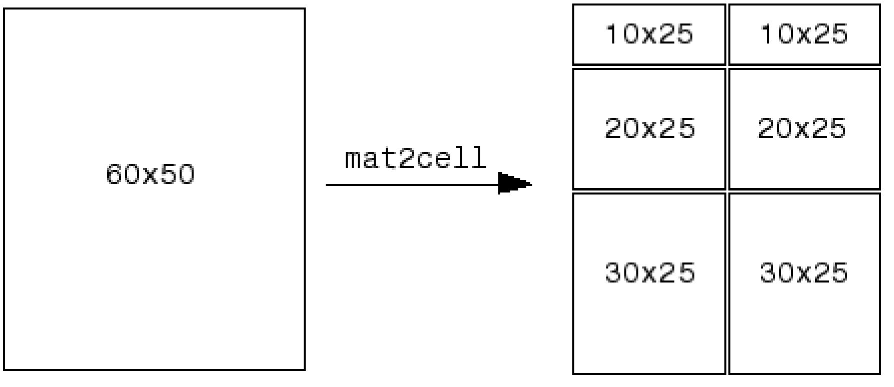
```
c = mat2cell(x, m, n)
c = mat2cell(x, d1, d2, ..., dn)
c = mat2cell(x, r)
```

Description

`c = mat2cell(x, m, n)` divides the two-dimensional matrix `x` into adjacent submatrices, each contained in a cell of the returned cell array `c`. Vectors `m` and `n` specify the number of rows and columns, respectively, to be assigned to the submatrices in `c`.

The example shown below divides a 60-by-50 matrix into six smaller matrices. MATLAB returns the new matrices in a 3-by-2 cell array:

```
mat2cell(x, [10 20 30], [25 25])
```



The sum of the element values in `m` must equal the total number of rows in `x`. And the sum of the element values in `n` must equal the number of columns in `x`.

The elements of `m` and `n` determine the size of each cell in `c` by satisfying the following formula for `i = 1:length(m)` and `j = 1:length(n)`:

```
size(c{i,j}) == [m(i) n(j)]
```

`c = mat2cell(x, d1, d2, ..., dn)` divides the multidimensional array `x` and returns a multidimensional cell array of adjacent submatrices of `x`. Each of the vector arguments `d1` through `dn` should sum to the respective dimension sizes of `x` such that, for `p = 1:n`,

```
size(x,p) == sum(dp)
```

The elements of `d1` through `dn` determine the size of each cell in `c` by satisfying the following formula for `ip = 1:length(dp)`:

```
size(c{i1,i2,...,in}) == [d1(i1) d2(i2) ... dn(in)]
```

If `x` is an empty array, `mat2cell` returns an empty cell array. This requires that all `dn` inputs that correspond to the zero dimensions of `x` be equal to `[]`.

For example,

```
a = rand(3,0,4);
c = mat2cell(a, [1 2], [], [2 1 1]);
```

`c = mat2cell(x, r)` divides an array `x` by returning a single-column cell array containing full rows of `x`. The sum of the element values in vector `r` must equal the number of rows of `x`.

The elements of `r` determine the size of each cell in `c`, subject to the following formula for `i = 1:length(r)`:

```
size(c{i},1) == r(i)
```

Remarks

`mat2cell` supports all array types.

Examples

Divide matrix `X` into 2-by-3 and 2-by-2 matrices contained in a cell array:

```
X = [1 2 3 4 5; 6 7 8 9 10; 11 12 13 14 15; 16 17 18 19 20]
X =
     1     2     3     4     5
     6     7     8     9    10
    11    12    13    14    15
```

```
    16    17    18    19    20

C = mat2cell(X, [2 2], [3 2])
C =
    [2x3 double]    [2x2 double]
    [2x3 double]    [2x2 double]

C{1,1}                          C{1,2}
ans =                           ans =
     1     2     3                   4     5
     6     7     8                   9    10

C{2,1}                          C{2,2}
ans =                           ans =
    11    12    13                  14    15
    16    17    18                  19    20
```

See Also

`cell2mat`, `num2cell`

Purpose

Convert matrix to string

Syntax

```
str = mat2str(A)
str = mat2str(A,n)
str = mat2str(A, 'class')
str = mat2str(A, n, 'class')
```

Description

`str = mat2str(A)` converts matrix `A` into a string. This string is suitable for input to the `eval` function such that `eval(str)` produces the original matrix to within 15 digits of precision.

`str = mat2str(A,n)` converts matrix `A` using `n` digits of precision.

`str = mat2str(A, 'class')` creates a string with the name of the class of `A` included. This option ensures that the result of evaluating `str` will also contain the class information.

`str = mat2str(A, n, 'class')` uses `n` digits of precision and includes the class information.

Limitations

The `mat2str` function is intended to operate on scalar, vector, or rectangular array inputs only. An error will result if `A` is a multidimensional array.

Examples

Example 1

Consider the matrix

```
x = [3.85 2.91; 7.74 8.99]
x =
    3.8500    2.9100
    7.7400    8.9900
```

The statement

```
A = mat2str(x)
```

produces

```
A =
```

```
[3.85 2.91;7.74 8.99]
```

where A is a string of 21 characters, including the square brackets, spaces, and a semicolon.

eval(mat2str(x)) reproduces x.

Example 2

Create a 1-by-6 matrix of signed 16-bit integers, and then use mat2str to convert the matrix to a 1-by-33 character array, A. Note that output string A includes the class name, int16:

```
x1 = int16([-300 407 213 418 32 -125]);

A = mat2str(x1, 'class')
A =
   int16([-300 407 213 418 32 -125])

class(A)
ans =
   char
```

Evaluating the string A gives you an output x2 that is the same as the original int16 matrix:

```
x2 = eval(A);

if isnumeric(x2) && isa(x2, 'int16') && all(x2 == x1)
   disp 'Conversion back to int16 worked'
end

Conversion back to int16 worked
```

See Also

num2str, int2str, str2num, sprintf, fprintf

Purpose

Control reflectance properties of surfaces and patches

Syntax

```
material shiny
material dull
material metal
material([ka kd ks])
material([ka kd ks n])
material([ka kd ks n sc])
material default
```

Description

`material` sets the lighting characteristics of `surface` and `patch` objects.

`material shiny` sets the reflectance properties so that the object has a high specular reflectance relative to the diffuse and ambient light, and the color of the specular light depends only on the color of the light source.

`material dull` sets the reflectance properties so that the object reflects more diffuse light and has no specular highlights, but the color of the reflected light depends only on the light source.

`material metal` sets the reflectance properties so that the object has a very high specular reflectance, very low ambient and diffuse reflectance, and the color of the reflected light depends on both the color of the light source and the color of the object.

`material([ka kd ks])` sets the ambient/diffuse/specular strength of the objects.

`material([ka kd ks n])` sets the ambient/diffuse/specular strength and specular exponent of the objects.

`material([ka kd ks n sc])` sets the ambient/diffuse/specular strength, specular exponent, and specular color reflectance of the objects.

`material default` sets the ambient/diffuse/specular strength, specular exponent, and specular color reflectance of the objects to their defaults.

Remarks

The `material` command sets the `AmbientStrength`, `DiffuseStrength`, `SpecularStrength`, `SpecularExponent`, and `SpecularColorReflectance` properties of all `surface` and `patch` objects in the axes. There must be visible `light` objects in the `axes` for lighting to be enabled. Look at the `materal.m` M-file to see the actual values set (enter the command `type material`).

See Also

`light`, `lighting`, `patch`, `surface`

Lighting as a Visualization Tool for more information on lighting

"Lighting" on page 1-100 for related functions

matlabcolon (matlab:)

Purpose

Run specified function via hyperlink

Syntax

```
disp('<a href="matlab: stmnt_1; stmnt_n;">hyperlink_text</a>')
```

Description

matlab: executes stmnt_1 through stmnt_n when you click (or press **Ctrl+Enter**) in hyperlink_text. This must be used with another function, such as disp, where disp creates and displays underlined and colored hyperlink_text in the Command Window. Use disp, error, fprintf, help, or warning functions to display the hyperlink. The hyperlink_text is interpreted as HTML—you might need to use HTML character entity references or ASCII values for some special characters. Include the full hypertext string, from '<a href= to ' within a single line, that is, do not continue a long string on a new line. No spaces are allowed after the opening < and before the closing >. A single space is required between a and href.

Remarks

The matlab: function behaves differently with diary, notebook, type, and similar functions than might be expected. For example, if you enter the following statement

```
disp('<a href="matlab:magic(4)">Generate magic square</a>')
```

the diary file, when viewed in a text editor, shows

```
disp('<a href="matlab:magic(4)">Generate magic square</a>')
<a href="matlab:magic(4)">Generate magic square</a>
```

If you view the output of diary in the Command Window, the Command Window interprets the <a href ...> statement and does display it as a hyperlink.

Examples

Single Function

The statement

```
disp('<a href="matlab:magic(4)">Generate magic square</a>')
```

displays

Generate magic square

in the Command Window. When you click the link `Generate magic square`, MATLAB runs `magic(4)`.

Multiple Functions

You can include multiple functions in the statement, such as

```
disp('<a href="matlab:  x=0:1:8;y=sin(x);plot(x,y)">Plot
x,y</a>')
```

which displays

Plot x,y

in the Command Window. When you click the link, MATLAB runs

```
x = 0:1:8;
y = sin(x);
plot(x,y)
```

Clicking the Hyperlink Again

After running the statements in the hyperlink `Plot x,y` defined in the previous example, “Multiple Functions” on page 2-2036, you can subsequently redefine `x` in the base workspace, for example, as

```
x = -2*pi:pi/16:2*pi;
```

If you then click the hyperlink, `Plot x,y`, it changes the current value of `x` back to

```
0:1:8
```

because the `matlab:` statement defines `x` in the base workspace. In the `matlab:` statement that displayed the hyperlink, `Plot x,y`, `x` was defined as 0:1:8.

Presenting Options

Use multiple matlab: statements in an M-file to present options, such as

```
disp('<a href = "matlab:state = 0">Disable feature</a>')
disp('<a href = "matlab:state = 1">Enable feature</a>')
```

The Command Window displays

Disable feature
Enable feature

and depending on which link is clicked, sets state to 0 or 1.

Special Characters

MATLAB correctly interprets most strings that includes special characters, such as a greater than sign. For example, the following statement includes a >

```
disp('<a href="matlab:str = ''Value > 0''">Positive</a>
```

and generates the following hyperlink.

Positive

Some symbols might not be interpreted correctly and you might need to use the HTML character entity reference for the symbol. For example, an alternative way to run the same statement is to use the > character entity reference instead of the > symbol:

```
disp('<a href="matlab:str = ''Value &gt; 0''">Positive</a>')
```

Instead of the HTML character entity reference, you can use the ASCII value for the symbol. For example, the greater than sign, >, is ASCII 62. The above example becomes

```
disp('<a href="matlab:str=[''Value '' char(62) '' 0'']">Positive</a>')
```

Here are some values for common special characters.

Character	HTML Character Entity Reference	ASCII Value
>	>	62
<	<	60
&	&	38
"	"	34

For a list of all HTML character entity references, see `http://www.w3.org/`.

Links from M-File Help

For functions you create, you can include `matlab:` links within the M-file help, but you do not need to include a `disp` or similar statement because the `help` function already includes it for displaying hyperlinks. Use the links to display additional help in a browser when the user clicks them. The M-file `soundspeed` contains the following statements:

```
function c=soundspeed(s,t,p)

% Speed of sound in water, using
% <a href="matlab: web('http://www.zu.edu')">Wilson's
formula</a>
% Where c is the speed of sound in water in m/s
```

etc.

Run `help soundspeed` and MATLAB displays the following in the Command Window.

```
>> help soundspeed
  Speed of sound in water, using
  Wilson's formula
  Where c is the speed of sound in water in m/s
```

When you click the link `Wilson's formula`, MATLAB displays the HTML page http://www.zu.edu in the Web browser. Note that this URL is only an example and is invalid.

See Also `disp`, `error`, `fprintf`, `input`, `run`, `warning`

Purpose

MATLAB startup M-file for single-user systems or system administrators

Description

At startup time, MATLAB automatically executes the master M-file `matlabrc.m` and, if it exists, `startup.m`. 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 MATLAB search path.

As an individual user, you can create a startup file in your own MATLAB directory. Use the startup file to define physical constants, engineering conversion factors, graphics defaults, or anything else you want predefined in your workspace.

Algorithm

Only `matlabrc` is actually invoked by MATLAB at startup. However, `matlabrc.m` contains the statements

```
if exist('startup') == 2
    startup
end
```

that invoke `startup.m`. Extend this process to create additional startup M-files, if required.

Remarks

You can also start MATLAB using options you define at the Command Window prompt or in your Windows shortcut for MATLAB.

Examples

Turning Off the Figure Window Toolbar

If you do not want the toolbar to appear in the figure window, remove the comment marks from the following line in the `matlabrc.m` file, or create a similar line in your own `startup.m` file.

```
%   set(0,'defaultfiguretoolbar','none')
```

See Also

`matlabroot`, `quit`, `restoredefaultpath`, `startup`

Startup Options in the MATLAB Desktop Tools and Development Environment documentation

matlabroot

Purpose Root directory of MATLAB installation

Syntax

```
matlabroot
rd = matlabroot
```

Description `matlabroot` returns the name of the directory in which the MATLAB software is installed. In compiled M-code, it returns the path to the executable. Use `matlabroot` to create a path to MATLAB and toolbox directories that does not depend on a specific platform, MATLAB version, or installation directory.

`rd = matlabroot` returns the name of the directory in which the MATLAB software is installed and assigns it to `rd`.

Remarks

matlabroot

Run

```
matlabroot
```

MATLAB returns, for example,

```
\\H:\Programs\matlab
```

matlabroot as Directory Name

The term *`matlabroot`* is sometimes used to represent the directory where MATLAB files are installed and should not be confused with the `matlabroot` function. For example, "save to *`matlabroot`*`/toolbox/local`" means save to the `toolbox/local` directory in the MATLAB root directory.

$matlabroot

Sometimes the term `$matlabroot` is used to represent the value returned by the `matlabroot` function.

But in some files, such as `info.xml` and `classpath.txt`, `$matlabroot`, the preceding `$` is literal. MATLAB actually interprets `$matlabroot` as the full path to the MATLAB root directory. For example, including the line

```
$matlabroot/toolbox/local/myfile.jar
```

in `classpath.txt`, adds `myfile.jar`, which is located in the `toolbox/local` directory, to `classpath.txt`.

Examples

```
fullfile(matlabroot,'toolbox','matlab','general')
```

produces a full path to the `toolbox/matlab/general` directory that is correct for the platform it is executed on.

`cd(matlabroot)` changes the current working directory to the MATLAB root directory.

`addpath([matlabroot '/toolbox/local/myfiles'])` adds the directory `myfiles` to the MATLAB search path.

See Also

`ctfroot` (in MATLAB Compiler), `fullfile`, `partialpath`, `path`, `toolboxdir`

matlab (UNIX)

Purpose

Start MATLAB (UNIX systems)

Syntax

```
matlab helpOption
matlab archOption
matlab dispOption
matlab modeOption
matlab mgrOption
matlab -c licensefile
matlab -r command
matlab -logfile filename
matlab -mwvisual visualid
matlab -nosplash
matlab -timing
matlab -debug
matlab -Ddebugger options
```

Note You can enter more than one of these options in the same MATLAB command. If you use `-Ddebugger` to start MATLAB in debug mode, the first option in the command must be `-Ddebugger`.

Description

`matlab` is a Bourne shell script that starts the MATLAB executable. (In this document, `matlab` refers to this script; MATLAB refers to the application program). Before actually initiating the execution of MATLAB, this script configures the run-time environment by

- Determining the MATLAB root directory
- Determining the host machine architecture
- Processing any command line options
- Reading the MATLAB startup file, `.matlab7rc.sh`
- Setting MATLAB environment variables

There are two ways in which you can control the way the `matlab` script works:

- By specifying command line options
- By assigning values in the MATLAB startup file, `.matlab7rc.sh`

Specifying Options at the Command Line

Options that you can enter at the command line are as follows:

`matlab helpOption` displays information that matches the specified `helpOption` argument without starting MATLAB. `helpOption` can be any one of the keywords shown in the table below. Enter only one `helpOption` keyword in a `matlab` command.

Values for helpOption

Option	Description
`-help`	Display `matlab` command usage.
`-h`	The same as **`-help`**.
`-n`	Display all the final values of the environment variables and arguments passed to the MATLAB executable as well as other diagnostic information.
`-e`	Display *all* environment variables and their values just prior to exiting. This argument must have been parsed before exiting for anything to be displayed. The last possible exiting point is just before the MATLAB image would have been executed and a status of `0` is returned. If the exit status is not `0` on return, then the variables and values may not be correct.

`matlab archOption` starts MATLAB and assumes that you are running on the system architecture specified by `arch`, or using the MATLAB version specified by `variant`, or both. The values for the `archOption` argument are shown in the table below. Enter only one of these options in a `matlab` command.

Values for archOption

Option	Description
-arch	Run MATLAB assuming this architecture rather than the actual architecture of the machine you are using. Replace the term arch with a string representing a recognized system architecture.
v=variant	Execute the version of MATLAB found in the directory bin/$ARCH/variant instead of bin/$ARCH. Replace the term variant with a string representing a MATLAB version.
v=arch/variant	Execute the version of MATLAB found in the directory bin/arch/variant instead of bin/$ARCH. Replace the terms arch and variant with strings representing a specific architecture and MATLAB version.

matlab dispOption starts MATLAB using one of the display options shown in the table below. Enter only one of these options in a matlab command.

Values for dispOption

Option	Description
-display xDisp	Send X commands to X Window Server display xDisp. This supersedes the value of the DISPLAY environment variable.
-nodisplay	Start the Java virtual machine, but do not start the MATLAB desktop. Do not display any X commands, and ignore the DISPLAY environment variable,

matlab modeOption starts MATLAB without its usual desktop component. Enter only one of the options shown below.

Values for modeOption

Option	Description
`-desktop`	Allow the MATLAB desktop to be started by a process without a controlling terminal. This is usually a required command line argument when attempting to start MATLAB from a window manager menu or desktop icon.
`-nodesktop`	Start MATLAB without its desktop. The Java virtual machine (JVM) is started. Use the current window to enter commands. Start any desktop tools using command equivalents, such as `helpbrowser` to open the Help browser. MATLAB does not save statements to the Command History.
`-nojvm`	Start MATLAB without the Java virtual machine (JVM). Use the current window to enter commands. The MATLAB desktop will not open and any tools that require Java, such as the desktop tools, cannot be used.

`matlab mgrOption` starts MATLAB in the memory management mode specified by `mgrOption`. Enter only one of the options shown below.

Values for mgrOption

Option	Description
-memmgr manager	Set environment variable MATLAB_MEM_MGR to manager. The manager argument can have one of the following values: • **cache** — The default. • **compact** — This is useful for large models or MATLAB code that uses many structure or object variables. It is not helpful for large arrays. (This option applies only to 32-bit architectures.) • **debug** — Does memory integrity checking and is useful for debugging memory problems caused by user-created MEX files.
-check_malloc	The same as using '**-memmgr debug**'.

matlab **-c** licensefile starts MATLAB using the specified license file. The licensefile argument can have the form port@host or it can be a colon-separated list of license filenames. This option causes the LM_LICENSE_FILE and MLM_LICENSE_FILE environment variables to be ignored.

matlab **-r** command starts MATLAB and executes the specified MATLAB command.

matlab **-logfile** filename starts MATLAB and makes a copy of any output to the command window in file log. This includes all crash reports.

matlab **-mwvisual** visualid starts MATLAB and uses visualid as the default X visual for figure windows. visualid is a hexadecimal number that can be found using xdpyinfo.

`matlab -nosplash` starts MATLAB but does not display the splash screen during startup.

`matlab -timing` starts MATLAB and prints a summary of startup time to the command window. This information is also recorded in a timing log, the name of which is printed to the shell window in which MATLAB is started. This option should be used only when working with a Technical Support Representative from The MathWorks, Inc.

`matlab -debug` starts MATLAB and displays debugging information that can be useful, especially for X based problems. This option should be used only when working with a Technical Support Representative from The MathWorks, Inc.

`matlab -Ddebugger options` starts MATLAB in debug mode, using the named `debugger` (e.g., `dbx`, `gdb`, `dde`, `xdb`, `cvd`). A full path can be specified for debugger.

The `options` argument can include *only* those options that follow the debugger name in the syntax of the actual debug command. For most debuggers, there is a very limited number of such options. Options that would normally be passed to the MATLAB executable should be used as parameters of a command inside the debugger (like `run`). They should not be used when running the MATLAB script.

If any other `matlab` command options are placed before the `-Ddebugger` argument, they will be handled as if they were part of the options after the `-Ddebugger` argument and will be treated as illegal options by most debuggers. The `MATLAB_DEBUG` environment variable is set to the filename part of the debugger argument.

To customize your debugging session, use a startup file. See your debugger documentation for details.

Note For certain debuggers like `gdb`, the `SHELL` environment variable is *always* set to `/bin/sh`.

Specifying Options in the MATLAB Startup File

The .matlab7rc.sh shell script contains definitions for a number of variables that the matlab script uses. These variables are defined within the matlab script, but can be redefined in .matlab7rc.sh. When invoked, matlab looks for the first occurrence of .matlab7rc.sh in the current directory, in the home directory ($HOME), and in the *matlabroot*/bin directory, where the template version of .matlab7rc.sh is located.

You can edit the template file to redefine information used by the matlab script. If you do not want your changes applied systemwide, copy the edited version of the script to your current or home directory. Ensure that you edit the section that applies to your machine architecture.

The following table lists the variables defined in the.matlab7rc.sh file. See the comments in the .matlab7rc.sh file for more information about these variables.

Variable	Definition and Standard Assignment Behavior
ARCH	The machine architecture. The value ARCH passed with the -arch or -arch/ext argument to the script is tried first, then the value of the environment variable MATLAB_ARCH is tried next, and finally it is computed. The first one that gives a valid architecture is used.
AUTOMOUNT_MAP	Path prefix map for automounting. The value set in .matlab7rc.sh (initially by the installer) is used unless the value differs from that determined by the script, in which case the value in the environment is used.

Variable	Definition and Standard Assignment Behavior
DISPLAY	The hostname of the X Window display MATLAB uses for output. The value of Xdisplay passed with the -display argument to the script is used; otherwise, the value in the environment is used. DISPLAY is ignored by MATLAB if the -nodisplay argument is passed.
LD_LIBRARY_PATH	Final Load library path. The name LD_LIBRARY_PATH is platform dependent. The final value is normally a colon-separated list of four sublists, each of which could be empty. The first sublist is defined in .matlab7rc.sh as LDPATH_PREFIX. The second sublist is computed in the script and includes directories inside the MATLAB root directory and relevant Java directories. The third sublist contains any nonempty value of LD_LIBRARY_PATH from the environment possibly augmented in .matlab7rc.sh. The final sublist is defined in .matlab7rc.sh as LDPATH_SUFFIX.

Variable	Definition and Standard Assignment Behavior
LM_LICENSE_FILE	The FLEX lm license variable. The license file value passed with the -c argument to the script is used; otherwise it is the value set in .matlab7rc.sh. In general, the final value is a colon-separated list of license files and/or port@host entries. The shipping .matlab7rc.sh file starts out the value by prepending LM_LICENSE_FILE in the environment to a default license.file. Later in the MATLAB script if the -c option is not used, the *matlabroot*/etc directory is searched for the files that start with license.dat.DEMO. These files are assumed to contain demo licenses and are added automatically to the end of the current list.
MATLAB	The MATLAB root directory. The default computed by the script is used unless MATLABdefault is reset in .matlab7rc.sh. Currently MATLABdefault is not reset in the shipping .matlab7rc.sh.
MATLAB_DEBUG	Normally set to the name of the debugger. The -Ddebugger argument passed to the script sets this variable. Otherwise, a nonempty value in the environment is used.

Variable	Definition and Standard Assignment Behavior
MATLAB_JAVA	The path to the root of the Java Runtime Environment. The default set in the script is used unless MATLAB_JAVA is already set. Any nonempty value from .matlab7rc.sh is used first, then any nonempty value from the environment. Currently there is no value set in the shipping .matlab67rc.sh, so that environment alone is used.
MATLAB_MEM_MGR	Turns on MATLAB memory integrity checking. The -check_malloc argument passed to the script sets this variable to 'debug'. Otherwise, a nonempty value set in .matlab7rc.sh is used, or a nonempty value in the environment is used. If a nonempty value is not found, the variable is not exported to the environment.
MATLABPATH	The MATLAB search path. The final value is a colon-separated list with the MATLABPATH from the environment prepended to a list of computed defaults.

Variable	Definition and Standard Assignment Behavior
SHELL	The shell to use when the "!" or unix command is issued in MATLAB. This is taken from the environment unless SHELL is reset in .matlab7rc.sh. Note that an additional environment variable called MATLAB_SHELL takes precedence over SHELL. MATLAB checks internally for MATLAB_SHELL first and, if empty or not defined, then checks SHELL. If SHELL is also empty or not defined, MATLAB uses /bin/sh. The value of MATLAB_SHELL should be an absolute path, i.e. /bin/sh, not simply sh. Currently, the shipping .matlab7rc.sh file does not reset SHELL and also does not reference or set MATLAB_SHELL.
TOOLBOX	Path of the toolbox directory. A nonempty value in the environment is used first. Otherwise, *matlabroot*/toolbox, computed by the script, is used unless TOOLBOX is reset in .matlab7rc.sh. Currently TOOLBOX is not reset in the shipping .matlab7rc.sh.

Variable	Definition and Standard Assignment Behavior
XAPPLRESDIR	The X application resource directory. A nonempty value in the environment is used first unless XAPPLRESDIR is reset in .matlab7rc.sh. Otherwise, *matlabroot*/X11/app-defaults, computed by the script, is used.
XKEYSYMDB	The X keysym database file. A nonempty value in the environment is used first unless XKEYSYMDB is reset in .matlab7rc.sh. Otherwise, *matlabroot*/X11/app-defaults/XKeysymDB, computed by the script, is used. The matlab script determines the path of the MATLAB root directory as one level up the directory tree from the location of the script. Information in the AUTOMOUNT_MAP variable is used to fix the path so that it is correct to force a mount. This can involve deleting part of the pathname from the front of the MATLAB root path. The MATLAB variable is then used to locate all files within the MATLAB directory tree.

The matlab script determines the path of the MATLAB root directory by looking up the directory tree from the *matlabroot*/bin directory (where the matlab script is located). The MATLAB variable is then used to locate all files within the MATLAB directory tree.

You can change the definition of MATLAB if, for example, you want to run a different version of MATLAB or if, for some reason, the path determined by the matlab script is not correct. (This can happen when certain types of automounting schemes are used by your system.)

AUTOMOUNT_MAP is used to modify the MATLAB root directory path. The pathname that is assigned to AUTOMOUNT_MAP is deleted from the front of the MATLAB root path. (It is unlikely that you will need to use this option.)

See Also

`mex`

"Startup Options" in the MATLAB Desktop Tools and Development Environment documentation

Purpose

Start MATLAB (Windows systems)

Syntax

```
matlab helpOption
matlab mgrOption
matlab -automation
matlab -c licensefile
matlab -logfile filename
matlab -nosplash
matlab -noFigureWindows
matlab -r "command"
matlab -regserver
matlab -sd "startdir"
matlab -timing
matlab -unregserver
```

Note You can enter more than one of these options in the same MATLAB command.

Description

`matlab` is a script that runs the main MATLAB executable. (In this document, the term `matlab` refers to the script, and MATLAB refers to the main executable). Before actually initiating the execution of MATLAB, it configures the run-time environment by

- Determining the MATLAB root directory
- Determining the host machine architecture
- Selectively processing command line options with the rest passed to MATLAB.
- Setting certain MATLAB environment variables

There are two ways in which you can control the way `matlab` works:

- By specifying command line options
- By setting environment variables before calling the program

Specifying Options at the Command Line

Options that you can enter at the command line are as follows:

`matlab` *`helpOption`* displays information that matches the specified *`helpOption`* argument without starting MATLAB. *`helpOption`* can be any one of the keywords shown in the table below. Enter only one *`helpOption`* keyword in a `matlab` command.

Values for helpOption

Option	Description
`-help`	Display `matlab` command usage.
`-h`	The same as **`-help`**.
`-?`	The same as **`-help`**.

`matlab` *`mgrOption`* starts MATLAB in the memory management mode specified by *`mgrOption`*. Enter only one of the options shown below.

Values for mgrOption

Option	Description
`-memmgr` *`manager`*	Set environment variable `MATLAB_MEM_MGR` to `manager`. The `manager` argument can have one of the following values: • **`cache`** — The default. • **`fast`** — For large models or MATLAB code that uses many structure or object variables. It is not helpful for large arrays. • **`debug`** — Does memory integrity checking and is useful for debugging memory problems caused by user-created MEX files.
`-check_malloc`	The same as using '**`-memmgr debug`**'.

`matlab` **`-automation`** starts MATLAB as an automation server. The server window is minimized, and the MATLAB splash screen is not displayed on startup.

`matlab` **`-c`** `licensefile` starts MATLAB using the specified license file. The `licensefile` argument can have the form `port@host`. This option causes the `LM_LICENSE_FILE` and `MLM_LICENSE_FILE` environment variables to be ignored.

`matlab` **`-logfile`** `filename` starts MATLAB and makes a copy of any output to the Command Window in `filename`. This includes all crash reports.

`matlab` **`-nosplash`** starts MATLAB but does not display the splash screen during startup.

`matlab` **`-noFigureWindows`** starts MATLAB but disables the display of any figure windows in MATLAB.

`matlab` **`-r`** `"command"` starts MATLAB and executes the specified MATLAB `command`. Any required M-file must be on the MATLAB path or in the startup directory.

`matlab` **`-regserver`** registers MATLAB as a Component Object Model (COM) server.

`matlab` **`-sd`** `"startdir"` specifies the startup directory for MATLAB, that is the current directory in MATLAB after startup. When you do not specify the **`-sd`** option, the startup directory is the directory from which you ran `matlab`. For more information, see "Startup Directory (Folder) on Windows Platforms".

`matlab` **`-timing`** starts MATLAB and prints a summary of startup time to the command window. This information is also recorded in a timing log, the name of which is printed to the MATLAB Command Window. This option should be used only when working with a Technical Support Representative from The MathWorks.

`matlab` **`-unregserver`** removes all MATLAB COM server entries from the registry.

Setting Environment Variables

You can set any of the following environment variables before starting MATLAB.

Variable Name	Description
`LM_LICENSE_FILE`	This is the FLEX lm license variable. The license file value passed with the **`-c`** argument to the script is used; otherwise it is the value set in the environment. The final value is a colon-separated list of license files and/or `port@host` entries.
`MATLAB_MEM_MGR`	This determines the type of memory manager used by MATLAB. If not set in the environment, it is controlled by passing its value via the '**`-memmgr`**' option. If no value is predefined, then MATLAB uses '**`cache`**'.

See Also

`mex`

"Startup Options" in the MATLAB Desktop Tools and Development Environment documentation

Purpose

Largest elements in array

Syntax

```
C = max(A)
C = max(A,B)
C = max(A,[],dim)
[C,I] = max(...)
```

Description

`C = max(A)` returns the largest elements along different dimensions of an array.

If `A` is a vector, `max(A)` returns the largest element in `A`.

If `A` is a matrix, `max(A)` treats the columns of `A` as vectors, returning a row vector containing the maximum element from each column.

If `A` is a multidimensional array, `max(A)` treats the values along the first non-singleton dimension as vectors, returning the maximum value of each vector.

`C = max(A,B)` returns an array the same size as `A` and `B` with the largest elements taken from `A` or `B`. The dimensions of `A` and `B` must match, or they may be scalar.

`C = max(A,[],dim)` returns the largest elements along the dimension of `A` specified by scalar `dim`. For example, `max(A,[],1)` produces the maximum values along the first dimension (the rows) of `A`.

`[C,I] = max(...)` finds the indices of the maximum values of `A`, and returns them in output vector `I`. If there are several identical maximum values, the index of the first one found is returned.

Remarks

For complex input `A`, `max` returns the complex number with the largest complex modulus (magnitude), computed with `max(abs(A))`. Then computes the largest phase angle with `max(angle(x))`, if necessary.

The `max` function ignores `NaN`s.

See Also

`isnan`, `mean`, `median`, `min`, `sort`

max (timeseries)

Purpose

Maximum value of `timeseries` data

Syntax

```
ts_max = max(ts)
ts_max = max(ts,'PropertyName1',PropertyValue1,...)
```

Description

`ts_max = max(ts)` returns the maximum value in the time-series data. When `ts.Data` is a vector, ts_max is the maximum value of `ts.Data` values. When `ts.Data` is a matrix, ts_max is a row vector containing the maximum value 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, `max` always operates along the first nonsingleton dimension of `ts.Data`.

`ts_max = max(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

The following example illustrates how to find the maximum values in multivariate time-series data.

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 Find the maximum in each data column for this `timeseries` object.

```
max(count_ts)

ans =

   114   145   257
```

The maximum is found independently for each data column in the `timeseries` object.

See Also

`iqr (timeseries)`, `min (timeseries)`, `median (timeseries)`, `mean (timeseries)`, `std (timeseries)`, `timeseries`, `var (timeseries)`

MaximizeCommandWindow

Purpose

Open server window on Windows desktop

Syntax

MATLAB Client

```
h.MaximizeCommandWindow
MaximizeCommandWindow(h)
invoke(h, 'MaximizeCommandWindow')
```

Method Signature

```
HRESULT MaximizeCommandWindow(void)
```

Visual Basic Client

```
MaximizeCommandWindow
```

Description

`MaximizeCommandWindow` displays the window for the server attached to handle `h`, and makes it the currently active window on the desktop. If the server window was not in a minimized state to begin with, then `MaximizeCommandWindow` does nothing.

Note `MaximizeCommandWindow` does not maximize the server window to its maximum possible size on the desktop. It restores the window to the size it had at the time it was minimized.

Remarks

Server function names, like `MaximizeCommandWindow`, 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.

Examples

Create a COM server and minimize its window. Then maximize the window and make it the currently active window.

MATLAB Client

```
h = actxserver('matlab.application');
```

```
h.MinimizeCommandWindow;
% Now return the server window to its former state on
% the desktop and make it the currently active window.
h.MaximizeCommandWindow;
```

Visual Basic.net Client

```
Dim Matlab As Object

Matlab = CreateObject("matlab.application")
Matlab.MinimizeCommandWindow

`Now return the server window to its former state on
`the desktop and make it the currently active window.

Matlab.MaximizeCommandWindow
```

See Also

MinimizeCommandWindow

Purpose Average or mean value of array

Syntax

```
M = mean(A)
M = mean(A,dim)
```

Description `M = mean(A)` returns the mean values of the elements along different dimensions of an array.

If `A` is a vector, `mean(A)` returns the mean value of `A`.

If `A` is a matrix, `mean(A)` treats the columns of `A` as vectors, returning a row vector of mean values.

If `A` is a multidimensional array, `mean(A)` treats the values along the first non-singleton dimension as vectors, returning an array of mean values.

`M = mean(A,dim)` returns the mean values for elements along the dimension of `A` specified by scalar `dim`. For matrices, `mean(A,2)` is a column vector containing the mean value of each row.

Examples

```
A = [1 2 3; 3 3 6; 4 6 8; 4 7 7];
mean(A)
ans =
    3.0000    4.5000    6.0000

mean(A,2)
ans =
    2.0000
    4.0000
    6.0000
    6.0000
```

See Also `corrcoef`, `cov`, `max`, `median`, `min`, `mode`, `std`, `var`

Purpose

Mean value of timeseries data

Syntax

```
ts_mn = mean(ts)
ts_mn = mean(ts,'PropertyName1',PropertyValue1,...)
```

Description

`ts_mn = mean(ts)` returns the mean value of `ts.Data`. When `ts.Data` is a vector, ts_mn is the mean value of `ts.Data` values. When `ts.Data` is a matrix, ts_mn is a row vector containing the mean value 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, `mean` always operates along the first nonsingleton dimension of `ts.Data`.

`ts_mn = mean(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

The following example illustrates how to find the mean values in multivariate time-series data.

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 Find the mean of each data column for this timeseries object.

```
mean(count_ts)

ans =

   32.0000   46.5417   65.5833
```

The mean is found independently for each data column in the timeseries object.

See Also

iqr (timeseries), max (timeseries), min (timeseries), median (timeseries), std (timeseries), timeseries, var (timeseries)

Purpose

Median value of array

Syntax

```
M = median(A)
M = median(A,dim)
```

Description

`M = median(A)` returns the median values of the elements along different dimensions of an array.

If `A` is a vector, `median(A)` returns the median value of `A`.

If `A` is a matrix, `median(A)` treats the columns of `A` as vectors, returning a row vector of median values.

If `A` is a multidimensional array, `median(A)` treats the values along the first nonsingleton dimension as vectors, returning an array of median values.

`M = median(A,dim)` returns the median values for elements along the dimension of `A` specified by scalar `dim`.

Examples

```
A = [1 2 4 4; 3 4 6 6; 5 6 8 8; 5 6 8 8];
median(A)

ans =

     4     5     7     7

median(A,2)

ans =

     3
     5
     7
     7
```

See Also

`corrcoef`, `cov`, `max`, `mean`, `min`, `mode`, `std`, `var`

median (timeseries)

Purpose

Median value of timeseries data

Syntax

```
ts_med = median(ts)
ts_med = median(ts,'PropertyName1',PropertyValue1,...)
```

Description

`ts_med = median(ts)` returns the median value of `ts.Data`. When `ts.Data` is a vector, ts_med is the median value of `ts.Data` values. When `ts.Data` is a matrix, ts_med is a row vector containing the median value 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, `median` always operates along the first nonsingleton dimension of `ts.Data`.

`ts_med = median(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

The following example illustrates how to find the median values in multivariate time-series data.

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 Find the median of each data column for this `timeseries` object.

```
median(count_ts)

ans =

   23.5000   36.0000   39.0000
```

The median is found independently for each data column in the `timeseries` object.

See Also

`iqr (timeseries)`, `max (timeseries)`, `min (timeseries)`, `mean (timeseries)`, `std (timeseries)`, `timeseries`, `var (timeseries)`

disp (memmapfile)

Purpose

Information about memmapfile object

Syntax

```
disp(obj)
```

Description

`disp(obj)` displays all properties and their values for `memmapfile` object `obj`.

MATLAB also displays this information when you construct a `memmapfile` object or set any of the object's property values, provided you do not terminate the command to do so with a semicolon.

Examples

Construct an object `m` of class `memmapfile`:

```
m = memmapfile('records.dat',                    ...
               'Offset', 2048,                   ...
               'Format', {                       ...
                  'int16'  [2 2] 'model';        ...
                  'uint32' [1 1] 'serialno';     ...
                  'single' [1 3] 'expenses'});
```

Use `disp` to display all the object's current properties:

```
disp(m)
    Filename: 'd:\matlab\mfiles\records.dat'
    Writable: false
      Offset: 2048
      Format: {'int16' [2 2] 'model'
               'uint32' [1 1] 'serialno'
               'single' [1 3] 'expenses'}
      Repeat: Inf
        Data: 753x1 struct array with fields:
            model
         serialno
         expenses
```

See Also

`memmapfile`, `get(memmapfile)`

get (memmapfile)

Purpose

Memmapfile object properties

Syntax

```
s = get(obj)
val = get(obj, prop)
```

Description

`s = get(obj)` returns the values of all properties of the `memmapfile` object `obj` in structure array `s`. Each property retrieved from the object is represented by a field in the output structure. The name and contents of each field are the same as the name and value of the property it represents.

Note Although property names of a `memmapfile` object are not case sensitive, field names of the output structure returned by `get` (named the same as the properties they represent) are case sensitive.

`val = get(obj, prop)` returns the value(s) of one or more properties specified by `prop`. The `prop` input can be a quoted string or a cell array of quoted strings, each containing a property name. If the latter is true, `get` returns the property values in a cell array.

Examples

You can use the `get` method of the `memmapfile` class to return information on any or all of the object's properties. Specify one or more property names to get the values of specific properties.

This example returns the values of the `Offset`, `Repeat`, and `Format` properties for a `memmapfile` object. Start by constructing the object:

```
m = memmapfile('records.dat',                  ...
               'Offset', 2048,                 ...
               'Format', {                     ...
                  'int16'  [2 2] 'model';      ...
                  'uint32' [1 1] 'serialno';   ...
                  'single' [1 3] 'expenses'});
```

Use the `get` method to return the specified property values in a 1-by-3 cell array `m_props`:

```
m_props = get(m, {'Offset', 'Repeat', 'Format'})
m_props =
    [2048]    [Inf]    {3x3 cell}

m_props{3}
ans =
    'int16'     [1x2 double]    'model'
    'uint32'    [1x2 double]    'serialno'
    'single'    [1x2 double]    'expenses'
```

Another way to return the same information is to use the `objname.property` syntax:

```
m_props = {m.Offset, m.Repeat, m.Format}
m_props =
    [2048]    [Inf]    {3x3 cell}
```

To return the values for all properties with `get`, pass just the object name:

```
s = get(m)
    Filename: 'd:\matlab\mfiles\records.dat'
    Writable: 0
      Offset: 2048
      Format: {3x3 cell}
      Repeat: Inf
        Data: [753 1]
```

To see just the `Format` field of the returned structure, type

```
s.Format
ans =
    'int16'     [1x2 double]    'model'
    'uint32'    [1x2 double]    'serialno'
    'single'    [1x2 double]    'expenses'
```

See Also

`memmapfile`, `disp(memmapfile)`

Purpose

Construct memmapfile object

Syntax

```
m = memmapfile(filename)
m = memmapfile(filename, prop1, value1, prop2, value2, ...)
```

Description

`m = memmapfile(filename)` constructs an object of the `memmapfile` class that maps file `filename` to memory using the default property values. The `filename` input is a quoted string that specifies the path and name of the file to be mapped into memory. `filename` must include a filename extension if the name of the file being mapped has an extension. The `filename` argument cannot include any wildcard characters (e.g., `*` or `?`), is case sensitive on UNIX platforms, but is not case sensitive on Windows.

`m = memmapfile(filename, prop1, value1, prop2, value2, ...)` constructs an object of the `memmapfile` class that maps file `filename` into memory and sets the properties of that object that are named in the argument list (`prop1`, `prop2`, etc.) to the given values (`value1`, `value2`, etc.). All property name arguments must be quoted strings (e.g., `'Writable'`). Any properties that are not specified are given their default values.

Optional properties are shown in the table below and are described in the sections that follow.

Property	Description	Data Type	Default
Format	Format of the contents of the mapped region, including data type, array shape, and variable or field name by which to access the data	char array or N-by-3 cell array	uint8
Offset	Number of bytes from the start of the file to the start of the mapped region. This number is zero-based. That is, offset 0 represents the start of the file.	double	0
Repeat	Number of times to apply the specified format to the mapped region of the file	double	Inf
Writable	Type of access allowed to the mapped region	logical	false

There are three different ways you can specify a value for the Format property. See the following sections in the MATLAB Programming documentation for more information on this:

- "Mapping a Single Data Type"
- "Formatting the Mapped Data to an Array"
- "Mapping Multiple Data Types and Arrays"

Any of the following data types can be used when you specify a `Format` value. The default type is `uint8`.

Format String	Data Type Description
`'int8'`	Signed 8-bit integers
`'int16'`	Signed 16-bit integers
`'int32'`	Signed 32-bit integers
`'int64'`	Signed 64-bit integers
`'uint8'`	Unsigned 8-bit integers
`'uint16'`	Unsigned 16-bit integers
`'uint32'`	Unsigned 32-bit integers
`'uint64'`	Unsigned 64-bit integers
`'single'`	32-bit floating-point
`'double'`	64-bit floating-point

Remarks

You can only map an existing file. You cannot create a new file and map that file to memory in one operation. Use the MATLAB file I/O functions to create the file before attempting to map it to memory.

Once `memmapfile` locates the file, MATLAB stores the absolute pathname for the file internally, and then uses this stored path to locate the file from that point on. This enables you to work in other directories outside your current work directory and retain access to the mapped file.

Once a `memmapfile` object has been constructed, you can change the value of any of its properties. Use the `objname.property` syntax in assigning the new value. To set a new offset value for memory map object `m`, type

```
m.Offset = 2048;
```

Property names are not case sensitive. For example, MATLAB considers `m.Offset` to be the same as `m.offset`.

Examples

Example 1

To construct a map for the file `records.dat` that resides in your current working directory, type the following:

```
m = memmapfile('records.dat');
```

MATLAB constructs an instance of the `memmapfile` class, assigns it to the variable `m`, and maps the entire `records.dat` file to memory, setting all properties of the object to their default values. In this example, the command maps the entire file as a sequence of unsigned 8-bit integers and gives the caller read-only access to its contents.

Example 2

To construct a map using nondefault values for the `Offset`, `Format`, and `Writable` properties, type the following, enclosing all property names in single quotation marks:

```
m = memmapfile('records.dat',         ...
               'Offset', 1024,        ...
               'Format', 'uint32',    ...
               'Writable', true);
```

Type the object name to see the current settings for all properties:

```
m

m =
    Filename: 'd:\matlab\mfiles\records.dat'
    Writable: true
      Offset: 1024
      Format: 'uint32'
      Repeat: Inf
        Data: 4778x1 uint32 array
```

Example 3

Construct a `memmapfile` object for the entire file `records.dat` and set the `Format` property for that object to `uint64`. Any read or write operations made via the memory map will read and write the file contents as a sequence of unsigned 64-bit integers:

```
m = memmapfile('records.dat', 'Format', 'uint64');
```

Example 4

Construct a `memmapfile` object for a region of `records.dat` such that the contents of the region are handled by MATLAB as a 4-by-10-by-18 array of unsigned 32-bit integers, and can be referenced in the structure of the returned object using the field name `x`:

```
m = memmapfile('records.dat',    ...
               'Offset', 1024,   ...
               'Format', {'uint32' [4 10 18] 'x'});

A = m.Data.x;

whos A
  Name      Size                     Bytes  Class

  A        4x10x18                   2880   uint32 array

Grand total is 720 elements using 2880 bytes
```

Example 5

Map a 24 kilobyte file containing data of three different data types: `int16`, `uint32`, and `single`. The `int16` data is mapped as a 2-by-2 matrix that can be accessed using the field name `model`. The `uint32` data is a scalar value accessed as field `serialno`. The `single` data is a 1-by-3 matrix named `expenses`.

Each of these fields belongs to the 800-by-1 structure array `m.Data`:

```
m = memmapfile('records.dat',                    ...
               'Offset', 2048,                   ...
```

```
                  'Format', {                          ...
                     'int16'  [2 2] 'model';           ...
                     'uint32' [1 1] 'serialno';        ...
                     'single' [1 3] 'expenses'});
```

Example 6

Map a file region identical to that of the previous example, except repeat the pattern of `int16`, `uint32`, and `single` data types only three times within the mapped region of the file. Allow write access to the file by setting the `Writable` property to `true`:

```
m = memmapfile('records.dat',                        ...
               'Offset', 2048,                       ...
               'Format', {                           ...
                  'int16'  [2 2] 'model';            ...
                  'uint32' [1 1] 'serialno';         ...
                  'single' [1 3] 'expenses'},        ...
               'Repeat', 3,                          ...
               'Writable', true);
```

See Also

`disp(memmapfile)`, `get(memmapfile)`

memory

Purpose Help for memory limitations

Description If the `out of memory` error message is encountered, there is no more room in memory for new variables. You must free some space before you can proceed. One way to free space is to use the `clear` function to remove some of the variables residing in memory. Another is to issue the `pack` command to compress data in memory. This opens larger contiguous blocks of memory for you to use.

Here are some additional system-specific tips:

Windows: Increase virtual memory by using System in the Control Panel.

UNIX: Ask your system manager to increase your swap space.

See Also `clear`, `pack`

The Technical Support Guide to Memory Management at
`http://www.mathworks.com/support/tech-notes/1100/1106.html`

Purpose

Generate menu of choices for user input

Syntax

```
k = menu('mtitle','opt1','opt2',...,'optn')
```

Description

`k = menu('mtitle','opt1','opt2',...,'optn')` displays the menu whose title is in the string variable *'mtitle'* and whose choices are string variables *'opt1'*, *'opt2'*, and so on. `menu` returns thenumber of the selected menu item.

If the user's terminal provides a graphics capability, `menu` displays the menu items as push buttons in a figure window (Example 1), otherwise they will be given as a numbered list in the command window (Example 2).

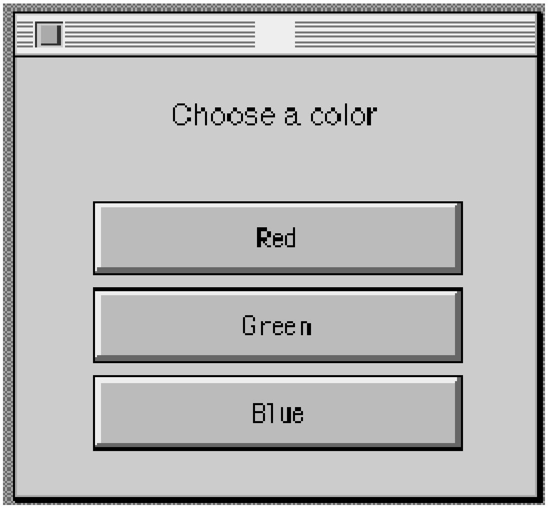
Remarks

To call `menu` from another ui object, set that object's `Interruptible` property to `'yes'`. For more information, see the MATLAB Graphics documentation.

Examples

Example 1

`k = menu('Choose a color','Red','Green','Blue')` displays



After input is accepted, use `k` to control the color of a graph.

```
color = ['r','g','b']
plot(t,s,color(k))
```

Example 2

```
K = menu('Choose a color','Red','Blue','Green')
```

displays on the Command Window

```
----- Choose a color -----
1) Red
2) Blue
3) Green
Select a menu number:
```

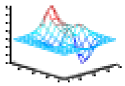
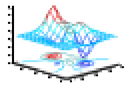
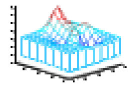
The number entered by the user in response to the prompt is returned as `K` (i.e. `K = 2` implies that the user selected `Blue`).

See Also

`guide`, `input`, `uicontrol`, `uimenu`

Purpose

Mesh 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

```
mesh(X,Y,Z)
mesh(Z)
mesh(...,C)
mesh(...,'PropertyName',PropertyValue,...)
mesh(axes_handles,...)
meshc(...)
meshz(...)
h = mesh(...)
hsurface = mesh('v6',...) hsurface = meshc('v6',...),
```

Description

`mesh`, `meshc`, and `meshz` create wireframe parametric surfaces specified by `X`, `Y`, and `Z`, with color specified by `C`.

`mesh(X,Y,Z)` draws a wireframe mesh with color determined by `Z` so color is proportional to surface height. If `X` and `Y` are vectors, `length(X) = n` and `length(Y) = m`, where `[m,n] = size(Z)`. In this case, $(X(j), Y(i), Z(i,j))$ are the intersections of the wireframe grid lines; `X` and `Y` correspond to the columns and rows of `Z`, respectively. If `X` and `Y` are matrices, $(X(i,j), Y(i,j), Z(i,j))$ are the intersections of the wireframe grid lines.

`mesh(Z)` draws a wireframe mesh using `X = 1:n` and `Y = 1:m`, where `[m,n] = size(Z)`. The height, `Z`, is a single-valued function defined over a rectangular grid. Color is proportional to surface height.

`mesh(...,C)` draws a wireframe mesh with color determined by matrix `C`. MATLAB performs a linear transformation on the data in `C` to obtain colors from the current colormap. If `X`, `Y`, and `Z` are matrices, they must be the same size as `C`.

`mesh(...,'PropertyName',PropertyValue,...)` sets the value of the specified surface property. Multiple property values can be set with a single statement.

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

`meshc(...)` draws a contour plot beneath the mesh.

`meshz(...)` draws a curtain plot (i.e., a reference plane) around the mesh.

`h = mesh(...)`, h = meshc(...), and h = meshz(...) return a handle to a surfaceplot graphics object.

Backward-Compatible Version

`hsurface = mesh('v6',...)` `hsurface = meshc('v6',...)`, and `hsurface` = meshc('v6',...) returns the handles of surface objects instead of surfaceplot objects for compatibility with MATLAB 6.5 and earlier.

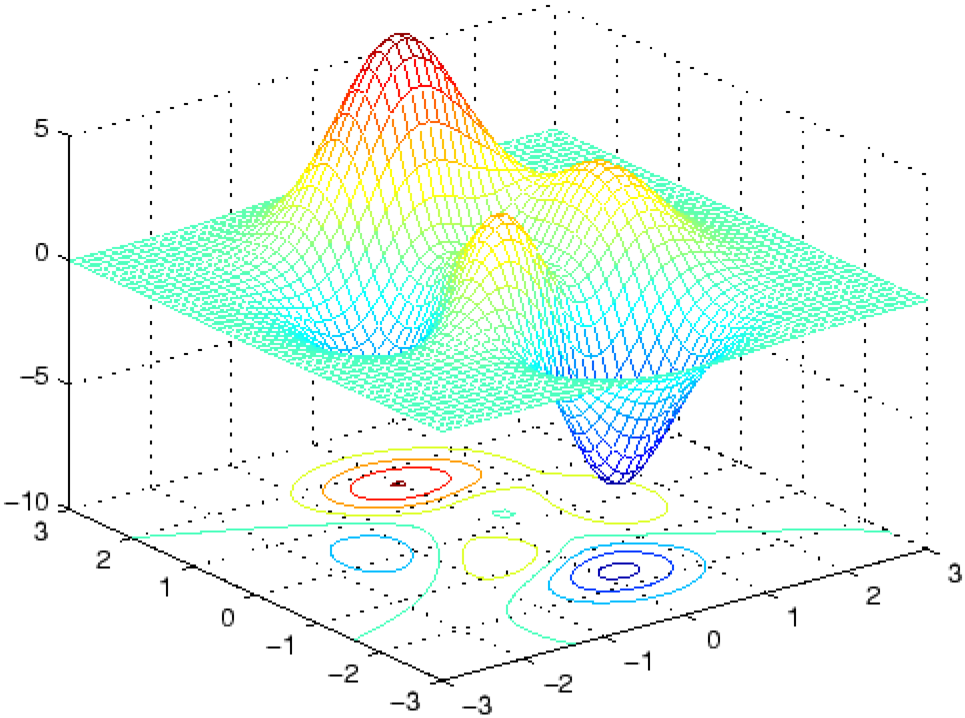
Remarks

A mesh is drawn as a surface graphics object with the viewpoint specified by `view(3)`. The face color is the same as the background color (to simulate a wireframe with hidden-surface elimination), or `none` when drawing a standard see-through wireframe. The current colormap determines the edge color. The `hidden` command controls the simulation of hidden-surface elimination in the mesh, and the `shading` command controls the shading model.

Examples

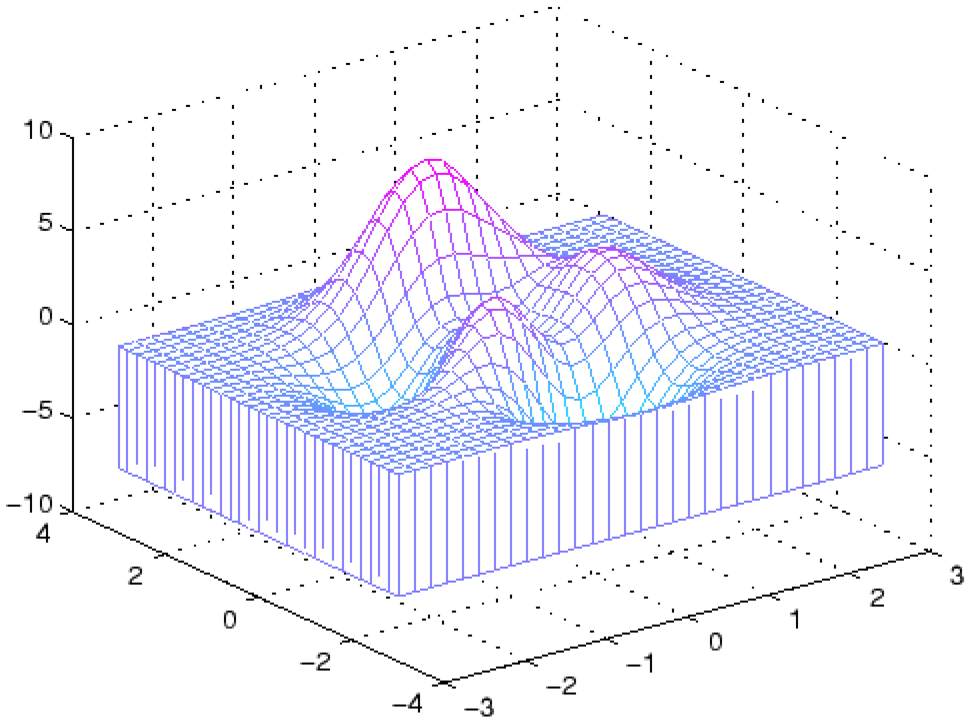
Produce a combination mesh and contour plot of the `peaks` surface:

```
[X,Y] = meshgrid(-3:.125:3);
Z = peaks(X,Y);
meshc(X,Y,Z);
axis([-3 3 -3 3 -10 5])
```



Generate the curtain plot for the peaks function:

```
[X,Y] = meshgrid(-3:.125:3);
Z = peaks(X,Y);
meshz(X,Y,Z)
```



Algorithm

The range of X, Y, and Z, or the current settings of the axes XLimMode, YLimMode, and ZLimMode properties, determine the axis limits. axis sets these properties.

The range of C, or the current settings of the axes CLim and CLimMode properties (also set by the caxis function), determine the color scaling. The scaled color values are used as indices into the current colormap.

The mesh rendering functions produce color values by mapping the *z* data values (or an explicit color array) onto the current colormap. The MATLAB default behavior is to compute the color limits automatically using the minimum and maximum data values (also set using caxis auto). The minimum data value maps to the first color value in the colormap and the maximum data value maps to the last color value in the colormap. MATLAB performs a linear transformation on the intermediate values to map them to the current colormap.

`meshc` calls `mesh`, turns `hold` on, and then calls `contour` and positions the contour on the *x-y* plane. For additional control over the appearance of the contours, you can issue these commands directly. You can combine other types of graphs in this manner, for example `surf` and `pcolor` plots.

`meshc` assumes that `X` and `Y` are monotonically increasing. If `X` or `Y` is irregularly spaced, `contour3` calculates contours using a regularly spaced contour grid, then transforms the data to `X` or `Y`.

See Also

`contour`, `hidden`, `meshgrid`, `surface`, `surf`, `surfc`, `surfl`, `waterfall`

“Creating Surfaces and Meshes” on page 1-96 for related functions

`Surfaceplot Properties` for a list of surfaceplot properties

The functions axis, `caxis`, `colormap`, `hold`, `shading`, and `view` all set graphics object properties that affect `mesh`, `meshc`, and `meshz`.

For a discussion of parametric surfaces plots, refer to `surf`.

meshgrid

Purpose

Generate X and Y arrays for 3-D plots

Syntax

```
[X,Y] = meshgrid(x,y)
[X,Y] = meshgrid(x)
[X,Y,Z] = meshgrid(x,y,z)
```

Description

`[X,Y] = meshgrid(x,y)` transforms the domain specified by vectors `x` and `y` into arrays `X` and `Y`, which can be used to evaluate functions of two variables and three-dimensional mesh/surface plots. The rows of the output array `X` are copies of the vector `x`; columns of the output array `Y` are copies of the vector `y`.

`[X,Y] = meshgrid(x)` is the same as `[X,Y] = meshgrid(x,x)`.

`[X,Y,Z] = meshgrid(x,y,z)` produces three-dimensional arrays used to evaluate functions of three variables and three-dimensional volumetric plots.

Remarks

The `meshgrid` function is similar to `ndgrid` except that the order of the first two input and output arguments is switched. That is, the statement

```
[X,Y,Z] = meshgrid(x,y,z)
```

produces the same result as

```
[Y,X,Z] = ndgrid(y,x,z)
```

Because of this, `meshgrid` is better suited to problems in two- or three-dimensional Cartesian space, while `ndgrid` is better suited to multidimensional problems that aren't spatially based.

`meshgrid` is limited to two- or three-dimensional Cartesian space.

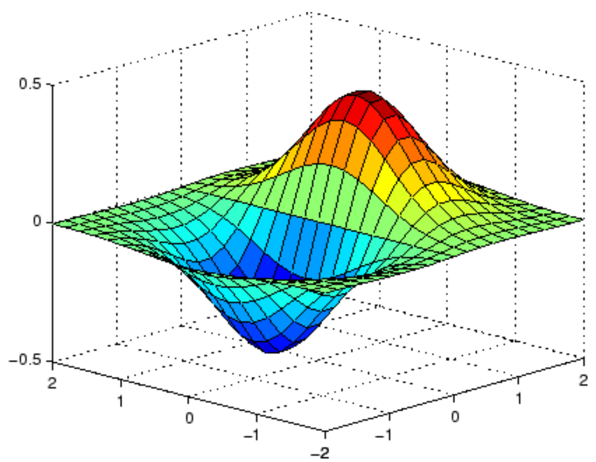
Examples

```
[X,Y] = meshgrid(1:3,10:14)

X =

     1     2     3
     1     2     3
```

```
        1     2     3
        1     2     3
        1     2     3

   Y =

       10    10    10
       11    11    11
       12    12    12
       13    13    13
       14    14    14
```

The following example shows how to use meshgrid to create a surface plot of a function.

```
   [X,Y] = meshgrid(-2:.2:2, -2:.2:2);
   Z = X .* exp(-X.^2 - Y.^2);
   surf(X,Y,Z)
```



See Also

griddata, mesh, ndgrid, slice, surf

methods

Purpose

Information on class methods

Syntax

```
m = methods('classname')
m = methods('object')
m = methods(..., '-full')
```

Description

`m = methods('classname')` returns, in a cell array of strings, the names of all methods for the MATLAB, COM, or Java class `classname`.

`m = methods('object')` returns the names of all methods for the MATLAB, COM, or Java class of which `object` is an instance.

`m = methods(..., '-full')` returns the full description of the methods defined for the class, including inheritance information and, for COM and Java methods, attributes and signatures. For any overloaded method, the returned array includes a description of each of its signatures.

For MATLAB classes, inheritance information is returned only if that class has been instantiated.

For some classes it may not be possible for MATLAB to know inherited methods until after the class has been instantiated. In these cases, `methods -full` displays only the methods defined by the class itself until after the class has been instantiated. After an instance has been created `methods -full` also shows inherited methods.

Examples

List the methods of MATLAB class `stock`:

```
m = methods('stock')
m =
    'display'
    'get'
    'set'
    'stock'
    'subsasgn'
    'subsref'
```

Create a MathWorks sample COM control and list its methods:

```
h = actxcontrol('mwsamp.mwsampctrl.1', [0 0 200 200]);
methods(h)

Methods for class com.mwsamp.mwsampctrl.1:

AboutBox          GetR8Array        SetR8             move
Beep              GetR8Vector       SetR8Array        propedit
FireClickEvent    GetVariantArray   SetR8Vector       release
GetBSTR           GetVariantVector  addproperty       save
GetBSTRArray      Redraw            delete            send
GetI4             SetBSTR           deleteproperty    set
GetI4Array        SetBSTRArray      events
GetI4Vector       SetI4             get
GetIDispatch      SetI4Array        invoke
GetR8             SetI4Vector       load
```

Display a full description of all methods on Java object `java.awt.Dimension`:

```
methods java.awt.Dimension -full

Dimension(java.awt.Dimension)
Dimension(int,int)
Dimension()
void wait() throws java.lang.InterruptedException
   % Inherited from java.lang.Object
void wait(long,int) throws java.lang.InterruptedException
   % Inherited from java.lang.Object
void wait(long) throws java.lang.InterruptedException
   % Inherited from java.lang.Object
java.lang.Class getClass()  % Inherited from java.lang.Object
            .
            .
```

See Also

`methodsview`, `invoke`, `ismethod`, `help`, `what`, `which`

methodsview

Purpose

Information on class methods in separate window

Syntax

```
methodsview packagename.classname
methodsview classname
methodsview(object)
```

Description

`methodsview packagename.classname` displays information describing the Java class `classname` that is available from the package of Java classes `packagename`.

`methodsview classname` displays information describing the MATLAB, COM, or imported Java class `classname`.

`methodsview(object)` displays information describing the `object` instantiated from a COM or Java class.

MATLAB creates a new window in response to the `methodsview` command. This window displays all the methods defined in the specified class. For each of these methods, the following additional information is supplied:

- Name of the method
- Method type qualifiers (for example, `abstract` or `synchronized`)
- Data type returned by the method
- Arguments passed to the method
- Possible exceptions thrown
- Parent of the specified class

Examples

The following command lists information on all methods in the `java.awt.MenuItem` class.

```
methodsview java.awt.MenuItem
```

MATLAB displays this information in a new window, as shown below

Methods of class java.awt.MenuItem

Qualifiers	Return Type	Name	Arguments
		MenuItem	()
		MenuItem	(java.lang.String)
		MenuItem	(java.lang.String,java.awt.MenuShortcut)
synchronized	void	addActionListener	(java.awt.event.ActionListener)
	void	addNotify	()
	void	deleteShortcut	()
synchronized	void	disable	()
	void	dispatchEvent	(java.awt.AWTEvent)
synchronized	void	enable	()
	void	enable	(boolean)
	boolean	equals	(java.lang.Object)
	java.lang.String	getActionCommand	()
	java.lang.Class	getClass	()
	java.awt.Font	getFont	()
	java.lang.String	getLabel	()
	java.lang.String	getName	()
	java.awt.MenuContainer	getParent	()
	java.awt.peer.MenuComponentPeer	getPeer	()
	java.awt.MenuShortcut	getShortcut	()
	int	hashCode	()
	boolean	isEnabled	()
	void	notify	()
	void	notifyAll	()

See Also

`methods`, `import`, `class`, `javaArray`

Purpose Compile MEX-function from C or Fortran source code

Syntax

```
mex options filenames
```

Description

`mex options filenames` compiles a MEX-function from the C, C++, or Fortran source code files specified in `filenames`. Include both file name and file extension in each `filename`. All nonsource code `filenames` passed as arguments are passed to the linker without being compiled.

All valid `options` are shown in the MEX Script Switches table. These options are available on all platforms except where noted.

MEX's execution is affected both by command-line `options` and by an options file. The options file contains all compiler-specific information necessary to create a MEX-function. The default name for this options file, if none is specified with the `-f` option, is `mexopts.bat` (Windows) and `mexopts.sh` (UNIX).

Note The MathWorks provides an option, setup, for the `mex` script that lets you set up a default options file on your system.

On UNIX, the options file is written in the Bourne shell script language. The `mex` script searches for the first occurrence of the options file called `mexopts.sh` in the following list:

- The current directory
- The user profile directory (returned by the `prefdir` function)
- The directory specified by `[matlabroot '/bin']`

`mex` uses the first occurrence of the options file it finds. If no options file is found, `mex` displays an error message. You can directly specify the name of the options file using the `-f` switch.

Any variable specified in the options file can be overridden at the command line by use of the `<name>=<def>` command-line argument. If

<def> has spaces in it, then it should be wrapped in single quotes (e.g., OPTFLAGS='opt1 opt2'). The definition can rely on other variables defined in the options file; in this case the variable referenced should have a prefixed $ (e.g., OPTFLAGS='$OPTFLAGS opt2').

On Windows, the options file is written in the Perl script language. The default options file is placed in your user profile directory after you configure your system by running mex -setup. The mex script searches for the first occurrence of the options file called mexopts.bat in the following list:

- The current directory
- The user profile directory (returned by the prefdir function)
- The directory specified by [matlabroot '\bin\win32\mexopts']

mex uses the first occurrence of the options file it finds. If no options file is found, mex searches your machine for a supported C compiler and uses the factory default options file for that compiler. If multiple compilers are found, you are prompted to select one.

No arguments can have an embedded equal sign (=); thus, -DFOO is valid, but -DFOO=BAR is not.

Remarks

mex compiles and links source files into a shared library, called a MEX-file, that is executable from within MATLAB. You can create MEX-files from a common source file on different platforms. See Using MEX-Files for file extension information.

See Also

dbmex, mexext, inmem

Purpose

MEX-filename extension

Syntax

```
ext = mexext
extlist = mexext('all')
```

Description

`ext = mexext` returns the filename extension for the current platform.

`extlist = mexext('all')` returns a struct with fields `arch` and `ext` describing MEX-file name extensions for the all platforms.

Remarks

See Using MEX-Files for a table of file extensions.

Examples

Find the MEX-file extension for the system you are currently working on:

```
ext = mexext

ext =
   mexw32
```

Find the MEX-file extension for a PowerPC Macintosh system:

```
extlist = mexext('all');

for k=1:length(extlist)
   if strcmp(extlist(k).arch, 'mac')
   disp(sprintf('Arch: %s      Ext: %s', ...
            extlist(k).arch, extlist(k).ext))
end, end

Arch: mac       Ext: mexmac
```

See Also

`mex`

Purpose

Name of currently running M-file

Syntax

```
mfilename
p = mfilename('fullpath')
c = mfilename('class')
```

Description

`mfilename` returns a string containing the name of the most recently invoked M-file. When called from within an M-file, it returns the name of that M-file, allowing an M-file to determine its name, even if the filename has been changed.

`p = mfilename('fullpath')` returns the full path and name of the M-file in which the call occurs, not including the filename extension.

`c = mfilename('class')` in a method, returns the class of the method, not including the leading `@` sign. If called from a nonmethod, it yields the empty string.

Remarks

If `mfilename` is called with any argument other than the above two, it behaves as if it were called with no argument.

When called from the command line, `mfilename` returns an empty string.

To get the names of the callers of an M-file, use `dbstack` with an output argument.

See Also

`dbstack`, `function`, `nargin`, `nargout`, `inputname`

Purpose

Download file from FTP server

Syntax

```
mget(f,'filename')
mget(f,'dirname')
mget(...,'target')
```

Description

`mget(f,'filename')` retrieves `filename` from the FTP server `f` into the MATLAB current directory, where `f` was created using `ftp`.

`mget(f,'dirname')` retrieves the directory `dirname` and its contents from the FTP server `f` into the MATLAB current directory, where `f` was created using `ftp`. You can use a `wildcard` (`*`) in `dirname`.

`mget(...,'target')` retrieves the specified items from the FTP server `f`, where `f` was created using `ftp`, into the local directory specified by `target`, where `target` is an absolute pathname.

Examples

Connect to an FTP server, change to the `documents/rfc` directory, and retrieve the file `rfc0959.txt` into the current MATLAB directory.

```
ftpobj = ftp('nic.merit.edu');
cd(ftpobj, 'documents/rfc');

mget(ftpobj, 'rfc0959.txt')
ans =
    'C:\work\rfc0959.txt'
```

See Also

`cd (ftp)`, `ftp`, `mput`

Purpose

Smallest elements in array

Syntax

```
C = min(A)
C = min(A,B)
C = min(A,[],dim)
[C,I] = min(...)
```

Description

`C = min(A)` returns the smallest elements along different dimensions of an array.

If `A` is a vector, `min(A)` returns the smallest element in `A`.

If `A` is a matrix, `min(A)` treats the columns of `A` as vectors, returning a row vector containing the minimum element from each column.

If `A` is a multidimensional array, `min` operates along the first nonsingleton dimension.

`C = min(A,B)` returns an array the same size as `A` and `B` with the smallest elements taken from `A` or `B`. The dimensions of `A` and `B` must match, or they may be scalar.

`C = min(A,[],dim)` returns the smallest elements along the dimension of `A` specified by scalar `dim`. For example, `min(A,[],1)` produces the minimum values along the first dimension (the rows) of `A`.

`[C,I] = min(...)` finds the indices of the minimum values of `A`, and returns them in output vector `I`. If there are several identical minimum values, the index of the first one found is returned.

Remarks

For complex input `A`, `min` returns the complex number with the largest complex modulus (magnitude), computed with `min(abs(A))`. Then computes the largest phase angle with `min(angle(x))`, if necessary.

The `min` function ignores `NaN`s.

See Also

`max`, `mean`, `median`, `sort`

min (timeseries)

Purpose

Minimum value of timeseries data

Syntax

```
ts_min = min(ts)
ts_min = min(ts,'PropertyName1',PropertyValue1,...)
```

Description

`ts_min = min(ts)` returns the minimum value in the time-series data. When `ts.Data` is a vector, ts_min is the minimum value of `ts.Data` values. When `ts.Data` is a matrix, ts_min is a row vector containing the minimum value 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, `min` always operates along the first nonsingleton dimension of `ts.Data`.

`ts_min = min(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

The following example illustrates how to find the minimum values in multivariate time-series data.

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 Find the minimum in each data column for this `timeseries` object.

```
min(count_ts)

ans =

     7     9     7
```

The minimum is found independently for each data column in the `timeseries` object.

See Also

`iqr (timeseries)`, `max (timeseries)`, `median (timeseries)`, `mean (timeseries)`, `std (timeseries)`, `timeseries`, `var (timeseries)`

MinimizeCommandWindow

Purpose

Minimize size of server window

Syntax

MATLAB Client

```
h.MinimizeCommandWindow
MinimizeCommandWindow(h)
invoke(h, 'MinimizeCommandWindow')
```

Method Signature

```
HRESULT MinimizeCommandWindow(void)
```

Visual Basic Client

```
MinimizeCommandWindow
```

Description

`MinimizeCommandWindow` minimizes the window for the server attached to handle `h`, and makes it inactive. If the server window was already in a minimized state to begin with, then `MinimizeCommandWindow` does nothing.

Remarks

Server function names, like `MinimizeCommandWindow`, 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.

Examples

Create a COM server and minimize its window. Then maximize the window and make it the currently active window.

MATLAB Client

```
h = actxserver('matlab.application');
h.MinimizeCommandWindow;
% Now return the server window to its former state on
% the desktop and make it the currently active window.
h.MaximizeCommandWindow;
```

Visual Basic.net Client

Create a COM server and minimize its window.

```
Dim Matlab As Object

Matlab = CreateObject("matlab.application")
Matlab.MinimizeCommandWindow

`Now return the server window to its former state on
`the desktop and make it the currently active window.

Matlab.MaximizeCommandWindow
```

See Also

`MaximizeCommandWindow`

minres

Purpose Minimum residual method

Syntax

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

Description

`x = minres(A,b)` attempts to find a minimum norm residual solution `x` to the system of linear equations `A*x=b`. The `n`-by-`n` coefficient matrix `A` must be symmetric but need not be positive definite. It should 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.

“Parameterizing Functions Called by Function 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 `minres` converges, a message to that effect is displayed. If `minres` fails to converge after the maximum number of iterations or halts for any reason, a warning message is printed displaying the relative residual `norm(b-A*x)/norm(b)` and the iteration number at which the method stopped or failed.

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

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

`minres(A,b,tol,maxit,M)` and `minres(A,b,tol,maxit,M1,M2)` use symmetric positive definite preconditioner `M` or `M = M1*M2` and effectively solve the system `inv(sqrt(M))*A*inv(sqrt(M))*y = inv(sqrt(M))*b` for `y` and then return `x = inv(sqrt(M))*y`. If `M` is `[]` then `minres` applies no preconditioner. `M` can be a function handle `mfun`, such that `mfun(x)` returns `M\x`.

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

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

Flag	Convergence
0	`minres` converged to the desired tolerance `tol` within `maxit` iterations.
1	`minres` iterated `maxit` times but did not converge.
2	Preconditioner `M` was ill-conditioned.
3	`minres` stagnated. (Two consecutive iterates were the same.)
4	One of the scalar quantities calculated during `minres` 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] = minres(A,b,...)` also returns the relative residual `norm(b-A*x)/norm(b)`. If `flag` is `0`, `relres <= tol`.

`[x,flag,relres,iter] = minres(A,b,...)` also returns the iteration number at which `x` was computed, where `0 <= iter <= maxit`.

`[x,flag,relres,iter,resvec] = minres(A,b,...)` also returns a vector of estimates of the `minres` residual norms at each iteration, including `norm(b-A*x0)`.

`[x,flag,relres,iter,resvec,resveccg] = minres(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 = minres(A,b,tol,maxit,M1);
minres converged at iteration 49 to a solution with relative
residual 4.7e-014
```

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_minres` that

- Calls `minres` with the function handle `@afun` as its first argument.
- Contains `afun` as a nested function, so that all variables in `run_minres` are available to `afun`.

The following shows the code for `run_minres`:

```
function x1 = run_minres
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;
M = spdiags(4*on,0,n,n);
x1 = minres(@afun,b,tol,maxit,M);
```

```
        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_minres;
```

MATLAB displays the message

```
minres converged at iteration 49 to a solution with relative
residual 4.7e-014
```

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.
```

displays the following message:

```
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, minres can handle the indefinite matrix A.

```
x = minres(A,b,1e-6,40);
minres converged at iteration 39 to a solution with relative
residual 1.3e-007
```

See Also

bicg, bicgstab, cgs, cholinc, gmres, lsqr, pcg, 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.

[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.

Purpose Determine whether M-file or MEX-file cannot be cleared from memory

Syntax

```
mislocked
mislocked(fun)
```

Description `mislocked` by itself returns logical `1` (`true`) if the currently running M-file or MEX-file is locked, and logical `0` (`false`) otherwise.

`mislocked(`*`fun`*`)` returns logical `1` (`true`) if the function named *`fun`* is locked in memory, and logical `0` (`false`) otherwise. Locked M-files and MEX-files cannot be removed with the `clear` function.

See Also `mlock`, `munlock`

mkdir

Purpose

Make new directory

Graphical Interface

As an alternative to the `mkdir` function, you can click the **New folder** button in the "Current Directory Browser" to add a directory.

Syntax

```
mkdir('dirname')
mkdir('parentdir','dirname')
status = mkdir(...,'dirname')
[status,message,messageid] = mkdir(...,'dirname')
```

Description

`mkdir('dirname')` creates the directory `dirname` in the current directory, if `dirname` represents a relative path. Otherwise, `dirname` represents an absolute path and `mkdir` attempts to create the absolute directory `dirname` in the root of the current volume. An absolute path starts with any one of the following: a Windows drive letter, a UNC path `'\\'` string, or a UNIX `'/'` character.

`mkdir('parentdir','dirname')` creates the directory `dirname` in the existing directory `parentdir`, where `parentdir` is an absolute or relative pathname. If `parentdir` does not exist, MATLAB attempts to create it. See the Remarks section below.

`status = mkdir(...,'dirname')` creates the specified directory and returns a `status` of logical 1 if the operation was successful, or logical 0 if unsuccessful.

`[status,message,messageid] = mkdir(...,'dirname')` creates the specified directory, and returns `status`, message string, and MATLAB error message ID. The value given to `status` is logical `1` for success and logical `0` for error.

See the help for `error` and `lasterror` for more information.)

Remarks

If the `dirname` or `parentdir` argument specifies not only a directory name, but also a directory path (e.g., '`mydir\xdir1\xdir2\targetdir'`), and this path includes one or more nonexistent directories (e.g., `xdir1` and/or `xdir2` in the path above), MATLAB attempts to create each nonexistent parent directory, in turn, in the process of creating the specified target directory.

Examples

Create a Subdirectory in Current Directory

To create a subdirectory in the current directory called `newdir`, type

```
mkdir('newdir')
```

Create a Subdirectory in Specified Parent Directory

To create a subdirectory called `newdir` in the directory `testdata`, which is at the same level as the current directory, type

```
mkdir('../testdata','newdir')
```

Return Status When Creating Directory

In this example, the first attempt to create `newdir` succeeds, returning a status of `1`, and no error or warning message or message identifier:

```
[s, mess, messid] = mkdir('../testdata', 'newdir')
s =
   1
mess =
   ''
messid =
   ''
```

If you attempt to create the same directory again, `mkdir` again returns a success status, and also a warning and message identifier informing you that the directory already existed:

```
[s,mess,messid] = mkdir('../testdata','newdir')
s =
   1
mess =
   Directory "newdir" already exists.
messid =
   MATLAB:MKDIR:DirectoryExists
```

See Also

copyfile, cd, dir, fileattrib, filebrowser, fileparts, ls, mfilename, movefile, rmdir

Purpose

Create new directory on FTP server

Syntax

```
mkdir(f,'dirname')
```

Description

`mkdir(f,'dirname')` creates the directory `dirname` in the current directory of the FTP server `f`, where `f` was created using `ftp`, and where `dirname` is a pathname relative to the current directory on `f`.

Examples

Connect to server `testsite`, view the contents, and create the directory `newdir` in the directory `testdir`.

```
test=ftp('ftp.testsite.com')
dir(test)
.              ..      otherfile.m          testdir
mkdir(test,'testdir/newdir');
dir(test,'testdir)
.              ..      newdir
```

See Also

`dir (ftp)`, `ftp`, `rmdir (ftp)`

mkpp

Purpose

Make piecewise polynomial

Syntax

```
pp = mkpp(breaks,coefs)
pp = mkpp(breaks,coefs,d)
```

Description

`pp = mkpp(breaks,coefs)` builds a piecewise polynomial `pp` from its breaks and coefficients. `breaks` is a vector of length `L+1` with strictly increasing elements which represent the start and end of each of `L` intervals. `coefs` is an `L`-by-`k` matrix with each row `coefs(i,:)` containing the coefficients of the terms, from highest to lowest exponent, of the order `k` polynomial on the interval `[breaks(i),breaks(i+1)]`.

`pp = mkpp(breaks,coefs,d)` indicates that the piecewise polynomial `pp` is `d`-vector valued, i.e., the value of each of its coefficients is a vector of length `d`. `breaks` is an increasing vector of length `L+1`. `coefs` is a `d`-by-`L`-by-`k` array with `coefs(r,i,:)` containing the `k` coefficients of the `i`th polynomial piece of the `r`th component of the piecewise polynomial.

Use `ppval` to evaluate the piecewise polynomial at specific points. Use `unmkpp` to extract details of the piecewise polynomial.

Note. The *order* of a polynomial tells you the number of coefficients used in its description. A *k*th order polynomial has the form

$$c_1x^{k-1} + c_2x^{k-2} + \ldots + c_{k-1}x + c_k$$

It has *k* coefficients, some of which can be 0, and maximum exponent *k*-1. So the order of a polynomial is usually one greater than its degree. For example, a cubic polynomial is of order 4.

Examples

The first plot shows the quadratic polynomial

$$1 - \left(\frac{x}{2} - 1\right)^2 = \frac{-x^2}{4} + x$$

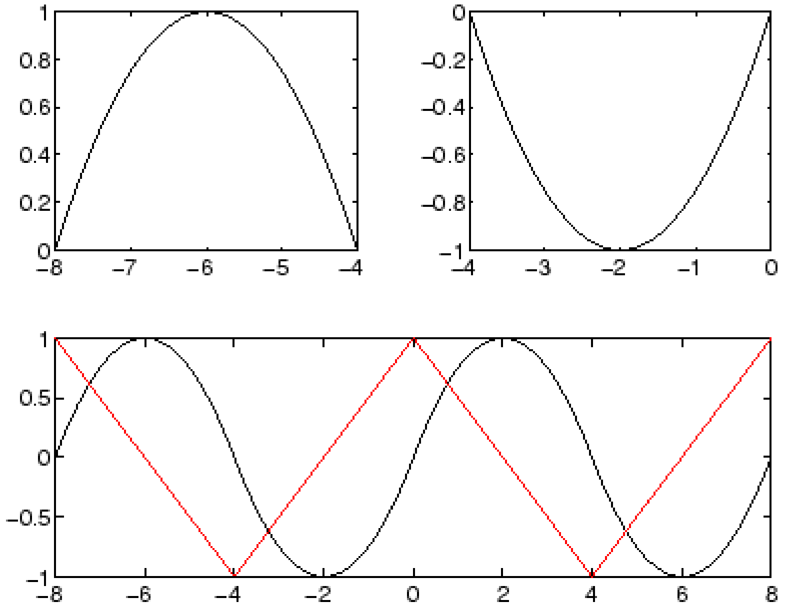
shifted to the interval [-8,-4]. The second plot shows its negative

$$\left(\frac{x}{2}-1\right)^2-1 = \frac{x^2}{4}-x$$

but shifted to the interval [-4,0].

The last plot shows a piecewise polynomial constructed by alternating these two quadratic pieces over four intervals. It also shows its first derivative, which was constructed after breaking the piecewise polynomial apart using unmkpp.

```
subplot(2,2,1)
cc = [-1/4 1 0];
pp1 = mkpp([-8 -4],cc);
xx1 = -8:0.1:-4;
plot(xx1,ppval(pp1,xx1),'k-')

subplot(2,2,2)
pp2 = mkpp([-4 0],-cc);
xx2 = -4:0.1:0;
plot(xx2,ppval(pp2,xx2),'k-')

subplot(2,1,2)
pp = mkpp([-8 -4 0 4 8],[cc;-cc;cc;-cc]);
xx = -8:0.1:8;
plot(xx,ppval(pp,xx),'k-')
[breaks,coefs,l,k,d] = unmkpp(pp);
dpp = mkpp(breaks,repmat(k-1:-1:1,d*l,1).*coefs(:,1:k-1),d);
hold on, plot(xx,ppval(dpp,xx),'r-'), hold off
```



See Also

`ppval`, `spline`, `unmkpp`

Purpose

Left or right matrix division

Syntax

```
mldivide(A,B)     A\B
mrdivide(B,A)     B/A
```

Description

`mldivide(A,B)` and the equivalent `A\B` perform matrix left division (back slash). `A` and `B` must be matrices that have the same number of rows, unless `A` is a scalar, in which case `A\B` performs element-wise division — that is, `A\B = A.\B`.

If `A` is a square matrix, `A\B` is roughly the same as `inv(A)*B`, except it is computed in a different way. If `A` is an `n`-by-`n` matrix and `B` is a column vector with `n` elements, or a matrix with several such columns, then `X = A\B` is the solution to the equation $AX = B$ computed by Gaussian elimination with partial pivoting (see "Algorithm" on page 2-2123 for details). A warning message is displayed if `A` is badly scaled or nearly singular.

If `A` is an `m`-by-`n` matrix with `m ~= n` and `B` is a column vector with `m` components, or a matrix with several such columns, then `X = A\B` is the solution in the least squares sense to the under- or overdetermined system of equations $AX = B$. In other words, `X` minimizes `norm(A*X - B)`, the length of the vector $AX - B$. The rank `k` of `A` is determined from the QR decomposition with column pivoting (see "Algorithm" on page 2-2123 for details). The computed solution `X` has at most `k` nonzero elements per column. If `k < n`, this is usually not the same solution as `x = pinv(A)*B`, which returns a least squares solution.

`mrdivide(B,A)` and the equivalent `B/A` perform matrix right division (forward slash). `B` and `A` must have the same number of columns.

If `A` is a square matrix, `B/A` is roughly the same as `B*inv(A)`. If `A` is an `n`-by-`n` matrix and `B` is a row vector with `n` elements, or a matrix with several such rows, then `X = B/A` is the solution to the equation $XA = B$ computed by Gaussian elimination with partial pivoting. A warning message is displayed if `A` is badly scaled or nearly singular.

If `B` is an `m`-by-`n` matrix with `m ~= n` and `A` is a column vector with `m` components, or a matrix with several such columns, then `X = B/A` is the solution in the least squares sense to the under- or overdetermined system of equations $XA = B$.

Note Matrix right division and matrix left division are related by the equation `B/A = (A'\B')'`.

Least Squares Solutions

If the equation $Ax = b$ does not have a solution (and A is not a square matrix), `x = A\b` returns a *least squares solution* — in other words, a solution that minimizes the length of the vector $Ax - b$, which is equal to `norm(A*x - b)`. See "Example 3" on page 2-2122 for an example of this.

Examples

Example 1

Suppose that `A` and `b` are the following.

```
A = magic(3)

A =

     8     1     6
     3     5     7
     4     9     2

b = [1;2;3]

b =

     1
     2
     3
```

To solve the matrix equation $Ax = b$, enter

```
x=A\b
```

```
x =

    0.0500
    0.3000
    0.0500
```

You can verify that x is the solution to the equation as follows.

```
A*x

ans =

    1.0000
    2.0000
    3.0000
```

Example 2 — A Singular

If A is singular, A\b returns the following warning.

```
Warning: Matrix is singular to working precision.
```

In this case, $Ax = b$ might not have a solution. For example,

```
A = magic(5);
A(:,1) = zeros(1,5); % Set column 1 of A to zeros
b = [1;2;5;7;7];
x = A\b
Warning: Matrix is singular to working precision.

ans =

   NaN
   NaN
   NaN
   NaN
   NaN
```

If you get this warning, you can still attempt to solve $Ax = b$ using the pseudoinverse function `pinv`.

```
x = pinv(A)*b

x =

         0
    0.0209
    0.2717
    0.0808
   -0.0321
```

The result `x` is least squares solution to $Ax = b$. To determine whether `x` is a exact solution — that is, a solution for which $Ax - b = 0$ — simply compute

```
A*x-b

ans =

   -0.0603
    0.6246
   -0.4320
    0.0141
    0.0415
```

The answer is not the zero vector, so `x` is not an exact solution.

"Pseudoinverses", in the online MATLAB Mathematics documentation, provides more examples of solving linear systems using `pinv`.

Example 3

Suppose that

```
A = [1 0 0;1 0 0];
b = [1; 2];
```

Note that $Ax = b$ cannot have a solution, because `A*x` has equal entries for any `x`. Entering

```
x = A\b
```

returns the least squares solution

```
x =

    1.5000
         0
         0
```

along with a warning that `A` is rank deficient. Note that `x` is not an exact solution:

```
A*x-b

ans =

    0.5000
   -0.5000
```

Data Type Support

When computing `X = A\B` or `X = A/B`, the matrices `A` and `B` can have data type `double` or `single`. The following rules determine the data type of the result:

- If both `A` and `B` have type `double`, `X` has type `double`.
- If either `A` or `B` has type single, `X` has type `single`.

Algorithm

The specific algorithm used for solving the simultaneous linear equations denoted by `X = A\B` and `X = B/A` depends upon the structure of the coefficient matrix `A`. To determine the structure of `A` and select the appropriate algorithm, MATLAB follows this precedence:

1. **If A is sparse and diagonal**, `X` is computed by dividing by the diagonal elements of `A`.

2 **If A is sparse, square, and banded**, then banded solvers are used. Band density is (# nonzeros in the band)/(# nonzeros in a full band). Band density = `1.0` if there are no zeros on any of the three diagonals.

- If `A` is real and tridiagonal, i.e., band density = `1.0`, and `B` is real with only one column, `X` is computed quickly using Gaussian elimination without pivoting.
- If the tridiagonal solver detects a need for pivoting, or if `A` or `B` is not real, or if `B` has more than one column, but `A` is banded with band density greater than the `spparms` parameter `'bandden'` (default = `0.5`), then `X` is computed using the Linear Algebra Package (LAPACK) routines in the following table.

	Real	**Complex**
`A` and `B` `double`	DGBTRF, DGBTRS	ZGBTRF, ZGBTRS
`A` or `B` `single`	SGBTRF, SGBTRS	CGBTRF, CGBTRS

3 **If A is an upper or lower triangular matrix**, then `X` is computed quickly with a backsubstitution algorithm for upper triangular matrices, or a forward substitution algorithm for lower triangular matrices. The check for triangularity is done for full matrices by testing for zero elements and for sparse matrices by accessing the sparse data structure.

If A is a full matrix, computations are performed using the Basic Linear Algebra Subprograms (BLAS) routines in the following table.

	Real	**Complex**
`A and B` `double`	DTRSV, DTRSM	ZTRSV, ZTRSM
`A` or `B` `single`	STRSV, STRSM	CTRSV, CTRSM

4 **If A is a permutation of a triangular matrix**, then `X` is computed with a permuted backsubstitution algorithm.

5 **If A is symmetric, or Hermitian, and has real positive diagonal elements**, then a Cholesky factorization is attempted (see `chol`). If `A` is found to be positive definite, the Cholesky factorization attempt is successful and requires less than half the time of a general factorization. Nonpositive definite matrices are usually detected almost immediately, so this check also requires little time.

If successful, the Cholesky factorization for full `A` is

```
A = R'*R
```

where `R` is upper triangular. The solution `X` is computed by solving two triangular systems,

```
X = R\(R'\B)
```

Computations are performed using the LAPACK routines in the following table.

	Real	Complex
`A` and `B` `double`	DLANSY, DPOTRF, DPOTRS, DPOCON	ZLANHE, ZPOTRF, ZPOTRS, ZPOCON
`A` or `B` `single`	SLANSY, SPOTRF, SPOTRS, SDPOCON	CLANHE, CPOTRF, CPOTRS, CPOCON

6 If `A` is sparse, then MATLAB uses CHOLMOD to compute `X`. The computations result in

```
P'*A*P = R'*R
```

where `P` is a permutation matrix generated by `amd`, and `R` is an upper triangular matrix. In this case,

```
X = P*(R\(R'\(P'*B)))
```

7 if A is not sparse but is symmetric, and the Cholesky factorization failed, then MATLAB solves the system using a symmetric, indefinite factorization. That is, MATLAB computes the factorization `P'*A*P=L*D*L'`, and computes the solution X by `X=P*(L'\(D\(L\(P*B))))`. Computations are performed using the LAPACK routines in the following table:

	Real	**Complex**
A and B double	DLANSY, DSYTRF, DSYTRS, DSYCON	ZLANHE, ZHETRF, ZHETRS, ZHECON
A or B single	SLANSY, SSYTRF, SSYTRS, SSYCON	CLANHE, CHETRF, CHETRS, CHECON

8 **If A is Hessenberg**, but not sparse, it is reduced to an upper triangular matrix and that system is solved via substitution.

9 **If A is square** and does not satisfy criteria 1 through 6, then a general triangular factorization is computed by Gaussian elimination with partial pivoting (see lu). This results in

```
A = L*U
```

where L is a permutation of a lower triangular matrix and U is an upper triangular matrix. Then X is computed by solving two permuted triangular systems.

```
X = U\(L\B)
```

If A is not sparse, computations are performed using the LAPACK routines in the following table.

	Real	Complex
A and B double	DLANGE, DGESV, DGECON	ZLANGE, ZGESV, ZGECON
A or B single	SLANGE, SGESV, SGECON	CLANGE, CGESV, CGECON

If A is sparse, then UMFPACK is used to compute X. The computations result in

```
P*(R\A)*Q = L*U
```

where

- P is a row permutation matrix
- R is a diagonal matrix that scales the rows of A
- Q is a column reordering matrix.

Then X = Q*(U\L\(P*(R\B))).

Note The factorization P*(R\A)*Q = L*U differs from the factorization used by the function lu, which does not scale the rows of A.

---

10 **If A is not square**, then Householder reflections are used to compute an orthogonal-triangular factorization.

```
A*P = Q*R
```

where P is a permutation, Q is orthogonal and R is upper triangular (see qr). The least squares solution X is computed with

```
X = P*(R\(Q'*B))
```

If A is sparse, MATLAB computes a least squares solution using the sparse qr factorization of A.

If A is full, MATLAB uses the LAPACK routines listed in the following table to compute these matrix factorizations.

	Real	Complex
A and B double	DGEQP3, DORMQR, DTRTRS	ZGEQP3, ZORMQR, ZTRTRS
A or B single	SGEQP3, SORMQR, STRTRS	CGEQP3, CORMQR, CTRTRS

Note To see information about choice of algorithm and storage allocation for sparse matrices, set the spparms parameter 'spumoni' = 1.

Note mldivide and mrdivide are not implemented for sparse matrices A that are complex but not square.

See Also

Arithmetic Operators, linsolve, ldivide, rdivide

Purpose

Check M-files for possible problems

GUI Alternatives

From the Current Directory browser, select **View > Directory Reports > M-Lint Code Check Report** on the menu bar. See also the automatic "M-Lint Code Analyzer" in the Editor/Debugger.

Syntax

```
mlint(filename)
inform=mlint(filename,'-struct')
msg=mlint(filename,'-string')
[inform,filepaths]=mlint(filename)
inform=mlint(filename,'-id')
inform=mlint(filename,'-fullpath')
inform=mlint(filename,'-notok')
%#ok
```

Description

`mlint(filename)` displays M-Lint information about filename, where the information reports potential problems and opportunities for code improvement, referred to as suspicious constructs. The line number in the message is a hyperlink that opens the file in the Editor/Debugger, scrolled to that line. If filename is a cell array, information is displayed for each file. For `mlint(F1,F2,F3,...)`, where each input is a character array, MATLAB displays information about each input filename. You cannot combine cell arrays and character arrays of filenames. Note that the exact text of the `mlint` messages is subject to some change between versions.

`inform=mlint(filename,'-struct')` returns the M-Lint information in a structure array whose length is the number of suspicious constructs found. The structure has the following fields:

Field	Description
`line`	Vector of line numbers to which the message refers

Field	Description
column	Two-column array of columns to which the message applies, for each line
message	Message describing the suspicious construct that M-Lint caught

If multiple filenames are input, or if a cell array is input, `inform` will contain a cell array of structures.

`msg=mlint(filename,'`**`-string`**`')` returns the M-Lint information as a string to the variable `msg`. If multiple filenames are input, or if a cell array is input, `msg` will contain a string where each file's information is separated by 10 equal sign characters (=), a space, the filename, a space, and 10 equal sign characters.

If the **`-struct`** or **`-string`** argument is omitted and an output argument is specified, the default behavior is **`-struct`**. If the argument is omitted and there are no output arguments, the default behavior is to display the information to the command line.

`[inform,filepaths]=mlint(filename)` additionally returns `filepaths`, the absolute paths to the filenames, in the same order as they were input.

`inform=mlint(filename,'`**`-id`**`')` requests the message ID from M-Lint, where ID is a string of the form `ABC...`. When returned to a structure, the output also has the `id` field, which is the ID associated with the message.

`inform=mlint(filename,'`**`-fullpath`**`')` assumes that the input filenames are absolute paths, so that M-Lint does not try to locate them.

`inform=mlint(filename,'`**`-notok`**`')` runs `mlint` for all lines in `filename`, even those lines that end with the `mlint` suppression syntax, `%#ok`.

`%#ok` at the end of a line in an M-file causes `mlint` to ignores those lines in the file. MATLAB comments can follow the `%#ok` pragma. `mlint` ignores specified messages 1 through *n* when `%#ok<id1,id2,...idn>` appears at the end of the line.

Examples

`lengthofline.m` is an example M-file with code that can be improved. It is found in *`matlabroot`*`/matlab/help/techdoc/matlab_env/examples`.

mlint for a File with No Options

To run `mlint` on the example file, `lengthofline`, run

```
mlint(fullfile(matlabroot,'help','techdoc','matlab_env','examples','lengthofline'))
```

MATLAB displays M-Lint messages for `lengthofline` in the Command Window:

```
L 22 (C 1-9): The value assigned here to variable 'nothandle' might never be used.
L 23 (C 12-15): NUMEL(x) is usually faster than PROD(SIZE(x)).
L 24 (C 5-11): 'notline' might be growing inside a loop. Consider preallocating for speed.
L 24 (C 44-49): Use STRCMPI(str1,str2) instead of using LOWER in a call to STRCMP.
L 28 (C 12-15): NUMEL(x) is usually faster than PROD(SIZE(x)).
L 34 (C 13-16): 'data' might be growing inside a loop. Consider preallocating for speed.
L 34 (C 24-31): Use dynamic fieldnames with structures instead of GETFIELD.
                Type 'doc struct' for more information.
L 38 (C 29): Use || instead of | as the OR operator in (scalar) conditional statements.
L 39 (C 47): Use || instead of | as the OR operator in (scalar) conditional statements.
L 40 (C 47): Use || instead of | as the OR operator in (scalar) conditional statements.
L 42 (C 13-16): 'data' might be growing inside a loop. Consider preallocating for speed.
L 43 (C 13-15): 'dim' might be growing inside a loop. Consider preallocating for speed.
L 45 (C 13-15): 'dim' might be growing inside a loop.Consider preallocating for speed.
L 48 (C 52): There may be a parenthesis imbalance around here.
L 48 (C 53): There may be a parenthesis imbalance around here.
L 48 (C 54): There may be a parenthesis imbalance around here.
L 48 (C 55): There may be a parenthesis imbalance around here.
L 49 (C 17): Terminate statement with semicolon to suppress output (in functions).
L 49 (C 23): Use of brackets [] is unnecessary. Use parentheses
to group, if needed.
```

For details about these messages and how to improve the code, see "Making Changes Based on M-Lint Messages" in the MATLAB Desktop Tools and Development Environment documentation.

mlint with Options to Show IDs and Return Results to a Structure

To store the results to a structure and include message IDs, run

```
inform=mlint('lengthofline','-id')
```

MATLAB returns

```
inform =

14x1 struct array with fields:
    message
    line
    column
    id
```

To see values for the first message, run

```
inform(1)
```

MATLAB displays

```
ans =

    message: 'The value assigned here to variable 'nothandle' might never be used.'
       line: 22
     column: [1 9]
         id: 'NASGU'
```

Here, `NASGU` is the ID for the message `'The value assigned here to variable 'nothandle' might never be used.'`.

Ignoring Messages on a Line with

This examples shows how to instruct `mlint` to ignore lines, where these are lines in the example M-file, `lengthofline`:

```
22 nothandle = ~ishandle(hline);
```

The M-Lint message is

```
L 22 (C 1-9): The value assigned here to variable 'nothandle' might never be used.
```

To suppress the message, add `%#ok` to the end of line 22 in the M-file:

```
22 nothandle = ~ishandle(hline); %#ok
```

When you run `mlint` for `lengthofline`, no messages are shown for line 22 because it contains the `%#ok` message suppression syntax.

Ignoring Specific Messages with mlint

When you add `%#ok` to a line, it suppresses all `mlint` messages for that line. If there are multiple messages in a line and you want to suppress some but not all of them, or if you want to suppress a specific message but not all messages that might arise in the future due to changes you make, use the `%#ok` syntax in conjunction with message IDs.

Run `mlint` with the `-id` option:

```
mlint('lengthofline','-id')
```

Results displayed to the Command Window show two messages for line 34:

```
L 34 (C 13-16): AGROW: 'data' might be growing inside a loop.
                Consider preallocating for speed.
L 34 (C 24-31): GFLD: Use dynamic fieldnames with structures instead of GETFIELD.
                 Type 'doc struct' for more information.
```

To suppress only the first message about `'data'` growing inside a loop, use its message ID, `GFLD`, with the `%#ok` syntax as shown here:

```
data{nd} = getfield(flds,fdata{nd}); %#ok<GFLD>
```

When you run `mlint` for `lengthofline`, only one message now displays for line 34.

To display multiple specific messages for a line, separate message IDs with commas in the `%#ok` syntax:

```
data{nd} = getfield(flds,fdata{nd}); %#ok<GFLD,AGROW>
```

Now when you run `mlint` for `lengthofline`, no messages display for line 34.

See Also

`mlintrpt`, `profile`

Purpose

Run `mlint` for file or directory, reporting results in browser

GUI Alternatives

From the Current Directory browser, select **View > Directory Reports > M-Lint Code Check Report** on the menu toolbar. See also the automatic "M-Lint Code Analyzer" in the Editor/Debugger.

Syntax

```
mlintrpt
mlintrpt(filename,'file')
mlintrpt(dirname,'dir')
mlintrpt(filename,'file', 'fullpath_to_configname.txt')
mlintrpt(dirname,'dir', 'fullpath_to_configname.txt')
```

Description

`mlintrpt` scans all M-files in the current directory for M-Lint messages and reports the results in a MATLAB Web browser.

`mlintrpt(filename,'file')` scans the M-file `filename` for messages and reports results. You can omit `'file'` in this form of the syntax because it is the default.

`mlintrpt(dirname,'dir')` scans the specified directory. Here, `dirname` can be in the current directory or can be a full pathname.

`mlintrpt(filename,'file', 'fullpath_to_configname.txt')` applies the M-Lint preference settings to enable or suppress messages as specified in the file `configname.txt`; you must specify the full pathname to `configname.txt`. For information about creating a `fullpath_to_configname.txt` file, select **File > Preferences > M-Lint**, and click **Help**.

`mlintrpt(dirname,'dir', 'fullpath_to_configname.txt')` applies the M-Lint preference settings specified in the file `fullpath_to_configname.txt`; you must specify the full pathname to `configname.txt`.

Examples

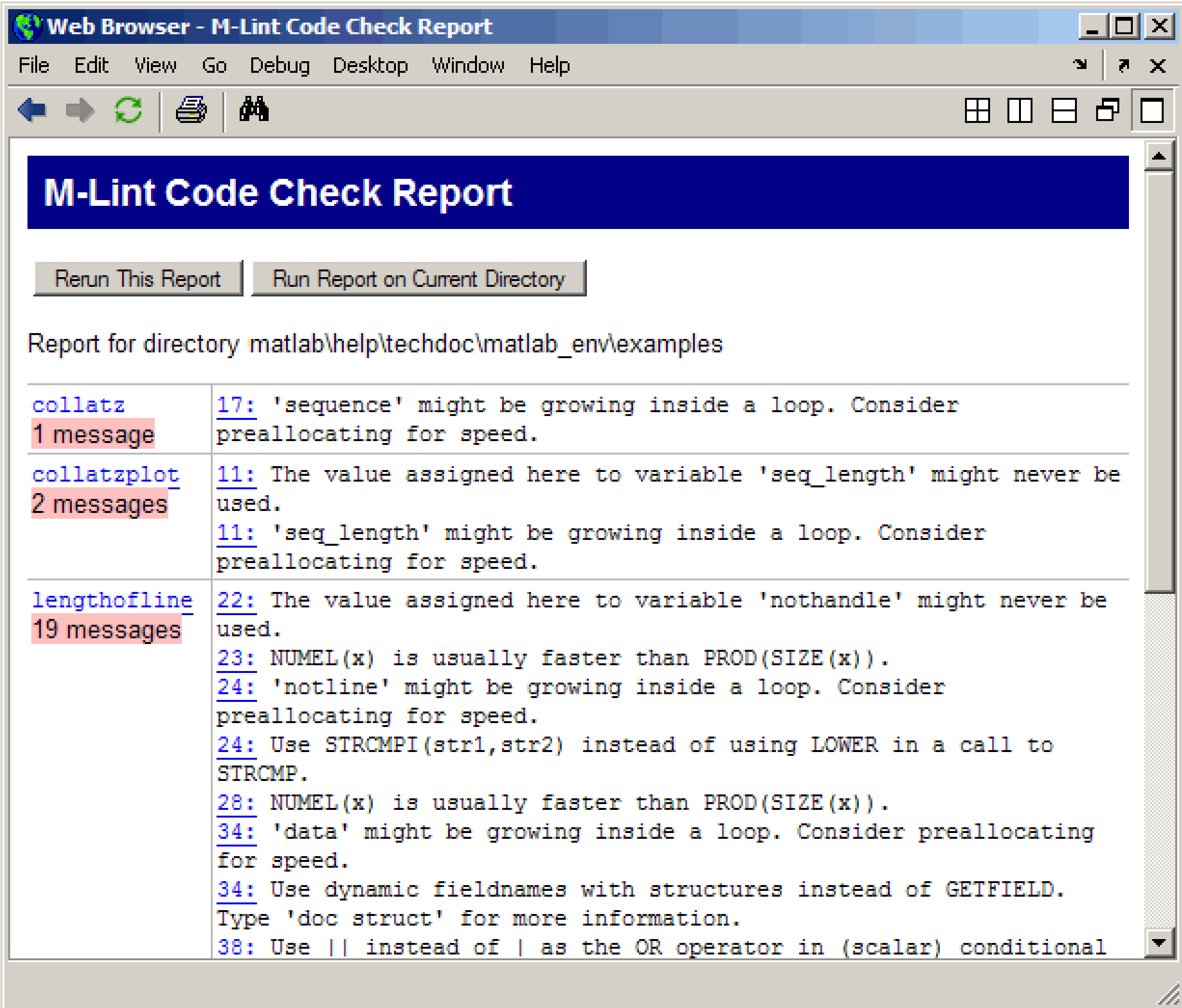
`lengthofline.m` is an example M-file with code that can be improved. It is found in *`matlabroot`*`/matlab/help/techdoc/matlab_env/examples`.

Run Report for All Files in a Directory

Run

```
mlintrpt(fullfile(matlabroot,'help','techdoc','matlab_env','examples'),'dir')
```

and MATLAB displays a report of potential problems and improvements for all M-files in the `examples` directory.



For details about these messages and how to improve the code, see "Making Changes Based on M-Lint Messages" in the MATLAB Desktop Tools and Development Environment documentation.

Run Report Using M-Lint Preference Settings

In **File > Preferences > M-Lint**, save preference settings to a file, for example, `MLintNoSemis.txt`. To apply those settings when you run `mlintrpt`, use the `file` option and supply the full path to the settings filename as shown in this example:

```
mlintrpt('lengthofline.m', 'file', ...
'C:\WINNT\Profiles\me\Application Data\MathWorks\MATLAB\R2007a\MLintNoSemis.txt')
```

Alternatively, use `fullfile` if the settings file is stored in the preferences directory:

```
mlintrpt('lengthofline.m', 'file', fullfile(prefdir,'MLintNoSemis.txt'))
```

Assuming that in that example `MLintNoSemis.txt` file, the setting for `Terminate statement with semicolon to suppress output` has been disabled, the results of `mlintrpt` for `lengthofline` do not show that message for line 49.

When `mlintrpt` cannot locate the settings file, the first message in the report is

```
0: Unable to open or read the configuration file
```

See Also

`mlint`

Purpose

Prevent clearing M-file or MEX-file from memory

Syntax

```
mlock
```

Description

`mlock` locks the currently running M-file or MEX-file in memory so that subsequent `clear` functions do not remove it.

Use the `munlock` function to return the file to its normal, clearable state.

Locking an M-file or MEX-file in memory also prevents any `persistent` variables defined in the file from getting reinitialized.

Examples

The function `testfun` begins with an `mlock` statement.

```
function testfun
mlock
  .
  .
```

When you execute this function, it becomes locked in memory. You can check this using the `mislocked` function.

```
testfun

mislocked('testfun')
ans =
     1
```

Using `munlock`, you unlock the `testfun` function in memory. Checking its status with `mislocked` shows that it is indeed unlocked at this point.

```
munlock('testfun')

mislocked('testfun')
ans =
     0
```

See Also

`mislocked`, `munlock`, `persistent`

Purpose

Information about multimedia file

Syntax

```
info = mmfileinfo(filename)
```

Description

`info = mmfileinfo(filename)` returns a structure, `info`, with fields containing information about the contents of the multimedia file identified by `filename`. The `filename` input is a string enclosed in single quotes.

Note `mmfileinfo` can be used only on Windows systems.

If `filename` is a URL, `mmfileinfo` might take a long time to return because it must first download the file. For large files, downloading can take several minutes. To avoid blocking the MATLAB command line while this processing takes place, download the file before calling `mmfileinfo`.

The `info` structure contains the following fields, listed in the order they appear in the structure.

Field	Description
`Filename`	String indicating the name of the file
`Duration`	Length of the file in seconds
`Audio`	Structure containing information about the audio data in the file. See "Audio Data" on page 2-2141 for more information about this data structure.
`Video`	Structure containing information about the video data in the file. See "Video Data" on page 2-2141 for more information about this data structure.

Audio Data

The Audio structure contains the following fields, listed in the order they appear in the structure. If the file does not contain audio data, the fields in the structure are empty.

Field	Description
Format	Text string, indicating the audio format
NumberOfChannels	Number of audio channels

Video Data

The Video structure contains the following fields, listed in the order they appear in the structure.

Field	Description
Format	Text string, indicating the video format
Height	Height of the video frame
Width	Width of the video frame

Examples

This example gets information about the contents of a file containing audio data.

```
info = mmfileinfo('my_audio_data.mp3')

info =

    Filename: 'my_audio_data.mp3'
    Duration: 1.6030e+002
       Audio: [1x1 struct]
       Video: [1x1 struct]
```

To look at the information returned about the audio data in the file, examine the fields in the Audio structure.

```
audio_data = info.Audio

audio_data =

              Format: 'MPEGLAYER3'
    NumberOfChannels: 2
```

Because the file contains only audio data, the fields in the `Video` structure are empty.

```
info.Video

ans =

    Format: ''
    Height: []
     Width: []
```

Purpose

Modulus after division

Syntax

```
M = mod(X,Y)
```

Description

`M = mod(X,Y)` if `Y ~= 0`, returns `X - n.*Y` where `n = floor(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.

The following are true by convention:

- `mod(X,0)` is `X`
- `mod(X,X)` is `0`
- `mod(X,Y)` for `X~=Y` and `Y~=0` has the same sign as `Y`.

Remarks

`rem(X,Y)` for `X~=Y` and `Y~=0` has the same sign as `X`.

`mod(X,Y)` and `rem(X,Y)` are equal if `X` and `Y` have the same sign, but differ by `Y` if `X` and `Y` have different signs.

The `mod` function is useful for congruence relationships:
x and y are congruent (mod m) if and only if `mod(x,m) == mod(y,m)`.

Examples

```
mod(13,5)
ans =
     3

mod([1:5],3)
ans =
     1     2     0     1     2

mod(magic(3),3)
ans =
     2     1     0
     0     2     1
     1     0     2
```

See Also `rem`

Purpose

Most frequent values in array

Syntax

```
M = mode(X)
M = mode(X, dim)
[M,F] = mode(X, ...)
[M,F,C] = mode(X, ...)
```

Description

`M = mode(X)` for vector `X` computes the sample mode `M`, (i.e., the most frequently occurring value in `X`). If `X` is a matrix, then `M` is a row vector containing the mode of each column of that matrix. If `X` is an N-dimensional array, then `M` is the mode of the elements along the first nonsingleton dimension of that array.

When there are multiple values occurring equally frequently, `mode` returns the smallest of those values. For complex inputs, this is taken to be the first value in a sorted list of values.

`M = mode(X, dim)` computes the mode along the dimension `dim` of `X`.

`[M,F] = mode(X, ...)` also returns array `F`, each element of which represents the number of occurrences of the corresponding element of `M`. The `M` and `F` output arrays are of equal size.

`[M,F,C] = mode(X, ...)` also returns cell array `C`, each element of which is a sorted vector of all values that have the same frequency as the corresponding element of `M`. All three output arrays `M`, `F`, and `C` are of equal size.

Remarks

The `mode` function is most useful with discrete or coarsely rounded data. The mode for a continuous probability distribution is defined as the peak of its density function. Applying the `mode` function to a sample from that distribution is unlikely to provide a good estimate of the peak; it would be better to compute a histogram or density estimate and calculate the peak of that estimate. Also, the `mode` function is not suitable for finding peaks in distributions having multiple modes.

Examples

Example 1

Find the mode of the 3-by-4 matrix shown here:

```
X = [3 3 1 4; 0 0 1 1; 0 1 2 4]
X =
     3     3     1     4
     0     0     1     1
     0     1     2     4

mode(X)
ans =
     0     0     1     4
```

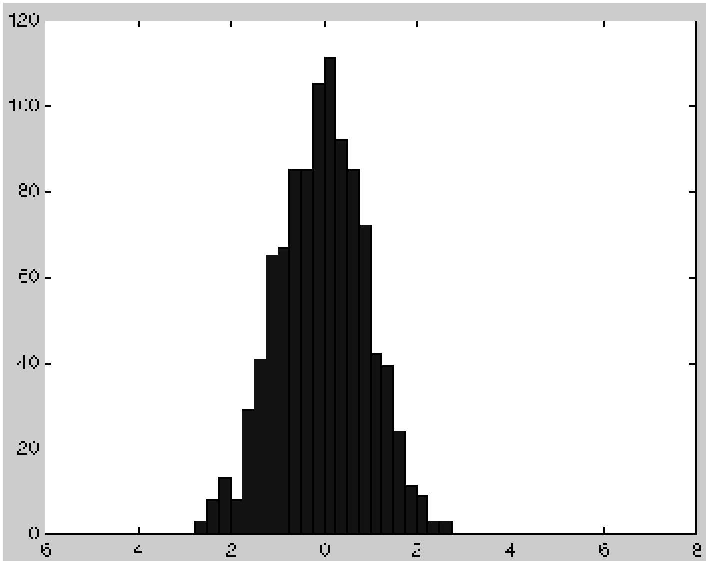
Find the mode along the second (row) dimension:

```
mode(X, 2)
ans =
     3
     0
     0
```

Example 2

Find the mode of a continuous variable grouped into bins:

```
randn('state', 0);       % Reset the random number generator

y = randn(1000,1);
edges = -6:.25:6;
[n,bin] = histc(y,edges);

m = mode(bin)
m =
    22

edges([m, m+1])
ans =
   -0.7500   -0.5000

hist(y,edges+.125)
```



See Also `mean`, `median`, `hist`, `histc`

more

Purpose

Control paged output for Command Window

Syntax

```
more on
more off
more(n)
A = more(state)
```

Description

`more on` enables paging of the output in the MATLAB Command Window. MATLAB displays output one page at a time. Use the keys defined in the table below to control paging.

`more off` disables paging of the output in the MATLAB Command Window.

`more(n)` defines the length of a page to be `n` lines.

`A = more(state)` returns in `A` the number of lines that are currently defined to be a page. The `state` input can be one of the quoted strings `'on'` or `'off'`, or the number of lines to set as the new page length.

By default, the length of a page is equal to the number of lines available for display in the MATLAB command window. Manually changing the size of the command window adjusts the page length accordingly.

If you set the page length to a specific value, MATLAB uses that value for the page size, regardless of the size of the command window. To have MATLAB return to matching page size to window size, type `more off` followed by `more on`.

To see the status of `more`, type `get(0,'More')`. MATLAB returns either `on` or `off` indicating the `more` status. You can also set status for `more` by using `set(0,'More', 'status')`, where `'status'` is either `'on'` or `'off'`.

When you have enabled `more` and are examining output, you can do the following.

Press the...	To...
Return key	Advance to the next line of output.
Space bar	Advance to the next page of output.
Q (for quit) key	Terminate display of the text. Do not use **Ctrl+C** to terminate `more` or you might generate error messages in the Command Window.

`more` is in the **`off`** state, by default.

See Also

`diary`

Purpose Move or resize control in parent window

Syntax

```
V = h.move(position)
V = move(h, position)
```

Description

`V = h.move(position)` moves the control to the position specified by the `position` argument. When you use move with only the handle argument, `h`, it returns a four-element vector indicating the current position of the control.

`V = move(h, position)` is an alternate syntax for the same operation.

The position argument is a four-element vector specifying the position and size of the control in the parent figure window. The elements of the vector are

```
[x, y, width, height]
```

where `x` and `y` are offsets, in pixels, from the bottom left corner of the figure window to the same corner of the control, and `width` and `height` are the size of the control itself.

Examples

This example moves the control:

```
f = figure('Position', [100 100 200 200]);
h = actxcontrol('mwsamp.mwsampctrl.1', [0 0 200 200], f);
pos = h.move([50 50 200 200])
pos =
    50    50   200   200
```

The next example resizes the control to always be centered in the figure as you resize the figure window. Start by creating the script `resizectrl.m` that contains

```
% Get the new position and size of the figure window
  fpos = get(gcbo, 'position');

% Resize the control accordingly
```

```
h.move([0 0 fpos(3) fpos(4)]);
```

Now execute the following in MATLAB or in an M-file:

```
f = figure('Position', [100 100 200 200]);
h = actxcontrol('mwsamp.mwsampctrl.1', [0 0 200 200]);
set(f, 'ResizeFcn', 'resizectrl');
```

As you resize the figure window, notice that the circle moves so that it is always positioned in the center of the window.

See Also

`set`, `get`

movefile

Purpose

Move file or directory

Graphical Interface

As an alternative to the `movefile` function, you can use the Current Directory browser to move files and directories.

Syntax

```
movefile('source')
movefile('source','destination')
movefile('source','destination','f')
[status,message,messageid]=movefile('source','destination',
   'f')
```

Description

`movefile('source')` moves the file or directory named `source` to the current directory, where `source` is the absolute or relative pathname for the directory or file. Use the wildcard `*` at the end of `source` to move all matching files. Note that the archive attribute of `source` is not preserved.

`movefile('source','destination')` moves the file or directory named `source` to the location `destination`, where `source` and `destination` are the absolute or relative pathnames for the directory or files. To rename a file or directory when moving it, make `destination` a different name than `source`. Use the wildcard `*` at the end of `source` to move all matching files.

`movefile('source','destination','f')` moves the file or directory named `source` to the location `destination`, regardless of the read-only attribute of `destination`.

`[status,message,messageid]=movefile('source','destination','f')` moves the file or directory named `source` to the location `destination`, returning the status, a message, and the MATLAB error message ID (see `error` and `lasterror`). Here, `status` is logical `1` for success or logical `0` for error. Only one output argument is required and the `f` input argument is optional.

The `*` wildcard in a path string is supported.

Examples

Move Source to Current Directory

To move the file myfiles/myfunction.m to the current directory, type

```
movefile('myfiles/myfunction.m')
```

If the current directory is `projects/testcases` and you want to move `projects/myfiles` and its contents to the current directory, use `../` in the source pathname to navigate up one level to get to the directory.

```
movefile('../myfiles')
```

Move All Matching Files by Using a Wildcard

To move all files in the directory `myfiles` whose names begin with my to the current directory, type

```
movefile('myfiles/my*')
```

Move Source to Destination

To move the file `myfunction.m` from the current directory to the directory `projects`, where `projects` and the current directory are at the same level, type

```
movefile('myfunction.m','../projects')
```

Move Directory Down One Level

This example moves the a directory down a level. For example to move the directory `projects/testcases` and all its contents down a level in `projects` to `projects/myfiles`, type

```
movefile('projects/testcases','projects/myfiles/')
```

The directory `testcases` and its contents now appear in the directory `myfiles`.

Rename When Moving File to Read-Only Directory

Move the file `myfile.m` from the current directory to `d:/work/restricted`, assigning it the name `test1.m`, where `restricted` is a read-only directory.

```
movefile('myfile.m','d:/work/restricted/test1.m','f')
```

The read-only file `myfile.m` is no longer in the current directory. The file `test1.m` is in `d:/work/restricted` and is read only.

Return Status When Moving Files

In this example, all files in the directory `myfiles` whose names start with `new` are to be moved to the current directory. However, if `new*` is accidentally written as `nex*`. As a result, the move is unsuccessful, as seen in the status and messages returned:

```
[s,mess,messid]=movefile('myfiles/nex*')

s =
     0

mess =

A duplicate filename exists, or the file cannot be found.

messid =

MATLAB:MOVEFILE:OSError
```

See Also

`cd`, `copyfile`, `delete`, `dir`, `fileattrib`, `filebrowser`, `ls`, `mkdir`, `rmdir`

Purpose

Move GUI figure to specified location on screen

Syntax

```
movegui(h,'position')
movegui('position')
movegui(h)
movegui
```

Description

`movegui(h,'position')` moves the figure identified by handle `h` to the specified screen location, preserving the figure's size. The *`position`* argument can be any of the following strings:

- `north` – top center edge of screen
- `south` – bottom center edge of screen
- `east` – right center edge of screen
- `west` – left center edge of screen
- `northeast` – top right corner of screen
- `northwest` – top left corner of screen
- `southeast` – bottom right corner of screen
- `southwest` – bottom left corner
- `center` – center of screen
- `onscreen` – nearest location with respect to current location that is on screen

The *`position`* argument can also be a two-element vector `[h,v]`, where depending on sign, `h` specifies the figure's offset from the left or right edge of the screen, and `v` specifies the figure's offset from the top or bottom of the screen, in pixels. The following table summarizes the possible values.

h (for h >= 0)	offset of left side from left edge of screen
h (for h < 0)	offset of right side from right edge of screen
v (for v >= 0)	offset of bottom edge from bottom of screen
v (for v < 0)	offset of top edge from top of screen

movegui('*position*') move the callback figure (gcbf) or the current figure (gcf) to the specified position.

movegui(h) moves the figure identified by the handle h to the onscreen position.

movegui moves the callback figure (gcbf) or the current figure (gcf) to the onscreen position. This is useful as a string-based CreateFcn callback for a saved figure. It ensures the figure appears on screen when reloaded, regardless of its saved position.

Examples

This example demonstrates the usefulness of movegui to ensure that saved GUIs appear on screen when reloaded, regardless of the target computer's screen sizes and resolution. It creates a figure off the screen, assigns movegui as its CreateFcn callback, then saves and reloads the figure.

```
f = figure('Position',[10000,10000,400,300]);
set(f,'CreateFcn','movegui')
hgsave(f,'onscreenfig')
close(f)
f2 = hgload('onscreenfig');
```

See Also

guide

"Creating GUIs" in the MATLAB documentation

Purpose Play recorded movie frames

Syntax

```
movie
movie(M)
movie(M,n)
movie(M,n,fps)
movie(h,...)
movie(h,M,n,fps,loc)
```

Description

`movie` plays the movie defined by a matrix whose columns are movie frames (usually produced by `getframe`).

`movie(M)` plays the movie in matrix `M` once, using the current axes as the default target. If you want to play the movie in the figure instad of the axes, specify the figure handle (or `gcf`) as the first argument: `movie(`*`figure_handle`*`,...)`. `M` must be an array of movie frames (usually from `getframe`).

`movie(M,n)` plays the movie `n` times. If `n` is negative, each cycle is shown forward then backward. If `n` is a vector, the first element is the number of times to play the movie, and the remaining elements make up a list of frames to play in the movie.

For example, if `M` has four frames then `n = [10 4 4 2 1]` plays the movie ten times, and the movie consists of frame `4` followed by frame `4` again, followed by frame `2` and finally frame `1`.

`movie(M,n,fps)` plays the movie at `fps` frames per second. The default is 12 frames per second. Computers that cannot achieve the specified speed play as fast as possible.

`movie(h,...)` plays the movie centered in the figure or axes identified by the handle `h`.

`movie(h,M,n,fps,loc)` specifies `loc`, a four-element location vector, `[x y 0 0]`, where the lower left corner of the movie frame is anchored (only the first two elements in the vector are used). The location is relative to the lower left corner of the figure or axes specified by `handle h` and in units of pixels, regardless of the object's `Units` property.

Remarks

The movie function uses a default figure size of 560-by-420 and does not resize figures to fit movies with larger or smaller frames. To accommodate other frame sizes, you can resize the figure to fit the movie, as shown in the second example below.

movie only accepts 8-bit image frames; it does not accept 16-bit grayscale or 24–bit truecolor image frames.

You can abort a movie by typing **Ctrl-C**.

Examples

Example 1: Animate the peaks function as you scale the values of Z:

```
Z = peaks; surf(Z);
axis tight
set(gca,'nextplot','replacechildren');
% Record the movie
for j = 1:20
 surf(sin(2*pi*j/20)*Z,Z)
 F(j) = getframe;
end
% Play the movie ten times
movie(F,10)
```

Example 2: Specify figure when calling movie to fit the movie to the figure:

```
r = subplot(2,1,1)
Z = peaks; surf(Z);
axis tight
set(gca,'nextplot','replacechildren');

s = subplot(2,1,2)
Z = peaks; surf(Z);
axis tight
set(gca,'nextplot','replacechildren');
% Record the movie
for j = 1:20
 axes(r)
```

```
    surf(sin(2*pi*j/20)*Z,Z)
 axes(s)
 surf(sin(2*pi*(j+5)/20)*Z,Z)
    F(j) = getframe(gcf);
 pause(.0333)
end
% Play the movie; note that it does not fit the figure properly:
h2 = figure;
movie(F,10)
% Use the figure handle to make the frames fit:
movie(h2,F,10)
```

Example 3: With larger frames, first adjust the figure's size to fit the movie:

```
figure('position',[100 100 850 600])
Z = peaks; surf(Z);
axis tight
set(gca,'nextplot','replacechildren');
% Record the movie
for j = 1:20
 surf(sin(2*pi*j/20)*Z,Z)
 F(j) = getframe;
end
[h, w, p] = size(F(1).cdata);  % use 1st frame to get dimensions
hf = figure;
% resize figure based on frame's w x h, and place at (150, 150)
set(hf, 'position', [150 150 w h]);
axis off
% tell movie command to place frames at bottom left
movie(hf,F,4,30,[0 0 0 0]);
```

See Also

`aviread`, `getframe`, `frame2im`, `im2frame`

"Animation" on page 1-90 for related functions

See Example – Visualizing an FFT as a Movie for another example

Purpose Create Audio/Video Interleaved (AVI) movie from MATLAB movie

Syntax

```
movie2avi(mov,filename)
movie2avi(mov,filename,param,value,param,value...)
```

Description

`movie2avi(mov,filename)` creates the AVI movie `filename` from the MATLAB movie `mov`. The `filename` input is a string enclosed in single quotes.

`movie2avi(mov,filename,param,value,param,value...)` creates the AVI movie `filename` from the MATLAB movie `mov` using the specified parameter settings.

Parameter	Value		Default
'colormap'	An `m`-by-3 matrix defining the colormap to be used for indexed AVI movies, where `m` must be no greater than 256 (236 if using `Indeo` compression).		There is no default colormap.
'compression'	A text string specifying the compression codec to use.		
	On Windows: 'Indeo3' 'Indeo5' 'Cinepak' 'MSVC' 'RLE' 'None'	On UNIX: 'None'	'Indeo5' on Windows. 'None' on UNIX.

Parameter	Value	Default
	To use a custom compression codec, specify the four-character code that identifies the codec (typically included in the codec documentation). The `addframe` function reports an error if it can not find the specified custom compressor.	
`'fps'`	A scalar value specifying the speed of the AVI movie in frames per second (fps).	15 fps
`'keyframe'`	For compressors that support temporal compression, this is the number of key frames per second.	2 key frames per second.
`'quality'`	A number between 0 and 100 the specifies the desired quality of the output. Higher numbers result in higher video quality and larger file sizes. Lower numbers result in lower video quality and smaller file sizes. This parameter has no effect on uncompressed movies.	75
`'videoname'`	A descriptive name for the video stream. This parameter must be no greater than 64 characters long.	The default is the `filename`.

See Also

`avifile`, `aviread`, `aviinfo`, `movie`

mput

Purpose Upload file or directory to FTP server

Syntax

```
mput(f,'filename')
mput(ftp,'directoryname')
mput(f,'wildcard')
```

Description

`mput(f,'filename')` uploads `filename` from the MATLAB current directory to the current directory of the FTP server `f`, where `filename` is a file, and where `f` was created using `ftp`. You can use a wildcard (*) in `filename`. MATLAB returns a cell array listing the full path to the uploaded files on the server.

`mput(ftp,'directoryname')` uploads the directory `directoryname` and its contents. MATLAB returns a cell array listing the full path to the uploaded files on the server.

`mput(f,'wildcard')` uploads a set of files or directories specified by a wildcard. MATLAB returns a cell array listing the full path to the uploaded files on the server.

See Also `ftp`, `mget`, `mkdir (ftp)`, `rename`

Purpose

Create and open message box

Syntax

```
h = msgbox(Message)
h = msgbox(Message,Title)
h = msgbox(Message,Title,Icon)
h = msgbox(Message,Title,'custom',IconData,IconCMap)
h = msgbox(...,CreateMode)
```

Description

`h = msgbox(Message)` creates a message dialog box that automatically wraps `Message` to fit an appropriately sized figure. `Message` is a string vector, string matrix, or cell array. `msgbox` returns the handle of the message box in `h`.

`h = msgbox(Message,Title)` specifies the title of the message box.

`h = msgbox(Message,Title,Icon)` specifies which icon to display in the message box. `Icon` is `'none'`, `'error'`, `'help'`, `'warn'`, or `'custom'`. The default is `'none'`.

`h = msgbox(Message,Title,'custom',IconData,IconCMap)` defines a customized icon. `IconData` contains image data defining the icon. `IconCMap` is the colormap used for the image.

`h = msgbox(...,CreateMode)` specifies whether the message box is modal or nonmodal. Optionally, it can also specify an interpreter for `Message` and `Title`.

If *`CreateMode`* is a string, it must be one of the values shown in the following table.

CreateMode Value	Description
'modal'	Replaces the message box having the specified Title, that was last created or clicked on, with a modal message box as specified. All other message boxes with the same title are deleted. The message box which is replaced can be either modal or nonmodal.
'non-modal' (default)	Creates a new nonmodal message box with the specified parameters. Existing message boxes with the same title are not deleted.
'replace'	Replaces the message box having the specified Title, that was last created or clicked on, with a nonmodal message box as specified. All other message boxes with the same title are deleted. The message 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 theuiwait function. For more information about modal dialog boxes, see WindowStyle in the MATLABFigure Properties.

If *CreateMode* is a structure, it can have fields WindowStyle and Interpreter. The WindowStyle field must be one of the values in the table above. Interpreter is one of the strings'tex' or 'none'. The default value for Interpreter is 'none'.

See Also

dialog, errordlg, helpdlg, inputdlg, listdlg, questdlg, warndlg

figure, textwrap, uiwait, uiresume

"Predefined Dialog Boxes" on page 1-103 for related functions

Purpose

Matrix multiplication

Syntax

```
C = A*B
```

Description

C = A*B is the linear algebraic product of the matrices A and B. If A is an m-by-p and B is a p-by-n matrix, the i,j entry of C is defined by

$$C(i, j) = \sum_{k=1}^{p} A(i, k)B(k, j)$$

The product C is an m-by-n matrix. For nonscalar A and B, the number of columns of A must equal the number of rows of B. You can multiply a scalar by a matrix of any size.

The preceding definition says that C(i,j) is the inner product of the ith row of A with the jth column of B. You can write this definition using the MATLAB colon operator as

```
C(i,j) = A(i,:)*B(:,j)
```

where A(i,:) is the ith row of A and B(:,j) is the jth row of B.

Note If A is an m-by-0 empty matrix and B is a 0-by-n empty matrix, where m and n are positive integers, A*B is an m-by-n matrix of all zeros.

Examples

Example 1

If A is a row vector and B is a column vector with the same number of elements as A, A*B is simply the inner product of A and B. For example,

```
A = [5 3 2 6]

A =

     5     3     2     6
```

```
B = [-4 9 0 1]'

B =

    -4
     9
     0
     1
A*B

ans =

    13
```

Example 2

```
A = [1 3 5; 2 4 7]

A =

     1     3     5
     2     4     7
B = [-5 8 11; 3 9 21;4 0 8]

B =

    -5     8    11
     3     9    21
     4     0     8
```

The product of A and B is

```
C = A*B

C =

    24    35   114
    30    52   162
```

Note that the second row of A is

```
A(2,:)

ans =

     2     4     7
```

while the third column of B is

```
B(:,3)

ans =

    11
    21
     8
```

The inner product of `A(2,:)` and `B(:,3)` is

```
A(2,:)*B(:,3)

ans =

   162
```

which is the same as `C(2,3)`.

Algorithm

`mtimes` uses the following Basic Linear Algebra Subroutines (BLAS):

- `DDOT`
- `DGEMV`
- `DGEMM`
- `DSYRK`
- `DSYRZK`

For inputs of type `single`, mtimes using corresponding routines that begin with “`S`” instead of “`D`”.

See Also

Arithmetic Operators

Purpose Convert mu-law audio signal to linear

Syntax `y = mu2lin(mu)`

Description `y = mu2lin(mu)` converts mu-law encoded 8-bit audio signals, stored as “flints” in the range `0` ≤ `mu` ≤ `255`, to linear signal amplitude in the range `-s < Y < s` where `s = 32124/32768 ~= .9803`. The input `mu` is often obtained using `fread(...,'uchar')` to read byte-encoded audio files. "Flints" are MATLAB integers — floating-point numbers whose values are integers.

See Also `auread`, `lin2mu`

Purpose

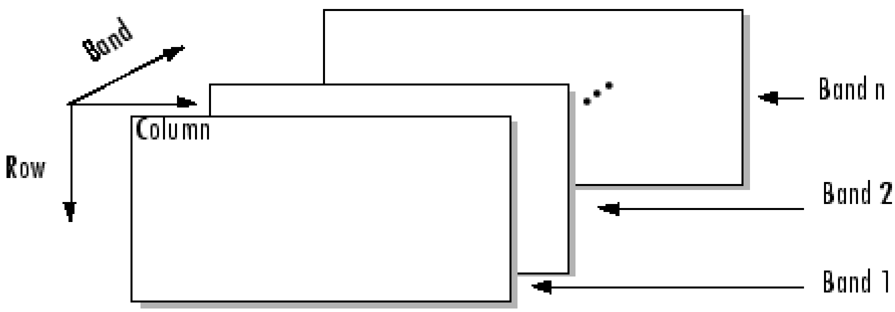
Read band-interleaved data from binary file

Syntax

```
X = multibandread(filename, size, precision, offset,
   interleave,  byteorder)
X = multibandread(...,subset1,subset2,subset3)
```

Description

`X = multibandread(filename, size, precision, offset, interleave, byteorder)` reads band-sequential (BSQ), band-interleaved-by-line (BIL), or band-interleaved-by-pixel (BIP) data from the binary file `filename`. The `filename` input is a string enclosed in single quotes. This function defines *band* as the third dimension in a 3-D array, as shown in this figure.



You can use the parameters to `multibandread` to specify many aspects of the read operation, such as which bands to read. See "Parameters" on page 2-2170 for more information.

`X` is a 2-D array if only one band is read; otherwise it is 3-D. `X` is returned as an array of data type `double` by default. Use the `precision` parameter to map the data to a different data type.

`X = multibandread(...,subset1,subset2,subset3)` reads a subset of the data in the file. You can use up to three subsetting parameters to specify the data subset along row, column, and band dimensions. See "Subsetting Parameters" on page 2-2172 for more information.

Parameters

This table describes the arguments accepted by `multibandread`.

Argument	Description
`filename`	String containing the name of the file to be read.
`size`	Three-element vector of integers consisting of `[height, width, N]`, where • `height` is the total number of rows • `width` is the total number of elements in each row • `N` is the total number of bands. This will be the dimensions of the data if it is read in its entirety.
`precision`	String specifying the format of the data to be read, such as `'uint8'`, `'double'`, `'integer*4'`, or any of the other precisions supported by the `fread` function. Note: You can also use the `precision` parameter to specify the format of the output data. For example, to read `uint8` data and output a `uint8` array, specify a precision of `'uint8=>uint8'` (or `'*uint8'`). To read `uint8` data and output it in MATLAB in single precision, specify `'uint8=>single'`. See `fread` for more information.
`offset`	Scalar specifying the zero-based location of the first data element in the file. This value represents the number of bytes from the beginning of the file to where the data begins.

Argument	Description
interleave	String specifying the format in which the data is stored • 'bsq' — Band-Sequential • 'bil'— Band-Interleaved-by-Line • 'bip'— Band-Interleaved-by-Pixel For more information about these interleave methods, see the multibandwrite reference page.
byteorder	String specifying the byte ordering (machine format) in which the data is stored, such as • 'ieee-le' — Little-endian • 'ieee-be' — Big-endian See fopen for a complete list of supported formats.

Subsetting Parameters

You can specify up to three subsetting parameters. Each subsetting parameter is a three-element cell array, {*dim*, *method*, index}, where

Parameter	Description
dim	Text string specifying the dimension to subset along. It can have any of these values: • 'Column' • 'Row' • 'Band'

Parameter	Description
method	Text string specifying the subsetting method. It can have either of these values: • 'Direct' • 'Range' If you leave out this element of the subset cell array, multibandread uses 'Direct' as the default.
index	If method is 'Direct', index is a vector specifying the indices to read along the Band dimension. If method is 'Range', index is a three-element vector of [start, increment, stop] specifying the range and step size to read along the dimension specified in dim. If index is a two-element vector, multibandread assumes that the value of increment is 1.

Examples

Example 1

Setup initial parameters for a data set.

```
rows=3; cols=3; bands=5;
filename = tempname;
```

Define the data set.

```
fid = fopen(filename, 'w', 'ieee-le');
fwrite(fid, 1:rows*cols*bands, 'double');
fclose(fid);
```

Read every other band of the data using the Band-Sequential format.

```
im1 = multibandread(filename, [rows cols bands], ...
                    'double', 0, 'bsq', 'ieee-le', ...
```

```
                    {'Band', 'Range', [1 2 bands]} )
```

Read the first two rows and columns of data using Band-Interleaved-by-Pixel format.

```
im2 = multibandread(filename, [rows cols bands], ...
                    'double', 0, 'bip', 'ieee-le', ...
                    {'Row', 'Range', [1 2]}, ...
                    {'Column', 'Range', [1 2]} )
```

Read the data using Band-Interleaved-by-Line format.

```
im3 = multibandread(filename, [rows cols bands], ...
                    'double', 0, 'bil', 'ieee-le')
```

Delete the file created in this example.

```
delete(filename);
```

Example 2

Read `int16` BIL data from the FITS file `tst0012.fits`, starting at byte 74880.

```
im4 = multibandread('tst0012.fits', [31 73 5], ...
                    'int16', 74880, 'bil', 'ieee-be', ...
                    {'Band', 'Range', [1 3]} );
im5 = double(im4)/max(max(max(im4)));
imagesc(im5);
```

See Also

`fread`, `fwrite`, `multibandwrite`

Purpose

Write band-interleaved data to file

Syntax

```
multibandwrite(data,filename,interleave)
multibandwrite(data,filename,interleave,start,totalsize)
multibandwrite(...,param,value...)
```

Description

`multibandwrite(data,filename,interleave)` writes `data`, a two- or three-dimensional numeric or logical array, to the binary file specified by `filename`. The `filename` input is a string enclosed in single quotes. The length of the third dimension of `data` determines the number of bands written to the file. The bands are written to the file in the form specified by `interleave`. See "Interleave Methods" on page 2-2177 for more information about this argument.

If filename already exists, `multibandwrite` overwrites it unless you specify the optional `offset` parameter. See the last alternate syntax for `multibandwrite` for information about other optional parameters.

`multibandwrite(data,filename,interleave,start,totalsize)` writes `data` to the binary file `filename` in chunks. In this syntax, `data` is a subset of the complete data set.

`start` is a 1-by-3 array `[firstrow firstcolumn firstband]` that specifies the location to start writing data. `firstrow` and `firstcolumn` specify the location of the upper left image pixel. `firstband` gives the index of the first band to write. For example, `data(I,J,K)` contains the data for the pixel at `[firstrow+I-1, firstcolumn+J-1]` in the `(firstband+K-1)`-th band.

`totalsize` is a 1-by-3 array, `[totalrows,totalcolumns,totalbands]`, which specifies the full, three-dimensional size of the data to be written to the file.

Note In this syntax, you must call `multibandwrite` multiple times to write all the data to the file. The first time it is called, `multibandwrite` writes the complete file, using the fill value for all values outside the data subset. In each subsequent call, `multibandwrite` overwrites these fill values with the data subset in `data`. The parameters `filename`, `interleave`, `offset`, and `totalsize` must remain constant throughout the writing of the file.

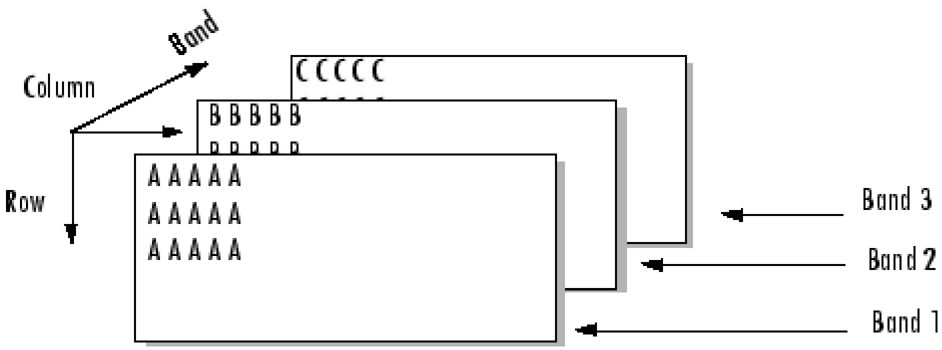
`multibandwrite(...,param,value...)` writes the multiband data to a file, specifying any of these optional parameter/value pairs.

Parameter	Description
`'precision'`	String specifying the form and size of each element written to the file. See the help for `fwrite` for a list of valid values. The default precision is the class of the data.
`'offset'`	The number of bytes to skip before the first data element. If the file does not already exist, `multibandwrite` writes ASCII null values to fill the space. To specify a different fill value, use the parameter `'fillvalue'`. This option is useful when you are writing a header to the file before or after writing the data. When writing the header to the file after the data is written, open the file with `fopen` using `'r+'` permission.

Parameter	Description
'machfmt'	String to control the format in which the data is written to the file. Typical values are 'ieee-le' for little endian and 'ieee-be' for big endian. See the help for fopen for a complete list of available formats. The default machine format is the local machine format.
'fillvalue'	A number specifying the value to use in place of missing data. 'fillvalue' can be a single number, specifying the fill value for all missing data, or a 1-by-Number-of-bands vector of numbers specifying the fill value for each band. This value is used to fill space when data is written in chunks.

Interleave Methods

interleave is a string that specifies how multibandwrite interleaves the bands as it writes data to the file. If data is two-dimensional, multibandwrite ignores the interleave argument. The following table lists the supported methods and uses this example multiband file to illustrate each method.



Supported methods of interleaving bands include those listed below.

Method	String	Description	Example
Band-Interleaved-by-Line	'bil'	Write an entire row from each band	AAAAABBBBBCCCCC AAAAABBBBBCCCCC AAAAABBBBBCCCCC
Band-Interleaved-by-Pixel	'bip'	Write a pixel from each band	ABCABCABCABCABC...
Band-Sequential	'bsq'	Write each band in its entirety	AAAAA AAAAA AAAAA BBBBB BBBBB BBBBB CCCCC CCCCC CCCCC

Examples

Note To run these examples successfully, you must be in a writable directory.

Example 1

Write all data (interleaved by line) to the file in one call.

```
data = reshape(uint16(1:600), [10 20 3]);
multibandwrite(data,'data.bil','bil');
```

Example 2

Write the bands (interleaved by pixel) to the file in separate calls.

```
totalRows    = size(data, 1);
totalColumns = size(data, 2);
totalBands   = size(data, 3);
for i = 1:totalBands
   bandData = data(:, :, i);
   multibandwrite(bandData, 'data.bip', 'bip', [1 1 i],...
                  [totalColumns, totalRows, totalBands]);
end
```

Example 3

Write a single-band tiled image with one call for each tile. This is only useful if a subset of each band is available at each call to `multibandwrite`.

```
numBands = 1;
dataDims = [1024 1024 numBands];
data = reshape(uint32(1:(1024 * 1024 * numBands)), dataDims);

for band = 1:numBands
   for row = 1:2
      for col = 1:2

         subsetRows = ((row - 1) * 512 + 1):(row * 512);
         subsetCols = ((col - 1) * 512 + 1):(col * 512);

         upperLeft = [subsetRows(1), subsetCols(1), band];
         multibandwrite(data(subsetRows, subsetCols, band), ...
                          'banddata.bsq', 'bsq', upperLeft, dataDims);

      end
   end
```

```
end
```

See Also

`multibandread`, `fwrite`, `fread`

Purpose Allow clearing M-file or MEX-file from memory

Syntax

```
munlock
munlock fun
munlock('fun')
```

Description munlock unlocks the currently running M-file or MEX-file in memory so that subsequent clear functions can remove it.

munlock fun unlocks the M-file or MEX-file named fun from memory. By default, these files are unlocked so that changes to the file are picked up. Calls to munlock are needed only to unlock M-files or MEX-files that have been locked with mlock.

munlock('fun') is the function form of munlock.

Examples The function testfun begins with an mlock statement.

```
function testfun
mlock
  .
  .
```

When you execute this function, it becomes locked in memory. You can check this using the mislocked function.

```
testfun

mislocked testfun
ans =
     1
```

Using munlock, you unlock the testfun function in memory. Checking its status with mislocked shows that it is indeed unlocked at this point.

```
munlock testfun

mislocked testfun
ans =
```

```
0
```

See Also

`mlock`, `mislocked`, `persistent`

Purpose

Maximum identifier length

Syntax

`len = namelengthmax`

Description

`len = namelengthmax` returns the maximum length allowed for MATLAB identifiers. MATLAB identifiers are

- Variable names
- Function and subfunction names
- Structure fieldnames
- Object names
- M-file names
- MEX-file names
- MDL-file names

Rather than hard-coding a specific maximum name length into your programs, use the `namelengthmax` function. This saves you the trouble of having to update these limits should the identifier length change in some future MATLAB release.

Examples

Call `namelengthmax` to get the maximum identifier length:

```
maxid = namelengthmax
maxid =
    63
```

See Also

`isvarname`, `genvarname`

Purpose

Not-a-Number

Syntax

```
NaN
```

Description

NaN returns the IEEE arithmetic representation for Not-a-Number (NaN). These result from operations which have undefined numerical results.

NaN('double') is the same as NaN with no inputs.

NaN('single') is the single precision representation of NaN.

NaN(n) is an n-by-n matrix of NaNs.

NaN(m,n) or NaN([m,n]) is an m-by-n matrix of NaNs.

NaN(m,n,p,...) or NaN([m,n,p,...]) is an m-by-n-by-p-by-... array of NaNs.

Note The size inputs m, n, p, ... should be nonnegative integers. Negative integers are treated as 0.

NaN(...,classname) is an array of NaNs of class specified by classname. classname must be either 'single' or 'double'.

Examples

These operations produce NaN:

- Any arithmetic operation on a NaN, such as sqrt(NaN)
- Addition or subtraction, such as magnitude subtraction of infinities as (+Inf)+(-Inf)
- Multiplication, such as 0*Inf
- Division, such as 0/0 and Inf/Inf
- Remainder, such as rem(x,y) where y is zero or x is infinity

Remarks

Because two NaNs are not equal to each other, logical operations involving NaNs always return false, except ~= (not equal). Consequently,

```
NaN ~= NaN
ans =
     1
NaN == NaN
ans =
     0
```

and the NaNs in a vector are treated as different unique elements.

```
unique([1 1 NaN NaN])
ans =
     1 NaN NaN
```

Use the isnan function to detect NaNs in an array.

```
isnan([1 1 NaN NaN])
ans =
     0     0     1     1
```

See Also

Inf, isnan

nargchk

Purpose

Validate number of input arguments

Syntax

```
msgstring = nargchk(minargs, maxargs, numargs)
msgstring = nargchk(minargs, maxargs, numargs, 'string')
msgstruct = nargchk(minargs, maxargs, numargs, 'struct')
```

Description

Use `nargchk` inside an M-file function to check that the desired number of input arguments is specified in the call to that function.

`msgstring = nargchk(minargs, maxargs, numargs)` returns an error message string `msgstring` if the number of inputs specified in the call `numargs` is less than `minargs` or greater than `maxargs`. If `numargs` is between `minargs` and `maxargs` (inclusive), `nargchk` returns an empty matrix.

It is common to use the `nargin` function to determine the number of input arguments specified in the call.

`msgstring = nargchk(minargs, maxargs, numargs, 'string')` is essentially the same as the command shown above, as `nargchk` returns a string by default.

`msgstruct = nargchk(minargs, maxargs, numargs, 'struct')` returns an error message structure `msgstruct` instead of a string. The fields of the return structure contain the error message string and a message identifier. If `numargs` is between `minargs` and `maxargs` (inclusive), `nargchk` returns an empty structure.

When too few inputs are supplied, the message string and identifier are

```
   message: 'Not enough input arguments.'
identifier: 'MATLAB:nargchk:notEnoughInputs'
```

When too many inputs are supplied, the message string and identifier are

```
   message: 'Too many input arguments.'
identifier: 'MATLAB:nargchk:tooManyInputs'
```

Remarks

`nargchk` is often used together with the `error` function. The `error` function accepts either type of return value from `nargchk`: a message string or message structure. For example, this command provides the `error` function with a message string and identifier regarding which error was caught:

```
error(nargchk(2, 4, nargin, 'struct'))
```

If `nargchk` detects no error, it returns an empty string or structure. When `nargchk` is used with the `error` function, as shown here, this empty string or structure is passed as an input to `error`. When `error` receives an empty string or structure, it simply returns and no error is generated.

Examples

Given the function `foo`,

```
function f = foo(x, y, z)
error(nargchk(2, 3, nargin))
```

Then typing `foo(1)` produces

```
Not enough input arguments.
```

See Also

`nargoutchk`, `nargin`, `nargout`, `varargin`, `varargout`, `error`

nargin, nargout

Purpose

Number of function arguments

Syntax

```
nargin
nargin(fun)
nargout
nargout(fun)
```

Description

In the body of a function M-file, `nargin` and `nargout` indicate how many input or output arguments, respectively, a user has supplied. Outside the body of a function M-file, `nargin` and `nargout` indicate the number of input or output arguments, respectively, for a given function. The number of arguments is negative if the function has a variable number of arguments.

`nargin` returns the number of input arguments specified for a function.

`nargin(fun)` returns the number of declared inputs for the function `fun`. If the function has a variable number of input arguments, `nargin` returns a negative value. `fun` may be the name of a function, or the name of "Function Handles" that map to specific functions.

`nargout` returns the number of output arguments specified for a function.

`nargout(fun)` returns the number of declared outputs for the function `fun`. `fun` may be the name of a function, or the name of "Function Handles" that map to specific functions.

Examples

This example shows portions of the code for a function called `myplot`, which accepts an optional number of input and output arguments:

```
function [x0, y0] = myplot(x, y, npts, angle, subdiv)
% MYPLOT  Plot a function.
% MYPLOT(x, y, npts, angle, subdiv)
%     The first two input arguments are
%     required; the other three have default values.
 ...
if nargin < 5, subdiv = 20; end
if nargin < 4, angle = 10; end
```

```
if nargin < 3, npts = 25; end
 ...
if nargout == 0
     plot(x, y)
else
     x0 = x;
     y0 = y;
end
```

See Also inputname, varargin, varargout, nargchk, nargoutchk

nargoutchk

Purpose

Validate number of output arguments

Syntax

```
msgstring = nargoutchk(minargs, maxargs, numargs)
msgstring = nargoutchk(minargs, maxargs, numargs, 'string')
msgstruct = nargoutchk(minargs, maxargs, numargs, 'struct')
```

Description

Use `nargoutchk` inside an M-file function to check that the desired number of output arguments is specified in the call to that function.

`msgstring = nargoutchk(minargs, maxargs, numargs)` returns an error message string `msgstring` if the number of outputs specified in the call, `numargs`, is less than `minargs` or greater than `maxargs`. If `numargs` is between `minargs` and `maxargs` (inclusive), `nargoutchk` returns an empty matrix.

It is common to use the `nargout` function to determine the number of output arguments specified in the call.

`msgstring = nargoutchk(minargs, maxargs, numargs, 'string')` is essentially the same as the command shown above, as `nargoutchk` returns a string by default.

`msgstruct = nargoutchk(minargs, maxargs, numargs, 'struct')` returns an error message structure `msgstruct` instead of a string. The fields of the return structure contain the error message string and a message identifier. If `numargs` is between `minargs` and `maxargs` (inclusive), `nargoutchk` returns an empty structure.

When too few outputs are supplied, the message string and identifier are

```
   message: 'Not enough output arguments.'
identifier: 'MATLAB:nargoutchk:notEnoughOutputs'
```

When too many outputs are supplied, the message string and identifier are

```
   message: 'Too many output arguments.'
identifier: 'MATLAB:nargoutchk:tooManyOutputs'
```

Remarks

nargoutchk is often used together with the error function. The error function accepts either type of return value from nargoutchk: a message string or message structure. For example, this command provides the error function with a message string and identifier regarding which error was caught:

```
error(nargoutchk(2, 4, nargout, 'struct'))
```

If nargoutchk detects no error, it returns an empty string or structure. When nargoutchk is used with the error function, as shown here, this empty string or structure is passed as an input to error. When error receives an empty string or structure, it simply returns and no error is generated.

Examples

You can use nargoutchk to determine if an M-file has been called with the correct number of output arguments. This example uses nargout to return the number of output arguments specified when the function was called. The function is designed to be called with one, two, or three output arguments. If called with no arguments or more than three arguments, nargoutchk returns an error message:

```
function [s, varargout] = mysize(x)
msg = nargoutchk(1, 3, nargout);
if isempty(msg)
    nout = max(nargout, 1) - 1;
    s = size(x);
    for k = 1:nout, varargout(k) = {s(k)}; end
else
    disp(msg)
end
```

See Also

nargchk, nargout, nargin, varargout, varargin, error

native2unicode

Purpose

Convert numeric bytes to Unicode characters

Syntax

```
unicodestr = native2unicode(bytes)
unicodestr = native2unicode(bytes, encoding)
```

Description

`unicodestr = native2unicode(bytes)` takes a vector containing numeric values in the range [0,255] and converts these values as a stream of 8-bit bytes to Unicode characters. The stream of bytes is assumed to be in MATLAB's default character encoding scheme. Return value `unicodestr` is a `char` vector that has the same general array shape as `bytes`.

`unicodestr = native2unicode(bytes, encoding)` does the conversion with the assumption that the byte stream is in the character encoding scheme specified by the string `encoding`. `encoding` must be the empty string (`''`) or a name or alias for an encoding scheme. Some examples are `'UTF-8'`, `'latin1'`, `'US-ASCII'`, and `'Shift_JIS'`. For common names and aliases, see the Web site http://www.iana.org/assignments/character-sets. If `encoding` is unspecified or is the empty string (`''`), MATLAB's default encoding scheme is used.

Note If `bytes` is a `char` vector, it is returned unchanged.

Examples

This example begins with a vector of bytes in an unknown character encoding scheme. The user-written function `detect_encoding` determines the encoding scheme. If successful, it returns the encoding scheme name or alias as a string. If unsuccessful, it throws an error. The example calls `native2unicode` to convert the bytes to Unicode characters.

```
try
 enc = detect_encoding(bytes);
 str = native2unicode(bytes, enc);
 disp(str);
```

```
catch
 rethrow(lasterror);
end
```

Note that the computer must be configured to display text in a language represented by the detected encoding scheme for the output of `disp(str)` to be correct.

See Also

`unicode2native`

Purpose

Binomial coefficient or all combinations

Syntax

```
C = nchoosek(n,k)
C = nchoosek(v,k)
```

Description

`C = nchoosek(n,k)` where `n` and `k` are nonnegative integers, returns $n!/((n-k)!\ k!)$. This is the number of combinations of n things taken k at a time.

`C = nchoosek(v,k)`, where `v` is a row vector of length `n`, creates a matrix whose rows consist of all possible combinations of the n elements of `v` taken k at a time. Matrix `C` contains $n!/((n-k)!\ k!)$ rows and k columns.

Inputs `n`, `k`, and `v` support classes of `float double` and `float single`.

Examples

The command `nchoosek(2:2:10,4)` returns the even numbers from two to ten, taken four at a time:

```
2    4    6     8
2    4    6    10
2    4    8    10
2    6    8    10
4    6    8    10
```

Limitations

When `C = nchoosek(n,k)` has a large coefficient, a warning will be produced indicating possible inexact results. In such cases, the result is only accurate to 15 digits for double-precision inputs, or 8 digits for single-precision inputs.

`C = nchoosek(v,k)` is only practical for situations where `n` is less than about 15.

See Also

`perms`

Purpose

Generate arrays for N-D functions and interpolation

Syntax

```
[X1,X2,X3,...] = ndgrid(x1,x2,x3,...)
[X1,X2,...] = ndgrid(x)
```

Description

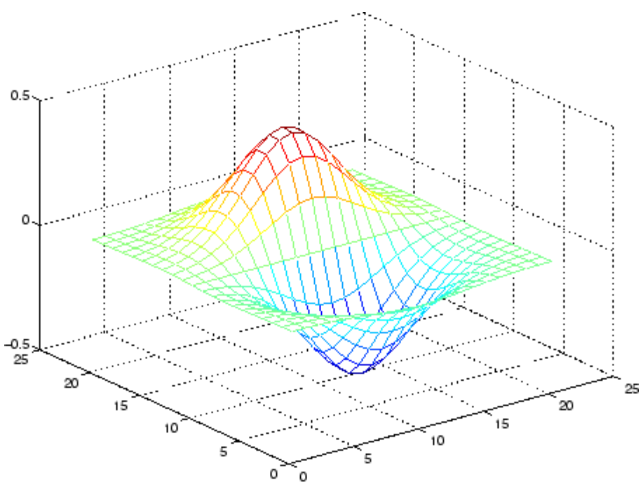
`[X1,X2,X3,...] = ndgrid(x1,x2,x3,...)` transforms the domain specified by vectors `x1,x2,x3...` into arrays `X1,X2,X3...` that can be used for the evaluation of functions of multiple variables and multidimensional interpolation. The `i`th dimension of the output array `Xi` are copies of elements of the vector `xi`.

`[X1,X2,...] = ndgrid(x)` is the same as `[X1,X2,...] = ndgrid(x,x,...)`.

Examples

Evaluate the function $x_1 e^{-x_1^2 - x_2^2}$ over the range $-2 < x_1 < 2, -2 < x_2 < 2$.

```
[X1,X2] = ndgrid(-2:.2:2, -2:.2:2);
Z = X1 .* exp(-X1.^2 - X2.^2);
mesh(Z)
```



Remarks

The `ndgrid` function is like `meshgrid` except that the order of the first two input arguments are switched. That is, the statement

```
[X1,X2,X3] = ndgrid(x1,x2,x3)
```

produces the same result as

```
[X2,X1,X3] = meshgrid(x2,x1,x3)
```

Because of this, `ndgrid` is better suited to multidimensional problems that aren't spatially based, while `meshgrid` is better suited to problems in two- or three-dimensional Cartesian space.

See Also

`meshgrid`, `interpn`

Purpose Number of array dimensions

Syntax

```
n = ndims(A)
```

Description `n = ndims(A)` returns the number of dimensions in the array `A`. The number of dimensions in an array is always greater than or equal to `2`. Trailing singleton dimensions are ignored. A singleton dimension is any dimension for which `size(A,dim) = 1`.

Algorithm `ndims(x)` is `length(size(x))`.

See Also `size`

Purpose

Test for inequality

Syntax

```
A ~= B
ne(A, B)
```

Description

`A ~= B` compares each element of array `A` with the corresponding element of array `B`, and returns an array with elements set to logical 1 (`true`) where `A` and `B` are unequal, or logical 0 (`false`) where they are equal. Each input of the expression can be an array or a scalar value.

If both `A` and `B` are scalar (i.e., 1-by-1 matrices), then MATLAB returns a scalar value.

If both `A` and `B` are nonscalar arrays, then these arrays must have the same dimensions, and MATLAB returns an array of the same dimensions as `A` and `B`.

If one input is scalar and the other a nonscalar array, then the scalar input is treated as if it were an array having the same dimensions as the nonscalar input array. In other words, if input `A` is the number 100, and `B` is a 3-by-5 matrix, then `A` is treated as if it were a 3-by-5 matrix of elements, each set to 100. MATLAB returns an array of the same dimensions as the nonscalar input array.

`ne(A, B)` is called for the syntax `A ~= B` when either `A` or `B` is an object.

Examples

Create two 6-by-6 matrices, `A` and `B`, and locate those elements of `A` that are not equal to the corresponding elements of `B`:

```
A = magic(6);
B = repmat(magic(3), 2, 2);

A ~= B
ans =
     1     0     0     1     1     1
     0     1     0     1     1     1
     1     0     0     1     1     1
     0     1     1     1     1     1
     1     0     1     1     1     1
```

```
0 1 1 1 1 1
```

See Also `eq`, `le`, `ge`, `lt`, `gt`, relational operators

newplot

Purpose

Determine where to draw graphics objects

Syntax

```
newplot
h = newplot
h = newplot(hsave)
```

Description

`newplot` prepares a figure and axes for subsequent graphics commands.

`h = newplot` prepares a figure and axes for subsequent graphics commands and returns a handle to the current axes.

`h = newplot(hsave)` prepares and returns an axes, but does not delete any objects whose handles appear in `hsave`. If `hsave` is specified, the figure and axes containing `hsave` are prepared for plotting instead of the current axes of the current figure. If `hsave` is empty, `newplot` behaves as if it were called without any inputs.

Remarks

Use `newplot` at the beginning of high-level graphics M-files to determine which figure and axes to target for graphics output. Calling `newplot` can change the current figure and current axes. Basically, there are three options when you are drawing graphics in existing figures and axes:

- Add the new graphics without changing any properties or deleting any objects.
- Delete all existing objects whose handles are not hidden before drawing the new objects.
- Delete all existing objects regardless of whether or not their handles are hidden, and reset most properties to their defaults before drawing the new objects (refer to the following table for specific information).

The figure and axes `NextPlot` properties determine how `newplot` behaves. The following two tables describe this behavior with various property values.

First, `newplot` reads the current figure's `NextPlot` property and acts accordingly.

NextPlot	What Happens
new	Create a new figure and use it as the current figure.
add	Draw to the current figure without clearing any graphics objects already present.
replacechildren	Remove all child objects whose HandleVisibility property is set to on and reset figure NextPlot property to add. This clears the current figure and is equivalent to issuing the clf command.
replace	Remove all child objects (regardless of the setting of the HandleVisibility property) and reset figure properties to their defaults, except NextPlot is reset to add regardless of user-defined defaults. • Position, Units, PaperPosition, and PaperUnits are not reset. This clears and resets the current figure and is equivalent to issuing the clf reset command.

After newplot establishes which figure to draw in, it reads the current axes' NextPlot property and acts accordingly.

NextPlot	Description
add	Draw into the current axes, retaining all graphics objects already present.

NextPlot	Description
replacechildren	Remove all child objects whose HandleVisibility property is set to on, but do not reset axes properties. This clears the current axes like the cla command.
replace	Remove all child objects (regardless of the setting of the HandleVisibility property) and reset axes properties to their defaults, except Position and Units. This clears and resets the current axes like the cla reset command.

See Also

axes, cla, clf, figure, hold, ishold, reset

The NextPlot property for figure and axes graphics objects

"Figure Windows" on page 1-94 for related functions

Controlling Graphics Output for more examples.

Purpose

Next higher power of 2

Syntax

```
p = nextpow2(A)
```

Description

`p = nextpow2(A)` returns the smallest power of two that is greater than or equal to the absolute value of `A`. (That is, `p` that satisfies `2^p >= abs(A)`).

This function is useful for optimizing FFT operations, which are most efficient when sequence length is an exact power of two.

If `A` is non-scalar, `nextpow2` returns the smallest power of two greater than or equal to `length(A)`.

Examples

For any integer `n` in the range from `513` to `1024`, `nextpow2(n)` is `10`.

For a 1-by-30 vector `A`, `length(A)` is `30` and `nextpow2(A)` is `5`.

See Also

`fft`, `log2`, `pow2`

Purpose

Number of nonzero matrix elements

Syntax

`n = nnz(X)`

Description

`n = nnz(X)` returns the number of nonzero elements in matrix `X`.

The density of a sparse matrix is `nnz(X)/prod(size(X))`.

Examples

The matrix

```
w = sparse(wilkinson(21));
```

is a tridiagonal matrix with 20 nonzeros on each of three diagonals, so `nnz(w) = 60`.

See Also

`find`, `isa`, `nonzeros`, `nzmax`, `size`, `whos`

Purpose

Change `EraseMode` of all objects to `normal`

Syntax

```
noanimate(state,fig_handle)
noanimate(state)
```

Description

`noanimate(state,fig_handle)` sets the `EraseMode` of all image, line, patch, surface, and text graphics objects in the specified figure to `normal`. `state` can be the following strings:

- `'save'` — Set the values of the `EraseMode` properties to `normal` for all the appropriate objects in the designated figure.
- `'restore'` — Restore the `EraseMode` properties to the previous values (i.e., the values before calling `noanimate` with the `'save'` argument).

`noanimate(state)` operates on the current figure.

`noanimate` is useful if you want to print the figure to a TIFF or JPEG format.

See Also

`print`

"Animation" on page 1-90 for related functions

Purpose

Nonzero matrix elements

Syntax

```
s = nonzeros(A)
```

Description

`s = nonzeros(A)` returns a full column vector of the nonzero elements in `A`, ordered by columns.

This gives the `s`, but not the `i` and `j`, from `[i,j,s] = find(A)`. Generally,

```
length(s) = nnz(A) <= nzmax(A) <= prod(size(A))
```

See Also

`find`, `isa`, `nnz`, `nzmax`, `size`, `whos`

Purpose

Vector and matrix norms

Syntax

```
n = norm(A)
n = norm(A,p)
```

Description

The *norm* of a matrix is a scalar that gives some measure of the magnitude of the elements of the matrix. The `norm` function calculates several different types of matrix norms:

`n = norm(A)` returns the largest singular value of `A`, `max(svd(A))`.

`n = norm(A,p)` returns a different kind of norm, depending on the value of `p`.

If `p` is...	Then `norm` returns...
`1`	The 1-norm, or largest column sum of `A`, `max(sum(abs(A)))`.
`2`	The largest singular value (same as `norm(A)`).
`inf`	The infinity norm, or largest row sum of `A`, `max(sum(abs(A')))`.
`'fro'`	The Frobenius-norm of matrix `A`, `sqrt(sum(diag(A'*A)))`.

When `A` is a vector:

`norm(A,p)`	Returns `sum(abs(A).^p)^(1/p)`, for any 1 <= `p` <= ∞.
`norm(A)`	Returns `norm(A,2)`.
`norm(A,inf)`	Returns `max(abs(A))`.
`norm(A,-inf)`	Returns `min(abs(A))`.

Remarks

Note that `norm(x)` is the Euclidean length of a vector `x`. On the other hand, MATLAB uses "length" to denote the number of elements `n` in a vector. This example uses `norm(x)/sqrt(n)` to obtain the root-mean-square (RMS) value of an `n`-element vector `x`.

```
x = [0 1 2 3]
x =
     0     1     2     3

sqrt(0+1+4+9)   % Euclidean length
ans =
    3.7417

norm(x)
ans =
    3.7417

n = length(x)   % Number of elements
n =
     4

rms = 3.7417/2  % rms = norm(x)/sqrt(n)
rms =
    1.8708
```

See Also

cond, condest, hypot, normest, rcond

Purpose

2-norm estimate

Syntax

```
nrm = normest(S)
nrm = normest(S,tol)
[nrm,count] = normest(...)
```

Description

This function is intended primarily for sparse matrices, although it works correctly and may be useful for large, full matrices as well.

`nrm = normest(S)` returns an estimate of the 2-norm of the matrix `S`.

`nrm = normest(S,tol)` uses relative error `tol` instead of the default tolerance `1.e-6`. The value of `tol` determines when the estimate is considered acceptable.

`[nrm,count] = normest(...)` returns an estimate of the 2-norm and also gives the number of power iterations used.

Examples

The matrix `W = gallery('wilkinson',101)` is a tridiagonal matrix. Its order, 101, is small enough that `norm(full(W))`, which involves `svd(full(W))`, is feasible. The computation takes 4.13 seconds (on one computer) and produces the exact norm, 50.7462. On the other hand, `normest(sparse(W))` requires only 1.56 seconds and produces the estimated norm, 50.7458.

Algorithm

The power iteration involves repeated multiplication by the matrix `S` and its transpose, `S'`. The iteration is carried out until two successive estimates agree to within the specified relative tolerance.

See Also

`cond`, `condest`, `norm`, `rcond`, `svd`

Purpose Find logical NOT of array or scalar input

Syntax

```
~A
not(A)
```

Description `~A` performs a logical NOT of input array `A`, and returns an array containing elements set to either logical 1 (`true`) or logical 0 (`false`). An element of the output array is set to 1 if the input array contains a zero value element at that same array location. Otherwise, that element is set to 0.

The input of the expression can be an array or can be a scalar value. If the input is an array, then the output is an array of the same dimensions. If the input is scalar, then the output is scalar.

`not(A)` is called for the syntax `~A` when `A` is an object.

Example If matrix `A` is

```
      0    29     0    36     0
     23    34    35     0    39
      0    24    31    27     0
      0    29     0     0    34
```

then

```
~A
ans =
      1     0     1     0     1
      0     0     0     1     0
      1     0     0     0     1
      1     0     1     1     0
```

See Also `bitcmp`, `and`, `or`, `xor`, `any`, `all`, “Logical Operators”, “Logical Types”, “Bit-Wise Functions”

Purpose

Open M-book in Microsoft Word (Windows)

Syntax

```
notebook
notebook('filename')
notebook('-setup')
```

Description

`notebook` starts Microsoft Word and creates a new M-book titled `Document 1`.

`notebook('filename')` starts Microsoft Word and opens the M-book `filename`, where filename is either in the MATLAB current directory or is a full pathname. If `filename` does not exist, MATLAB creates a new M-book titled `filename`. If the `filename` extension is not specified, MATLAB assumes `.doc`.

`notebook('-setup')` runs an interactive setup function for Notebook. It copies the Notebook template, `m-book.dot`, to the Microsoft Word template directory, whose location MATLAB automatically determines from the Windows system registry. Upon completion, MATLAB displays a message indicating whether or not the setup was successful.

See Also

Notebook for Publishing to Word and "Publishing to HTML, XML, LaTeX, Word, and PowerPoint Using Cells" in the MATLAB Desktop Tools and Development Environment documentation.

now

Purpose Current date and time

Syntax

```
t = now
```

Description

`t = now` returns the current date and time as a serial date number. To return the time only, use `rem(now,1)`. To return the date only, use `floor(now)`.

Examples

```
t1 = now, t2 = rem(now,1)

t1 =

   7.2908e+05


t2 =

     0.4013
```

See Also `clock`, `date`, `datenum`

Purpose

Real nth root of real numbers

Syntax

```
y = nthroot(X, n)
```

Description

y = nthroot(X, n) returns the real nth root of the elements of X. Both X and n must be real and n must be a scalar. If X has negative entries, n must be an odd integer.

Example

```
nthroot(-2, 3)
```

returns the real cube root of -2.

```
ans =

   -1.2599
```

By comparison,

```
(-2)^(1/3)
```

returns a complex cube root of -2.

```
ans =

   0.6300 + 1.0911i
```

See Also

power

Purpose Null space

Syntax

```
Z = null(A)
Z = null(A,'r')
```

Description

`Z = null(A)` is an orthonormal basis for the null space of `A` obtained from the singular value decomposition. That is, `A*Z` has negligible elements, `size(Z,2)` is the nullity of `A`, and `Z'*Z = I`.

`Z = null(A,'r')` is a "rational" basis for the null space obtained from the reduced row echelon form. `A*Z` is zero, `size(Z,2)` is an estimate for the nullity of `A`, and, if `A` is a small matrix with integer elements, the elements of the reduced row echelon form (as computed using `rref`) are ratios of small integers.

The orthonormal basis is preferable numerically, while the rational basis may be preferable pedagogically.

Example

Example 1

Compute the orthonormal basis for the null space of a matrix A.

```
A = [1     2     3
     1     2     3
     1     2     3];

Z = null(A);
A*Z

ans =
  1.0e-015 *
     0.2220    0.2220
     0.2220    0.2220
     0.2220    0.2220

Z'*Z

ans =
```

```
     1.0000   -0.0000
    -0.0000    1.0000
```

Example 2

Compute the 1-norm of the matrix A*Z and determine that it is within a small tolerance.

```
norm(A*Z,1) < 1e-12
ans =
    1
```

Example 3

Compute the rational basis for the null space of the same matrix A.

```
ZR = null(A,'r')

ZR =
    -2    -3
     1     0
     0     1

A*ZR

ans =

     0     0
     0     0
     0     0
```

See Also

orth, rank, rref, svd

num2cell

Purpose

Convert numeric array to cell array

Syntax

```
c = num2cell(A)
c = num2cell(A, dims)
```

Description

`c = num2cell(A)` converts the matrix `A` into a cell array by placing each element of `A` into a separate cell. Cell array `c` will be the same size as matrix `A`.

`c = num2cell(A, dims)` converts the matrix `A` into a cell array by placing the dimensions specified by `dims` into separate cells. `C` will be the same size as `A` except that the dimensions matching `dims` will be `1`.

Examples

The statement

```
num2cell(A,2)
```

places the rows of `A` into separate cells. Similarly

```
num2cell(A,[1 3])
```

places the column-depth pages of `A` into separate cells.

See Also

`cat`, `mat2cell`, `cell2mat`

Purpose

Convert singles and doubles to IEEE hexadecimal strings

Syntax

`num2hex(X)`

Description

If `X` is a single or double precision array with n elements, `num2hex(X)` is an n-by-8 or n-by-16 char array of the hexadecimal floating-point representation. The same representation is printed with format `hex`.

Examples

```
num2hex([1 0 0.1 -pi Inf NaN])
```

returns

```
ans =

3ff0000000000000
0000000000000000
3fb999999999999a
c00921fb54442d18
7ff0000000000000
fff8000000000000
num2hex(single([1 0 0.1 -pi Inf NaN]))
```

returns

```
ans =

3f800000
00000000
3dcccccd
c0490fdb
7f800000
ffc00000
```

See Also

`hex2num`, `dec2hex`, `format`

Purpose Convert number to string

Syntax

```
str = num2str(A)
str = num2str(A, precision)
str = num2str(A, format)
```

Description The `num2str` function converts numbers to their string representations. This function is useful for labeling and titling plots with numeric values.

`str = num2str(A)` converts array `A` into a string representation `str` with roughly four digits of precision and an exponent if required.

`str = num2str(A, precision)` converts the array `A` into a string representation `str` with maximum precision specified by *`precision`*. Argument *`precision`* specifies the number of digits the output string is to contain. The default is four.

`str = num2str(A, format)` converts array `A` using the supplied *`format`*. (See `fprintf` for format string details.) By default, `num2str` displays floating point values using `'%11.4g'` format (four significant digits in exponential or fixed-point notation, whichever is shorter).

If the input array is integer-valued, `num2str` returns the exact string representation of that integer. The term integer-valued includes large floating-point numbers that lose precision due to limitations of the hardware.

`num2str` removes any leading spaces from the output string. Thus, `num2str(42.67, '%10.2f')` returns a 1-by-5 character array `'42.67'`.

Examples `num2str(pi)` is `3.142`.

`num2str(eps)` is `2.22e-16`.

`num2str` with a format of `%10.5e\n` returns a matrix of strings in exponential format, having 5 decimal places, with each element separated by a `newline` character:

```
x = rand(3) * 9999;              % Create a 2-by-3 matrix.
x(3,:) = [];
```

```
A = num2str(x, '%10.5e\n')       % Convert to string array.
A =
6.87255e+003
1.55597e+003
8.55890e+003

3.46077e+003
1.91097e+003
4.90201e+003
```

See Also

mat2str, int2str, str2num, sprintf, fprintf

numel

Purpose

Number of elements in array or subscripted array expression

Syntax

```
n = numel(A)
n = numel(A, index1, index2, ... indexn)
```

Description

`n = numel(A)` returns the number of elements, `n`, in array `A`.

`n = numel(A, index1, index2, ...  indexn)` returns the number of subscripted elements, `n`, in `A(index1, index2, ..., indexn)`. To handle the variable number of arguments, `numel` is typically written with the header `function n = numel(A, varargin)`, where `varargin` is a cell array with elements `index1`, `index2, ... indexn`.

MATLAB implicitly calls the `numel` built-in function whenever an expression generates a comma-separated list. This includes brace indexing (i.e., `A{index1,index2,...,indexN}`), and dot indexing (i.e., `A.fieldname`).

Remarks

It is important to note the significance of `numel` with regards to the overloaded `subsref` and `subsasgn` functions. In the case of the overloaded `subsref` function for brace and dot indexing (as described in the last paragraph), `numel` is used to compute the number of expected outputs (`nargout`) returned from `subsref`. For the overloaded `subsasgn` function, `numel` is used to compute the number of expected inputs (`nargin`) to be assigned using `subsasgn`. The `nargin` value for the overloaded `subsasgn` function is the value returned by `numel` plus 2 (one for the variable being assigned to, and one for the structure array of subscripts).

As a class designer, you must ensure that the value of `n` returned by the built-in `numel` function is consistent with the class design for that object. If `n` is different from either the `nargout` for the overloaded `subsref` function or the `nargin` for the overloaded `subsasgn` function, then you need to overload `numel` to return a value of `n` that is consistent with the class' `subsref` and `subsasgn` functions. Otherwise, MATLAB produces errors when calling these functions.

Examples

Create a 4-by-4-by-2 matrix. `numel` counts 32 elements in the matrix.

```
a = magic(4);
a(:,:,2) = a'

a(:,:,1) =
    16     2     3    13
     5    11    10     8
     9     7     6    12
     4    14    15     1

a(:,:,2) =
    16     5     9     4
     2    11     7    14
     3    10     6    15
    13     8    12     1

numel(a)
ans =
    32
```

See Also

`nargin`, `nargout`, `prod`, `size`, `subsasgn`, `subsref`

Purpose Amount of storage allocated for nonzero matrix elements

Syntax

```
n = nzmax(S)
```

Description `n = nzmax(S)` returns the amount of storage allocated for nonzero elements.

If `S` is a sparse matrix...	`nzmax(S)` is the number of storage locations allocated for the nonzero elements in `S`.
If `S` is a full matrix...	`nzmax(S) = prod(size(S))`.

Often, `nnz(S)` and `nzmax(S)` are the same. But if `S` is created by an operation which produces fill-in matrix elements, such as sparse matrix multiplication or sparse LU factorization, more storage may be allocated than is actually required, and `nzmax(S)` reflects this. Alternatively, `sparse(i,j,s,m,n,nzmax)` or its simpler form, `spalloc(m,n,nzmax)`, can set `nzmax` in anticipation of later fill-in.

See Also `find`, `isa`, `nnz`, `nonzeros`, `size`, `whos`

Purpose

Solve fully implicit differential equations, variable order method

Syntax

```
[T,Y] = ode15i(odefun,tspan,y0,yp0)
[T,Y] = ode15i(odefun,tspan,y0,yp0,options)
[T,Y,TE,YE,IE] = ode15i(odefun,tspan,y0,yp0,options...)
sol = ode15i(odefun,[t0 tfinal],y0,yp0,...)
```

Arguments

The following table lists the input arguments for `ode15i`.

`odefun`	A function handle that evaluates the left side of the differential equations, which are of the form $f(t, y, y') = 0$. See "Function Handles" in the MATLAB Programming documentation for more information.
`tspan`	A vector specifying the interval of integration, `[t0,tf]`. To obtain solutions at specific times (all increasing or all decreasing), use `tspan = [t0,t1,...,tf]`.
`y0, yp0`	Vectors of initial conditions for y and y' respectively.
`options`	Optional integration argument created using the `odeset` function. See `odeset` for details.

The following table lists the output arguments for `ode15i`.

`T`	Column vector of time points
`Y`	Solution array. Each row in `y` corresponds to the solution at a time returned in the corresponding row of `t`.

Description

`[T,Y] = ode15i(odefun,tspan,y0,yp0)` with `tspan = [t0 tf]` integrates the system of differential equations $f(t, y, y') = 0$ from time `t0` to `tf` with initial conditions `y0` and `yp0`. `odefun` is a function handle. Function `ode15i` solves ODEs and DAEs of index 1. The initial conditions must be consistent, meaning that $f(\mathrm{t0}, \mathrm{y0}, \mathrm{yp0}) = 0$. You can use the function `decic` to compute consistent initial conditions close to guessed values. Function `odefun(t,y,yp)`, for a scalar `t` and column vectors `y` and `yp`, must return a column vector corresponding to $f(t, y, y')$. Each row in the solution array `Y` corresponds to a time returned in the column vector `T`. To obtain solutions at specific times `t0,t1,...,tf` (all increasing or all decreasing), use `tspan = [t0,t1,...,tf]`.

"Parameterizing Functions Called by Function Functions", in the MATLAB Mathematics documentation, explains how to provide additional parameters to the function `odefun`, if necessary.

`[T,Y] = ode15i(odefun,tspan,y0,yp0,options)` solves as above with default integration parameters replaced by property values specified in `options`, an argument created with the `odeset` function. Commonly used options include a scalar relative error tolerance `RelTol` (`1e-3` by default) and a vector of absolute error tolerances `AbsTol` (all components `1e-6` by default). See `odeset` for details.

`[T,Y,TE,YE,IE] = ode15i(odefun,tspan,y0,yp0,options...)` with the `'Events'` property in `options` set to a function `events`, solves as above while also finding where functions of (t, y, y'), called event functions, are zero. The function `events` is of the form `[value,isterminal,direction] = events(t,y,yp) and includes` the necessary event functions. Code the function `events` so that the `ith` element of each output vector corresponds to the `ith` event. For the `ith` event function in `events`:

- `value(i)` is the value of the function.
- `isterminal(i) = 1` if the integration is to terminate at a zero of this event function and `0` otherwise.
- `direction(i) = 0` if all zeros are to be computed (the default), `+1` if only the zeros where the event function increases, and `-1` if only the zeros where the event function decreases.

Output `TE` is a column vector of times at which events occur. Rows of `YE` are the corresponding solutions, and indices in vector `IE` specify which event occurred. See "Changing ODE Integration Properties" in the MATLAB Mathematics documentation for more information.

`sol = ode15i(odefun,[t0 tfinal],y0,yp0,...)` returns a structure that can be used with `deval` to evaluate the solution at any point between `t0` and `tfinal`. The structure `sol` always includes these fields:

`sol.x`	Steps chosen by the solver. If you specify the `Events` option and a terminal event is detected, `sol.x(end)` contains the end of the step at which the event occurred.
`sol.y`	Each column `sol.y(:,i)` contains the solution at `sol.x(i)`.

If you specify the `Events` option and events are detected, `sol` also includes these fields:

`sol.xe`	Points at which events, if any, occurred. `sol.xe(end)` contains the exact point of a terminal event, if any.
`sol.ye`	Solutions that correspond to events in `sol.xe`.
`sol.ie`	Indices into the vector returned by the function specified in the `Events` option. The values indicate which event the solver detected.

Options

`ode15i` accepts the following parameters in `options`. For more information, see `odeset` and Changing ODE Integration Properties in the MATLAB documentation.

Error control	`RelTol`, `AbsTol`, `NormControl`
Solver output	`OutputFcn`, `OutputSel`, `Refine`, `Stats`
Event location	`Events`

Step size	MaxStep, InitialStep
Jacobian matrix	Jacobian, JPattern, Vectorized

Solver Output

If you specify an output function as the value of the OutputFcn property, the solver calls it with the computed solution after each time step. Four output functions are provided: odeplot, odephas2, odephas3, odeprint. When you call the solver with no output arguments, it calls the default odeplot to plot the solution as it is computed. odephas2 and odephas3 produce two- and three-dimensional phase plane plots, respectively. odeprint displays the solution components on the screen. By default, the ODE solver passes all components of the solution to the output function. You can pass only specific components by providing a vector of indices as the value of the OutputSel property. For example, if you call the solver with no output arguments and set the value of OutputSel to [1,3], the solver plots solution components 1 and 3 as they are computed.

Jacobian Matrices

The Jacobian matrices $\partial f / \partial y$ and $\partial f / \partial y'$ are critical to reliability and efficiency. You can provide these matrices as one of the following:

- Function of the form [dfdy,dfdyp] = FJAC(t,y,yp) that computes the Jacobian matrices. If FJAC returns an empty matrix [] for either dfdy or dfdyp, then ode15i approximates that matrix by finite differences.
- Cell array of two constant matrices {dfdy,dfdyp}, either of which could be empty.

Use odeset to set the Jacobian option to the function or cell array. If you do not set the Jacobian option, ode15i approximates both Jacobian matrices by finite differences.

For ode15i, Vectorized is a two-element cell array. Set the first element to 'on' if odefun(t,[y1,y2,...],yp) returns `[odefun(t,y1,yp),odefun(t,y2,yp),...]`. Set the second element to `'on'` if `odefun(t,y,[yp1,yp2,...])` returns `[odefun(t,y,yp1),odefun(t,y,yp2),...]`. The default value of `Vectorized` is `{'off','off'}`.

For `ode15i`, `JPattern` is also a two-element sparse matrix cell array. If $\partial f/\partial y$ or $\partial f/\partial y'$ is a sparse matrix, set `JPattern` to the sparsity patterns, `{SPDY,SPDYP}`. A sparsity pattern of $\partial f/\partial y$ is a sparse matrix `SPDY` with `SPDY(i,j) = 1` if component `i` of `f(t,y,yp)` depends on component `j` of `y`, and `0` otherwise. Use `SPDY = []` to indicate that $\partial f/\partial y$ is a full matrix. Similarly for $\partial f/\partial y'$ and `SPDYP`. The default value of `JPattern` is `{[],[]}`.

Examples

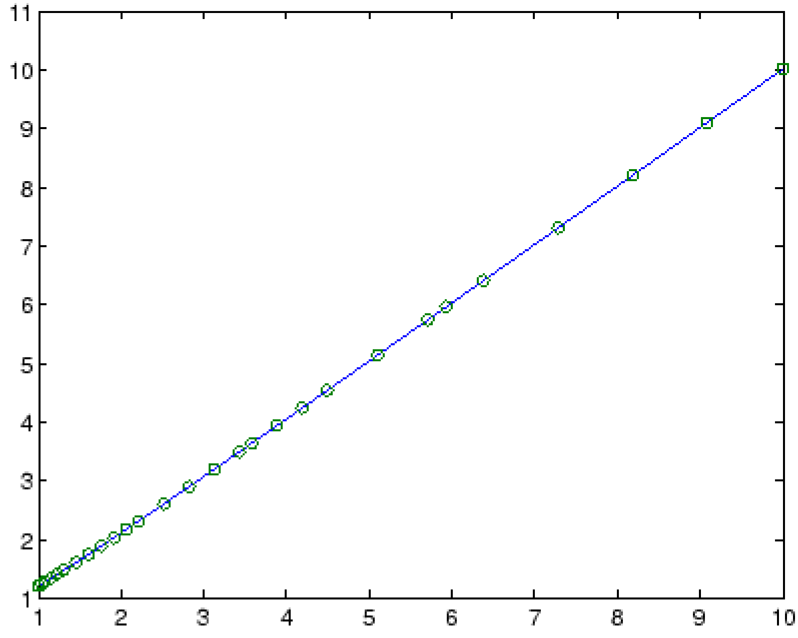
Example 1

This example uses a helper function `decic` to hold fixed the initial value for $y(t_0)$ and compute a consistent initial value for $y'(t_0)$ for the Weissinger implicit ODE. The Weissinger function evaluates the residual of the implicit ODE.

```
t0 = 1;
y0 = sqrt(3/2);
yp0 = 0;
[y0,yp0] = decic(@weissinger,t0,y0,1,yp0,0);
```

The example uses `ode15i` to solve the ODE, and then plots the numerical solution against the analytical solution.

```
[t,y] = ode15i(@weissinger,[1 10],y0,yp0);
ytrue = sqrt(t.^2 + 0.5);
plot(t,y,t,ytrue,'o');
```



Other Examples

These demos provide examples of implicit ODEs: `ihb1dae`, `iburgersode`.

See Also

`decic`, `deval`, `odeget`, `odeset`, `function_handle` (`@`)

Other ODE initial value problem solvers: `ode45`, `ode23`, `ode113`, `ode15s`, `ode23s`, `ode23t`, `ode23tb`

ode23, ode45, ode113, ode15s, ode23s, ode23t, ode23tb

Purpose

Solve initial value problems for ordinary differential equations

Syntax

```
[T,Y] = solver(odefun,tspan,y0)
[T,Y] = solver(odefun,tspan,y0,options)
[T,Y,TE,YE,IE] = solver(odefun,tspan,y0,options)
sol = solver(odefun,[t0 tf],y0...)
```

where *solver* is one of ode45, ode23, ode113, ode15s, ode23s, ode23t, or ode23tb.

Arguments

The following table describes the input arguments to the solvers.

`odefun`	A function handle that evaluates the right side of the differential equations. See "Function Handles" in the MATLAB Programming documentation for more information. All solvers solve systems of equations in the form $y' = f(t, y)$ or problems that involve a mass matrix, $M(t, y)y' = f(t, y)$. The `ode23s` solver can solve only equations with constant mass matrices. `ode15s` and `ode23t` can solve problems with a mass matrix that is singular, i.e., differential-algebraic equations (DAEs).
`tspan`	A vector specifying the interval of integration, `[t0,tf]`. The solver imposes the initial conditions at `tspan(1)`, and integrates from `tspan(1)` to `tspan(end)`. To obtain solutions at specific times (all increasing or all decreasing), use `tspan = [t0,t1,...,tf]`. For `tspan` vectors with two elements `[t0 tf]`, the solver returns the solution evaluated at every integration step. For `tspan` vectors with more than two elements, the solver returns solutions evaluated at the given time points. The time values must be in order, either increasing or decreasing.

	Specifying tspan with more than two elements does not affect the internal time steps that the solver uses to traverse the interval from tspan(1) to tspan(end). All solvers in the ODE suite obtain output values by means of continuous extensions of the basic formulas. Although a solver does not necessarily step precisely to a time point specified in tspan, the solutions produced at the specified time points are of the same order of accuracy as the solutions computed at the internal time points. Specifying tspan with more than two elements has little effect on the efficiency of computation, but for large systems, affects memory management.
y0	A vector of initial conditions.
options	Structure of optional parameters that change the default integration properties. This is the fourth input argument. `[t,y] = solver(odefun,tspan,y0,options)` You can create options using the odeset function. See odeset for details.

The following table lists the output arguments for the solvers.

T	Column vector of time points
Y	Solution array. Each row in y corresponds to the solution at a time returned in the corresponding row of t.

Description

[T,Y] = *solver*(odefun,tspan,y0) with tspan = [t0 tf] integrates the system of differential equations $y' = f(t, y)$ from time t0 to tf with initial conditions `y0`. `odefun` is a function handle. See Function Handles in the MATLAB Programming documentation for more information. Function `f = odefun(t,y)`, for a scalar `t` and a column vector `y`, must return a column vector `f` corresponding to $f(t, y)$. Each row in the solution array `Y` corresponds to a time returned in column vector `T`. To obtain solutions at the specific times `t0, t1,...,tf` (all increasing or all decreasing), use `tspan = [t0,t1,...,tf]`.

"Parameterizing Functions Called by Function Functions", in the MATLAB Mathematics documentation, explains how to provide additional parameters to the function `fun`, if necessary.

`[T,Y] = solver(odefun,tspan,y0,options)` solves as above with default integration parameters replaced by property values specified in `options`, an argument created with the `odeset` function. Commonly used properties include a scalar relative error tolerance `RelTol` (`1e-3` by default) and a vector of absolute error tolerances `AbsTol` (all components are `1e-6` by default). If certain components of the solution must be nonnegative, use the `odeset` function to set the `NonNegative` property to the indices of these components. See `odeset` for details.

`[T,Y,TE,YE,IE] = solver(odefun,tspan,y0,options)` solves as above while also finding where functions of (t,y), called event functions, are zero. For each event function, you specify whether the integration is to terminate at a zero and whether the direction of the zero crossing matters. Do this by setting the `'Events'` property to a function, e.g., `events` or `@events`, and creating a function `[value,isterminal,direction] = events(t,y)`. For the ith event function in `events`,

- `value(i)` is the value of the function.
- `isterminal(i) = 1`, if the integration is to terminate at a zero of this event function and `0` otherwise.
- `direction(i) = 0` if all zeros are to be computed (the default), `+1` if only the zeros where the event function increases, and `-1` if only the zeros where the event function decreases.

Corresponding entries in `TE`, `YE`, and `IE` return, respectively, the time at which an event occurs, the solution at the time of the event, and the index `i` of the event function that vanishes.

`sol = solver(odefun,[t0 tf],y0...)` returns a structure that you can use with `deval` to evaluate the solution at any point on the interval `[t0,tf]`. You must pass `odefun` as a function handle. The structure `sol` always includes these fields:

`sol.x`	Steps chosen by the solver.
`sol.y`	Each column `sol.y(:,i)` contains the solution at `sol.x(i)`.
`sol.solver`	Solver name.

If you specify the `Events` option and events are detected, `sol` also includes these fields:

`sol.xe`	Points at which events, if any, occurred. `sol.xe(end)` contains the exact point of a terminal event, if any.
`sol.ye`	Solutions that correspond to events in `sol.xe`.
`sol.ie`	Indices into the vector returned by the function specified in the `Events` option. The values indicate which event the solver detected.

If you specify an output function as the value of the `OutputFcn` property, the solver calls it with the computed solution after each time step. Four output functions are provided: `odeplot`, `odephas2`, `odephas3`, `odeprint`. When you call the solver with no output arguments, it calls the default `odeplot` to plot the solution as it is computed. `odephas2` and `odephas3` produce two- and three-dimensional phase plane plots, respectively. `odeprint` displays the solution components on the screen. By default, the ODE solver passes all components of the solution to the output function. You can pass only specific components by providing a vector of indices as the value of the `OutputSel` property. For example, if you call the solver with no output arguments and set the value of

OutputSel to [1,3], the solver plots solution components 1 and 3 as they are computed.

For the stiff solvers ode15s, ode23s, ode23t, and ode23tb, the Jacobian matrix $\partial f / \partial y$ is critical to reliability and efficiency. Use odeset to set Jacobian to @FJAC if FJAC(T,Y) returns the Jacobian $\partial f / \partial y$ or to the matrix $\partial f / \partial y$ if the Jacobian is constant. If the Jacobian property is not set (the default), $\partial f / \partial y$ is approximated by finite differences. Set the Vectorized property 'on' if the ODE function is coded so that odefun(T,[Y1,Y2 ...]) returns [odefun(T,Y1),odefun(T,Y2) ...]. If $\partial f / \partial y$ is a sparse matrix, set the JPattern property to the sparsity pattern of $\partial f / \partial y$, i.e., a sparse matrix S with S(i,j) = 1 if the ith component of $f(t, y)$ depends on the jth component of y, and 0 otherwise.

The solvers of the ODE suite can solve problems of the form $M(t, y)y' = f(t, y)$, with time- and state-dependent mass matrix M. (The ode23s solver can solve only equations with constant mass matrices.) If a problem has a mass matrix, create a function M = MASS(t,y) that returns the value of the mass matrix, and use odeset to set the Mass property to @MASS. If the mass matrix is constant, the matrix should be used as the value of the Mass property. Problems with state-dependent mass matrices are more difficult:

- If the mass matrix does not depend on the state variable y and the function MASS is to be called with one input argument, t, set the MStateDependence property to 'none'.
- If the mass matrix depends weakly on y, set MStateDependence to 'weak' (the default); otherwise, set it to 'strong'. In either case, the function MASS is called with the two arguments (t,y).

If there are many differential equations, it is important to exploit sparsity:

- Return a sparse $M(t, y)$.

- Supply the sparsity pattern of $\partial f/\partial y$ using the `JPattern` property or a sparse $\partial f/\partial y$ using the `Jacobian` property.
- For strongly state-dependent $M(t, y)$, set `MvPattern` to a sparse matrix `S` with `S(i,j) = 1` if for any `k`, the `(i,k)` component of $M(t, y)$ depends on component `j` of y, and `0` otherwise.

If the mass matrix M is singular, then $M(t, y)y' = f(t, y)$ is a system of differential algebraic equations. DAEs have solutions only when y_0 is consistent, that is, if there is a vector yp_0 such that $M(t_0, y_0)yp_0 = f(t_0, y_0)$. The `ode15s` and `ode23t` solvers can solve DAEs of index 1 provided that `y0` is sufficiently close to being consistent. If there is a mass matrix, you can use `odeset` to set the `MassSingular` property to `'yes'`, `'no'`, or `'maybe'`. The default value of `'maybe'` causes the solver to test whether the problem is a DAE. You can provide `yp0` as the value of the `InitialSlope` property. The default is the zero vector. If a problem is a DAE, and `y0` and `yp0` are not consistent, the solver treats them as guesses, attempts to compute consistent values that are close to the guesses, and continues to solve the problem. When solving DAEs, it is very advantageous to formulate the problem so that M is a diagonal matrix (a semi-explicit DAE).

Solver	Problem Type	Order of Accuracy	When to Use
`ode45`	Nonstiff	Medium	Most of the time. This should be the first solver you try.
`ode23`	Nonstiff	Low	For problems with crude error tolerances or for solving moderately stiff problems.

Solver	Problem Type	Order of Accuracy	When to Use
ode113	Nonstiff	Low to high	For problems with stringent error tolerances or for solving computationally intensive problems.
ode15s	Stiff	Low to medium	If ode45 is slow because the problem is stiff.
ode23s	Stiff	Low	If using crude error tolerances to solve stiff systems and the mass matrix is constant.
ode23t	Moderately Stiff	Low	For moderately stiff problems if you need a solution without numerical damping.
ode23tb	Stiff	Low	If using crude error tolerances to solve stiff systems.

The algorithms used in the ODE solvers vary according to order of accuracy [6] and the type of systems (stiff or nonstiff) they are designed to solve. See “Algorithms” on page 2-2242 for more details.

Options

Different solvers accept different parameters in the options list. For more information, see odeset and “Changing ODE Integration Properties” in the MATLAB Mathematics documentation.

Parameters	ode45	ode23	ode113	ode15s	ode23s	ode23t	ode23tb
RelTol, AbsTol, NormControl	√	√	√	√	√	√	√
OutputFcn, OutputSel, Refine, Stats	√	√	√	√	√	√	√
NonNegative	√	√	√	√ *	—	√ *	√ *
Events	√	√	√	√	√	√	√
MaxStep, InitialStep	√	√	√	√	√	√	√
Jacobian, JPattern, Vectorized	—	—	—	√	√	√	√
Mass MStateDependence MvPattern MassSingular	√ √ — —	√ √ — —	√ √ — —	√ √ √ √	√ — — —	√ √ √ √	√ √ √ —
InitialSlope	—	—	—	√	—	√	—
MaxOrder, BDF	—	—	—	√	—	—	—

Note You can use the `NonNegative` parameter with `ode15s`, `ode23t`, and `ode23tb` only for those problems for which there is no mass matrix.

Examples

Example 1

An example of a nonstiff system is the system of equations describing the motion of a rigid body without external forces.

$$y'_1 = y_2 y_3 \qquad y_1(0) = 0$$
$$y'_2 = -y_1 y_3 \qquad y_2(0) = 1$$
$$y'_3 = -0.51 y_1 y_2 \qquad y_3(0) = 1$$

To simulate this system, create a function `rigid` containing the equations

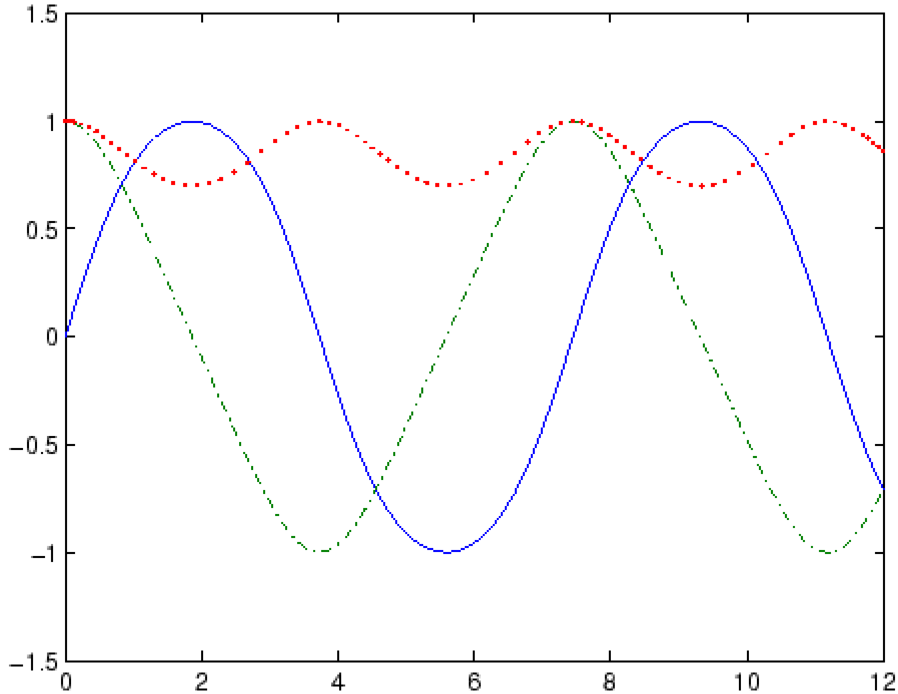
```
function dy = rigid(t,y)
dy = zeros(3,1);    % a column vector
dy(1) = y(2) * y(3);
dy(2) = -y(1) * y(3);
dy(3) = -0.51 * y(1) * y(2);
```

In this example we change the error tolerances using the `odeset` command and solve on a time interval `[0 12]` with an initial condition vector `[0 1 1]` at time `0`.

```
options = odeset('RelTol',1e-4,'AbsTol',[1e-4 1e-4 1e-5]);
[T,Y] = ode45(@rigid,[0 12],[0 1 1],options);
```

Plotting the columns of the returned array `Y` versus `T` shows the solution

```
plot(T,Y(:,1),'-',T,Y(:,2),'-.',T,Y(:,3),'.')
```



Example 2

An example of a stiff system is provided by the van der Pol equations in relaxation oscillation. The limit cycle has portions where the solution components change slowly and the problem is quite stiff, alternating with regions of very sharp change where it is not stiff.

$$y'_1 = y_2 \qquad y_1(0) = 0$$
$$y'_2 = 1000(1 - y_1^2)y_2 - y_1 \qquad y_2(0) = 1$$

To simulate this system, create a function vdp1000 containing the equations

```
function dy = vdp1000(t,y)
dy = zeros(2,1);    % a column vector
```

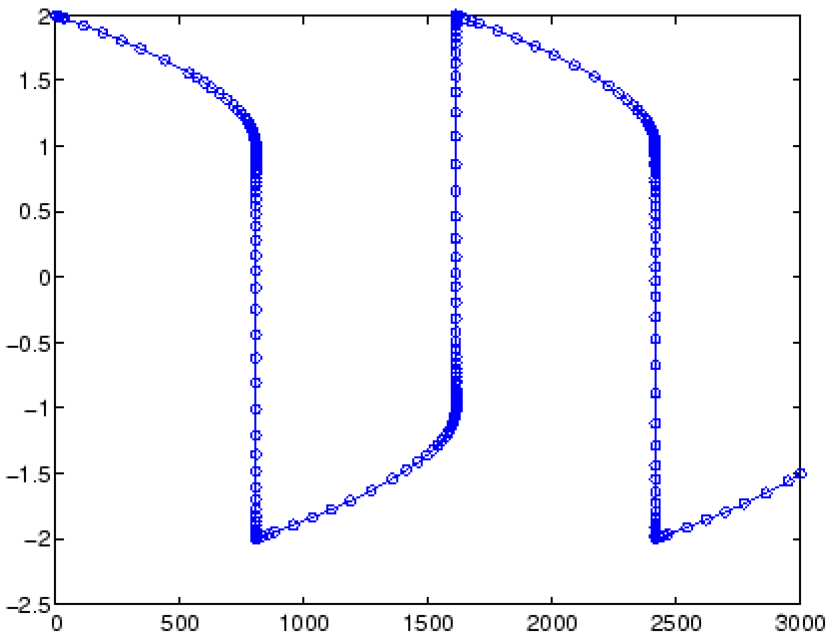
```
dy(1) = y(2);
dy(2) = 1000*(1 - y(1)^2)*y(2) - y(1);
```

For this problem, we will use the default relative and absolute tolerances (`1e-3` and `1e-6`, respectively) and solve on a time interval of `[0 3000]` with initial condition vector `[2 0]` at time `0`.

```
[T,Y] = ode15s(@vdp1000,[0 3000],[2 0]);
```

Plotting the first column of the returned matrix `Y` versus `T` shows the solution

```
plot(T,Y(:,1),'-o')
```



Example 3

This example solves an ordinary differential equation with time-dependent terms.

Consider the following ODE, with time-dependent parameters defined only through the set of data points given in two vectors:

```
y'(t) + f(t)y(t) = g(t)
```

The initial condition is `y(0) = 0`, where the function `f(t)` is defined through the `n`-by-`1` vectors `tf` and `f`, and the function `g(t)` is defined through the `m`-by-`1` vectors `tg` and `g`.

First, define the time-dependent parameters `f(t)` and `g(t)` as the following:

```
ft = linspace(0,5,25); % Generate t for f
f = ft.^2 - ft - 3; % Generate f(t)
gt = linspace(1,6,25); % Generate t for g
g = 3*sin(gt-0.25); % Generate g(t)
```

Write an M-file function to interpolate the data sets specified above to obtain the value of the time-dependent terms at the specified time:

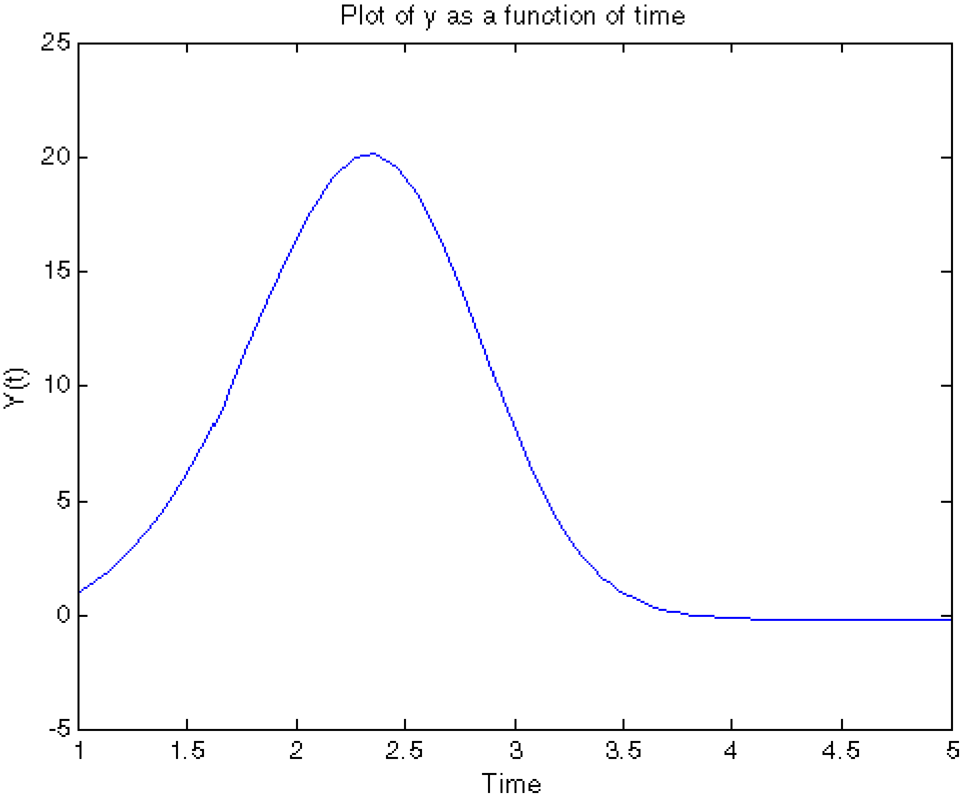
```
function dydt = myode(t,y,ft,f,gt,g)
f = interp1(ft,f,t); % Interpolate the data set (ft,f) at time t
g = interp1(gt,g,t); % Interpolate the data set (gt,g) at time t
dydt = -f.*y + g; % Evalute ODE at time t
```

Call the derivative function `myode.m` within the MATLAB `ode45` function specifying time as the first input argument :

```
Tspan = [1 5]; % Solve from t=1 to t=5
IC = 1; % y(t=0) = 1
[T Y] = ode45(@(t,y) myode(t,y,ft,f,gt,g),TSPAN,IC); % Solve ODE
```

Plot the solution `y(t)` as a function of time:

```
plot(T, Y);
title('Plot of y as a function of time');
xlabel('Time'); ylabel('Y(t)');
```



Algorithms

`ode45` is based on an explicit Runge-Kutta (4,5) formula, the Dormand-Prince pair. It is a *one-step* solver – in computing `y(`t_n`)`, it needs only the solution at the immediately preceding time point, `y(`t_{n-1}`)`. In general, `ode45` is the best function to apply as a *first try* for most problems. [3]

`ode23` is an implementation of an explicit Runge-Kutta (2,3) pair of Bogacki and Shampine. It may be more efficient than `ode45` at crude tolerances and in the presence of moderate stiffness. Like `ode45`, `ode23` is a one-step solver. [2]

ode113 is a variable order Adams-Bashforth-Moulton PECE solver. It may be more efficient than ode45 at stringent tolerances and when the ODE file function is particularly expensive to evaluate. ode113 is a *multistep* solver — it normally needs the solutions at several preceding time points to compute the current solution. [7]

The above algorithms are intended to solve nonstiff systems. If they appear to be unduly slow, try using one of the stiff solvers below.

ode15s is a variable order solver based on the numerical differentiation formulas (NDFs). Optionally, it uses the backward differentiation formulas (BDFs, also known as Gear's method) that are usually less efficient. Like ode113, ode15s is a multistep solver. Try ode15s when ode45 fails, or is very inefficient, and you suspect that the problem is stiff, or when solving a differential-algebraic problem. [9], [10]

ode23s is based on a modified Rosenbrock formula of order 2. Because it is a one-step solver, it may be more efficient than ode15s at crude tolerances. It can solve some kinds of stiff problems for which ode15s is not effective. [9]

ode23t is an implementation of the trapezoidal rule using a "free" interpolant. Use this solver if the problem is only moderately stiff and you need a solution without numerical damping. ode23t can solve DAEs. [10]

ode23tb is an implementation of TR-BDF2, an implicit Runge-Kutta formula with a first stage that is a trapezoidal rule step and a second stage that is a backward differentiation formula of order two. By construction, the same iteration matrix is used in evaluating both stages. Like ode23s, this solver may be more efficient than ode15s at crude tolerances. [8], [1]

See Also

deval, ode15i, odeget, odeset, function_handle (@)

References

[1] Bank, R. E., W. C. Coughran, Jr., W. Fichtner, E. Grosse, D. Rose, and R. Smith, "Transient Simulation of Silicon Devices and Circuits," *IEEE Trans. CAD*, 4 (1985), pp 436-451.

[2] Bogacki, P. and L. F. Shampine, "A 3(2) pair of Runge-Kutta formulas," *Appl. Math. Letters*, Vol. 2, 1989, pp 1-9.

[3] Dormand, J. R. and P. J. Prince, "A family of embedded Runge-Kutta formulae," *J. Comp. Appl. Math.*, Vol. 6, 1980, pp 19-26.

[4] Forsythe, G. , M. Malcolm, and C. Moler, *Computer Methods for Mathematical Computations*, Prentice-Hall, New Jersey, 1977.

[5] Kahaner, D. , C. Moler, and S. Nash, *Numerical Methods and Software*, Prentice-Hall, New Jersey, 1989.

[6] Shampine, L. F. , *Numerical Solution of Ordinary Differential Equations*, Chapman & Hall, New York, 1994.

[7] Shampine, L. F. and M. K. Gordon, *Computer Solution of Ordinary Differential Equations: the Initial Value Problem*, W. H. Freeman, San Francisco, 1975.

[8] Shampine, L. F. and M. E. Hosea, "Analysis and Implementation of TR-BDF2," *Applied Numerical Mathematics 20*, 1996.

[9] Shampine, L. F. and M. W. Reichelt, "The MATLAB ODE Suite," *SIAM Journal on Scientific Computing,* Vol. 18, 1997, pp 1-22.

[10] Shampine, L. F., M. W. Reichelt, and J.A. Kierzenka, "Solving Index-1 DAEs in MATLAB and Simulink," *SIAM Review*, Vol. 41, 1999, pp 538-552.

Purpose

Define differential equation problem for ordinary differential equation solvers

---

Note This reference page describes the `odefile` and the syntax of the ODE solvers used in MATLAB, Version 5. MATLAB, Version 6, supports the `odefile` for backward compatibility, however the new solver syntax does not use an ODE file. New functionality is available only with the new syntax. For information about the new syntax, see `odeset` or any of the ODE solvers.

Description

`odefile` is not a command or function. It is a help entry that describes how to create an M-file defining the system of equations to be solved. This definition is the first step in using any of the MATLAB ODE solvers. In MATLAB documentation, this M-file is referred to as an `odefile`, although you can give your M-file any name you like.

You can use the `odefile` M-file to define a system of differential equations in one of these forms

$$y' = f(t, y)$$

or

$$M(t, y)y' = f(t, y)v$$

where:

- t is a scalar independent variable, typically representing time.
- y is a vector of dependent variables.
- f is a function of t and y returning a column vector the same length as y.
- $M(t, y)$ is a time-and-state-dependent mass matrix.

The ODE file must accept the arguments t and y, although it does not have to use them. By default, the ODE file must return a column vector the same length as y.

All of the solvers of the ODE suite can solve $M(t, y)y' = f(t, y)$, except ode23s, which can only solve problems with constant mass matrices. The ode15s and ode23t solvers can solve some differential-algebraic equations (DAEs) of the form $M(t)y' = f(t, y)$.

Beyond defining a system of differential equations, you can specify an entire initial value problem (IVP) within the ODE M-file, eliminating the need to supply time and initial value vectors at the command line (see “Examples” on page 2-2248).

To Use the ODE File Template

- Enter the command help odefile to display the help entry.
- Cut and paste the ODE file text into a separate file.
- Edit the file to eliminate any cases not applicable to your IVP.
- Insert the appropriate information where indicated. The definition of the ODE system is required information.

```
switch flag
 case ''  % Return dy/dt = f(t,y).
   varargout{1} = f(t,y,p1,p2);
 case 'init'  % Return default [tspan,y0,options].
   [varargout{1:3}] = init(p1,p2);
 case 'jacobian'  % Return Jacobian matrix df/dy.
   varargout{1} = jacobian(t,y,p1,p2);
 case 'jpattern'  % Return sparsity pattern matrix S.
   varargout{1} = jpattern(t,y,p1,p2);
 case 'mass'  % Return mass matrix.
   varargout{1} = mass(t,y,p1,p2);
 case 'events'  % Return [value,isterminal,direction].
   [varargout{1:3}] = events(t,y,p1,p2);
 otherwise
   error(['Unknown flag ''' flag '''.']);
```

```
 end
% ------------------------------------------------------------
function dydt = f(t,y,p1,p2)
 dydt = Insert a function of t and/or y, p1, and p2 here.>
% ------------------------------------------------------------
function [tspan,y0,options] = init(p1,p2)
 tspan = <Insert tspan here.>;
 y0 = <Insert y0 here.>;
 options = <Insert options = odeset(...) or [] here.>;
% ------------------------------------------------------------
function dfdy = jacobian(t,y,p1,p2)
 dfdy = <Insert Jacobian matrix here.>;
% ------------------------------------------------------------
function S = jpattern(t,y,p1,p2)
 S = <Insert Jacobian matrix sparsity pattern here.>;
% ------------------------------------------------------------
function M = mass(t,y,p1,p2)
 M = <Insert mass matrix here.>;
% ------------------------------------------------------------
function [value,isterminal,direction] = events(t,y,p1,p2)
 value = <Insert event function vector here.>
 isterminal = <Insert logical ISTERMINAL vector here.>;
 direction = <Insert DIRECTION vector here.>;
```

Notes

1 The ODE file must accept `t` and `y` vectors from the ODE solvers and must return a column vector the same length as `y`. The optional input argument `flag` determines the type of output (mass matrix, Jacobian, etc.) returned by the ODE file.

2 The solvers repeatedly call the ODE file to evaluate the system of differential equations at various times. *This is required information* – you must define the ODE system to be solved.

3 The `switch` statement determines the type of output required, so that the ODE file can pass the appropriate information to the solver. (See notes 4 - 9.)

4 In the default *initial conditions* ('init') case, the ODE file returns basic information (time span, initial conditions, options) to the solver. If you omit this case, you must supply all the basic information on the command line.

5 In the 'jacobian' case, the ODE file returns a Jacobian matrix to the solver. You need only provide this case when you want to improve the performance of the stiff solvers ode15s, ode23s, ode23t, and ode23tb.

6 In the 'jpattern' case, the ODE file returns the Jacobian sparsity pattern matrix to the solver. You need to provide this case only when you want to generate sparse Jacobian matrices numerically for a stiff solver.

7 In the 'mass' case, the ODE file returns a mass matrix to the solver. You need to provide this case only when you want to solve a system in the form $M(t, y)y' = f(t, y)$.

8 In the 'events' case, the ODE file returns to the solver the values that it needs to perform event location. When the Events property is set to on, the ODE solvers examine any elements of the event vector for transitions to, from, or through zero. If the corresponding element of the logical isterminal vector is set to 1, integration will halt when a zero-crossing is detected. The elements of the direction vector are -1, 1, or 0, specifying that the corresponding event must be decreasing, increasing, or that any crossing is to be detected.

9 An unrecognized flag generates an error.

Examples

The van der Pol equation, $y''_1 - \mu(1 - y_1^2)y' + y_1 = 0$, is equivalent to a system of coupled first-order differential equations.

$$y'_1 = y_2$$

$$y'_2 = \mu(1 - y_1^2)y_2 - y_1$$

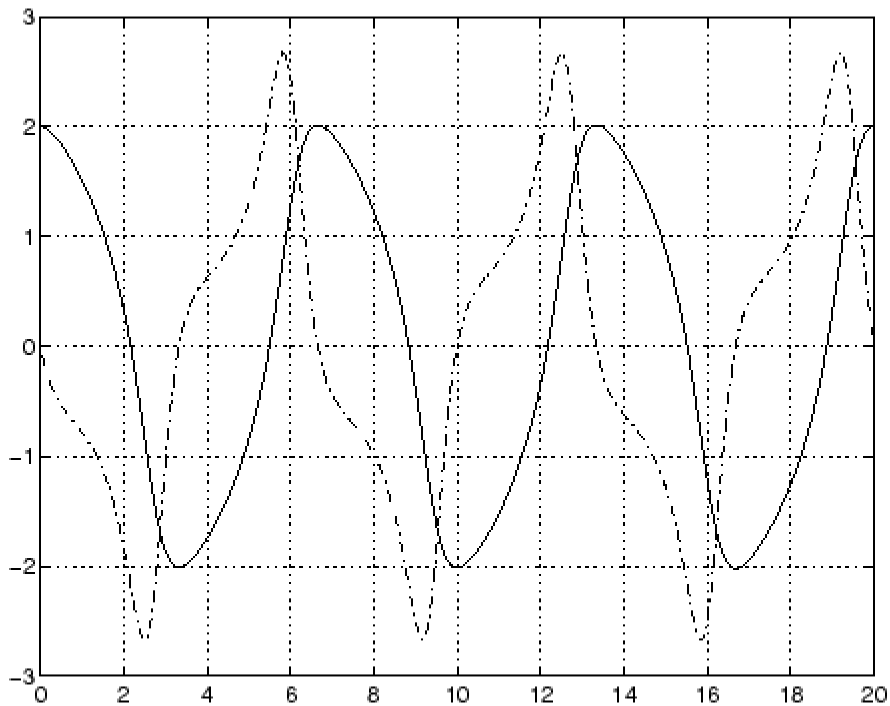
The M-file

```
function out1 = vdp1(t,y)
out1 = [y(2); (1-y(1)^2)*y(2) - y(1)];
```

defines this system of equations (with $\mu = 1$).

To solve the van der Pol system on the time interval `[0 20]` with initial values (at time `0`) of `y(1) = 2` and `y(2) = 0`, use

```
[t,y] = ode45('vdp1',[0 20],[2; 0]);
plot(t,y(:,1),'-',t,y(:,2),'-.')
```



To specify the entire initial value problem (IVP) within the M-file, rewrite `vdp1` as follows.

```
function [out1,out2,out3] = vdp1(t,y,flag)
if nargin < 3 | isempty(flag)
  out1 = [y(1).*(1-y(2).^2)-y(2); y(1)];
else
  switch(flag)
    case 'init'               % Return tspan, y0, and options.
      out1 = [0 20];
      out2 = [2; 0];
      out3 = [];
  otherwise
    error(['Unknown request ''' flag '''.']);
  end
end
```

You can now solve the IVP without entering any arguments from the command line.

```
[t,Y] = ode23('vdp1')
```

In this example the `ode23` function looks to the `vdp1` M-file to supply the missing arguments. Note that, once you've called `odeset` to define `options`, the calling syntax

```
[t,Y] = ode23('vdp1',[],[],options)
```

also works, and that any options supplied via the command line override corresponding options specified in the M-file (see `odeset`).

See Also

The MATLAB Version 5 help entries for the ODE solvers and their associated functions: `ode23`, `ode45`, `ode113`, `ode15s`, `ode23s`, `ode23t`, `ode23tb`, `odeget`, `odeset`

Type at the MATLAB command line:
`more on, type function, more off`. The Version 5 help follows the Version 6 help.

Purpose

Ordinary differential equation options parameters

Syntax

```
o = odeget(options,'name')
o = odeget(options,'name',default)
```

Description

`o = odeget(options,'name')` extracts the value of the property specified by string `'name'` from integrator options structure `options`, returning an empty matrix if the property value is not specified in `options`. It is only necessary to type the leading characters that uniquely identify the property name. Case is ignored for property names. The empty matrix `[]` is a valid `options` argument.

`o = odeget(options,'name',default)` returns `o = default` if the named property is not specified in `options`.

Example

Having constructed an ODE options structure,

```
options = odeset('RelTol',1e-4,'AbsTol',[1e-3 2e-3 3e-3]);
```

you can view these property settings with `odeget`.

```
odeget(options,'RelTol')
ans =

      1.0000e-04

odeget(options,'AbsTol')
ans =

    0.0010    0.0020    0.0030
```

See Also

`odeset`

odeset

Purpose

Create or alter options structure for ordinary differential equation solvers

Syntax

```
options = odeset('name1',value1,'name2',value2,...)
options = odeset(oldopts,'name1',value1,...)
options = odeset(oldopts,newopts)
odeset
```

Description

The `odeset` function lets you adjust the integration parameters of the following ODE solvers.

For solving fully implicit differential equations:

```
ode15i
```

For solving initial value problems:

```
ode23, ode45, ode113, ode15s, ode23s, ode23t, ode23tb
```

See below for information about the integration parameters.

`options = odeset('name1',value1,'name2',value2,...)` creates an options structure that you can pass as an argument to any of the ODE solvers. In the resulting structure, `options`, the named properties have the specified values. For example, `'name1'` has the value `value1`. Any unspecified properties have default values. It is sufficient to type only the leading characters that uniquely identify a property name. Case is ignored for property names.

`options = odeset(oldopts,'name1',value1,...)` alters an existing options structure `oldopts`. This sets `options` equal to the existing structure `oldopts`, overwrites any values in `oldopts` that are respecified using name/value pairs, and adds any new pairs to the structure. The modified structure is returned as an output argument.

`options = odeset(oldopts,newopts)` alters an existing options structure `oldopts` by combining it with a new options structure `newopts`. Any new options not equal to the empty matrix overwrite corresponding options in `oldopts`.

`odeset` with no input arguments displays all property names as well as their possible and default values.

ODE Properties

The following sections describe the properties that you can set using `odeset`. The available properties depend on the ODE solver you are using. There are several categories of properties:

- "Error Control Properties" on page 2-2253
- "Solver Output Properties" on page 2-2255
- "Step-Size Properties" on page 2-2259
- "Event Location Property" on page 2-2260
- "Jacobian Matrix Properties" on page 2-2262
- "Mass Matrix and DAE Properties" on page 2-2266
- "ode15s and ode15i-Specific Properties" on page 2-2268

Note This reference page describes the ODE properties for MATLAB, Version 7. The Version 5 properties are supported only for backward compatibility. For information on the Version 5 properties, type at the MATLAB command line: `more on, type odeset, more off`.

Error Control Properties

At each step, the solver estimates the local error `e` in the `i`th component of the solution. This error must be less than or equal to the acceptable error, which is a function of the specified relative tolerance, `RelTol`, and the specified absolute tolerance, `AbsTol`.

```
|e(i)| ≤ max(RelTol*abs(y(i)),AbsTol(i))
```

For routine problems, the ODE solvers deliver accuracy roughly equivalent to the accuracy you request. They deliver less accuracy for problems integrated over "long" intervals and problems that are moderately unstable. Difficult problems may require tighter tolerances than the default values. For relative accuracy, adjust `RelTol`. For the absolute error tolerance, the scaling of the solution components is important: if `|y|` is somewhat smaller than `AbsTol`, the solver is not constrained to obtain any correct digits in `y`. You might have to solve a problem more than once to discover the scale of solution components.

Roughly speaking, this means that you want `RelTol` correct digits in all solution components except those smaller than thresholds `AbsTol(i)`. Even if you are not interested in a component `y(i)` when it is small, you may have to specify `AbsTol(i)` small enough to get some correct digits in `y(i)` so that you can accurately compute more interesting components.

The following table describes the error control properties. Further information on each property is given following the table.

Property	Value	Description
`RelTol`	Positive scalar `{1e-3}`	Relative error tolerance that applies to all components of the solution vector `y`.
`AbsTol`	Positive scalar or vector `{1e-6}`	Absolute error tolerances that apply to the individual components of the solution vector.
`NormControl`	`on	{off}`	Control error relative to norm of solution.

Description of Error Control Properties

`RelTol` — This tolerance is a measure of the error relative to the size of each solution component. Roughly, it controls the number of correct digits in all solution components, except those smaller than thresholds `AbsTol(i)`.

The default, `1e-3`, corresponds to 0.1% accuracy.

`AbsTol` — `AbsTol(i)` is a threshold below which the value of the `i`th solution component is unimportant. The absolute error tolerances determine the accuracy when the solution approaches zero.

If `AbsTol` is a vector, the length of `AbsTol` must be the same as the length of the solution vector `y`. If `AbsTol` is a scalar, the value applies to all components of `y`.

`NormControl` — Set this property `on` to request that the solvers control the error in each integration step with `norm(e) <= max(RelTol*norm(y),AbsTol)`. By default the solvers use a more stringent componentwise error control.

Solver Output Properties

The following table lists the solver output properties that control the output that the solvers generate. Further information on each property is given following the table.

Property	Value	Description
`NonNegative`	Vector of integers	Specifies which components of the solution vector must be nonnegative. The default value is `[]`.
`OutputFcn`	Function handle	A function for the solver to call after every successful integration step.
`OutputSel`	Vector of indices	Specifies which components of the solution vector are to be passed to the output function.
`Refine`	Positive integer	Increases the number of output points by a factor of `Refine`.
`Stats`	`on` | `{off}`	Determines whether the solver should display statistics about its computations. By default, `Stats` is `off`.

Description of Solver Output Properties

`NonNegative` — The `NonNegative` property is not available in `ode23s`, `ode15i`. In `ode15s`, `ode23t`, and `ode23tb`, `NonNegative` is not available for problems where there is a mass matrix.

OutputFcn — To specify an output function, set 'OutputFcn' to a function handle. For example,

```
options = odeset('OutputFcn',@myfun)
```

sets 'OutputFcn' to @myfun, a handle to the function myfun. See "Function Handles" in the MATLAB Programming documentation for more information.

The output function must be of the form

```
status = myfun(t,y,flag)
```

"Parameterizing Functions Called by Function Functions", in the MATLAB Mathematics documentation, explains how to provide additional parameters to myfun, if necessary.

The solver calls the specified output function with the following flags. Note that the syntax of the call differs with the flag. The function must respond appropriately:

Flag	Description
init	The solver calls myfun(tspan,y0,'init') before beginning the integration to allow the output function to initialize. tspan and y0 are the input arguments to the ODE solver.

Flag	Description
{[]}	The solver calls status = myfun(t,y,[]) after each integration step on which output is requested. t contains points where output was generated during the step, and y is the numerical solution at the points in t. If t is a vector, the ith column of y corresponds to the ith element of t. When length(tspan) > 2 the output is produced at every point in tspan. When length(tspan) = 2 the output is produced according to the Refine option. myfun must return a status output value of 0 or 1. If status = 1, the solver halts integration. You can use this mechanism, for instance, to implement a **Stop** button.
done	The solver calls myfun([],[],'done') when integration is complete to allow the output function to perform any cleanup chores.

You can use these general purpose output functions or you can edit them to create your own. Type help function at the command line for more information.

- odeplot — Time series plotting (default when you call the solver with no output arguments and you have not specified an output function)
- odephas2 — Two-dimensional phase plane plotting
- odephas3 — Three-dimensional phase plane plotting
- odeprint — Print solution as it is computed

Note If you call the solver with no output arguments, the solver does not allocate storage to hold the entire solution history.

OutputSel — Use OutputSel to specify which components of the solution vector you want passed to the output function. For example, if you want to use the `odeplot` output function, but you want to plot only the first and third components of the solution, you can do this using

```
options = ...
odeset('OutputFcn',@odeplot,'OutputSel',[1 3]);
```

By default, the solver passes all components of the solution to the output function.

`Refine` — If `Refine` is `1`, the solver returns solutions only at the end of each time step. If `Refine` is `n >1`, the solver subdivides each time step into `n` smaller intervals and returns solutions at each time point. `Refine` does not apply when `length(tspan)>2`.

Note In all the solvers, the default value of `Refine` is `1`. Within `ode45`, however, the default is `4` to compensate for the solver's large step sizes. To override this and see only the time steps chosen by `ode45`, set `Refine` to `1`.

The extra values produced for `Refine` are computed by means of continuous extension formulas. These are specialized formulas used by the ODE solvers to obtain accurate solutions between computed time steps without significant increase in computation time.

`Stats` — By default, `Stats` is `off`. If it is `on`, after solving the problem the solver displays

- Number of successful steps
- Number of failed attempts
- Number of times the ODE function was called to evaluate $f(t,y)$

Solvers based on implicit methods, including `ode23s`, `ode23t`, `ode23t`, `ode15s`, and `ode15i`, also display

- Number of times that the partial derivatives matrix $\partial f / \partial x$ was formed
- Number of LU decompositions
- Number of solutions of linear systems

Step-Size Properties

The step-size properties specify the size of the first step the solver tries, potentially helping it to better recognize the scale of the problem. In addition, you can specify bounds on the sizes of subsequent time steps.

The following table describes the step-size properties. Further information on each property is given following the table.

Property	Value	Description
`InitialStep`	Positive scalar	Suggested initial step size.
`MaxStep`	Positive scalar {`0.1*abs(t0-tf)`}	Upper bound on solver step size.

Description of Step-Size Properties

`InitialStep` — `InitialStep` sets an upper bound on the magnitude of the first step size the solver tries. If you do not set `InitialStep`, the initial step size is based on the slope of the solution at the initial time `tspan(1)`, and if the slope of all solution components is zero, the procedure might try a step size that is much too large. If you know this is happening or you want to be sure that the solver resolves important behavior at the start of the integration, help the code start by providing a suitable `InitialStep`.

`MaxStep` — If the differential equation has periodic coefficients or solutions, it might be a good idea to set `MaxStep` to some fraction (such as 1/4) of the period. This guarantees that the solver does not enlarge the time step too much and step over a period of interest. Do *not* reduce `MaxStep` for any of the following purposes:

- To produce more output points. This can significantly slow down solution time. Instead, use `Refine` to compute additional outputs by continuous extension at very low cost.
- When the solution does not appear to be accurate enough. Instead, reduce the relative error tolerance `RelTol`, and use the solution you just computed to determine appropriate values for the absolute error tolerance vector `AbsTol`. See "Error Control Properties" on page 2-2253 for a description of the error tolerance properties.
- To make sure that the solver doesn't step over some behavior that occurs only once during the simulation interval. If you know the time at which the change occurs, break the simulation interval into two pieces and call the solver twice. If you do not know the time at which the change occurs, try reducing the error tolerances `RelTol` and `AbsTol`. Use `MaxStep` as a last resort.

Event Location Property

In some ODE problems the times of specific events are important, such as the time at which a ball hits the ground, or the time at which a spaceship returns to the earth. While solving a problem, the ODE solvers can detect such events by locating transitions to, from, or through zeros of user-defined functions.

The following table describes the `Events` property. Further information on each property is given following the table.

ODE Events Property

String	Value	Description
`Events`	Function handle	Handle to a function that includes one or more event functions.

Description of Event Location Properties

`Events` — The function is of the form

```
[value,isterminal,direction] = events(t,y)
```

`value`, `isterminal`, and `direction` are vectors for which the `i`th element corresponds to the `i`th event function:

- `value(i)` is the value of the `i`th event function.
- `isterminal(i) = 1` if the integration is to terminate at a zero of this event function, otherwise, `0`.
- `direction(i) = 0` if all zeros are to be located (the default), `+1` if only zeros where the event function is increasing, and `-1` if only zeros where the event function is decreasing.

If you specify an events function and events are detected, the solver returns three additional outputs:

- `A` column vector of times at which events occur
- Solution values corresponding to these times
- Indices into the vector returned by the events function. The values indicate which event the solver detected.

If you call the solver as

```
[T,Y,TE,YE,IE] = solver(odefun,tspan,y0,options)
```

the solver returns these outputs as `TE`, `YE`, and `IE` respectively. If you call the solver as

```
sol = solver(odefun,tspan,y0,options)
```

the solver returns these outputs as `sol.xe`, `sol.ye`, and `sol.ie`, respectively.

For examples that use an event function, see “Example: Simple Event Location” and “Example: Advanced Event Location” in the MATLAB Mathematics documentation.

Jacobian Matrix Properties

The stiff ODE solvers often execute faster if you provide additional information about the Jacobian matrix $\partial f / \partial y$, a matrix of partial derivatives of the function that defines the differential equations.

$$\frac{\partial f}{\partial y} = \begin{bmatrix} \frac{\partial f_1}{\partial y_1} & \frac{\partial f_1}{\partial y_2} & \cdots \\ \frac{\partial f_2}{\partial y_1} & \frac{\partial f_2}{\partial y_2} & \cdots \\ \vdots & \vdots & \end{bmatrix}$$

The Jacobian matrix properties pertain only to those solvers for stiff problems (`ode15s`, `ode23s`, `ode23t`, `ode23tb`, and `ode15i`) for which the Jacobian matrix $\partial f / \partial y$ can be critical to reliability and efficiency. If you do not provide a function to calculate the Jacobian, these solvers approximate the Jacobian numerically using finite differences. In this case, you might want to use the `Vectorized` or `JPattern` properties.

The following table describes the Jacobian matrix properties for all implicit solvers except `ode15i`. Further information on each property is given following the table. See Jacobian Properties for ode15i on page 2-2265 for `ode15i`-specific information.

Jacobian Properties for All Implicit Solvers Except ode15i

Property	Value	Description
`Jacobian`	Function | handle constant matrix	Matrix or function that evaluates the Jacobian.

Property	Value	Description
JPattern	Sparse matrix of {0,1}	Generates a sparse Jacobian matrix numerically.
Vectorized	on | {off}	Allows the solver to reduce the number of function evaluations required.

Description of Jacobian Properties

Jacobian — Supplying an analytical Jacobian often increases the speed and reliability of the solution for stiff problems. Set this property to a function FJac, where FJac(t,y) computes $\partial f / \partial y$, or to the constant value of $\partial f / \partial y$.

The Jacobian for the stiff van der Pol problem example, described in the MATLAB Mathematics documentation, can be coded as

```
function J = vdp1000jac(t,y)
J = [  0                   1
     (-2000*y(1)*y(2)-1)  (1000*(1-y(1)^2)) ];
```

JPattern — JPattern is a sparsity pattern with 1s where there might be nonzero entries in the Jacobian.

Note If you specify Jacobian, the solver ignores any setting for JPattern.

Set this property to a sparse matrix S with $S(i,j) = 1$ if component i of $f(t,y)$ depends on component j of y, and 0 otherwise. The solver uses this sparsity pattern to generate a sparse Jacobian matrix numerically. If the Jacobian matrix is large and sparse, this can greatly accelerate execution. For an example using the JPattern property, see Example: Large, Stiff, Sparse Problem in the MATLAB Mathematics documentation.

Vectorized — The Vectorized property allows the solver to reduce the number of function evaluations required to compute all the columns of the Jacobian matrix, and might significantly reduce solution time.

Set on to inform the solver that you have coded the ODE function F so that F(t,[y1 y2 ...]) returns [F(t,y1) F(t,y2) ...]. This allows the solver to reduce the number of function evaluations required to compute all the columns of the Jacobian matrix, and might significantly reduce solution time.

Note If you specify Jacobian, the solver ignores a setting of 'on' for 'Vectorized'.

With the MATLAB array notation, it is typically an easy matter to vectorize an ODE function. For example, you can vectorize the stiff van der Pol problem example, described in the MATLAB Mathematics documentation, by introducing colon notation into the subscripts and by using the array power (.^) and array multiplication (.*) operators.

```
function dydt = vdp1000(t,y)
dydt = [y(2,:); 1000*(1-y(1,:).^2).*y(2,:)-y(1,:)];
```

Note Vectorization of the ODE function used by the ODE solvers differs from the vectorization used by the boundary value problem (BVP) solver, bvp4c. For the ODE solvers, the ODE function is vectorized only with respect to the second argument, while bvp4c requires vectorization with respect to the first and second arguments.

The following table describes the Jacobian matrix properties for ode15i.

Jacobian Properties for ode15i

Property	Value	Description
Jacobian	Function handle | Cell array of constant values	Function that evaluates the Jacobian or a cell array of constant values.
JPattern	Sparse matrices of {0,1}	Generates a sparse Jacobian matrix numerically.
Vectorized	on | {off}	Vectorized ODE function

Description of Jacobian Properties for ode15i

Jacobian — Supplying an analytical Jacobian often increases the speed and reliability of the solution for stiff problems. Set this property to a function

```
[dFdy, dFdp] = Fjac(t,y,yp)
```

or to a cell array of constant values $\{\partial F/\partial y, (\partial F/\partial y)'\}$.

JPattern — JPattern is a sparsity pattern with 1's where there might be nonzero entries in the Jacobian.

Set this property to {dFdyPattern, dFdypPattern}, the sparsity patterns of $\partial F/\partial y$ and $\partial F/\partial y'$, respectively.

Vectorized —

Set this property to {yVect, ypVect}. Setting yVect to 'on' indicates that

```
F(t, [y1 y2 ...], yp)
```

returns

```
[F(t,y1,yp), F(t,y2,yp) ...]
```

Setting ypVect to 'on' indicates that

```
F(t,y,[yp1 yp2 ...])
```

returns

```
[F(t,y,yp1) F(t,y,yp2) ...]
```

Mass Matrix and DAE Properties

This section describes mass matrix and differential-algebraic equation (DAE) properties, which apply to all the solvers except `ode15i`. These properties are not applicable to `ode15i` and their settings do not affect its behavior.

The solvers of the ODE suite can solve ODEs of the form

$$M(t,y)y' = f(t,y) \tag{2-1}$$

with a mass matrix $M(t,y)$ that can be sparse.

When $M(t,y)$ is nonsingular, the equation above is equivalent to $y' = M^{-1}f(t,y)$ and the ODE has a solution for any initial values y_0 at t_0. The more general form (Equation 2-1) is convenient when you express a model naturally in terms of a mass matrix. For large, sparse $M(t,y)$, solving Equation 2-1 directly reduces the storage and run-time needed to solve the problem.

When $M(t,y)$ is singular, then $M(t,y)$ times $M(t,y)y' = f(t,y)$ is a DAE. A DAE has a solution only when y_0 is consistent; that is, there exists an initial slope yp_0 such that $M(t_0,y_0)yp_0 = f(t_0,y_0)$. If y_0 and yp_0 are not consistent, the solver treats them as guesses, attempts to compute consistent values that are close to the guesses, and continues to solve the problem. For DAEs of index 1, solving an initial value problem with consistent initial conditions is much like solving an ODE.

The `ode15s` and `ode23t` solvers can solve DAEs of index 1. For examples of DAE problems, see Example: Differential-Algebraic Problem, in the MATLAB Mathematics documentation, and the examples `amp1dae` and `hb1dae`.

The following table describes the mass matrix and DAE properties. Further information on each property is given following the table.

Mass Matrix and DAE Properties (Solvers Other Than ode15i)

Property	Value	Description
`Mass`	Matrix | function handle	Mass matrix or a function that evaluates the mass matrix $M(t, y)$.
`MStateDependence`	`none` | `{weak}` | `strong`	Dependence of the mass matrix on y.
`MvPattern`	Sparse matrix	$\partial(M(t, y)v)/\partial y$ sparsity pattern.
`MassSingular`	`yes` | `no` | `{maybe}`	Indicates whether the mass matrix is singular.
`InitialSlope`	Vector {zero vector}	Vector representing the consistent initial slope yp_0.

Description of Mass Matrix and DAE Properties

`Mass` — For problems of the form $M(t)y' = f(t, y)$, set `'Mass'` to a mass matrix M. For problems of the form $M(t)y' = f(t, y)$, set `'Mass'` to a function handle `@Mfun`, where `Mfun(t,y)` evaluates the mass matrix $M(t, y)$. The `ode23s` solver can only solve problems with a constant mass matrix M. When solving DAEs, using `ode15s` or `ode23t`, it is advantageous to formulate the problem so that$M$ is a diagonal matrix (a semiexplicit DAE).

For example problems, see “Example: Finite Element Discretization” in the MATLAB Mathematics documentation, or the examples `fem2ode` or `batonode`.

MStateDependence — Set this property to none for problems

$M(t)y' = f(t, y)$. Both weak and strong indicate $M(t, y)$, but weak results in implicit solvers using approximations when solving algebraic equations.

MvPattern — Set this property to a sparse matrix S with $S(i,j) = 1$ if, for any k, the (i,k) component of $M(t, y)$ depends on component j of y, and 0 otherwise. For use with the ode15s, ode23t, and ode23tb solvers when MStateDependence is strong. See burgersode as an example.

MassSingular — Set this property to no if the mass matrix is not singular and you are using either the ode15s or ode23t solver. The default value of maybe causes the solver to test whether the problem is a DAE, by testing whether $M(t_0, y_0)$ is singular.

InitialSlope — Vector representing the consistent initial slope yp_0, where yp_0 satisfies $M(t_0, y_0) \cdot y'_0 = f(t_0, y_0)$. The default is the zero vector.

This property is for use with the ode15s and ode23t solvers when solving DAEs.

ode15s and ode15i-Specific Properties

ode15s is a variable-order solver for stiff problems. It is based on the numerical differentiation formulas (NDFs). The NDFs are generally more efficient than the closely related family of backward differentiation formulas (BDFs), also known as Gear's methods. The ode15s properties let you choose among these formulas, as well as specifying the maximum order for the formula used.

ode15i solves fully implicit differential equations of the form

$$f(t, y, y') = 0$$

using the variable order BDF method.

The following table describes the ode15s and ode15i-specific properties. Further information on each property is given following the table. Use odeset to set these properties.

ode15s and ode15i-Specific Properties

Property	Value	Description
MaxOrder	1 | 2 | 3 | 4 | {5}	Maximum order formula used to compute the solution.
BDF (ode15s only)	on | {off}	Specifies whether you want to use the BDFs instead of the default NDFs.

Description of ode15s and ode15i-Specific Properties

MaxOrder — Maximum order formula used to compute the solution.

BDF (ode15s only) — Set BDF on to have ode15s use the BDFs.

For both the NDFs and BDFs, the formulas of orders 1 and 2 are A-stable (the stability region includes the entire left half complex plane). The higher order formulas are not as stable, and the higher the order the worse the stability. There is a class of stiff problems (stiff oscillatory) that is solved more efficiently if MaxOrder is reduced (for example to 2) so that only the most stable formulas are used.

See Also

deval, odeget, ode45, ode23, ode23t, ode23tb, ode113, ode15s, ode23s, function_handle (@)

Purpose

Extend solution of initial value problem for ordinary differential equation

Syntax

```
solext = odextend(sol, odefun, tfinal)
solext = odextend(sol, [], tfinal)
solext = odextend(sol, odefun, tfinal, yinit)
solext = odextend(sol, odefun, tfinal, [yinit, ypinit])
solext = odextend(sol, odefun, tfinal, yinit, options)
```

Description

`solext = odextend(sol, odefun, tfinal)` extends the solution stored in `sol` to an interval with upper bound `tfinal` for the independent variable. `odefun` is a function handle. See “Function Handles” in the MATLAB Programming documentation for more information. `sol` is an ODE solution structure created using an ODE solver. The lower bound for the independent variable in `solext` is the same as in `sol`. If you created `sol` with an ODE solver other than `ode15i`, the function `odefun` computes the right-hand side of the ODE equation, which is of the form $y' = f(t, y)$. If you created `sol` using `ode15i`, the function `odefun` computes the left-hand side of the ODE equation, which is of the form $f(t, y, y') = 0$.

“Parameterizing Functions Called by Function Functions”, in the MATLAB Mathematics documentation, explains how to provide additional parameters to the function `odefun`, if necessary.

`odextend` extends the solution by integrating `odefun` from the upper bound for the independent variable in `sol` to `tfinal`, using the same ODE solver that created `sol`. By default, `odextend` uses

- The initial conditions `y = sol.y(:, end)` for the subsequent integration
- The same integration properties and additional input arguments the ODE solver originally used to compute `sol`. This information is stored as part of the solution structure `sol` and is subsequently passed to `solext`. Unless you want to change these values, you do not need to pass them to `odextend`.

`solext = odextend(sol, [], tfinal)` uses the same ODE function that the ODE solver uses to compute `sol` to extend the solution. It is not necessary to pass in `odefun` explicitly unless it differs from the original ODE function.

`solext = odextend(sol, odefun, tfinal, yinit)` uses the column vector `yinit` as new initial conditions for the subsequent integration, instead of the vector `sol.y(end)`.

Note To extend solutions obtained with `ode15i`, use the following syntax, in which the column vector `ypinit` is the initial derivative of the solution:

```
solext = odextend(sol, odefun, tfinal, [yinit, ypinit])
```

`solext = odextend(sol, odefun, tfinal, yinit, options)` uses the integration properties specified in `options` instead of the options the ODE solver originally used to compute `sol`. The new options are then stored within the structure `solext`. See `odeset` for details on setting `options` properties. Set `yinit = []` as a placeholder to specify the default initial conditions.

Example

The following command

```
sol=ode45(@vdp1,[0 10],[2 0]);
```

uses `ode45` to solve the system `y' = vdp1(t,y)`, where `vdp1` is an example of an ODE function provided with MATLAB, on the interval `[0 10]`. Then, the commands

```
sol=odextend(sol,@vdp1,20);
plot(sol.x,sol.y(1,:));
```

extend the solution to the interval `[0 20]` and plot the first component of the solution on `[0 20]`.

See Also

`deval`, `ode23`, `ode45`, `ode113`, `ode15s`, `ode23s`, `ode23t`, `ode23tb`, `ode15i`, `odeset`, `odeget`, `deval`, `function_handle` (`@`)

Purpose

Create array of all ones

Syntax

```
Y = ones(n)
Y = ones(m,n)
Y = ones([m n])
Y = ones(m,n,p,...)
Y = ones([m n p ...])
Y = ones(size(A))
ones(m, n,...,classname)
ones([m,n,...],classname)
```

Description

`Y = ones(n)` returns an `n`-by-`n` matrix of `1`s. An error message appears if `n` is not a scalar.

`Y = ones(m,n)` or `Y = ones([m n])` returns an `m`-by-`n` matrix of ones.

`Y = ones(m,n,p,...)` or `Y = ones([m n p ...])` returns an `m`-by-`n`-by-`p`-by-`...` array of `1`s.

Note The size inputs `m`, `n`, `p`, `...` should be nonnegative integers. Negative integers are treated as 0.

`Y = ones(size(A))` returns an array of `1`s that is the same size as `A`.

`ones(m, n,...,classname)` or `ones([m,n,...],classname)` is an `m`-by-`n`-by-... array of ones 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 = ones(2,3,'int8');
```

See Also

`eye`, `zeros`, `complex`

Purpose Open files based on extension

Syntax

```
open('name')
```

Description

`open('name')` opens the object specified by the string `name`. The specific action taken upon opening depends on the type of object specified by `name`.

name	Action
DOC file (`*.doc`)	Open document in Microsoft Word.
EXE file (`*.exe`)	Run Microsoft Windows executable file.
Figure file (`*.fig`)	Open figure in a MATLAB figure window.
HTML file (`*.html, *.htm`)	Open HTML document in a separate window.
M-file (`name.m`)	Open M-file `name` in M-file Editor.
MAT-file (`name.mat`)	Open MAT-file and store variables in a structure in the workspace.
Model (`name.mdl`)	Open model `name` in Simulink.
P-file (`name.p`)	Open the corresponding M-file, `name.m`, if it exists, in the M-file Editor.
PDF file (`*.pdf`)	Open PDF document in Adobe Acrobat.
PPT file (`*.ppt`)	Open document in Microsoft PowerPoint.
Project file (`*.prj`)	Open the project file in the MATLAB Compiler Deployment Tool. If the MATLAB Compiler or Deployment Tool is not installed, open the project file in a text editor.
URL file (`*.url`)	Open an Internet location in your default Web browser
Variable	Open array `name` in the Array Editor (the array must be numeric).

name	Action
Other extensions (name.xxx)	Open name.xxx by calling the helper function openxxx, where openxxx is a user-defined function.
No extension (name)	Open name in the default editor. If name does not exist, then open checks to see if name.mdl or name.m is on the path or in the current directory and, if so, opens the file returned by which('name').

If more than one file with the specified filename name exists on the MATLAB path, then open opens the file returned by which('name').

If no such file name exists, then open displays an error message.

You can create your own openxxx functions to set up handlers for new file types. This does not apply to the file types shown in the table above. open('filename.xxx') calls the openxxx function it finds on the path. For example, create a function openlog if you want a handler for opening files with file extension .log.

Examples

Example 1 — Opening a File on the Path

To open the M-file copyfile.m, type

```
open copyfile.m
```

MATLAB opens the copyfile.m file that resides in toolbox\matlab\general. If you have a copyfile.m file in a directory that is before toolbox\matlab\general on the MATLAB path, then open opens that file instead.

Example 2 — Opening a File Not on the Path

To open a file that is not on the MATLAB path, enter the complete file specification. If no such file is found, then MATLAB displays an error message.

```
open('D:\temp\data.mat')
```

Example 3 — Specifying a File Without a File Extension

When you specify a file without including its file extension, MATLAB determines which file to open for you. It does this by calling

```
which('filename')
```

In this example, `open matrixdemos` could open either an M-file or a Simulink model of the same name, since both exist on the path.

```
dir matrixdemos.*

  matrixdemos.m    matrixdemos.mdl
```

Because the call `which('matrixdemos')` returns the name of the Simulink model, `open` opens the `matrixdemos` model rather than the M-file of that name.

```
open matrixdemos          % Opens model matrixdemos.mdl
```

Example 4 — Opening a MAT-File

This example opens a MAT-file containing MATLAB data and then keeps just one of the variables from that file. The others are overwritten when `ans` is reused by MATLAB.

```
% Open a MAT-file containing miscellaneous data.
open D:\temp\data.mat

ans =

          x: [3x2x2 double]
          y: {4x5 cell}
          k: 8
    spArray: [5x5 double]
   dblArray: [4x1 java.lang.Double[][]]
   strArray: {2x5 cell}


% Keep the dblArray value by assigning it to a variable.
```

```
dbl = ans.dblArray

dbl =

java.lang.Double[][]:
    [ 5.7200]    [ 6.7200]    [ 7.7200]
    [10.4400]    [11.4400]    [12.4400]
    [15.1600]    [16.1600]    [17.1600]
    [19.8800]    [20.8800]    [21.8800]
```

Example 5 — Using a User-Defined Handler Function

If you create an M-file function called `opencht` to handle files with extension `.cht`, and then issue the command

```
open myfigure.cht
```

`open` calls your handler function with the following syntax:

```
opencht('myfigure.cht')
```

See Also

`edit`, `load`, `save`, `saveas`, `uiopen`, `which`, `file_formats`, `path`

Purpose Open new copy or raise existing copy of saved figure

Syntax

```
openfig('filename.fig','new')
openfig('filename.fig','new','visible')
openfig('filename.fig','new','visible')
openfig('filename.fig','reuse')
openfig('filename.fig')
openfig(...,'PropertyName',PropertyValue,...)
figure_handle = openfig(...)
```

Description `openfig` is designed for use with GUI figures. Use this function to:

- Open the FIG-file creating the GUI and ensure it is displayed on screen. This provides compatibility with different screen sizes and resolutions.
- Control whether MATLAB displays one or multiple instances of the GUI at any given time.
- Return the handle of the figure created, which is typically hidden for GUI figures.

`openfig('filename.fig','new')` opens the figure contained in the FIG-file, `filename.fig`, and ensures it is visible and positioned completely on screen. You do not have to specify the full path to the FIG-file as long as it is on your MATLAB path. The `.fig` extension is optional.

openfig('filename.fig','new','invisible') or openfig('filename.fig','reuse','invisible') opens the figure as in the preceding example, while forcing the figure to be invisible.

`openfig('filename.fig','new','visible')` or `openfig('filename.fig','new','visible')` opens the figure, while forcing the figure to be visible.

`openfig('filename.fig','reuse')` opens the figure contained in the FIG-file only if a copy is not currently open; otherwise `openfig` brings the existing copy forward, making sure it is still visible and completely on screen.

`openfig('filename.fig')` is the same as `openfig('filename.fig','new')`.

`openfig(...,'PropertyName',PropertyValue,...)` opens the FIG-file setting the specified figure properties before displaying the figure.

`figure_handle = openfig(...)` returns the handle to the figure.

Remarks

If the FIG-file contains an invisible figure, `openfig` returns its handle and leaves it invisible. The caller should make the figure visible when appropriate.

See Also

`guide`, `guihandles`, `movegui`, `open`, `hgload`, `save`

See Deploying User Interfaces in the MATLAB documentation for related functions

Purpose

Control OpenGL rendering

Syntax

```
opengl info
s = opengl('data')
opengl software
opengl hardware
opengl verbose
opengl quiet
opengl DriverBugWorkaround
opengl('DriverBugWorkaround',WorkaroundState)
```

Description

The OpenGL autoselection mode applies when the `RendererMode` of the figure is `auto`. Possible values for *`selection_mode`* are

- `autoselect` – allows OpenGL to be automatically selected if OpenGL is available and if there is graphics hardware on the host machine.
- `neverselect` – disables autoselection of OpenGL.
- `advise` – prints a message to the command window if OpenGL rendering is advised, but `RenderMode` is set to `manual`.

`opengl`, by itself, returns the current autoselection state.

Note that the autoselection state only specifies whether OpenGL should or should not be considered for rendering; it does not explicitly set the rendering to OpenGL. You can do this by setting the `Renderer` property of the figure to `OpenGL`. For example,

```
set(figure_handle,'Renderer','OpenGL')
```

`opengl info` prints information with the version and vendor of the OpenGL on your system. Also indicates wether your system is currently using hardware of software OpenGL and the state of various driver bug workarounds. Note that calling `opengl info` loads the OpenGL Library.

For example, the following output is generated on a Windows XP computer that uses ATI Technologies graphics hardware:

```
>> opengl info
Version         = 1.3.4010 WinXP Release
Vendor          = ATI Technologies Inc.
Renderer        = RADEON 9600SE x86/SSE2
MaxTextureSize  = 2048
Visual          = 05 (RGB 16 bits(05 06 05 00) zdepth 16, Hardware
Accelerated, Opengl, Double Buffered, Window)
Software        = false
# of Extensions = 85
Driver Bug Workarounds:
OpenGLBitmapZbufferBug    = 0
OpenGLWobbleTesselatorBug = 0
OpenGLLineSmoothingBug    = 0
OpenGLDockingBug          = 0
OpenGLClippedImageBug     = 0
```

Note that different computer systems may not list all OpenGL bugs.

`s = opengl('data')` returns a structure containing the same data that is displayed when you call `opengl info`, with the exception of the driver bug workaround state.

`opengl software` forces MATLAB to use software OpenGL rendering instead of hardware OpenGL.

`opengl hardware` reverses the `opengl software` command and enables MATLAB to use hardware OpenGL rendering if it is available. If your computer does not have OpenGL hardware acceleration, MATLAB automatically switches to software OpenGL rendering.

Note that on UNIX systems, the `software` or `hardware` options with the `opengl` command works only if MATLAB has not yet used the OpenGL renderer or you have not issued the `opengl info` command (which attempts to load the OpenGL Library).

`opengl verbose` displays verbose messages about OpenGL initialization (if OpenGL is not already loaded) and other runtime messages.

`opengl quiet` disables verbose message setting.

`opengl` *`DriverBugWorkaround`* queries the state of the specified driver bug workaround. Use the command `opengl info` to see a list of all driver bug workarounds. See "Driver Bug Workarounds" on page 2-2282 for more information.

`opengl('`*`DriverBugWorkaround`*`',WorkaroundState)` sets the state of the specified driver bug workaround. You can set WorkaroundState to one of three values:

- `0` – Disable the specified *`DriverBugWorkaround`* (if enabled) and do not allow MATLAB to autoselect this workaround.
- `1` – Enable the specified *`DriverBugWorkaround`*.
- `-1` – Set the specified *`DriverBugWorkaround`* to autoselection mode, which allows MATLAB to enable this workaround if the requisite conditions exist.

Driver Bug Workarounds

MATLAB enables various OpenGL driver bug workarounds when it detects certain known problems with installed hardware. However, because there are many versions of graphics drivers, you might encounter situations when MATLAB does not enable a workaround that would solve a problem you are having with OpenGL rendering.

This section describes the symptoms that each workaround is designed to correct so you can decide if you want to try using one to fix an OpenGL rendering problem.

Use the `opengl info` command to see what driver bug workarounds are available on your computer.

Note These workarounds have not been tested under all driver combinations and therefore might produce undesirable results under certain conditions.

OpenGLBitmapZbufferBug

Symptom: text with background color (including data tips) and text displayed on image, patch, or surface objects is not visible when using OpenGL renderer.

Possible side effect: text is always on top of other objects.

Command to enable:

```
opengl('OpenGLBitmapZbufferBug',1)
```

OpenGLWobbleTesselatorBug

Symptom: Rendering complex patch object causes segmentation violation and returns a tesselator error message in the stack trace.

Command to enable:

```
opengl('OpenGLWobbleTesselatorBug',1)
```

OpenGLLineSmoothingBug

Symptom: Lines with a `LineWidth` greater than 3 look bad.

Command to enable:

```
opengl('OpenGLLineSmoothingBug',1)
```

OpenGLDockingBug

Symptom: MATLAB crashes when you dock a figure that has its `Renderer` property set to `opengl`.

Command to enable:

```
opengl('OpenGLDockingBug',1)
```

OpenGLClippedImageBug

Symptom: Images (as well as `colorbar` displays) do not display when the `Renderer` property set to `opengl`.

Command to enable:

```
opengl('OpenGLClippedImageBug',1)
```

OpenGLEraseModeBug

Symptom: Graphics objects with `EraseMode` property set to non-normal erase modes (`xor`, `none`, or `background`) do not draw when the figure `Renderer` property is set to `opengl`.

Command to enable:

```
opengl('OpenGLEraseModeBug',1)
```

See Also

Figure `Renderer` property for information on autoselection.

Purpose

Open workspace variable in Array Editor or other tool for graphical editing

GUI Alternatives

As an alternative to the `openvar` function, double-click a variable in the Workspace browser.

Syntax

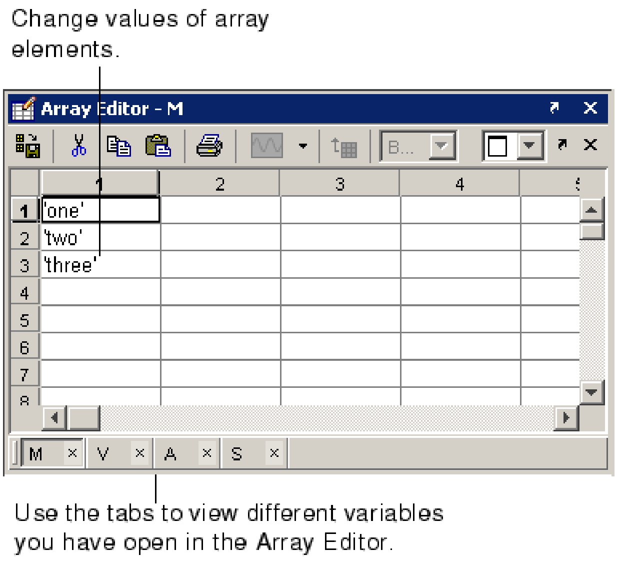
```
openvar('name')
```

Description

`openvar('name')` opens the workspace variable `name` in the Array Editor for graphical editing, where `name` is a numeric array, string, or cell array of strings.

MATLAB does not impose any limitation on the size of an array that can be opened in the Array Editor. Array size is limited only by the operating system or the amount of physical memory installed on your system.

For some toolboxes, `openvar` instead opens a tool appropriate for viewing or editing that type of object.



See Also `load`, `save`, `workspace`

Purpose

Optimization options values

Syntax

```
val = optimget(options,'param')
val = optimget(options,'param',default)
```

Description

`val = optimget(options,'param')` returns the value of the specified parameter in the optimization options structure `options`. You need to type only enough leading characters to define the parameter name uniquely. Case is ignored for parameter names.

`val = optimget(options,'param',default)` returns `default` if the specified parameter is not defined in the optimization options structure `options`. Note that this form of the function is used primarily by other optimization functions.

Examples

This statement returns the value of the `Display` optimization options parameter in the structure called `my_options`.

```
val = optimget(my_options,'Display')
```

This statement returns the value of the `Display` optimization options parameter in the structure called `my_options` (as in the previous example) except that if the `Display` parameter is not defined, it returns the value `'final'`.

```
optnew = optimget(my_options,'Display','final');
```

See Also

`optimset`, `fminbnd`, `fminsearch`, `fzero`, `lsqnonneg`

optimset

Purpose

Create or edit optimization options structure

Syntax

```
options = optimset('param1',value1,'param2',value2,...)
optimset
options = optimset
options = optimset(optimfun)
options = optimset(oldopts,'param1',value1,...)
options = optimset(oldopts,newopts)
```

Description

The function `optimset` creates an `options` structure that you can pass as an input argument to the following four MATLAB optimization functions:

- `fminbnd`
- `fminsearch`
- `fzero`
- `lsqnonneg`

You can use the `options` structure to change the default parameters for these functions.

Note If you have purchased the Optimization Toolbox, you can also use `optimset` to create an expanded `options` structure containing additional options specifically designed for the functions provided in that toolbox. See the reference page for the enhanced `optimset` function in the Optimization Toolbox for more information about these additional options.

`options = optimset('param1',value1,'param2',value2,...)` creates an optimization options structure called `options`, in which the specified parameters (`param`) have specified values. Any unspecified parameters are set to `[]` (parameters with value `[]` indicate to use the default value for that parameter when `options` is passed to the optimization function). It is sufficient to type only enough leading characters to define the parameter name uniquely. Case is ignored for parameter names.

`optimset` with no input or output arguments displays a complete list of parameters with their valid values.

`options = optimset` (with no input arguments) creates an options structure `options` where all fields are set to `[]`.

`options = optimset(optimfun)` creates an options structure `options` with all parameter names and default values relevant to the optimization function `optimfun`.

`options = optimset(oldopts,'param1',value1,...)` creates a copy of `oldopts`, modifying the specified parameters with the specified values.

`options = optimset(oldopts,newopts)` combines an existing options structure `oldopts` with a new options structure `newopts`. Any parameters in `newopts` with nonempty values overwrite the corresponding old parameters in `oldopts`.

Options

The following table lists the available options for the MATLAB optimization functions.

Option	Value	Description
`Display`	`'off'` | `’iter'` | `{'final'}` | `'notify'`	Level of display. `'off'` displays no output; `'iter'` displays output at each iteration; `'final'` displays just the final output; `'notify'` displays output only if the function does not converge.

Option	Value	Description
FunValCheck	{'off'} | 'on'	Check whether objective function values are valid. 'on' displays an error when the objective function returns a value that is complex or NaN. 'off' displays no error.
MaxFunEvals	positive integer	Maximum number of function evaluations allowed.
MaxIter	positive integer	Maximum number of iterations allowed.
OutputFcn	function | {[]}	User-defined function that an optimization function calls at each iteration. See "Output Function" in the Optimization Toolbox for more information.
PlotFcns	function | {[]}	User-defined plot function that an optimization function calls at each iteration. See "Plot Functions" in the Optimization Toolbox for more information.
TolFun	positive scalar	Termination tolerance on the function value.
TolX	positive scalar	Termination tolerance on x.

Examples

This statement creates an optimization options structure called `options` in which the `Display` parameter is set to `'iter'` and the `TolFun` parameter is set to `1e-8`.

```
options = optimset('Display','iter','TolFun',1e-8)
```

This statement makes a copy of the options structure called `options`, changing the value of the `TolX` parameter and storing new values in `optnew`.

```
optnew = optimset(options,'TolX',1e-4);
```

This statement returns an optimization options structure that contains all the parameter names and default values relevant to the function `fminbnd`.

```
optimset('fminbnd')
```

See Also

`optimset` (Optimization Toolbox version), `optimget`, `fminbnd`, `fminsearch`, `fzero`, `lsqnonneg`

Purpose Find logical OR of array or scalar inputs

Syntax

```
A | B | ...
or(A, B)
```

Description `A | B | ...` performs a logical OR of all input arrays `A`, `B`, etc., and returns an array containing elements set to either logical 1 (`true`) or logical 0 (`false`). An element of the output array is set to 1 if any input arrays contain a nonzero element at that same array location. Otherwise, that element is set to 0.

Each input of the expression can be an array or can be a scalar value. All nonscalar input arrays must have equal dimensions. If one or more inputs are an array, then the output is an array of the same dimensions. If all inputs are scalar, then the output is scalar.

If the expression contains both scalar and nonscalar inputs, then each scalar input is treated as if it were an array having the same dimensions as the other input arrays. In other words, if input `A` is a 3-by-5 matrix and input `B` is the number 1, then `B` is treated as if it were a 3-by-5 matrix of ones.

`or(A, B)` is called for the syntax `A | B` when either `A` or `B` is an object.

Note The symbols `|` and `||` perform different operations in MATLAB. The element-wise OR operator described here is `|`. The short-circuit OR operator is `||`.

Example If matrix `A` is

```
    0.4235    0.5798         0    0.7942         0
    0.5155         0         0         0    0.8744
         0         0         0    0.4451    0.0150
    0.4329    0.6405    0.6808         0         0
```

and matrix `B` is

```
        0     1     0     1     0
        1     1     0     0     1
        0     0     0     1     0
        0     1     0     0     1
```

then

```
A | B
ans =
        1     1     0     1     0
        1     1     0     0     1
        0     0     0     1     1
        1     1     1     0     1
```

See Also

`bitor`, `and`, `xor`, `not`, `any`, `all`, logical operators, logical types, bitwise functions

ordeig

Purpose

Eigenvalues of quasitriangular matrices

Syntax

```
E = ordeig(T)
E = ordeig(AA,BB)
```

Description

`E = ordeig(T)` takes a quasitriangular Schur matrix `T`, typically produced by `schur`, and returns the vector `E` of eigenvalues in their order of appearance down the diagonal of T.

`E = ordeig(AA,BB)` takes a quasitriangular matrix pair `AA` and `BB`, typically produced by `qz`, and returns the generalized eigenvalues in their order of appearance down the diagonal of `AA-λ*BB`.

`ordeig` is an order-preserving version of `eig` for use with `ordschur` and `ordqz`. It is also faster than `eig` for quasitriangular matrices.

Examples

Example 1

```
T=diag([1 -1 3 -5 2]);
```

`ordeig(T)` returns the eigenvalues of `T` in the same order they appear on the diagonal.

```
ordeig(T)

ans =

     1
    -1
     3
    -5
     2
```

`eig(T)`, on the other hand, returns the eigenvalues in order of increasing magnitude.

```
eig(T)

ans =
```

```
    -5
    -1
     1
     2
     3
```

Example 2

```
A = rand(10);
[U, T] = schur(A);
abs(ordeig(T))

ans =

    5.3786
    0.7564
    0.7564
    0.7802
    0.7080
    0.7080
    0.5855
    0.5855
    0.1445
    0.0812
% Move eigenvalues with magnitude < 0.5 to the
% upper-left corner of T.
[U,T] = ordschur(U,T,abs(E)<0.5);
abs(ordeig(T))

ans =

    0.1445
    0.0812
    5.3786
    0.7564
    0.7564
    0.7802
```

```
0.7080
0.7080
0.5855
0.5855
```

See Also

`schur`, `qz`, `ordschur`, `ordqz`, `eig`

Purpose

Order fields of structure array

Syntax

```
s = orderfields(s1)
s = orderfields(s1, s2)
s = orderfields(s1, c)
s = orderfields(s1, perm)
[s, perm] = orderfields(...)
```

Description

`s = orderfields(s1)` orders the fields in `s1` so that the new structure array `s` has field names in ASCII dictionary order.

`s = orderfields(s1, s2)` orders the fields in `s1` so that the new structure array `s` has field names in the same order as those in `s2`. Structures `s1` and `s2` must have the same fields.

`s = orderfields(s1, c)` orders the fields in `s1` so that the new structure array `s` has field names in the same order as those in the cell array of field name strings `c`. Structure `s1` and cell array `c` must contain the same field names.

`s = orderfields(s1, perm)` orders the fields in `s1` so that the new structure array `s` has fieldnames in the order specified by the indices in permutation vector `perm`.

If `s1` has `N` fieldnames, the elements of `perm` must be an arrangement of the numbers from `1` to `N`. This is particularly useful if you have more than one structure array that you would like to reorder in the same way.

`[s, perm] = orderfields(...)` returns a permutation vector representing the change in order performed on the fields of the structure array that results in `s`.

Remarks

`orderfields` only orders top-level fields. It is not recursive.

Examples

Create a structure `s`. Then create a new structure from `s`, but with the fields ordered alphabetically:

```
s = struct('b', 2, 'c', 3, 'a', 1)
s =
```

```
    b: 2
    c: 3
    a: 1

snew = orderfields(s)
snew =
    a: 1
    b: 2
    c: 3
```

Arrange the fields of `s` in the order specified by the second (cell array) argument of `orderfields`. Return the new structure in `snew` and the permutation vector used to create it in `perm`:

```
[snew, perm] = orderfields(s, {'b', 'a', 'c'})
snew =
    b: 2
    a: 1
    c: 3
perm =
     1
     3
     2
```

Now create a new structure, `s2`, having the same fieldnames as `s`. Reorder the fields using the permutation vector returned in the previous operation:

```
s2 = struct('b', 3, 'c', 7, 'a', 4)
s2 =
    b: 3
    c: 7
    a: 4

snew = orderfields(s2, perm)
snew =
    b: 3
    a: 4
```

```
c: 7
```

See Also

`struct`, `fieldnames`, `setfield`, `getfield`, `isfield`, `rmfield`, "Using Dynamic Field Names"

Purpose

Reorder eigenvalues in QZ factorization

Syntax

```
[AAS,BBS,QS,ZS] = ordqz(AA,BB,Q,Z,select)
[...] = ordqz(AA,BB,Q,Z,keyword)
[...] = ordqz(AA,BB,Q,Z,clusters)
```

Description

`[AAS,BBS,QS,ZS] = ordqz(AA,BB,Q,Z,select)` reorders the QZ factorizations `Q*A*Z = AA` and `Q*B*Z = BB` produced by the `qz` function for a matrix pair `(A,B)`. It returns the reordered pair `(AAS,BBS)` and the cumulative orthogonal transformations `QS` and `ZS` such that `QS*A*ZS = AAS` and `QS*B*ZS = BBS`. In this reordering, the selected cluster of eigenvalues appears in the leading (upper left) diagonal blocks of the quasitriangular pair `(AAS,BBS)`, and the corresponding invariant subspace is spanned by the leading columns of `ZS`. The logical vector `select` specifies the selected cluster as `E(select)` where `E` is the vector of eigenvalues as they appear along the diagonal of `AA-λ*BB`.

Note To extract `E` from `AA` and `BB`, use `ordeig(BB)`, instead of `eig`. This ensures that the eigenvalues in `E` occur in the same order as they appear on the diagonal of `AA-λ*BB`.

`[...]  = ordqz(AA,BB,Q,Z,keyword)` sets the selected cluster to include all eigenvalues in the region specified by `keyword`:

keyword	Selected Region
'lhp'	Left-half plane (`real(E) < 0`)
'rhp'	Right-half plane (`real(E) > 0`)
'udi'	Interior of unit disk (`abs(E) < 1`)
'udo'	Exterior of unit disk (`abs(E) > 1`)

`[...]  = ordqz(AA,BB,Q,Z,clusters)` reorders multiple clusters at once. Given a vector `clusters` of cluster indices commensurate with `E = ordeig(AA,BB)`, such that all eigenvalues with the same `clusters` value form one cluster, `ordqz` sorts the specified clusters in descending order along the diagonal of `(AAS,BBS)`. The cluster with highest index appears in the upper left corner.

Algorithm

For full matrices `AA` and `BB`, `qz` uses the LAPACK routines listed in the following table.

	AA and BB Real	AA or BB Complex
`A` and `B` `double`	`DTGSEN`	`ZTGSEN`
`A` or `B` `single`	`STGSEN`	`CTGSEN`

See Also

`ordeig`, `ordschur`, `qz`

Purpose

Reorder eigenvalues in Schur factorization

Syntax

```
[US,TS] = ordschur(U,T,select)
[US,TS] = ordschur(U,T,keyword)
[US,TS] = ordschur(U,T,clusters)
```

Description

`[US,TS] = ordschur(U,T,select)` reorders the Schur factorization `X = U*T*U'` produced by the `schur` function and returns the reordered Schur matrix `TS` and the cumulative orthogonal transformation `US` such that `X = US*TS*US'`. In this reordering, the selected cluster of eigenvalues appears in the leading (upper left) diagonal blocks of the quasitriangular Schur matrix `TS`, and the corresponding invariant subspace is spanned by the leading columns of `US`. The logical vector `select` specifies the selected cluster as `E(select)` where `E` is the vector of eigenvalues as they appear along `T`'s diagonal.

Note To extract `E` from `T`, use `E = ordeig(T)`, instead of `eig`. This ensures that the eigenvalues in `E` occur in the same order as they appear on the diagonal of `TS`.

`[US,TS] = ordschur(U,T,keyword)` sets the selected cluster to include all eigenvalues in one of the following regions:

keyword	Selected Region
`'lhp'`	Left-half plane (`real(E) < 0`)
`'rhp'`	Right-half plane (`real(E) > 0`)
`'udi'`	Interior of unit disk (`abs(E) < 1`)
`'udo'`	Exterior of unit disk (`abs(E) > 1`)

`[US,TS] = ordschur(U,T,clusters)` reorders multiple clusters at once. Given a vector `clusters` of cluster indices, commensurate with `E = ordeig(T)`, and such that all eigenvalues with the same `clusters` value form one cluster, `ordschur` sorts the specified clusters in descending order along the diagonal of TS, the cluster with highest index appearing in the upper left corner.

Algorithm

Input of Type Double

If U and T have type double, ordschur uses the LAPACK routines listed in the following table to compute the Schur form of a matrix:

Matrix Type	Routine
Real	DTRSEN
Complex	ZTRSEN

Input of Type Single

If U and T have type single, ordschur uses the LAPACK routines listed in the following table to reorder the Schur form of a matrix:

Matrix Type	Routine
Real	STRSEN
Complex	CTRSEN

See Also

ordeig, ordqz, schur

Purpose Hardcopy paper orientation

GUI Alternative Use **File —> Print Preview** on the figure window menu to directly manipulate print layout, paper size, headers, fonts and other properties when printing figures. For details, see Using Print Preview in the MATLAB Graphics documentation.

Syntax

```
orient
orient landscape
orient portrait
orient tall
orient(fig_handle), orient(simulink_model)
orient(fig_handle,orientation), orient(simulink_model,
   orientation)
```

Description

`orient` returns a string with the current paper orientation: `portrait`, `landscape`, or `tall`.

`orient landscape` sets the paper orientation of the current figure to full-page landscape, orienting the longest page dimension horizontally. The figure is centered on the page and scaled to fit the page with a 0.25 inch border.

`orient portrait` sets the paper orientation of the current figure to portrait, orienting the longest page dimension vertically. The `portrait` option returns the page orientation to the MATLAB default. (Note that the result of using the `portrait` option is affected by changes you make to figure properties. See the "Algorithm" section for more specific information.)

`orient tall` maps the current figure to the entire page in portrait orientation, leaving a 0.25 inch border.

`orient(fig_handle), orient(simulink_model)` returns the current orientation of the specified figure or Simulink model.

`orient(fig_handle,`*`orientation`*`),`
`orient(simulink_model,`*`orientation`*`)` sets the

orientation for the specified figure or Simulink model to the specified orientation (landscape, portrait, or tall).

Algorithm

orient sets the PaperOrientation, PaperPosition, and PaperUnits properties of the current figure. Subsequent print operations use these properties. The result of using the portrait option can be affected by default property values as follows:

- If the current figure PaperType is the same as the default figure PaperType and the default figure PaperOrientation has been set to landscape, then the orient portrait command uses the current values of PaperOrientation and PaperPosition to place the figure on the page.
- If the current figure PaperType is the same as the default figure PaperType and the default figure PaperOrientation has been set to landscape, then the orient portrait command uses the default figure PaperPosition with the x, y and width, height values reversed (i.e., [y,x,height,width]) to position the figure on the page.
- If the current figure PaperType is different from the default figure PaperType, then the orient portrait command uses the current figure PaperPosition with the x, y and width, height values reversed (i.e., [y,x,height,width]) to position the figure on the page.

See Also

print, printpreview, set

PaperOrientation, PaperPosition, PaperSize, PaperType, and PaperUnits properties of figure graphics objects

“Printing” on page 1-91 for related functions

Purpose

Range space of matrix

Syntax

```
B = orth(A)
```

Description

`B = orth(A)` returns an orthonormal basis for the range of `A`. The columns of `B` span the same space as the columns of `A`, and the columns of `B` are orthogonal, so that `B'*B = eye(rank(A))`. The number of columns of `B` is the rank of `A`.

See Also

`null`, `svd`, `rank`

Purpose

Default part of switch statement

Syntax

```
switch switch_expr
 case case_expr
    statement, ..., statement
  case {case_expr1, case_expr2, case_expr3, ...}
    statement, ..., statement
  otherwise
    statement, ..., statement
end
```

Description

`otherwise` is part of the `switch` statement syntax, which allows for conditional execution. The statements following `otherwise` are executed only if none of the preceding case expressions (`case_expr`) matches the switch expression (`sw_expr`).

Examples

The general form of the `switch` statement is

```
switch sw_expr
    case case_expr
        statement
        statement
    case {case_expr1,case_expr2,case_expr3}
        statement
        statement
    otherwise
        statement
        statement
end
```

See `switch` for more details.

See Also

`switch`, `case`, `end`, `if`, `else`, `elseif`, `while`

Index

B

C

D

E

G

J

K

M

N

O

P

S

V

X

Y

Z