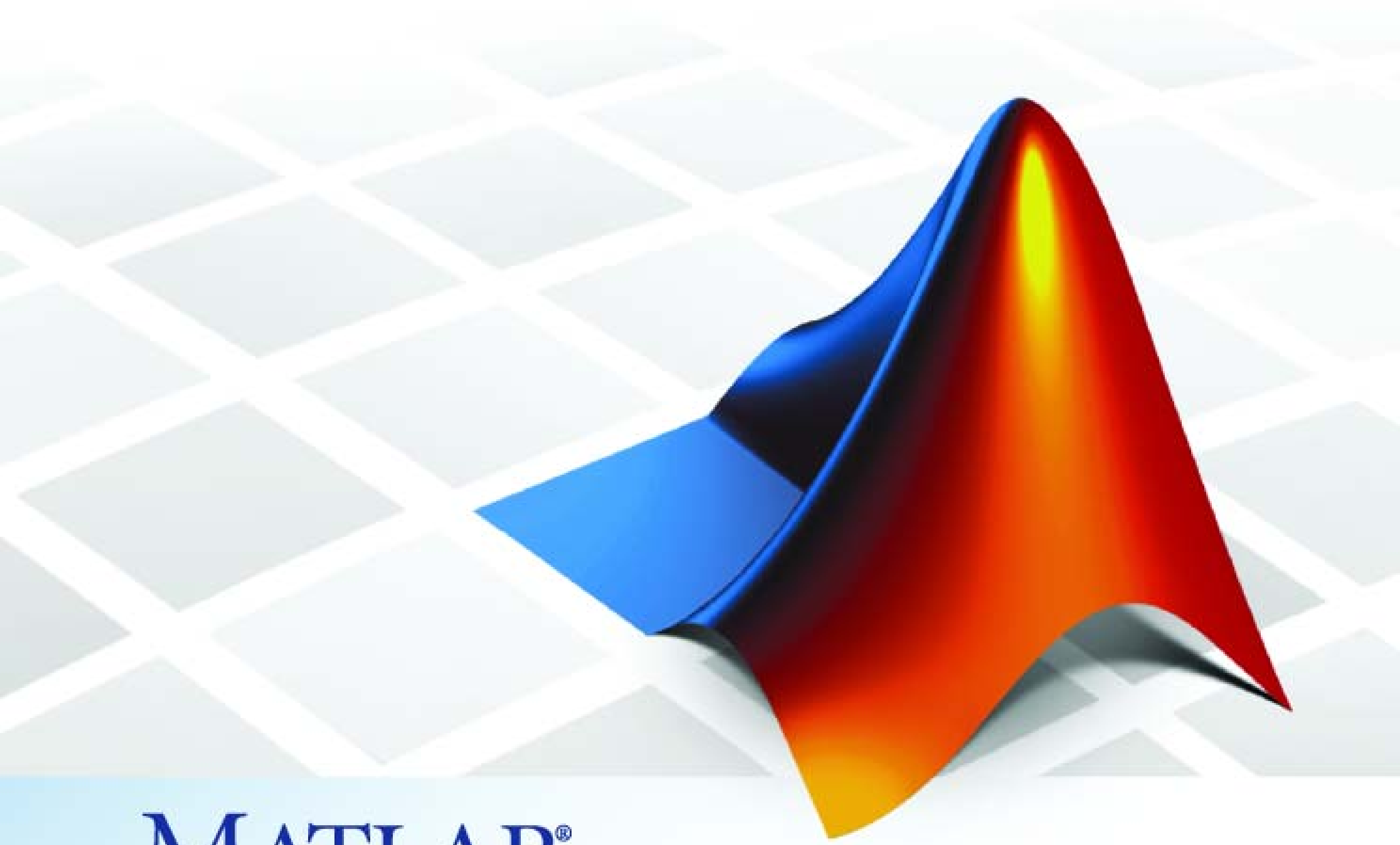
MATLAB 7
Function Reference: Volume 1(A-E)



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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

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Contents

1 Functions — By Category

Functions — Alphabetical List

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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

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 (p. 1-29)	Data interpolation, data gridding, polynomial evaluation, nearest point search
Delaunay Triangulation and Tessellation (p. 1-30)	Delaunay triangulation and tessellation, triangular surface and mesh plots
Convex Hull (p. 1-30)	Plot convex hull, plotting functions
Voronoi Diagrams (p. 1-30)	Plot Voronoi diagram, patch graphics object, plotting functions
Domain Generation (p. 1-31)	Generate arrays for 3-D plots, or for N-D functions and interpolation

Interpolation

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

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

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

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

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

asind
asinh
assert
assignin
atan
atan2
atand
atanh
audioplayer
audiorecorder
aufinfo
auread
auwrite
avifile
aviinfo
aviread
axes
Axes Properties
axis
balance
bar, barh
bar3, bar3h
Barseries Properties
base2dec
beep
besselh
besseli
besselj
besselk
bessely
beta
betainc
betaln
bicg
bicgstab
bin2dec
binary

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

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

mldivide \, mrdivide /
mlint
mlintrpt
mlock
mmfileinfo
mod
mode
more
move
movefile
movegui
movie
movie2avi
mput
msgbox
mtimes
mu2lin
multibandread
multibandwrite
munlock
namelengthmax
NaN
nargchk
nargin, nargout
nargoutchk
native2unicode
nchoosek
ndgrid
ndims
ne
newplot
nextpow2
nnz
noanimate
nonzeros
norm
normest

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

rem
removets
rename
repmat
resample (timeseries)
resample (tscollection)
reset
reshape
residue
restoredefaultpath
rethrow
return
rgb2hsv
rgbplot
ribbon
rmappdata
rmdir
rmdir (ftp)
rmfield
rmpath
rmpref
root object
Root Properties
roots
rose
rosser
rot90
rotate
rotate3d
round
rref
rsf2csf
run
save
save (COM)
save (serial)
saveas

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

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

Arithmetic Operators + - * / \ ^ ′

Purpose

Matrix and array arithmetic

Syntax

```
A+B
A-B
A*B
A.*B
A/B
A./B
A\B
A.\B
A^B
A.^B
A'
A.'
```

Description

MATLAB has two different types of arithmetic operations. Matrix arithmetic operations are defined by the rules of linear algebra. Array arithmetic operations are carried out element by element, and can be used with multidimensional arrays. The period character (`.`) distinguishes the array operations from the matrix operations. However, since the matrix and array operations are the same for addition and subtraction, the character pairs `.+` and `.-` are not used.

+	Addition or unary plus. `A+B` adds `A` and `B`. `A` and `B` must have the same size, unless one is a scalar. A scalar can be added to a matrix of any size.
-	Subtraction or unary minus. `A-B` subtracts `B` from `A`. `A` and `B` must have the same size, unless one is a scalar. A scalar can be subtracted from a matrix of any size.

`*` Matrix multiplication. `C = A*B` is the linear algebraic product of the matrices `A` and `B`. More precisely,

$$C(i,j) = \sum_{k=1}^{n} A(i,k)B(k,j)$$

For nonscalar `A` and `B`, the number of columns of `A` must equal the number of rows of `B`. A scalar can multiply a matrix of any size.

`.*` Array multiplication. `A.*B` is the element-by-element product of the arrays `A` and `B`. `A` and `B` must have the same size, unless one of them is a scalar.

`/` Slash or matrix right division. `B/A` is roughly the same as `B*inv(A)`. More precisely, `B/A = (A'\B')'`. See the reference page for `mrdivide` for more information.

`./` Array right division. `A./B` is the matrix with elements `A(i,j)/B(i,j)`. `A` and `B` must have the same size, unless one of them is a scalar.

`\` Backslash or matrix left division. 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` components, or a matrix with several such columns, then `X = A\B` is the solution to the equation $AX = B$ computed by Gaussian elimination. A warning message is displayed if `A` is badly scaled or nearly singular. See the reference page for `mldivide` for more information.

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 $AX = B$. The effective rank, `k`, of `A` is determined from the QR decomposition with pivoting (see "Algorithm" on page 2-2123 for details). A solution `X` is computed that has at most `k` nonzero components per column. If `k < n`, this is usually not the same solution as `pinv(A)*B`, which is the least squares solution with the smallest norm $\|X\|$.

`.\`	Array left division. `A.\B` is the matrix with elements `B(i,j)/A(i,j)`. `A` and `B` must have the same size, unless one of them is a scalar.
`^`	Matrix power. `X^p` is `X` to the power `p`, if `p` is a scalar. If `p` is an integer, the power is computed by repeated squaring. If the integer is negative, `X` is inverted first. For other values of `p`, the calculation involves eigenvalues and eigenvectors, such that if `[V,D] = eig(X)`, then `X^p = V*D.^p/V`. If `x` is a scalar and `P` is a matrix, `x^P` is `x` raised to the matrix power `P` using eigenvalues and eigenvectors. `X^P`, where `X` and `P` are both matrices, is an error.
`.^`	Array power. `A.^B` is the matrix with elements `A(i,j)` to the `B(i,j)` power. `A` and `B` must have the same size, unless one of them is a scalar.
`'`	Matrix transpose. `A'` is the linear algebraic transpose of `A`. For complex matrices, this is the complex conjugate transpose.
`.'`	Array transpose. `A.'` is the array transpose of `A`. For complex matrices, this does not involve conjugation.

Nondouble Data Type Support

This section describes the arithmetic operators' support for data types other than `double`.

Data Type single

You can apply any of the arithmetic operators to arrays of type `single` and MATLAB returns an answer of type `single`. You can also combine an array of type `double` with an array of type `single`, and the result has type `single`.

Integer Data Types

You can apply most of the arithmetic operators to real arrays of the following integer data types:

- `int8` and `uint8`
- `int16` and `uint16`
- `int32` and `uint32`

All operands must have the same integer data type and MATLAB returns an answer of that type.

Note The arithmetic operators do not support operations on the data types `int64` or `uint64`. Except for the unary operators `+A` and `A.'`, the arithmetic operators do not support operations on complex arrays of any integer data type.

For example,

```
x = int8(3) + int8(4);
class(x)

ans =

int8
```

The following table lists the binary arithmetic operators that you can apply to arrays of the same integer data type. In the table, `A` and `B` are arrays of the same integer data type and `c` is a scalar of type `double` or the same type as `A` and `B`.

Operation	Support when A and B Have Same Integer Type
`+A, -A`	Yes
`A+B, A+c, c+B`	Yes
`A-B, A-c, c-B`	Yes
`A.*B`	Yes
`A*c, c*B`	Yes
`A*B`	No
`A/c, c/B`	Yes
`A.\B, A./B`	Yes
`A\B, A/B`	No
`A.^B`	Yes, if `B` has nonnegative integer values.
`c^k`	Yes, for a scalar `c` and a nonnegative scalar integer `k`, which have the same integer data type or one of which has type `double`
`A.', A'`	Yes

Combining Integer Data Types with Type Double

For the operations that support integer data types, you can combine a scalar or array of an integer data type with a scalar, but not an array, of type `double` and the result has the same integer data type as the input of integer type. For example,

```
y = 5 + int32(7);
class(y)
```

```
ans =

int32
```

However, you cannot combine an array of an integer data type with either of the following:

- A scalar or array of a different integer data type
- A scalar or array of type `single`

The section “Numeric Types”, under “Data Types” in the MATLAB Programming documentation, provides more information about operations on nondouble data types.

Remarks

The arithmetic operators have M-file function equivalents, as shown:

Binary addition	`A+B`	`plus(A,B)`
Unary plus	`+A`	`uplus(A)`
Binary subtraction	`A-B`	`minus(A,B)`
Unary minus	`-A`	`uminus(A)`
Matrix multiplication	`A*B`	`mtimes(A,B)`
Arraywise multiplication	`A.*B`	`times(A,B)`
Matrix right division	`A/B`	`mrdivide(A,B)`
Arraywise right division	`A./B`	`rdivide(A,B)`
Matrix left division	`A\B`	`mldivide(A,B)`
Arraywise left division	`A.\B`	`ldivide(A,B)`

Matrix power	`A^B`	`mpower(A,B)`
Arraywise power	`A.^B`	`power(A,B)`
Complex transpose	`A'`	`ctranspose(A)`
Matrix transpose	`A.'`	`transpose(A)`

Note For some toolboxes, the arithmetic operators are overloaded, that is, they perform differently in the context of that toolbox. To see the toolboxes that overload a given operator, type `help` followed by the operator name. For example, type `help plus`. The toolboxes that overload `plus` (+) are listed. For information about using the operator in that toolbox, see the documentation for the toolbox.

Examples

Here are two vectors, and the results of various matrix and array operations on them, printed with `format rat`.

Matrix Operations		Array Operations	
`x`	1 2 3	`y`	4 5 6
`x'`	1 2 3	`y'`	4 5 6
`x+y`	5 7 9	`x-y`	-3 -3 -3
`x + 2`	3 4 5	`x-2`	-1 0 1

Matrix Operations		Array Operations	
x * y	Error	x.*y	4 10 18
x'*y	32	x'.*y	Error
x*y'	4 5 6 8 10 12 12 15 18	x.*y'	Error
x*2	2 4 6	x.*2	2 4 6
x\y	16/7	x.\y	4 5/2 2
2\x	1/2 1 3/2	2./x	2 1 2/3
x/y	0 0 1/6 0 0 1/3 0 0 1/2	x./y	1/4 2/5 1/2
x/2	1/2 1 3/2	x./2	1/2 1 3/2

Matrix Operations		Array Operations	
`x^y`	Error	`x.^y`	1 32 729
`x^2`	Error	`x.^2`	1 4 9
`2^x`	Error	`2.^x`	2 4 8
`(x+i*y)'`	`1 - 4i 2 - 5i 3 - 6i`		
`(x+i*y).'`	`1 + 4i 2 + 5i 3 + 6i`		

Diagnostics

- From matrix division, if a square `A` is singular,

```
Warning: Matrix is singular to working precision.
```

- From elementwise division, if the divisor has zero elements,

```
Warning: Divide by zero.
```

  Matrix division and elementwise division can produce `NaN`s or `Inf`s where appropriate.

- If the inverse was found, but is not reliable,

```
Warning: Matrix is close to singular or badly scaled.
    Results may be inaccurate.  RCOND = xxx
```

- From matrix division, if a nonsquare `A` is rank deficient,

```
Warning: Rank deficient, rank = xxx tol = xxx
```

See Also

`mldivide`, `mrdivide`, `chol`, `det`, `inv`, `lu`, `orth`, `permute`, `ipermute`, `qr`, `rref`

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.

[3] Davis, T. A., *CHOLMOD Version 1.0 User Guide* (`http://www.cise.ufl.edu/research/sparse/cholmod`), Dept. of Computer and Information Science and Engineering, Univ. of Florida, Gainesville, FL, 2005.

Relational Operators < > <= >= == ~=

Purpose

Relational operations

Syntax

```
A < B
A > B
A <= B
A >= B
A == B
A ~= B
```

Description

The relational operators are <, >, <=, >=, ==, and ~=. Relational operators perform element-by-element comparisons between two arrays. They return a `logical` array of the same size, with elements set to logical `1` (`true`) where the relation is true, and elements set to logical `0` (`false`) where it is not.

The operators <, >, <=, and >= use only the real part of their operands for the comparison. The operators == and ~= test real and imaginary parts.

To test if two strings are equivalent, use `strcmp`, which allows vectors of dissimilar length to be compared.

Note For some toolboxes, the relational operators are overloaded, that is, they perform differently in the context of that toolbox. To see the toolboxes that overload a given operator, type `help` followed by the operator name. For example, type `help lt`. The toolboxes that overload `lt (<)` are listed. For information about using the operator in that toolbox, see the documentation for the toolbox.

Examples

If one of the operands is a scalar and the other a matrix, the scalar expands to the size of the matrix. For example, the two pairs of statements

```
X = 5; X >= [1 2 3; 4 5 6; 7 8 10]
X = 5*ones(3,3); X >= [1 2 3; 4 5 6; 7 8 10]
```

produce the same result:

```
ans =

     1     1     1
     1     1     0
     0     0     0
```

See Also

all, any, find, strcmp

Logical Operators: Elementwise & | ~, Logical Operators: Short-circuit && ||

Logical Operators: Elementwise & | ~

Purpose Elementwise logical operations on arrays

Syntax

```
A & B
A | B
~A
```

Description The symbols &, |, and ~ are the logical array operators AND, OR, and NOT. They work element by element on arrays, with logical 0 representing `false`, and logical 1 or any nonzero element representing `true`. The logical operators return a `logical` array with elements set to 1 (`true`) or 0 (`false`), as appropriate.

The & operator does a logical AND, the | operator does a logical OR, and ~A complements the elements of A. The function `xor(A,B)` implements the exclusive OR operation. The truth table for these operators and functions is shown below.

<table>
<tr><th colspan="2">Inputs</th><th>and</th><th>or</th><th>not</th><th>xor</th></tr>
<tr><th>A</th><th>B</th><th>A & B</th><th>A | B</th><th>~A</th><th>xor(A,B)</th></tr>
<tr><td>0</td><td>0</td><td>0</td><td>0</td><td>1</td><td>0</td></tr>
<tr><td>0</td><td>1</td><td>0</td><td>1</td><td>1</td><td>1</td></tr>
<tr><td>1</td><td>0</td><td>0</td><td>1</td><td>0</td><td>1</td></tr>
<tr><td>1</td><td>1</td><td>1</td><td>1</td><td>0</td><td>0</td></tr>
</table>

The precedence for the logical operators with respect to each other is

<table>
<tr><th>Operator</th><th>Operation</th><th>Priority</th></tr>
<tr><td>~</td><td>NOT</td><td>Highest</td></tr>
<tr><td>&</td><td>Elementwise AND</td><td></td></tr>
<tr><td>|</td><td>Elementwise OR</td><td></td></tr>
<tr><td>&&</td><td>Short-circuit AND</td><td></td></tr>
<tr><td>||</td><td>Short-circuit OR</td><td>Lowest</td></tr>
</table>

Remarks

MATLAB always gives the `&` operator precedence over the `|` operator. Although MATLAB typically evaluates expressions from left to right, the expression `a|b&c` is evaluated as `a|(b&c)`. It is a good idea to use parentheses to explicitly specify the intended precedence of statements containing combinations of `&` and `|`.

These logical operators have M-file function equivalents, as shown.

Logical Operation	Equivalent Function
`A & B`	`and(A,B)`
`A | B`	`or(A,B)`
`~A`	`not(A)`

Examples

This example shows the logical `OR` of the elements in the vector `u` with the corresponding elements in the vector `v`:

```
u = [0 0 1 1 0 1];
v = [0 1 1 0 0 1];
u | v

ans =
     0     1     1     1     0     1
```

See Also

`all`, `any`, `find`, `logical`, `xor`, `true`, `false`

`Logical Operators:  Short-circuit && ||`

`Relational Operators < > <= >= == ~=`

Logical Operators: Short-circuit && ||

Purpose

Logical operations, with short-circuiting capability

Syntax

```
expr1 && expr2
expr1 || expr2
```

Description

`expr1 && expr2` represents a logical `AND` operation that employs short-circuiting behavior. With short-circuiting, the second operand `expr2` is evaluated only when the result is not fully determined by the first operand `expr1`. For example, if `A` = 0, then the following statement evaluates to `false`, regardless of the value of `B`, so MATLAB does not evaluate `B`:

```
A && B
```

These two expressions must each be a valid MATLAB statement that evaluates to a scalar logical result.

`expr1 || expr2` represents a logical `OR` operation that employs short-circuiting behavior.

Note Always use the `&&` and `||` operators when short-circuiting is required. Using the elementwise operators (`&` and `|`) for short-circuiting can yield unexpected results.

Examples

In the following statement, it doesn't make sense to evaluate the relation on the right if the divisor, `b`, is zero. The test on the left is put in to avoid generating a warning under these circumstances:

```
x = (b ~= 0) && (a/b > 18.5)
```

By definition, if any operands of an `AND` expression are `false`, the entire expression must be `false`. So, if `(b ~= 0)` evaluates to `false`, MATLAB assumes the entire expression to be `false` and terminates its evaluation of the expression early. This avoids the warning that would be generated if MATLAB were to evaluate the operand on the right.

See Also

`all`, `any`, `find`, `logical`, `xor`, `true`, `false`

`Logical Operators: Elementwise & | ~`

`Relational Operators < > <= >= == ~=`

Special Characters [ ] ( ) {} = ' . ... , ; : % ! @

Purpose

Special characters

Syntax

```
[  ]
{  }
(  )
=
'
.
.
.(  )
..
...
,
;
:
%
%{  %}
!
@
```

Description

`[ ]` Brackets are used to form vectors and matrices. `[6.9 9.64 sqrt(-1)]` is a vector with three elements separated by blanks. `[6.9, 9.64, i]` is the same thing. `[1+j 2-j 3]` and `[1 +j 2 -j 3]` are not the same. The first has three elements, the second has five.

`[11 12 13; 21 22 23]` is a 2-by-3 matrix. The semicolon ends the first row.

Vectors and matrices can be used inside `[ ]` brackets. `[A B;C]` is allowed if the number of rows of `A` equals the number of rows of `B` and the number of columns of `A` plus the number of columns of `B` equals the number of columns of `C`. This rule generalizes in a hopefully obvious way to allow fairly complicated constructions.

`A = [ ]` stores an empty matrix in `A`. `A(m,:) = [ ]` deletes row `m` of `A`. `A(:,n) = [ ]` deletes column `n` of `A`. `A(n) = [ ]` reshapes `A` into a column vector and deletes the third element.

`[A1,A2,A3...] = function` assigns function output to multiple variables.

For the use of `[` and `]` on the left of an "=" in multiple assignment statements, see `lu`, `eig`, `svd`, and so on.

`{ }` Curly braces are used in cell array assignment statements. For example, `A(2,1) = {[1 2 3; 4 5 6]}`, or `A{2,2} = ('str')`. See `help paren` for more information about `{ }`.

`( )` Parentheses are used to indicate precedence in arithmetic expressions in the usual way. They are used to enclose arguments of functions in the usual way. They are also used to enclose subscripts of vectors and matrices in a manner somewhat more general than usual. If `X` and `V` are vectors, then `X(V)` is `[X(V(1)), X(V(2)), ..., X(V(n))]`. The components of `V` must be integers to be used as subscripts. An error occurs if any such subscript is less than 1 or greater than the size of `X`. Some examples are

- `X(3)` is the third element of `X`.
- `X([1 2 3])` is the first three elements of `X`.

  See `help paren` for more information about `( )`.

If `X` has `n` components, `X(n: 1:1)` reverses them. The same indirect subscripting works in matrices. If `V` has `m` components and `W` has `n` components, then `A(V,W)` is the `m`-by-`n` matrix formed from the elements of `A` whose subscripts are the elements of `V` and `W`. For example, `A([1,5],:)  = A([5,1],:)` interchanges rows 1 and 5 of `A`.

`=` Used in assignment statements. `B = A` stores the elements of `A` in `B`. == is the relational equals operator. See the `Relational Operators < > <= >= == ~=` page.

`'` Matrix transpose. `X'` is the complex conjugate transpose of `X`. `X.'` is the nonconjugate transpose.

Quotation mark. `'any text'` is a vector whose components are the ASCII codes for the characters. A quotation mark within the text is indicated by two quotation marks.

`.` Decimal point. `314/100`, `3.14`, and `.314e1` are all the same.

Element-by-element operations. These are obtained using `.*` , `.^`, `./`, or `.\`. See the Arithmetic Operators page.

`.` Field access. `S(m).f` when `S` is a structure, accesses the contents of field `f` of that structure.

`.( )` Dynamic Field access. `S.(df)` when `A` is a structure, accesses the contents of dynamic field `df` of that structure. Dynamic field names are defined at runtime.

`..` Parent directory. See `cd`.

`...` Continuation. Three or more periods at the end of a line continue the current function on the next line. Three or more periods before the end of a line cause MATLAB to ignore the remaining text on the current line and continue the function on the next line. This effectively makes a comment out of anything on the current line that follows the three periods. See "Entering Long Statements (Line Continuation)" for more information.

`,` Comma. Used to separate matrix subscripts and function arguments. Used to separate statements in multistatement lines. For multistatement lines, the comma can be replaced by a semicolon to suppress printing.

`;` Semicolon. Used inside brackets to end rows. Used after an expression or statement to suppress printing or to separate statements.

`:` Colon. Create vectors, array subscripting, and `for` loop iterations. See `colon (:)` for details.

`%` Percent. The percent symbol denotes a comment; it indicates a logical end of line. Any following text is ignored. MATLAB displays the first contiguous comment lines in a M-file in response to a `help` command.

`%{` `%}` Percent-brace. The text enclosed within the `%{` and `%}` symbols is a comment block. Use these symbols to insert comments that take up more than a single line in your M-file code. Any text between these two symbols is ignored by MATLAB.

With the exception of whitespace characters, the %{ and %} operators must appear alone on the lines that immediately precede and follow the block of help text. Do not include any other text on these lines.

`!`	Exclamation point. Indicates that the rest of the input line is issued as a command to the operating system. See "Running External Programs" for more information.
`@`	Function handle. MATLAB data type that is a handle to a function. See `function_handle (@)` for details.

Remarks

Some uses of special characters have M-file function equivalents, as shown:

Horizontal concatenation	`[A,B,C...]`	`horzcat(A,B,C...)`
Vertical concatenation	`[A;B;C...]`	`vertcat(A,B,C...)`
Subscript reference	`A(i,j,k...)`	`subsref(A,S)`. See `help subsref`.
Subscript assignment	`A(i,j,k...)=B`	`subsasgn(A,S,B)`. See `help subsasgn`.

Note For some toolboxes, the special characters are overloaded, that is, they perform differently in the context of that toolbox. To see the toolboxes that overload a given character, type `help` followed by the character name. For example, type `help transpose`. The toolboxes that overload `transpose (.')` are listed. For information about using the character in that toolbox, see the documentation for the toolbox.

See Also

`Arithmetic Operators + - * / \ ^ '`

`Relational Operators < > <= >= == ~=`

`Logical Operators:  Elementwise & | ~,`

Purpose

Create vectors, array subscripting, and `for`-loop iterators

Description

The colon is one of the most useful operators in MATLAB. It can create vectors, subscript arrays, and specify `for` iterations.

The colon operator uses the following rules to create regularly spaced vectors:

`j:k`	is the same as `[j,j+1,...,k]`
`j:k`	is empty if `j > k`
`j:i:k`	is the same as `[j,j+i,j+2i, ...,k]`
`j:i:k`	is empty if `i == 0`, if `i > 0` and `j > k`, or if `i < 0` and `j < k`

where `i`, `j`, and `k` are all scalars.

Below are the definitions that govern the use of the colon to pick out selected rows, columns, and elements of vectors, matrices, and higher-dimensional arrays:

`A(:,j)`	is the `j`th column of `A`
`A(i,:)`	is the `i`th row of `A`
`A(:,:)`	is the equivalent two-dimensional array. For matrices this is the same as `A`.
`A(j:k)`	is `A(j), A(j+1),...,A(k)`
`A(:,j:k)`	is `A(:,j), A(:,j+1),...,A(:,k)`
`A(:,:,k)`	is the `k`th page of three-dimensional array `A`.
`A(i,j,k,:)`	is a vector in four-dimensional array `A`. The vector includes `A(i,j,k,1)`, `A(i,j,k,2)`, `A(i,j,k,3)`, and so on.
`A(:)`	is all the elements of `A`, regarded as a single column. On the left side of an assignment statement, `A(:)` fills `A`, preserving its shape from before. In this case, the right side must contain the same number of elements as `A`.

Examples

Using the colon with integers,

```
D = 1:4
```

results in

```
D =
     1     2     3     4
```

Using two colons to create a vector with arbitrary real increments between the elements,

```
E = 0:.1:.5
```

results in

```
E =
     0    0.1000    0.2000    0.3000    0.4000    0.5000
```

The command

```
A(:,:,2) = pascal(3)
```

generates a three-dimensional array whose first page is all zeros.

```
A(:,:,1) =
      0     0     0
      0     0     0
      0     0     0

A(:,:,2) =
      1     1     1
      1     2     3
      1     3     6
```

See Also

`for`, `linspace`, `logspace`, `reshape`

Purpose

Absolute value and complex magnitude

Syntax

```
abs(X)
```

Description

`abs(X)` returns an array `Y` such that each element of `Y` is the absolute value of the corresponding element of `X`.

If `X` is complex, `abs(X)` returns the complex modulus (magnitude), which is the same as

```
sqrt(real(X).^2 + imag(X).^2)
```

Examples

```
abs(-5)
ans =
     5

abs(3+4i)
ans =
     5
```

See Also

`angle`, `sign`, `unwrap`

Purpose Construct array with accumulation

Syntax

```
A = accumarray(subs, val)
A = accumarray(subs,val,sz)
A = accumarray(subs,val,sz,fun)
A = accumarray(subs,val,sz,fun,fillval)
A = accumarray(subs,val,sz,fun,fillval,issparse)
A = accumarray({subs1, subs2, ...}, val, ...)
```

Description

`A = accumarray(subs, val)` creates an array `A` by accumulating elements of the vector `val` using the subscript in `subs`. Each row of the `m`-by-`n` matrix `subs` defines an N-dimensional subscript into the output `A`. Each element of `val` has a corresponding row in `subs`. `accumarray` collects all elements of `val` that correspond to identical subscripts in `subs`, sums those values, and stores the result in the element of `A` that corresponds to the subscript. Elements of `A` that are not referred to by any row of `subs` contain zero.

If `subs` is a nonempty matrix with N>1 columns, then `A` is an N-dimensional array of size `max(subs,[],1)`. If `subs` is empty with N>1 columns, then `A` is an N-dimensional empty array with size 0-by-0-by-`...`-by-0. `subs` can also be a column vector, in which case a second column of ones is implied, and `A` is a column vector. `subs` must contain positive integers.

`subs` can also be a cell vector with one or more elements, each element a vector of positive integers. All the vectors must have the same length. In this case, `subs` is treated as if the vectors formed columns of an index matrix.

`val` must be a numeric, logical, or character vector with the same length as the number of rows in `subs`. `val` can also be a scalar whose value is repeated for all the rows of `subs`.

`accumarray` sums values from `val` using the default behavior of `sum`.

`A = accumarray(subs,val,sz)` creates an array `A` with size `sz`, where `sz` is a vector of positive integers. If `subs` is nonempty with N>1 columns, then `sz` must have N elements, where `all(sz >=`

max(subs,[],1)). If subs is a nonempty column vector, then sz must be [M 1], where M >= MAX(subs). Specify sz as [] for the default behavior.

A = accumarray(subs,val,sz,fun) applies function fun to each subset of elements of val. You must specify the fun input using the @ symbol (e.g., @sin). The function fun must accept a column vector and return a numeric, logical, or character scalar, or a scalar cell. Return value A has the same class as the values returned by fun. Specify fun as [] for the default behavior. fun is @sum by default.

Note If the subscripts in subs are not sorted, fun should not depend on the order of the values in its input data.

A = accumarray(subs,val,sz,fun,fillval) puts the scalar value fillval in elements of A that are not referred to by any row of subs. For example, if subs is empty, then A is repmat(fillval,sz). fillval and the values returned by fun must belong to the same class.

A = accumarray(subs,val,sz,fun,fillval,issparse) creates an array A that is sparse if the scalar input issparse is equal to logical 1 (i.e., true), or full if issparse is equal to logical 0 (false). A is full by default. If issparse is true, then fillval must be zero or [], and val and the output of fun must be double.

A = accumarray({subs1, subs2, ...}, val, ...) passes multiple subs vectors in a cell array. You can use any of the four optional inputs (sz, fun, fillval, or issparse) with this syntax.

Examples

Example 1

Create a 5-by-1 vector, and sum values for repeated 1-dimensional subscripts:

```
val = 101:105;
subs = [1; 2; 4; 2; 4]
subs =
```

```
         1       % Subscript 1 of result <= val(1)
         2       % Subscript 2 of result <= val(2)
         4       % Subscript 4 of result <= val(3)
         2       % Subscript 2 of result <= val(4)
         4       % Subscript 4 of result <= val(5)

A = accumarray(subs, val)
A =
   101       % A(1) = val(1) = 101
   206       % A(2) = val(2)+val(4) = 102+104 = 206
     0       % A(3) = 0
   208       % A(4) = val(3)+val(5) = 103+105 = 208
```

Example 2

Create a 2-by-3-by-2 array, and sum values for repeated three-dimensional subscripts:

```
val = 101:105;
subs = [1 1 1; 2 1 2; 2 3 2; 2 1 2; 2 3 2];

A = accumarray(subs, val)
A(:,:,1) =
   101     0     0
     0     0     0
A(:,:,2) =
     0     0     0
   206     0   208
```

Example 3

Create a 2-by-3-by-2 array, and sum values natively:

```
val = 101:105;
subs = [1 1 1; 2 1 2; 2 3 2; 2 1 2; 2 3 2];

A = accumarray(subs, int8(val), [], @(x) sum(x,'native'))
A(:,:,1) =
  101    0    0
```

```
     0     0     0
A(:,:,2) =
     0     0     0
   127     0   127

class(A)
ans =
    int8
```

Example 4

Pass multiple subscript arguments in a cell array.

Create a 12-element vector V:

```
V = 101:112;
```

Create three 12-element vectors, one for each dimension of the resulting array A. Note how the indices of these vectors determine which elements of V are accumulated in A:

```
%         index 1   index 6 => V(1)+V(6) => A(1,3,1)
%           |         |
rowsubs = [1 3 3 2 3 1 2 2 3 3 1 2];
colsubs = [3 4 2 1 4 3 4 2 2 4 3 4];
pagsubs = [1 1 2 2 1 1 2 1 1 1 2 2];
%                 |
%               index 4 => V(4) => A(2,1,2)
%
% A(1,3,1) = V(1) + V(6) = 101 + 106 = 207
% A(2,1,2) = V(4) = 104
```

Call accumarray, passing the subscript vectors in a cell array:

```
A = accumarray({rowsubs colsubs pagsubs}, V)
A(:,:,1) =
     0     0   207     0        % A(1,3,1) is 207
     0   108     0     0
     0   109     0   317
```

```
A(:,:,2) =
     0     0   111     0
   104     0     0   219         % A(2,1,2) is 104
     0   103     0     0
```

Example 5

Create an array with the `max` function, and fill all empty elements of that array with `NaN`:

```
val = 101:105;
subs = [1 1; 2 1; 2 3; 2 1; 2 3];

A = accumarray(subs, val, [2 4], @max, NaN)
A =
   101   NaN   NaN   NaN
   104   NaN   105   NaN
```

Example 6

Create a sparse matrix using the `prod` function:

```
val = 101:105;
subs = [1 1; 2 1; 2 3; 2 1; 2 3];

A = accumarray(subs, val, [2 4], @prod, 0, true)
A =
   (1,1)            101
   (2,1)          10608
   (2,3)          10815
```

Example 7

Count the number of subscripts for each bin:

```
val = 1;
subs = [1 1; 2 1; 2 3; 2 1; 2 3];

A = accumarray(subs, val, [2 4])
A =
```

```
     1     0     0     0
     2     0     2     0
```

Example 8

Create a logical array that shows which bins have two or more values:

```
val = 101:105;
subs = [1 1; 2 1; 2 3; 2 1; 2 3];

A = accumarray(subs, val, [2 4], @(x) length(x) > 1)
A =
     0     0     0     0
     1     0     1     0
```

Example 9

Group values in a cell array:

```
val = 101:105;
subs = [1 1; 2 1; 2 3; 2 1; 2 3];

A = accumarray(subs, val, [2 4], @(x) {x})
A =
    [       101]    []                []    []
    [2x1 double]    []    [2x1 double]    []

A{2}
ans =
   104
   102
```

See Also

`full`, `sparse`, `sum`

Purpose

Inverse cosine; result in radians

Syntax

```
Y = acos(X)
```

Description

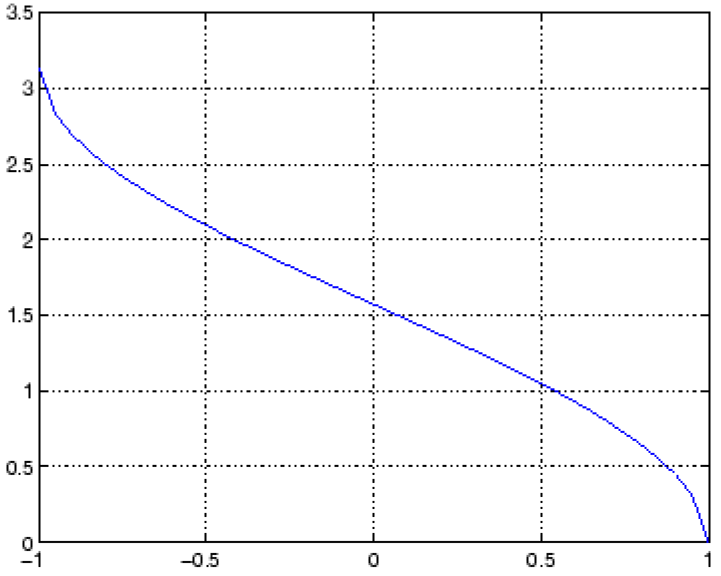
`Y = acos(X)` returns the inverse cosine (arccosine) for each element of `X`. For real elements of `X` in the domain $[-1, 1]$, `acos(X)` is real and in the range $[0, \pi]$. For real elements of `X` outside the domain $[-1, 1]$, `acos(X)` is complex.

The `acos` function operates element-wise on arrays. The function's domains and ranges include complex values. All angles are in radians.

Examples

Graph the inverse cosine function over the domain $-1 \leq x \leq 1$.

```
x = -1:.05:1;
plot(x,acos(x)), grid on
```



Definition

The inverse cosine can be defined as

$$\cos^{-1}(z) \quad = \quad -i \log\left[z + i(1-z^2)^{\frac{1}{2}} \right]$$

Algorithm

`acos` 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

`acosd`, `acosh`, `cos`

acosd

Purpose Inverse cosine; result in degrees

Syntax `Y = acosd(X)`

Description `Y = acosd(X)` is the inverse cosine, expressed in degrees, of the elements of `X`.

See Also `cosd`, `acos`

Purpose

Inverse hyperbolic cosine

Syntax

```
Y = acosh(X)
```

Description

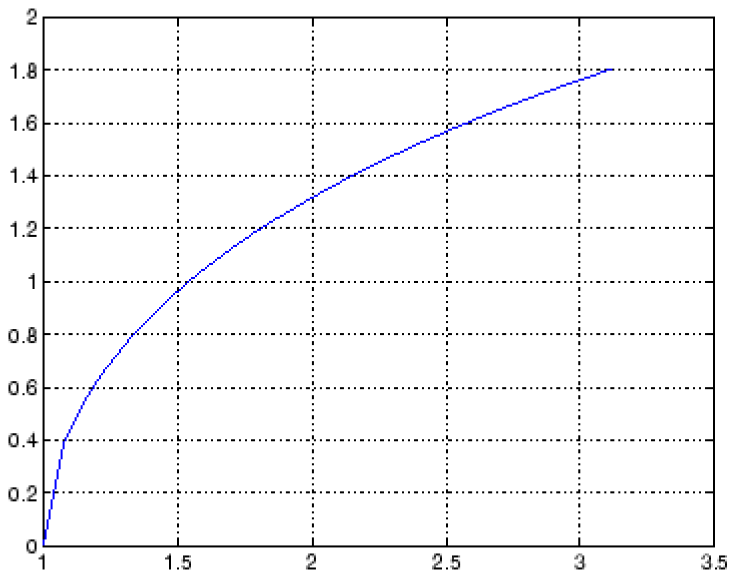
`Y = acosh(X)` returns the inverse hyperbolic cosine for each element of `X`.

The `acosh` function operates element-wise on arrays. The function's domains and ranges include complex values. All angles are in radians.

Examples

Graph the inverse hyperbolic cosine function over the domain $1 \le x \le \pi$.

```
x = 1:pi/40:pi;
plot(x,acosh(x)), grid on
```



Definition

The hyperbolic inverse cosine can be defined as

$$\cosh^{-1}(z) = \log\left[z + (z^2 - 1)^{\frac{1}{2}}\right]$$

Algorithm

`acosh` 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

`acos`, `cosh`

Purpose

Inverse cotangent; result in radians

Syntax

```
Y = acot(X)
```

Description

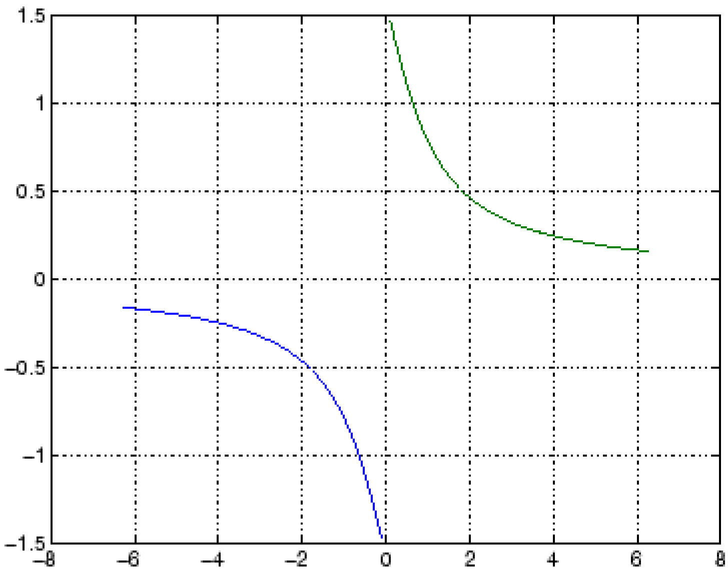
`Y = acot(X)` returns the inverse cotangent (arccotangent) for each element of `X`.

The `acot` function operates element-wise on arrays. The function's domains and ranges include complex values. All angles are in radians.

Examples

Graph the inverse cotangent over the domains $-2\pi \le x < 0$ and $0 < x \le 2\pi$.

```
x1 = -2*pi:pi/30:-0.1;
x2 = 0.1:pi/30:2*pi;
plot(x1,acot(x1),x2,acot(x2)), grid on
```



Definition

The inverse cotangent can be defined as

$$\cot^{-1}(z) = \tan^{-1}\left(\frac{1}{z}\right)$$

Algorithm

`acot` 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

`cot`, `acotd`, `acoth`

Purpose Inverse cotangent; result in degrees

Syntax

```
Y = acosd(X)
```

Description `Y = acosd(X)` is the inverse cotangent, expressed in degrees, of the elements of `X`.

See Also `cotd`, `acot`

acoth

Purpose

Inverse hyperbolic cotangent

Syntax

```
Y = acoth(X)
```

Description

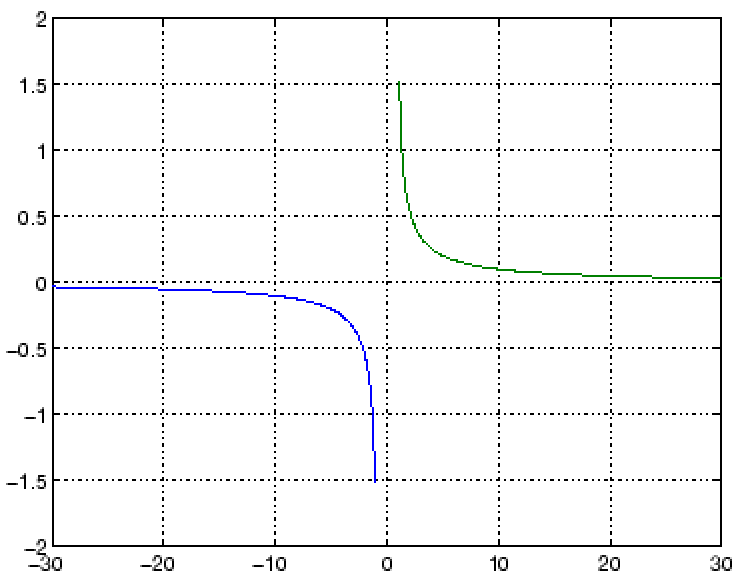
`Y = acoth(X)` returns the inverse hyperbolic cotangent for each element of `X`.

The `acoth` function operates element-wise on arrays. The function's domains and ranges include complex values. All angles are in radians.

Examples

Graph the inverse hyperbolic cotangent over the domains $-30 \le x < -1$ and $1 < x \le 30$.

```
x1 = -30:0.1:-1.1;
x2 = 1.1:0.1:30;
plot(x1,acoth(x1),x2,acoth(x2)), grid on
```



Definition

The hyperbolic inverse cotangent can be defined as

$$\coth^{-1}(z) = \tanh^{-1}\left(\frac{1}{z}\right)$$

Algorithm

`acoth` 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

`acot`, `coth`

Purpose Inverse cosecant; result in radians

Syntax

```
Y = acsc(X)
```

Description

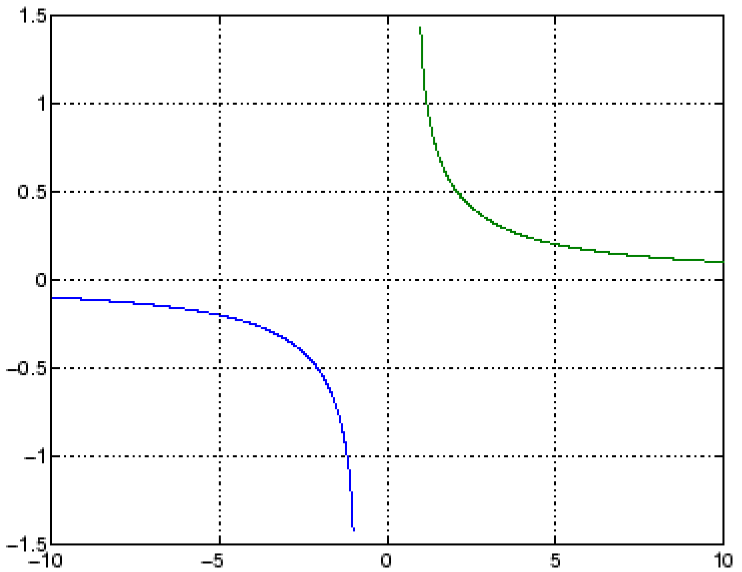
`Y = acsc(X)` returns the inverse cosecant (arccosecant) for each element of `X`.

The `acsc` function operates element-wise on arrays. The function's domains and ranges include complex values. All angles are in radians.

Examples

Graph the inverse cosecant over the domains $-10 \le x < -1$ and $1 < x \le 10$.

```
x1 = -10:0.01:-1.01;
x2 = 1.01:0.01:10;
plot(x1,acsc(x1),x2,acsc(x2)), grid on
```



Definition

The inverse cosecant can be defined as

$$\csc^{-1}(z) = \sin^{-1}\left(\frac{1}{z}\right)$$

Algorithm

`acsc` 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

`csc`, `acscd`, `acsch`

acscd

Purpose Inverse cosecant; result in degrees

Syntax `Y = acscd(X)`

Description `Y = acscd(X)` is the inverse cotangent, expressed in degrees, of the elements of `X`.

See Also `cscd`, `acsc`

Purpose

Inverse hyperbolic cosecant

Syntax

```
Y = acsch(X)
```

Description

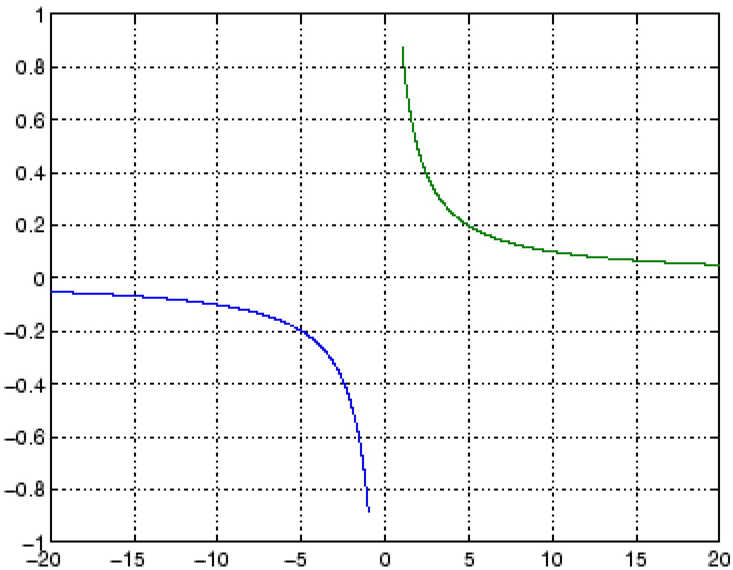
`Y = acsch(X)` returns the inverse hyperbolic cosecant for each element of `X`.

The `acsch` function operates element-wise on arrays. The function's domains and ranges include complex values. All angles are in radians.

Examples

Graph the inverse hyperbolic cosecant over the domains $-20 \le x \le -1$ and $1 \le x \le 20$.

```
x1 = -20:0.01:-1;
x2 = 1:0.01:20;
plot(x1,acsch(x1),x2,acsch(x2)), grid on
```



Definition

The hyperbolic inverse cosecant can be defined as

$$\operatorname{csch}^{-1}(z) = \sinh^{-1}\left(\frac{1}{z}\right)$$

Algorithm

acsc 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

`acsc`, `csch`

Purpose

Create ActiveX control in figure window

Syntax

```
h = actxcontrol('progid')
h = actxcontrol('progid','param1',value1,...)
h = actxcontrol('progid', position)
h = actxcontrol('progid', position, fig_handle)
h = actxcontrol('progid',position,fig_handle,event_handler)
h = actxcontrol('progid',position,fig_handle,event_handler,
    'filename')
```

Description

`h = actxcontrol('progid')` creates an ActiveX control in a figure window. The type of control created is determined by the string `progid`, the programmatic identifier (`progid`) for the control. (See the documentation provided by the control vendor to get this string.) The returned object, `h`, represents the default interface for the control.

Note that `progid` cannot be an ActiveX server because MATLAB cannot insert ActiveX servers in a figure. See `actxserver` for use with ActiveX servers.

`h = actxcontrol('progid','param1',value1,...)` creates an ActiveX control using the optional parameter name/value pairs. Parameter names include:

- `position` — MATLAB position vector specifying the control's position. The format is [left, bottom, width, height] using pixel units.
- `parent` — Handle to parent figure, model, or command window.
- `callback` — Name of event handler. Specify a single name to use the same handler for all events. Specify a cell array of event name/event handler pairs to handle specific events.
- `filename` — Sets the control's initial conditions to those in the previously saved control.
- `licensekey` — License key to create licensed ActiveX controls that require design-time licenses. See "Deploying ActiveX Controls Requiring Run-Time Licenses" for information on how to use controls that require run-time licenses.

For example:

```
h = actxcontrol('progid','position',[0 0 200 200],...
 'parent',gcf,...
 'callback',{`Click' 'myClickHandler';...
 'DblClick' 'myDblClickHandler';...
 'MouseDown' 'myMouseDownHandler'});
```

The following syntaxes are deprecated and will not become obsolete. They are included for reference, but the above syntaxes are preferred.

`h = actxcontrol('progid', position)` creates an ActiveX control having the location and size specified in the vector, `position`. The format of this vector is

```
[x y width height]
```

The first two elements of the vector determine where the control is placed in the figure window, with `x` and `y` being offsets, in pixels, from the bottom left corner of the figure window to the same corner of the control. The last two elements, `width` and `height`, determine the size of the control itself.

The default `position` vector is `[20 20 60 60]`.

`h = actxcontrol('progid', position, fig_handle)` creates an ActiveX control at the specified `position` in an existing figure window. This window is identified by the Handle Graphics handle, `fig_handle`.

The current figure handle is returned by the `gcf` command.

Note If the figure window designated by `fig_handle` is invisible, the control is invisible. If you want the control you are creating to be invisible, use the handle of an invisible figure window.

`h = actxcontrol('progid',position,fig_handle,event_handler)` creates an ActiveX control that responds to events. Controls respond to events by invoking an M-file function whenever an event (such as clicking a mouse button) is fired. The event_handler argument identifies one or more M-file functions to be used in handling events (see "Specifying Event Handlers" on page 2-83 below).

h = actxcontrol('progid',position,fig_handle,event_handler,'filename') creates an ActiveX control with the first four arguments, and sets its initial state to that of a previously saved control. MATLAB loads the initial state from the file specified in the string filename.

If you don't want to specify an event_handler, you can use an empty string ('') as the fourth argument.

The progid argument must match the progid of the saved control.

Specifying Event Handlers

There is more than one valid format for the event_handler argument. Use this argument to specify one of the following:

- A different event handler routine for each event supported by the control
- One common routine to handle selected events
- One common routine to handle all events

In the first case, use a cell array for the event_handler argument, with each row of the array specifying an event and handler pair:

```
{'event' 'eventhandler'; 'event2' 'eventhandler2'; ...}
```

event can be either a string containing the event name or a numeric event identifier (see Example 2 below), and eventhandler is a string identifying the M-file function you want the control to use in handling the event. Include only those events that you want enabled.

In the second case, use the same cell array syntax just described, but specify the same eventhandler for each event. Again, include only those events that you want enabled.

In the third case, make `event_handler` a string (instead of a cell array) that contains the name of the one M-file function that is to handle all events for the control.

There is no limit to the number of event and handler pairs you can specify in the `event_handler` cell array.

Event handler functions should accept a variable number of arguments.

Strings used in the `event_handler` argument are not case sensitive.

Note Although using a single handler for all events may be easier in some cases, specifying an individual handler for each event creates more efficient code that results in better performance.

Remarks

If the control implements any custom interfaces, use the `interfaces` function to list them, and the `invoke` function to get a handle to a selected interface.

When you no longer need the control, call `release` to release the interface and free memory and other resources used by the interface. Note that releasing the interface does not delete the control itself. Use the `delete` function to do this.

For more information on handling control events, see the section, "Writing Event Handlers" in the External Interfaces documentation.

For an example event handler, see the file `sampev.m` in the `toolbox\matlab\winfun\comcli` directory.

Note If you encounter problems creating Microsoft Forms 2.0 controls in MATLAB or other non-VBA container applications, see "Using Microsoft Forms 2.0 Controls" in the External Interfaces documentation.

Examples

Example 1 — Basic Control Methods

Start by creating a figure window to contain the control. Then create a control to run a Microsoft Calendar application in the window. Position the control at a [0 0] x-y offset from the bottom left of the figure window, and make it the same size (600 x 500 pixels) as the figure window.

```
f = figure('position', [300 300 600 500]);
cal = actxcontrol('mscal.calendar', [0 0 600 500], f)
cal =
    COM.mscal.calendar
```

Call the get method on cal to list all properties of the calendar:

```
cal.get
        BackColor: 2.1475e+009
              Day: 23
          DayFont: [1x1 Interface.Standard_OLE_Types.Font]
            Value: '8/20/2001'
                   .
                   .
```

Read just one property to record today's date:

```
date = cal.Value
date =
   8/23/2001
```

Set the Day property to a new value:

```
cal.Day = 5;
date = cal.Value
date =
   8/5/2001
```

Call invoke with no arguments to list all available methods:

```
meth = cal.invoke
meth =
```

```
             NextDay: 'HRESULT NextDay(handle)'
           NextMonth: 'HRESULT NextMonth(handle)'
            NextWeek: 'HRESULT NextWeek(handle)'
            NextYear: 'HRESULT NextYear(handle)'
                .
                .
```

Invoke the `NextWeek` method to advance the current date by one week:

```
cal.NextWeek;
date = cal.Value
date =
   8/12/2001
```

Call `events` to list all calendar events that can be triggered:

```
cal.events
ans =
   Click = void Click()
   DblClick = void DblClick()
   KeyDown = void KeyDown(int16 KeyCode, int16 Shift)
   KeyPress = void KeyPress(int16 KeyAscii)
   KeyUp = void KeyUp(int16 KeyCode, int16 Shift)
   BeforeUpdate = void BeforeUpdate(int16 Cancel)
   AfterUpdate = void AfterUpdate()
   NewMonth = void NewMonth()
   NewYear = void NewYear()
```

Example 2 — Event Handling

The `event_handler` argument specifies how you want the control to handle any events that occur. The control can handle all events with one common handler function, selected events with a common handler function, or each type of event can be handled by a separate function.

This command creates an `mwsamp` control that uses one event handler, `sampev`, to respond to all events:

```
h = actxcontrol('mwsamp.mwsampctrl.2', [0 0 200 200], ...
```

```
    gcf, 'sampev')
```

The next command also uses a common event handler, but will only invoke the handler when selected events, `Click` and `DblClick` are fired:

```
h = actxcontrol('mwsamp.mwsampctrl.2', [0 0 200 200], ...
   gcf, {'Click' 'sampev'; 'DblClick' 'sampev'})
```

This command assigns a different handler routine to each event. For example, `Click` is an event, and `myclick` is the routine that executes whenever a `Click` event is fired:

```
h = actxcontrol('mwsamp.mwsampctrl.2', [0 0 200 200], ...
   gcf, {'Click', 'myclick'; 'DblClick' 'my2click'; ...
   'MouseDown' 'mymoused'});
```

The next command does the same thing, but specifies the events using numeric event identifiers:

```
h = actxcontrol('mwsamp.mwsampctrl.2', [0 0 200 200], ...
gcf, {-600, 'myclick'; -601 'my2click'; -605 'mymoused'});
```

See the section, “Sample Event Handlers” in the External Interfaces documentation for examples of event handler functions and how to register them with MATLAB.

See Also

`actxserver`, `release`, `delete`, `save`, `load`, `interfaces`

actxcontrollist

Purpose

List all currently installed ActiveX controls

Syntax

```
C = actxcontrollist
```

Description

`C = actxcontrollist` returns a list of each control, including its name, programmatic identifier (or ProgID), and filename, in output cell array `C`.

Examples

Here is an example of the information that might be returned for several controls:

```
list = actxcontrollist;

for k = 1:2
   sprintf(' Name = %s\n ProgID = %s\n File = %s\n', ...
           list{k,:})
end

ans =
   Name = ActiveXPlugin Object
   ProgID = Microsoft.ActiveXPlugin.1
   File = C:\WINNT\System32\plugin.ocx

ans =
   Name = Adaptec CD Guide
   ProgID = Adaptec.EasyCDGuide
   File = D:\APPLIC~1\Adaptec\Shared\CDGuide\CDGuide.ocx
```

See Also

`actxcontrolselect`, `actxcontrol`

Purpose

Open GUI to create ActiveX control

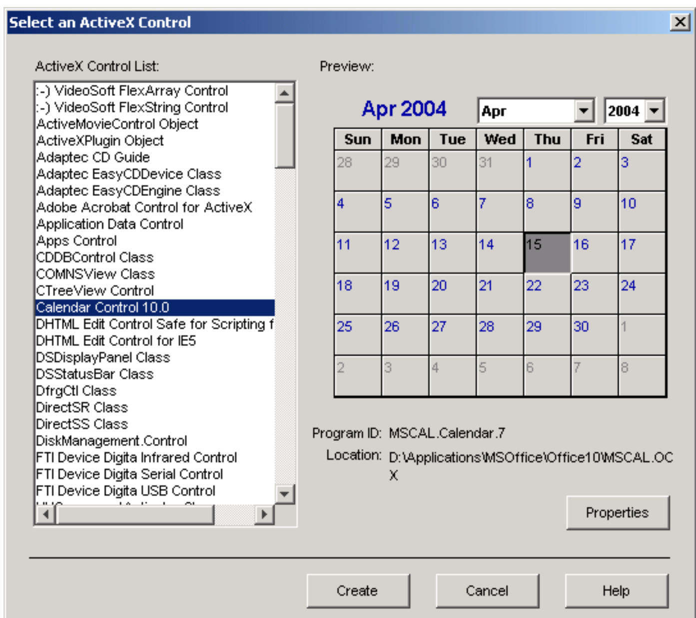
Syntax

```
h = actxcontrolselect
[h, info] = actxcontrolselect
```

Description

`h = actxcontrolselect` displays a graphical interface that lists all ActiveX controls installed on the system and creates the one that you select from the list. The function returns a handle `h` for the object. Use the handle to identify this particular control object when calling other MATLAB COM functions.

`[h, info] = actxcontrolselect` returns the handle `h` and also the 1-by-3 cell array `info` containing information about the control. The information returned in the cell array shows the name, programmatic identifier (or ProgID), and filename for the control.

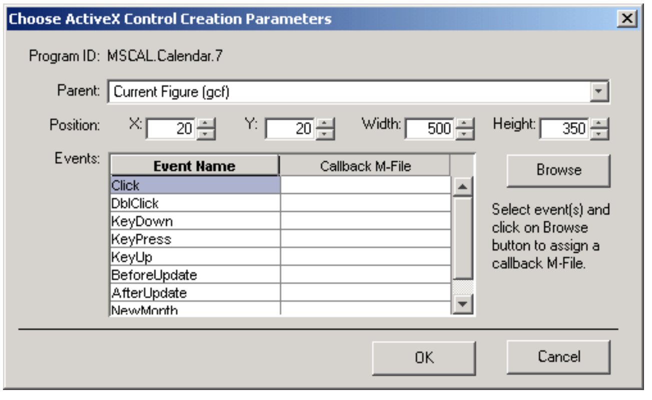


The `actxcontrolselect` interface has a selection panel at the left of the window and a preview panel at the right. Click on one of the control names in the selection panel to see a preview of the control displayed. (If MATLAB cannot create the control, an error message is displayed in the preview panel.) Select an item from the list and click the **Create** button at the bottom.

Remarks

Click the **Properties** button on the `actxcontrolselect` window to enter nondefault values for properties when creating the control. You can select which figure window to put the control in (**Parent** field), where to position it in the window (**X** and **Y** fields), and what size to make the control (**Width** and **Height**).

You can also register any events you want the control to respond to and what event handling routines to use when any of these events fire. Do this by entering the name of the appropriate event handling routine to the right of the event, or clicking the **Browse** button to search for the event handler file.



Note If you encounter problems creating Microsoft Forms 2.0 controls in MATLAB or other non-VBA container applications, see "Using Microsoft Forms 2.0 Controls" in the External Interfaces documentation.

Examples

Select `Calendar Control 9.0` in the `actxcontrolselect` window and then click **Properties** to open the window shown above. Enter new values for the size of the control, setting **Width** to `500` and **Height** to `350`, then click **OK**. Click **Create** in the `actxcontrolselect` window to create the control.

The control appears in a MATLAB figure window and the `actxcontrolselect` function returns these values:

```
h =
   COM.mscal.calendar.7
info =
    [1x20 char]    'MSCAL.Calendar.7'    [1x41 char]
```

Expand the `info` cell array to show the control name, ProgID, and filename:

```
info{:}
ans =
   Calendar Control 9.0
ans =
   MSCAL.Calendar.7
ans =
   D:\Applications\MSOffice\Office\MSCAL.OCX
```

See Also

`actxcontrollist`, `actxcontrol`

actxGetRunningServer

Purpose Get handle to running instance of Automation server

Syntax

```
h = actxGetRunningServer('progid')
```

Description

`h = actxGetRunningServer('progid')` gets a reference to a running instance of the OLE Automation server, where `progid` is the programmatic identifier of the Automation server object and `h` is the handle to the server object's default interface.

The function issues an error if the server specified by `progid` is not currently running or if the server object is not registered. When there are multiple instances of the Automation server already running, the behavior of this function is controlled by the operating system.

Example

```
h = actxGetRunningServer('Excel.Application')
```

See Also `actxcontrol`, `actxserver`

Purpose

Create COM server

Syntax

```
h = actxserver('progid')
h = actxserver('progid', 'machine', 'machineName')
h = actxserver('progid', 'interface', 'interfaceName')
h = actxserver('progid', 'machine', 'machineName',
   'interface', 'interfaceName')
h = actxserver('progid', machine)
```

Description

`h = actxserver('progid')` creates a local OLE Automation server, where `progid` is the programmatic identifier of the COM server, and `h` is the handle of the server's default interface.

Get `progid` from the control or server vendor's documentation. To see the `progid` values for MATLAB, refer to "Programmatic Identifiers" in the MATLAB External Interfaces documentation.

`h = actxserver('progid', 'machine', 'machineName')` creates an OLE Automation server on a remote machine, where `machineName` is a string specifying the name of the machine on which to launch the server.

`h = actxserver('progid', 'interface', 'interfaceName')` creates a Custom interface server, where `interfaceName` is a string specifying the interface name of the COM object. Values for `interfaceName` are

- `IUnknown` — Use the IUnknown interface.
- The Custom interface name

You must know the name of the interface and have the server vendor's documentation in order to use the `interfaceName` value. See "Automation, Custom, and Dual Server Types" in the MATLAB External Interfaces documentation for information about Custom COM servers and interfaces.

`h = actxserver('progid', 'machine', 'machineName', 'interface', 'interfaceName')` creates a Custom interface server on a remote machine.

The following syntaxes are deprecated and will not become obsolete. They are included for reference, but the syntaxes described earlier are preferred:

`h = actxserver('progid', machine)` creates a COM server running on the remote system named by the `machine` argument. This can be an IP address or a DNS name. Use this syntax only in environments that support Distributed Component Object Model (DCOM).

Remarks

For components implemented in a dynamic link library (DLL), `actxserver` creates an in-process server. For components implemented as an executable (EXE), `actxserver` creates an out-of-process server. Out-of-process servers can be created either on the client system or on any other system on a network that supports DCOM.

If the control implements any Custom interfaces, use the `interfaces` function to list them, and the `invoke` function to get a handle to a selected interface.

You can register events for COM servers.

Run Microsoft Excel Example

This example creates an OLE Automation server, Microsoft Excel version 9.0, and manipulates a workbook in the application:

```
%  Create a COM server running Microsoft Excel
e = actxserver ('Excel.Application')

% e =
%     COM.excel.application

% Make the Excel frame window visible
e.Visible = 1;

% Use the get method on the Excel object "e"
% to list all properties of the application:
e.get

% ans =
```

```
%        Application: [1x1Interface.Microsoft_Excel_9.0_
%Object_Library._Application]
%            Creator: 'xlCreatorCode'
%          Workbooks: [1x1 Interface.Microsoft_Excel_9.0_
%Object_Library.Workbooks]
%            Caption: 'Microsoft Excel - Book1'
%     CellDragAndDrop: 0
%    ClipboardFormats: {3x1 cell}
%              Cursor: 'xlNorthwestArrow'
%                .
%                .

% Create an interface "eWorkBooks"
eWorkbooks = e.Workbooks

% eWorkbooks =
%     Interface.Microsoft_Excel_9.0_Object_Library.Workbooks

% List all methods for that interface
eWorkbooks.invoke

% ans =
%       Add: 'handle Add(handle, [Optional]Variant)'
%     Close: 'void Close(handle)'
%      Item: 'handle Item(handle, Variant)'
%      Open: 'handle Open(handle, string, [Optional]Variant)'
%  OpenText: 'void OpenText(handle, string, [Optional]Variant)'

% Add a new workbook "w",
% also creating a new interface
w = eWorkbooks.Add

% w =
%     Interface.Microsoft_Excel_9.0_Object_Library._Workbook

% Close Excel and delete the object
e.Quit;
```

```
e.delete;
```

See Also

`actxcontrol`, `release`, `delete`, `save`, `load`, `interfaces`

Purpose

Add event to `timeseries` object

Syntax

```
ts = addevent(ts,e)
ts = addevent(ts,Name,Time)
```

Description

`ts = addevent(ts,e)` adds one or more `tsdata.event` objects, `e`, to the `timeseries` object `ts`. `e` is either a single `tsdata.event` object or an array of `tsdata.event` objects.

`ts = addevent(ts,Name,Time)` constructs one or more `tsdata.event` objects and adds them to the `Events` property of `ts`. `Name` is a cell array of event name strings. `Time` is a cell array of event times.

Examples

Create a time-series object and add an event to this object.

```
%% Import the sample data
load count.dat

%% Create time-series object
count1=timeseries(count(:,1),1:24,'name', 'data');

%% Modify the time units to be 'hours' ('seconds' is default)
count1.TimeInfo.Units = 'hours';

%% Construct and add the first event at 8 AM
e1 = tsdata.event('AMCommute',8);

%% Specify the time units of the time
e1.Units = 'hours';
```

View the properties (`EventData`, `Name`, `Time`, `Units`, and `StartDate`) of the event object.

```
get(e1)
```

MATLAB responds with

```
     EventData: []
```

```
             Name: 'AMCommute'
             Time: 8
            Units: 'hours'
        StartDate: ''
%% Add the event to count1
count1 = addevent(count1,e1);
```

An alternative syntax for adding two events to the time series `count1` is as follows:

```
count1 = addevent(count1,{'AMCommute' 'PMCommute'},{8 18})
```

See Also

`timeseries`, `tsdata.event`, `tsprops`

Purpose

Add frame to Audio/Video Interleaved (AVI) file

Syntax

```
aviobj = addframe(aviobj,frame)
aviobj = addframe(aviobj,frame1,frame2,frame3,...)
aviobj = addframe(aviobj,mov)
aviobj = addframe(aviobj,h)
```

Description

`aviobj = addframe(aviobj,frame)` appends the data in `frame` to the AVI file identified by `aviobj`, which was created by a previous call to `avifile`. `frame` can be either an indexed image (`m`-by-`n`) or a truecolor image (`m`-by-`n`-by-3) of `double` or `uint8` precision. If `frame` is not the first frame added to the AVI file, it must be consistent with the dimensions of the previous frames.

`addframe` returns a handle to the updated AVI file object, `aviobj`. For example, `addframe` updates the `TotalFrames` property of the AVI file object each time it adds a frame to the AVI file.

`aviobj = addframe(aviobj,frame1,frame2,frame3,...)` adds multiple frames to an AVI file.

`aviobj = addframe(aviobj,mov)` appends the frames contained in the MATLAB movie `mov` to the AVI file `aviobj`. MATLAB movies that store frames as indexed images use the colormap in the first frame as the colormap for the AVI file, unless the colormap has been previously set.

`aviobj = addframe(aviobj,h)` captures a frame from the figure or axis handle `h` and appends this frame to the AVI file. `addframe` renders the figure into an offscreen array before appending it to the AVI file. This ensures that the figure is written correctly to the AVI file even if the figure is obscured on the screen by another window or screen saver.

Note If an animation uses XOR graphics, you must use `getframe` to capture the graphics into a frame of a MATLAB movie. You can then add the frame to an AVI movie using the `addframe` syntax `aviobj = addframe(aviobj,mov)`. See the example for an illustration.

Example

This example calls `addframe` to add frames to the AVI file object `aviobj`.

```
fig=figure;
set(fig,'DoubleBuffer','on');
set(gca,'xlim',[-80 80],'ylim',[-80 80],...
 'nextplot','replace','Visible','off')

aviobj = avifile('example.avi')

x = -pi:.1:pi;
radius = 0:length(x);
for i=1:length(x)
 h = patch(sin(x)*radius(i),cos(x)*radius(i),...
   [abs(cos(x(i))) 0 0]);
 set(h,'EraseMode','xor');
 frame = getframe(gca);
 aviobj = addframe(aviobj,frame);
end

aviobj = close(aviobj);
```

See Also

`avifile`, `close`, `movie2avi`

Purpose

Add optional argument to `inputParser` schema

Syntax

```
p.addOptional(argname, default, validator)
addOptional(p, argname, default, validator)
```

Description

`p.addOptional(argname, default, validator)` updates the schema for `inputParser` object `p` by adding an optional argument, `argname`. Specify the argument name in a string enclosed within single quotation marks. The `default` input specifies the value to use when the optional argument `argname` is not present in the actual inputs to the function. The optional `validator` input is a handle to a function that MATLAB uses during parsing to validate the input arguments. If the validator function returns `false` or errors, the parsing fails and MATLAB throws an error.

MATLAB parses parameter-value arguments after required arguments and optional arguments.

`addOptional(p, argname, default, validator)` is functionally the same as the syntax above.

Note For more information on the `inputParser` class, see Parsing Inputs with inputParser in the MATLAB Programming documentation.

Examples

Write an M-file function called `publish_ip`, based on the MATLAB `publish` function, to illustrate the use of the `inputParser` class.

There are three calling syntaxes for this function:

```
publish_ip('script')
publish_ip('script', 'format')
publish_ip('script', options)
```

From these three syntaxes, you can see that there is one required argument (`script`), one optional argument (`format`), and some number of optional arguments that are specified as parameter-value pairs (options).

Begin writing the example publish_ip M-file by entering the following two statements. The second statement calls the class constructor for inputParser to create an instance of the class. This class instance, or object, gives you access to all of the methods and properties of the class:

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

Following the constructor, add this block of code to the M-file. This code uses the addRequired(inputParser), addOptional, and addParamValue(inputParser) methods to define the input arguments to the function:

```
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);
```

Also add the next two lines to the M-file. The Parameters property of inputParser lists all of the arguments that belong to the object p:

```
disp 'The input parameters for this program are
disp(p.Parameters)'
```

Save the M-file using the **Save** option on the MATLAB **File** menu, and then run it to see the following list displayed:

```
The input parameters for this program are
    'format'
    'maxHeight'
    'maxWidth'
    'outputDir'
    'script'
```

See Also

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

addParamValue (inputParser)

Purpose

Add parameter-value argument to `inputParser` schema

Syntax

```
p.addParamValue(argname, default, validator)
addParamValue(p, argname, default, validator)
```

Description

`p.addParamValue(argname, default, validator)` updates the schema for `inputParser` object `p` by adding a parameter-value argument, `argname`. Specify the argument name in a string enclosed within single quotation marks. The `default` input specifies the value to use when the optional argument name is not present in the actual inputs to the function. The optional `validator` is a handle to a function that MATLAB uses during parsing to validate the input arguments. If the validator function returns `false` or errors, the parsing fails and MATLAB throws an error.

MATLAB parses parameter-value arguments after required arguments and optional arguments.

`addParamValue(p, argname, default, validator)` is functionally the same as the syntax above.

Note For more information on the `inputParser` class, see Parsing Inputs with inputParser in the MATLAB Programming documentation.

Examples

Write an M-file function called `publish_ip`, based on the MATLAB `publish` function, to illustrate the use of the `inputParser` class. There are three calling syntaxes for this function:

```
publish_ip('script')
publish_ip('script', 'format')
publish_ip('script', options)
```

From these calling syntaxes, you can see that there is one required argument (`script`), one optional argument (`format`), and a number of optional arguments that are specified as parameter-value pairs (`options`).

Begin writing the example publish_ip M-file by entering the following two statements. Call the class constructor for inputParser to create an instance of the class. This class instance, or object, gives you access to all of the methods and properties of the class:

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

After calling the constructor, add the following lines to the M-file. This code uses the addRequired(inputParser), addOptional(inputParser), and addParamValue methods to define the input arguments to the function:

```
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);
```

Also add the next two lines to the M-file. The Parameters property of inputParser lists all of the arguments that belong to the object p:

```
disp 'The input parameters for this program are
disp(p.Parameters)'
```

Save the M-file using the **Save** option on the MATLAB **File** menu, and then run it to see the following list displayed:

```
The input parameters for this program are
    'format'
    'maxHeight'
    'maxWidth'
    'outputDir'
    'script'
```

See Also

inputParser, addRequired(inputParser), addOptional(inputParser), parse(inputParser), createCopy(inputParser)

Purpose

Add directories to MATLAB search path

GUI Alternatives

As an alternative to the `addpath` function, use **File > Set Path** to open the Set Path dialog box.

Syntax

```
addpath('directory')
addpath('dir','dir2','dir3' ...)
addpath('dir','dir2','dir3' ...'-flag')
addpath dir1 dir2 dir3 ... -flag
```

Description

`addpath('directory')` adds the specified directory to the top (also called front) of the current MATLAB search path. Use the full pathname for `directory`.

`addpath('dir','dir2','dir3' ...)` adds all the specified directories to the top of the path. Use the full pathname for each `dir`.

`addpath('dir','dir2','dir3' ...'-`*`flag`*`')` adds the specified directories to either the top or bottom of the path, depending on the value of `flag`.

flag Argument	Result
`0` or `begin`	Add specified directories to the top of the path
`1` or `end`	Add specified directories to the bottom (also called end) of the path

`addpath dir1 dir2 dir3 ...  -`*`flag`* is the unquoted form of the syntax.

Remarks

To recursively add subdirectories of your directory in addition to the directory itself, run

```
addpath(genpath('directory'))
```

Use addpath statements in your startup.m file to use the modified path in future sessions. For details, see "Modifying the Path in a startup.m File" in the MATLAB Desktop Tools and Development Environment Documentation.

Examples

For the current path, viewed by typing path,

```
MATLABPATH
c:\matlab\toolbox\general
c:\matlab\toolbox\ops
c:\matlab\toolbox\strfun
```

you can add c:/matlab/mymfiles to the front of the path by typing

```
addpath('c:/matlab/mymfiles')
```

Verify that the files were added to the path by typing

```
path
```

and MATLAB returns

```
MATLABPATH
c:\matlab\mymfiles
c:\matlab\toolbox\general
c:\matlab\toolbox\ops
c:\matlab\toolbox\strfun
```

You can also use genpath in conjunction with addpath to add subdirectories to the path from the command line. For example, to add /control and its subdirectories to the path, use

```
addpath(genpath(fullfile(matlabroot,'toolbox/control')))
```

See Also

genpath, path, pathdef, pathsep, pathtool, rehash, restoredefaultpath, rmpath, savepath, startup

"Search Path" in the MATLAB Desktop Tools and Development Environment Documentation

Purpose Add preference

Syntax

```
addpref('group','pref',val)
addpref('group',{'pref1','pref2',...'prefn'},{val1,val2,
   ...valn})
```

Description

`addpref('group','pref',val)` creates the preference specified by `group` and `pref` and sets its value to `val`. It is an error to add a preference that already exists.

`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.

`addpref('group',{'pref1','pref2',...'prefn'},{val1,val2,...valn})` creates the preferences specified by the cell array of names `'pref1'`, `'pref2',...,'prefn'`, setting each to the corresponding value.

Note Preference values are persistent and maintain their values between MATLAB sessions. Where they are stored is system dependent.

Examples

This example adds a preference called `version` to the `mytoolbox` group of preferences and sets its value to the string `1.0`.

```
addpref('mytoolbox','version','1.0')
```

See Also

`getpref`, `ispref`, `rmpref`, `setpref`, `uigetpref`, `uisetpref`

addproperty

Purpose

Add custom property to object

Syntax

```
h.addproperty('propertyname')
addproperty(h, 'propertyname')
```

Description

`h.addproperty('propertyname')` adds the custom property specified in the string, `propertyname`, to the object or interface, `h`. Use `set` to assign a value to the property.

`addproperty(h, 'propertyname')` is an alternate syntax for the same operation.

Examples

Create an `mwsamp` control and add a new property named `Position` to it. Assign an array value to the property:

```
f = figure('position', [100 200 200 200]);
h = actxcontrol('mwsamp.mwsampctrl.2', [0 0 200 200], f);
h.get
     Label: 'Label'
    Radius: 20

h.addproperty('Position');
h.Position = [200 120];
h.get
     Label: 'Label'
    Radius: 20
  Position: [200 120]

h.get('Position')
ans =
   200   120
```

Delete the custom `Position` property:

```
h.deleteproperty('Position');
h.get
     Label: 'Label'
    Radius: 20
```

See Also

`deleteproperty`, `get`, `set`, `inspect`

addRequired (inputParser)

Purpose Add required argument to `inputParser` schema

Syntax

```
p.addRequired(argname, validator)
addRequired(p, argname, validator)
```

Description `p.addRequired(argname, validator)` updates the schema for `inputParser` object `p` by adding a required argument, `argname`. Specify the argument name in a string enclosed within single quotation marks. The optional `validator` is a handle to a function that MATLAB uses during parsing to validate the input arguments. If the validator function returns `false` or errors, the parsing fails and MATLAB throws an error.

MATLAB parses required arguments before optional or parameter-value arguments.

`addRequired(p, argname, validator)` is functionally the same as the syntax above.

Note For more information on the `inputParser` class, see Parsing Inputs with inputParser in the MATLAB Programming documentation.

Examples Write an M-file function called `publish_ip`, based on the MATLAB `publish` function, to illustrate the use of the `inputParser` class. There are three calling syntaxes for this function:

```
publish_ip('script')
publish_ip('script', 'format')
publish_ip('script', options)
```

From these calling syntaxes, you can see that there is one required argument (`script`), one optional argument (`format`), and a number of optional arguments that are specified as parameter-value pairs (`options`).

Begin writing the example `publish_ip` M-file by entering the following two statements. Call the class constructor for `inputParser` to create an instance of the class. This class instance, or object, gives you access to all of the methods and properties of the class:

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

After calling the constructor, add the following lines to the M-file. This code uses the `addRequired`, `addOptional(inputParser)`, and `addParamValue(inputParser)` methods to define the input arguments to the function:

```
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);
```

Also add the next two lines to the M-file. The `Parameters` property of `inputParser` lists all of the arguments that belong to the object `p`:

```
disp 'The input parameters for this program are
disp(p.Parameters)'
```

Save the M-file using the **Save** option on the MATLAB **File** menu, and then run it to see the following list displayed:

```
The input parameters for this program are
    'format'
    'maxHeight'
    'maxWidth'
    'outputDir'
    'script'
```

See Also

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

addsample

Purpose

Add data sample to `timeseries` object

Syntax

```
ts = addsample(ts,'Field1',Value1,'Field2',Value2,...)
ts = addsample(ts,s)
```

Description

`ts = addsample(ts,'Field1',Value1,'Field2',Value2,...)` adds one or more data samples to the `timeseries` object `ts`, where one field must specify `Time` and another must specify `Data`. You can also specify the following optional property-value pairs:

- `'Quality'` — Array of data quality codes
- `'OverwriteFlag'` — Logical value that controls whether to overwrite a data sample at the same time with the new sample you are adding to your `timeseries` object. When set to `true`, the new sample overwrites the old sample at the same time.

`ts = addsample(ts,s)` adds one or more new samples stored in a structure `s` to the `timeseries` object `ts`. You must define the fields of the structure `s` before passing it as an argument to `addsample` by assigning values to the following optional `s` fields:

- `s.data`
- `s.time`
- `s.quality`
- `s.overwriteflag`

Remarks

A time-series *data sample* consists of one or more values recorded at a specific time. The number of data samples in a time series is the same as the length of the time vector.

The `Time` value must be a valid time vector.

Suppose that `N` is the number of samples. The sample size of each time series is given by `SampleSize = getsamplesize(ts)`. When `ts.IsTimeFirst` is `true`, the size of the data is `N`-by-`SampleSize`. When `ts.IsTimeFirst` is `false`, the size of the data is `SampleSize`-by-`N`.

Examples

Add a data value of `420` at time `3`.

```
ts = ts.addsample('Time',3,'Data',420);
```

Add a data value of `420` at time `3` and specify quality code `1` for this data value. Set the flag to overwrite an existing value at time `3`.

```
ts = ts.addsample('Data',3.2,'Quality',1,'OverwriteFlag',...
        true,'Time',3);
```

See Also

`delsample`, `getdatasamplesize`, `tsprops`

addsampletocollection

Purpose

Add sample to `tscollection` object

Syntax

```
tsc = addsampletocollection(tsc,'time',Time,TS1Name,TS1Data,
   TSnName,TSnData)
```

Description

`tsc = addsampletocollection(tsc,'time',Time,TS1Name,TS1Data, TSnName,TSnData)` adds data samples `TSnData` to the collection member `TSnName` in the `tscollection` object `tsc` at one or more `Time` values. Here, `TSnName` is the string that represents the name of a time series in `tsc`, and `TSnData` is an array containing data samples.

Remarks

If you do not specify data samples for a time-series member in tsc, that time-series member will contain missing data at the times given by Time (for numerical time-series data), `NaN` values, or (for logical time-series data) `false` values.

When a time-series member requires `Quality` values, you can specify data quality codes together with the data samples by using the following syntax:

```
tsc = addsampletocollection(tsc,'time',time,TS1Name,...
         ts1cellarray,TS2Name,ts2cellarray,...)
```

Specify data in the first cell array element and `Quality` in the second cell array element.

Note If a time-series member already has `Quality` values but you only provide data samples, `0`s are added to the existing `Quality` array at the times given by `Time`.

Examples

The following example shows how to create a `tscollection` that consists of two `timeseries` objects, where one `timeseries` does not have quality codes and the other does. The final step of the example adds a sample to the `tscollection`.

1 Create two timeseries objects, ts1 and ts2.

```
ts1 = timeseries([1.1 2.9 3.7 4.0 3.0],1:5,...
                 'name','acceleration');
ts2 = timeseries([3.2 4.2 6.2 8.5 1.1],1:5,...
                 'name','speed');
```

2 Define a dictionary of quality codes and descriptions for ts2.

```
ts2.QualityInfo.Code = [0 1];
ts2.QualityInfo.Description = {'bad','good'};
```

3 Assign a quality of code of 1, which is equivalent to 'good', to each data value in ts2.

```
ts2.Quality = ones(5,1);
```

4 Create a time-series collection tsc, which includes time series ts1 and ts2.

```
tsc = tscollection({ts1,ts2});
```

5 Add a data sample to the collection tsc at 3.5 seconds.

```
tsc = addsampletocollection(tsc,'time',3.5,'acceleration',10,
          'speed',{5 1});
```

The cell array for the timeseries object 'speed' specifies both the data value 5 and the quality code 1.

Note If you do not specify a quality code when adding a data sample to a time series that has quality codes, then the lowest quality code is assigned to the new sample by default.

See Also

delsamplefromcollection, tscollection, tsprops

addtodate

Purpose

Modify date number by field

Syntax

```
R = addtodate(D, Q, F)
```

Description

`R = addtodate(D, Q, F)` adds quantity `Q` to the indicated date field `F` of a scalar serial date number `D`, returning the updated date number `R`.

The quantity `Q` to be added must be a double scalar whole number, and can be either positive or negative. The date field `F` must be a 1-by-`N` character array equal to one of the following: `'year'`, `'month'`, or `'day'`.

If the addition to the date field causes the field to roll over, MATLAB adjusts the next more significant fields accordingly. Adding a negative quantity to the indicated date field rolls back the calender on the indicated field. If the addition causes the field to roll back, MATLAB adjusts the next less significant fields accordingly.

Examples

Adding `20` days to the given date in late December causes the calendar to roll over to January of the next year:

```
R = addtodate(datenum('12/24/1984 12:45'), 20, 'day');

datestr(R)
ans =
   13-Jan-1985 12:45:00
```

See Also

`date`, `datenum`, `datestr`, `datevec`

Purpose

Add `timeseries` object to `tscollection` object

Syntax

```
tsc = addts(tsc,ts)
tsc = addts(tsc,ts)
tsc = addts(tsc,ts,Name)
tsc = addts(tsc,Data,Name)
```

Description

`tsc = addts(tsc,ts)` adds the `timeseries` object ts to `tscollection` object tsc.

`tsc = addts(tsc,ts)` adds a cell array of `timeseries` objects ts to the `tscollection` tsc.

`tsc = addts(tsc,ts,Name)` adds a cell array of `timeseries` objects ts to `tscollection` tsc. Name is a cell array of strings that gives the names of the `timeseries` objects in `ts`.

`tsc = addts(tsc,Data,Name)` creates a new `timeseries` object from Data with the name Name and adds it to the `tscollection` object tsc. Data is a numerical array and Name is a string.

Remarks

The `timeseries` objects you add to the collection must have the same time vector as the collection. That is, the time vectors must have the same time values and units.

Suppose that the time vector of a `timeseries` object is associated with calendar dates. When you add this `timeseries` to a collection with a time vector without calendar dates, the time vectors are compared based on the units and the values relative to the `StartDate` property. For more information about properties, see the `timeseries` reference page.

Examples

The following example shows how to add a time series to a time-series collection:

1. Create two `timeseries` objects, `ts1` and `ts2`.

   ```
   ts1 = timeseries([1.1 2.9 3.7 4.0 3.0],1:5,...
                    'name','acceleration');
   ```

```
ts2 = timeseries([3.2 4.2 6.2 8.5 1.1],1:5,...
                 'name','speed');
```

2 Create a time-series collection `tsc`, which includes `ts1`.

```
tsc = tscollection(ts1);
```

3 Add `ts2` to the `tsc` collection.

```
tsc = addts(tsc, ts2);
```

4 To view the members of `tsc`, type

```
tsc
```

at the MATLAB prompt. MATLAB responds with

```
Time Series Collection Object: unnamed

Time vector characteristics

      Start time            1 seconds
      End time              5 seconds

Member Time Series Objects:

      acceleration
      speed
```

The members of `tsc` are listed by name at the bottom: `acceleration` and `speed`. These are the `Name` properties of the `timeseries` objects `ts1` and `ts2`, respectively.

See Also

`removets`, `tscollection`

Purpose

Airy functions

Syntax

```
W = airy(Z)
W = airy(k,Z)
[W,ierr] = airy(k,Z)
```

Definition

The Airy functions form a pair of linearly independent solutions to

$$\frac{d^2 W}{dZ^2} - ZW = 0$$

The relationship between the Airy and modified Bessel functions is

$$Ai(Z) = \left[\frac{1}{\pi}\sqrt{Z/3}\right] K_{1/3}(\zeta)$$

$$Bi(Z) = \sqrt{Z/3}\ [I_{-1/3}(\zeta) + I_{1/3}(\zeta)]$$

where

$$\zeta = \frac{2}{3}Z^{3/2}$$

Description

`W = airy(Z)` returns the Airy function, $Ai(Z)$, for each element of the complex array `Z`.

`W = airy(k,Z)` returns different results depending on the value of `k`.

k	Returns
0	The same result as `airy(Z)`
1	The derivative, $Ai'(Z)$

k	Returns
2	The Airy function of the second kind, $Bi(Z)$
3	The derivative, $Bi'(Z)$

`[W,ierr] = airy(k,Z)` also returns completion flags in an array the same size as `W`.

ierr	Description
0	`airy` successfully computed the Airy function for this element.
1	Illegal arguments
2	Overflow. Returns `Inf`
3	Some loss of accuracy in argument reduction
4	Unacceptable loss of accuracy, `Z` too large
5	No convergence. Returns `NaN`

See Also

`besseli`, `besselj`, `besselk`, `bessely`

References

[1] Amos, D. E., “A Subroutine Package for Bessel Functions of a Complex Argument and Nonnegative Order,” *Sandia National Laboratory Report*, SAND85-1018, May, 1985.

[2] Amos, D. E., “A Portable Package for Bessel Functions of a Complex Argument and Nonnegative Order,” *Trans. Math. Software*, 1986.

Purpose

Align user interface controls (uicontrols) and axes

Syntax

```
align(HandleList,'HorizontalAlignment','VerticalAlignment')
Positions = align(HandleList,'HorizontalAlignment',
   'VerticalAlignment')
Positions = align(CurPositions,'HorizontalAlignment',
   'VerticalAlignment')
```

Description

`align(HandleList,'HorizontalAlignment','VerticalAlignment')` aligns the `uicontrol` and `axes` objects in `HandleList`, a vector of handles, according to the options `HorizontalAlignment` and `VerticalAlignment`. The following table shows the possible values for `HorizontalAlignment` and `VerticalAlignment`.

Argument	Possible Values
HorizontalAlignment	`None`, `Left`, `Center`, `Right`, `Distribute`, `Fixed`
VerticalAlignment	`None`, `Top`, `Middle`, `Bottom`, `Distribute`, `Fixed`

All alignment options align the objects within the bounding box that encloses the objects. `Distribute` and `Fixed` align objects to the bottom left of the bounding box. `Distribute` evenly distributes the objects while `Fixed` distributes the objects with a fixed distance (in points) between them.

If you use `Fixed` for `Horizontal Alignment` or `Vertical Alignment`, then you must specify the distance, in points, as an extra argument. These are some examples:

```
align(HandleList,'Fixed',Distance,'VerticalAlignment')
```

distributes the specified components `Distance` points horizontally and aligns them vertically as specified.

```
align(HandleList,'HorizontalAlignment','Fixed',Distance)
```

aligns the specified components horizontally as specified and distributes them `Distance` points vertically.

```
align(HandleList,'Fixed','HorizontalDistance',...
      'Fixed','VerticalDistance')
```

distributes the specified components `HorizontalDistance` points horizontally and distributes them `VerticalDistance` points vertically.

Note 72 points equals 1 inch.

`Positions = align(HandleList,'HorizontalAlignment', 'VerticalAlignment')` returns updated positions for the specified objects as a vector of `Position` vectors. The position of the objects on the figure does not change.

`Positions = align(CurPositions,'HorizontalAlignment', 'VerticalAlignment')` returns updated positions for the objects whose positions are contained in `CurPositions`, where `CurPositions` is a vector of `Position` vectors. The position of the objects on the figure does not change.

Purpose Set or query axes alpha limits

Syntax

```
alpha_limits = alim
alim([amin amax])
alim_mode = alim('mode')
alim('alim_mode')
alim(axes_handle,...)
```

Description

`alpha_limits = alim` returns the alpha limits (the axes `ALim` property) of the current axes.

`alim([amin amax])` sets the alpha limits to the specified values. `amin` is the value of the data mapped to the first alpha value in the alphamap, and `amax` is the value of the data mapped to the last alpha value in the alphamap. Data values in between are linearly interpolated across the alphamap, while data values outside are clamped to either the first or last alphamap value, whichever is closest.

`alim_mode = alim('mode')` returns the alpha limits mode (the axes `ALimMode` property) of the current axes.

`alim('alim_mode')` sets the alpha limits mode on the current axes. `alim_mode` can be

- auto — MATLAB automatically sets the alpha limits based on the alpha data of the objects in the axes.
- `manual` — MATLAB does not change the alpha limits.

`alim(axes_handle,...)` operates on the specified axes.

See Also

`alpha`, `alphamap`, `caxis`

Axes `ALim` and `ALimMode` properties

Patch `FaceVertexAlphaData` property

Image and surface `AlphaData` properties

Transparency for related functions

"Transparency" in 3-D Visualization for examples

Purpose

Determine whether all array elements are nonzero

Syntax

```
B = all(A)
B = all(A, dim)
```

Description

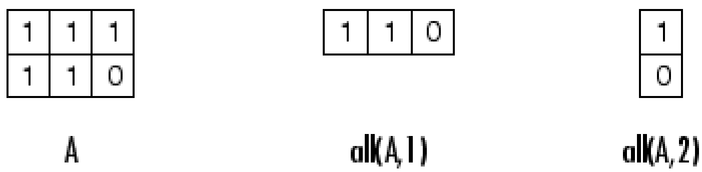
`B = all(A)` tests whether *all* the elements along various dimensions of an array are nonzero or logical `1` (`true`).

If `A` is a vector, `all(A)` returns logical `1` (`true`) if all the elements are nonzero and returns logical `0` (`false`) if one or more elements are zero.

If `A` is a matrix, `all(A)` treats the columns of `A` as vectors, returning a row vector of logical `1`'s and `0`'s.

If `A` is a multidimensional array, `all(A)` treats the values along the first nonsingleton dimension as vectors, returning a logical condition for each vector.

`B = all(A, dim)` tests along the dimension of `A` specified by scalar *`dim`*.



Examples

Given

```
A = [0.53 0.67 0.01 0.38 0.07 0.42 0.69]
```

then `B = (A < 0.5)` returns logical `1` (`true`) only where `A` is less than one half:

```
0    0    1    1    1    1    0
```

The `all` function reduces such a vector of logical conditions to a single condition. In this case, `all(B)` yields `0`.

This makes `all` particularly useful in `if` statements:

```
if all(A < 0.5)
    do something
end
```

where code is executed depending on a single condition, not a vector of possibly conflicting conditions.

Applying the `all` function twice to a matrix, as in `all(all(A))`, always reduces it to a scalar condition.

```
all(all(eye(3)))
ans =
   0
```

See Also

`any`, logical operators (elementwise and short-circuit), relational operators, `colon`

Other functions that collapse an array's dimensions include `max`, `mean`, `median`, `min`, `prod`, `std`, `sum`, and `trapz`.

Purpose Find all children of specified objects

Syntax

```
child_handles = allchild(handle_list)
```

Description `child_handles = allchild(handle_list)` returns the list of all children (including ones with hidden handles) for each handle. If `handle_list` is a single element, `allchild` returns the output in a vector. Otherwise, the output is a cell array.

Examples Compare the results returned by these two statements.

```
get(gca,'Children')
allchild(gca)
```

See Also `findall`, `findobj`

alpha

Purpose

Set transparency properties for objects in current axes

Syntax

```
alpha
alpha(face_alpha)
alpha(alpha_data)
alpha(alpha_data)
alpha(alpha_data)
alpha(alpha_data_mapping)
alpha(object_handle,value)
```

Description

`alpha` sets one of three transparency properties, depending on what arguments you specify with the call to this function.

FaceAlpha

`alpha(face_alpha)` sets the `FaceAlpha` property of all image, patch, and surface objects in the current axes. You can set `face_alpha` to

- A scalar — Set the `FaceAlpha` property to the specified value (for images, set the `AlphaData` property to the specified value).
- `'flat'` — Set the `FaceAlpha` property to `flat`.
- `'interp'` — Set the `FaceAlpha` property to `interp`.
- `'texture'` — Set the `FaceAlpha` property to `texture`.
- `'opaque'` — Set the `FaceAlpha` property to `1`.
- `'clear'` — Set the `FaceAlpha` property to `0`.

See “Specifying a Single Transparency Value” for more information.

AlphaData (Surface Objects)

`alpha(alpha_data)` sets the `AlphaData` property of all surface objects in the current axes. You can set `alpha_data` to

- A matrix the same size as `CData` — Set the `AlphaData` property to the specified values.
- `'x'` — Set the `AlphaData` property to be the same as `XData`.

- 'y' — Set the AlphaData property to be the same as YData.
- 'z' — Set the AlphaData property to be the same as ZData.
- 'color' — Set the AlphaData property to be the same as CData.
- 'rand' — Set the AlphaData property to a matrix of random values equal in size to CData.

AlphaData (Image Objects)

alpha(alpha_data) sets the AlphaData property of all image objects in the current axes. You can set alpha_data to

- A matrix the same size as CData — Set the AlphaData property to the specified value.
- 'x' — Ignored.
- 'y' — Ignored.
- 'z' — Ignored.
- 'color' — Set the AlphaData property to be the same as CData.
- 'rand' — Set the AlphaData property to a matrix of random values equal in size to CData.

FaceVertexAlphaData (Patch Objects)

alpha(alpha_data) sets the FaceVertexAlphaData property of all patch objects in the current axes. You can set alpha_data to

- A matrix the same size as FaceVertexCData — Set the FaceVertexAlphaData property to the specified value.
- 'x' — Set the FaceVertexAlphaData property to be the same as Vertices(:,1).
- 'y' — Set the FaceVertexAlphaData property to be the same as Vertices(:,2).
- 'z' — Set the FaceVertexAlphaData property to be the same as Vertices(:,3).

- 'color' — Set the FaceVertexAlphaData property to be the same as FaceVertexCData.
- 'rand' — Set the FaceVertexAlphaData property to random values.

See Mapping Data to Transparency for more information.

AlphaDataMapping

alpha(alpha_data_mapping) sets the AlphaDataMapping property of all image, patch, and surface objects in the current axes. You can set alpha_data_mapping to

- 'scaled' — Set the AlphaDataMapping property to scaled.
- 'direct' — Set the AlphaDataMapping property to direct.
- 'none' — Set the AlphaDataMapping property to none.

alpha(object_handle,value) sets the transparency property only on the object identified by object_handle.

See Also

alim, alphamap

Image: AlphaData, AlphaDataMapping

Patch: FaceAlpha, FaceVertexAlphaData, AlphaDataMapping

Surface: FaceAlpha, AlphaData, AlphaDataMapping

Transparency for related functions

“Transparency” in 3-D Visualization for examples

Purpose

Specify figure alphamap (transparency)

Syntax

```
alphamap
alphamap(alpha_map)
alphamap('parameter')
alphamap('parameter',length)
alphamap('parameter',delta)
alphamap(figure_handle,...)
alpha_map = alphamap
alpha_map = alphamap(figure_handle)
alpha_map = alphamap('parameter')
```

Description

`alphamap` enables you to set or modify a figure's `Alphamap` property. Unless you specify a figure handle as the first argument, `alphamap` operates on the current figure.

`alphamap(alpha_map)` sets the `AlphaMap` of the current figure to the specified m-by-1 array of alpha values.

`alphamap('parameter')` creates a new alphamap or modifies the current alphamap. You can specify the following parameters:

- `default` — Set the `AlphaMap` property to the figure's default alphamap.
- `rampup` — Create a linear alphamap with increasing opacity (default `length` equals the current alphamap length).
- `rampdown` — Create a linear alphamap with decreasing opacity (default `length` equals the current alphamap length).
- `vup` — Create an alphamap that is opaque in the center and becomes more transparent linearly towards the beginning and end (default `length` equals the current alphamap length).
- `vdown` — Create an alphamap that is transparent in the center and becomes more opaque linearly towards the beginning and end (default `length` equals the current alphamap length).

- `increase` — Modify the alphamap making it more opaque (default `delta` is `.1`, which is added to the current values).
- `decrease` — Modify the alphamap making it more transparent (default `delta` is `.1`, which is subtracted from the current values).
- `spin` — Rotate the current alphamap (default `delta` is 1; note that `delta` must be an integer).

`alphamap('parameter',length)` creates a new alphamap with the length specified by `length` (used with parameters `rampup`, `rampdown`, `vup`, `vdown`).

`alphamap('parameter',delta)` modifies the existing alphamap using the value specified by `delta` (used with parameters `increase`, `decrease`, `spin`).

`alphamap(figure_handle,...)` performs the operation on the alphamap of the figure identified by `figure_handle`.

`alpha_map = alphamap` returns the current alphamap.

`alpha_map = alphamap(figure_handle)` returns the current alphamap from the figure identified by `figure_handle`.

`alpha_map = alphamap('parameter')` returns the alphamap modified by the `parameter`, but does not set the `AlphaMap` property.

See Also

`alim`, `alpha`

Image: `AlphaData`, `AlphaDataMapping`

Patch: `FaceAlpha`, `FaceVertexAlphaData`, `AlphaDataMapping`

Surface: `FaceAlpha`, `AlphaData`, `AlphaDataMapping`

Transparency for related functions

“Transparency” in 3-D Visualization for examples

Purpose

Approximate minimum degree permutation

Syntax

```
P = amd(A)
P = amd(A,opts)
```

Description

`P = amd(A)` returns the approximate minimum degree permutation vector for the sparse matrix `C = A + A'`. The Cholesky factorization of `C(P,P)` or `A(P,P)` tends to be sparser than that of `C` or `A`. The `amd` function tends to be faster than `symamd`, and also tends to return better orderings than `symamd`. Matrix `A` must be square. If `A` is a full matrix, then `amd(A)` is equivalent to `amd(sparse(A))`.

`P = amd(A,opts)` allows additional options for the reordering. The `opts` input is a structure with the two fields shown below. You only need to set the fields of interest:

- **dense** — A nonnegative scalar value that indicates what is considered to be dense. If A is n-by-n, then rows and columns with more than `max(16,(dense*sqrt(n)))` entries in `A + A'` are considered to be "dense" and are ignored during the ordering. MATLAB places these rows and columns last in the output permutation. The default value for this field is 10.0 if this option is not present.
- **aggressive** — A scalar value controlling aggressive absorption. If this field is set to a nonzero value, then aggressive absorption is performed. This is the default if this option is not present.

MATLAB performs an assembly tree post-ordering, which is typically the same as an elimination tree post-ordering. It is not always identical because of the approximate degree update used, and because “dense” rows and columns do not take part in the post-order. It well-suited for a subsequent `chol` operation, however, If you require a precise elimination tree post-ordering, you can use the following code:

```
P = amd(S);
C = spones(S)+spones(S'); % Skip this line if S is already symmetri
[ignore, Q] = etree(C(P,P));
P = P(Q);
```

Examples

This example constructs a sparse matrix and computes a two Cholesky factors: one of the original matrix and one of the original matrix preordered by `amd`. Note how much sparser the Cholesky factor of the preordered matrix is compared to the factor of the matrix in its natural ordering:

```
A = gallery('wathen',50,50);
p = amd(A);
L = chol(A,'lower');
Lp = chol(A(p,p),'lower');

figure;
subplot(2,2,1);    spy(A);
title('Sparsity structure of A');

subplot(2,2,2); spy(A(p,p));
title('Sparsity structure of AMD ordered A');

subplot(2,2,3); spy(L);
title('Sparsity structure of Cholesky factor of A');

subplot(2,2,4); spy(Lp);
title('Sparsity structure of Cholesky factor of AMD ordered A');

set(gcf,'Position',[100 100 800 700]);
```

See Also

`colamd`, `colperm`, `symamd`, `symrcm`, `/`

References

AMD Version 1.2 is written and copyrighted by Timothy A. Davis, Patrick R. Amestoy, and Iain S. Duff. It is available at `http://www.cise.ufl.edu/research/sparse/amd`.

The authors of the code for `symamd` are Stefan I. Larimore and Timothy A. Davis (`davis@cise.ufl.edu`), University of Florida. The algorithm was developed in collaboration with John Gilbert, Xerox PARC, and Esmond Ng, Oak Ridge National Laboratory.

Sparse Matrix Algorithms Research at the University of Florida:
`http://www.cise.ufl.edu/research/sparse/`

Purpose

Ancestor of graphics object

Syntax

```
p = ancestor(h,type)
p = ancestor(h,type,'toplevel')
```

Description

`p = ancestor(h,type)` returns the handle of the closest ancestor of `h`, if the ancestor is one of the types of graphics objects specified by `type`. `type` can be:

- a string that is the name of a single type of object. For example, `'figure'`
- a cell array containing the names of multiple objects. For example, `{'hgtransform','hggroup','axes'}`

If MATLAB cannot find an ancestor of `h` that is one of the specified types, then `ancestor` returns `p` as empty.

Note that `ancestor` returns `p` as empty but does not issue an error if `h` is not the handle of a Handle Graphics object.

`p = ancestor(h,type,'toplevel')` returns the highest-level ancestor of `h`, if this type appears in the `type` argument.

Examples

Create some line objects and parent them to an hggroup object.

```
hgg = hggroup;
hgl = line(randn(5),randn(5),'Parent',hgg);
```

Now get the ancestor of the lines.

```
p = ancestor(hgg,{'figure','axes','hggroup'});
get(p,'Type')
ans =

hggroup
```

Now get the top-level ancestor

```
p=ancestor(hgg,{'figure','axes','hggroup'},'toplevel');
get(p,'type')
ans =

figure
```

See Also

`findobj`

Purpose

Find logical AND of array or scalar inputs

Syntax

```
A & B & ...
and(A, B)
```

Description

`A & B & ...` performs a logical AND 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 all 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.

`and(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 AND operator described here is `&`. The short-circuit AND operator is `&&`.

Examples

If matrix `A` is

```
0.4235    0.5798         0    0.7942         0
0.5155         0    0.7833    0.0592    0.8744
0.3340         0         0         0    0.0150
0.4329    0.6405    0.6808    0.0503         0
```

and matrix `B` is

```
        0     1     0     1     0
        1     1     1     0     1
        0     1     1     1     0
        0     1     0     0     1
```

then

```
A & B
ans =
        0     1     0     1     0
        1     0     1     0     1
        0     0     0     0     0
        0     1     0     0     0
```

See Also

`bitand`, `or`, `xor`, `not`, `any`, `all`, logical operators, logical types, bitwise functions

angle

Purpose Phase angle

Syntax

```
P = angle(Z)
```

Description

`P = angle(Z)` returns the phase angles, in radians, for each element of complex array `Z`. The angles lie between $\pm\pi$.

For complex `Z`, the magnitude `R` and phase angle `theta` are given by

```
R = abs(Z)
theta = angle(Z)
```

and the statement

```
Z = R.*exp(i*theta)
```

converts back to the original complex `Z`.

Examples

```
Z = [ 1 - 1i   2 + 1i   3 - 1i   4 + 1i
      1 + 2i   2 - 2i   3 + 2i   4 - 2i
      1 - 3i   2 + 3i   3 - 3i   4 + 3i
      1 + 4i   2 - 4i   3 + 4i   4 - 4i ]

P = angle(Z)

P =
   -0.7854    0.4636   -0.3218    0.2450
    1.1071   -0.7854    0.5880   -0.4636
   -1.2490    0.9828   -0.7854    0.6435
    1.3258   -1.1071    0.9273   -0.7854
```

Algorithm

The `angle` function can be expressed as `angle(z) = imag(log(z)) = atan2(imag(z),real(z))`.

See Also

`abs`, `atan2`, `unwrap`

Purpose

Create annotation objects

GUI Alternatives

Create several types of annotations with the Figure Palette and modify annotations with the Property Editor, components of the plotting tools. Directly manipulate annotations in *plot edit* mode. For details, see "How to Annotate Graphs" and "Using Plot Edit Mode" in the MATLAB Graphics documentation.

Syntax

```
annotation(annotation_type)
annotation('line',x,y)
annotation('arrow',x,y)
annotation('doublearrow',x,y)
annotation('textarrow',x,y)
annotation('textbox',[x y w h])
annotation('ellipse',[x y w h])
annotation('rectangle',[x y w h])
annotation(figure_handle,...)
annotation(...,'PropertyName',PropertyValue,...)
anno_obj_handle = annotation(...)
```

Description

`annotation(`*`annotation_type`*`)` creates the specified annotation type using default values for all properties. *`annotation_type`* can be one of the following strings:

- `'line'`
- `'arrow'`
- `'doublearrow'` (two-headed arrow),
- `'textarrow'` (arrow with attached text box),
- `'textbox'`
- `'ellipse'`
- `'rectangle'`

`annotation('line',x,y)` creates a line annotation object that extends from the point defined by `x(1)`,`y(1)` to the point defined by `x(2)`,`y(2)`, specified in normalized figure units.

`annotation('arrow',x,y)` creates an arrow annotation object that extends from the point defined by `x(1)`,`y(1)` to the point defined by `x(2)`,`y(2)`, specified in normalized figure units.

`annotation('doublearrow',x,y)` creates a two-headed annotation object that extends from the point defined by `x(1)`,`y(1)` to the point defined by `x(2)`,`y(2)`, specified in normalized figure units.

`annotation('textarrow',x,y)` creates a textarrow annotation object that extends from the point defined by `x(1)`,`y(1)` to the point defined by `x(2)`,`y(2)`, specified in normalized figure units. The tail end of the arrow is attached to an editable text box.

`annotation('textbox',[x y w h])` creates an editable text box annotation with its lower left corner at the point `x`,`y`, a width `w`, and a height `h`, specified in normalized figure units. Specify `x`, `y`, `w`, and `h` in a single vector.

To type in the text box, enable plot edit mode (`plotedit`) and double-click within the box.

`annotation('ellipse',[x y w h])` creates an ellipse annotation with the lower left corner of the bounding rectangle at the point `x`,`y`, a width `w`, and a height `h`, specified in normalized figure units. Specify `x`, `y`, `w`, and `h` in a single vector.

`annotation('rectangle',[x y w h])` creates a rectangle annotation with the lower left corner of the rectangle at the point `x`,`y`, a width `w`, and a height `h`, specified in normalized figure units. Specify `x`, `y`, `w`, and `h` in a single vector.

`annotation(figure_handle,...)` creates the annotation in the specified figure.

`annotation(...,'`*`PropertyName`*`',PropertyValue,...)` creates the annotation and sets the specified properties to the specified values.

`anno_obj_handle = annotation(...)` returns the handle to the annotation object that is created.

Annotation Layer

All annotation objects are displayed in an overlay axes that covers the figure. This layer is designed to display only annotation objects. You should not parent objects to this axes nor set any properties of this axes. See the See Also section for information on the properties of annotation objects that you can set.

Objects in the Plotting Axes

You can create lines, text, rectangles, and ellipses in data coordinates in the axes of a graph using the `line`, `text`, and `rectangle` functions. These objects are not placed in the annotation axes and must be located inside their parent axes.

Deleting Annotations

Existing annotations persist on a plot when you replace its data. This might not be what you want to do. If it is not, or if you want to remove annotation objects for any reason, you can do so manually, or sometimes programmatically, in several ways:

- To manually delete, click the **Edit Plot** tool or invoke `plottools`, select the annotation(s) you want to remove, and do one of the following:
  - Press the **Delete** key.
  - Press the **Backspace** key.
  - Select **Clear** from the **Edit** menu.
  - Select **Delete** from the context menu (one annotation at a time).
- If you obtained a handle for the annotation when you created it, use the `delete` function:

  ```
  delete(anno_obj_handle)
  ```

  There is no reliable way to obtain handles for annotations from a figure's property set; you must keep track of them yourself.

- To delete all annotations at once (as well as all plot contents), type

```
clf
```

Normalized Coordinates

By default, annotation objects use normalized coordinates to specify locations within the figure. In normalized coordinates, the point 0,0 is always the lower left corner and the point 1,1 is always the upper right corner of the figure window, regardless of the figure size and proportions. Set the `Units` property of annotation objects to change their coordinates from `normalized` to `inches`, `centimeters`, `points`, `pixels`, or `characters`.

When their `Units` property is other than `normalized`, annotation objects have absolute positions with respect to the figure's origin, and fixed sizes. Therefore, they will shift position with respect to axes when you resize figures. When units are normalized, annotations shrink and grow when you resize figures; this can cause lines of text in textbox annotations to wrap. However, if you set the `FontUnits` property of an annotation textbox object to `normalized`, the text changes size rather than wraps if the textbox size changes.

You can use either the `set` command or the Inspector to change a selected annotation object's `Units` property:

```
set(gco,'Units','inches')  % or
inspect(gco)
```

See Also

Properties for the annotation objects `Annotation Arrow Properties`, `Annotation Doublearrow Properties`, `Annotation Ellipse Properties`, `Annotation Line Properties`, `Annotation Rectangle Properties`, `Annotation Textarrow Properties`, `Annotation Textbox Properties`

See “Annotating Graphs” and “Annotation Objects” for more information.

Purpose

Define annotation arrow properties

Modifying Properties

You can set and query annotation object properties using the `set` and `get` functions and the Property Editor (displayed with the `propertyeditor` command).

Use the `annotation` function to create annotation objects and obtain their handles. For an example of its use, see "Positioning Annotations in Data Space" in the MATLAB Graphics documentation.

Annotation Arrow Property Descriptions

Properties You Can Modify

This section lists the properties you can modify on an annotation arrow 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.

`HeadLength`

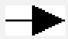
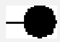
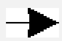
scalar value in points

Length of the arrowhead. Specify this property in points (1 point = 1/72 inch). See also `HeadWidth`.

`HeadStyle`

select string from list

Style of the arrowhead. Specify this property as one of the strings from the following table.

Head Style String	Head	Head Style String	Head
`none`		`star4`	
`plain`		`rectangle`	
`ellipse`		`diamond`	
`vback1`		`rose`	
`vback2` (Default)		`hypocycloid`	
`vback3`		`astroid`	
`cback1`		`deltoid`	
`cback2`			
`cback3`			

`HeadWidth`

scalar value in points

Width of the arrowhead. Specify this property in points (1 point = 1/72 inch). See also `HeadLength`.

`LineStyle`

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

Line style. This property specifies the line style of the object. Available line styles are shown in the following table.

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

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

`LineWidth`
scalar

The width of linear objects and edges of filled areas. Specify this value in points (1 point = $^1/_{72}$ inch). The default `LineWidth` is 0.5 points.

`Position`
four-element vector [x, y, width, height]

Size and location of the object. Specify the lower left corner of the object with the first two elements of the vector defining the point *x, y* in units normalized to the figure (when `Units` property is `normalized`). The third and fourth elements specify the object's *dx* and *dy*, respectively, in units normalized to the figure.

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

position units. MATLAB uses this property to determine the units used by the `Position` property. All positions are measured from the lower left corner of the figure window. Normalized units interpret `Position` as a fraction of the width and height of the parent axes. When you resize the axes, MATLAB modifies the size of the object accordingly. `pixels`, `inches`, `centimeters`, and `points` are absolute units (1 point = 1/72 inch).

`X`

vector [X_{begin} X_{end}]

X-coordinates of the beginning and ending points for line. Specify this property as a vector of *x*-axis (horizontal) values that specify the beginning and ending points of the line, units normalized to the figure.

`Y`

vector [Y_{begin} Y_{end}]

Y-coordinates of the beginning and ending points for line. Specify this property as a vector of *y*-axis (vertical) values that specify the beginning and ending points of the line, units normalized to the figure.

Purpose

Define annotation doublearrow properties

Modifying Properties

You can set and query annotation object properties using the `set` and `get` functions and the Property Editor (displayed with the `propertyeditor` command).

Use the `annotation` function to create annotation objects and obtain their handles. For an example of its use, see “Positioning Annotations in Data Space” in the MATLAB Graphics documentation.

Annotation Doublearrow Property Descriptions

Properties You Can Modify

This section lists the properties you can modify on an annotation doublearrow 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.

`Head1Length`

scalar value in points

Length of the first arrowhead. Specify this property in points (1 point = 1/72 inch). See also `Head1Width`.

The first arrowhead is located at the end defined by the point `x(1), y(1)`. See also the `X` and `Y` properties.

`Head2Length`

scalar value in points

Length of the second arrowhead. Specify this property in points (1 point = 1/72 inch). See also `Head1Width`.

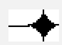
The first arrowhead is located at the end defined by the point `x(end)`, `y(end)`. See also the `X` and `Y` properties.

`Head1Style`
select string from list

Style of the first arrowhead. Specify this property as one of the strings from the following table

`Head2Style`
select string from list

Style of the second arrowhead. Specify this property as one of the strings from the following table.

Head Style String	Head	Head Style String	Head
`none`		`star4`	
`plain`		`rectangle`	
`ellipse`		`diamond`	
`vback1`		`rose`	
`vback2` (Default)		`hypocycloid`	
`vback3`		`astroid`	
`cback1`		`deltoid`	

Head Style String	Head	Head Style String	Head
cback2			
cback3			

`Head1Width`

scalar value in points

Width of the first arrowhead. Specify this property in points (1 point = 1/72 inch). See also Head1Length.

`Head2Width`

scalar value in points

Width of the second arrowhead. Specify this property in points (1 point = 1/72 inch). See also Head2Length.

`LineStyle`

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

Line style. This property specifies the line style of the object. Available line styles are shown in the following table.

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

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

`LineWidth`
scalar

The width of linear objects and edges of filled areas. Specify this value in points (1 point = $^1/_{72}$ inch). The default `LineWidth` is 0.5 points.

`Position`
four-element vector [x, y, width, height]

Size and location of the object. Specify the lower left corner of the object with the first two elements of the vector defining the point *x, y* in units normalized to the figure (when `Units` property is `normalized`). The third and fourth elements specify the object's *dx* and *dy*, respectively, in units normalized to the figure.

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

position units. MATLAB uses this property to determine the units used by the `Position` property. All positions are measured from the lower left corner of the figure window. Normalized units interpret `Position` as a fraction of the width and height of the parent axes. When you resize the axes, MATLAB modifies the size of the object accordingly. `pixels`, `inches`, `centimeters`, and `points` are absolute units (1 point = 1/72 inch).

`X`
vector [X_{begin} X_{end}]

X-coordinates of the beginning and ending points for line. Specify this property as a vector of *x*-axis (horizontal) values that specify the beginning and ending points of the line, units normalized to the figure.

Y

vector [Y_{begin} Y_{end}]

Y-coordinates of the beginning and ending points for line. Specify this property as a vector of *y*-axis (vertical) values that specify the beginning and ending points of the line, units normalized to the figure.

Annotation Ellipse Properties

Purpose

Define annotation ellipse properties

Modifying Properties

You can set and query annotation object properties using the `set` and `get` functions and the Property Editor (displayed with the `propertyeditor` command).

Use the `annotation` function to create annotation objects and obtain their handles. For an example of its use, see "Positioning Annotations in Data Space" in the MATLAB Graphics documentation.

Annotation Ellipse Property Descriptions

Properties You Can Modify

This section lists the properties you can modify on an annotation ellipse object.

`EdgeColor`

ColorSpec `{[0 0 0]} | none |`

Color of the object's edges. A three-element RGB vector or one of the MATLAB predefined names, specifying the edge color.

See the `ColorSpec` reference page for more information on specifying color.

`FaceColor`

`{flat} | none | ColorSpec`

Color of filled areas. This property can be any of the following:

- `ColorSpec` — A three-element RGB vector or one of the MATLAB predefined names, specifying a single color for all filled areas. See `ColorSpec` for more information on specifying color.
- `none` — Do not draw faces. Note that `EdgeColor` is drawn independently of `FaceColor`
- `flat` — The color of the filled areas is determined by the figure colormap. See `colormap` for information on setting the colormap.

See the `ColorSpec` reference page for more information on specifying color.

`LineStyle`
`{-} | -- | : | -. | none`

Line style. This property specifies the line style of the object. Available line styles are shown in the following table.

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

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

`LineWidth`
scalar

The width of linear objects and edges of filled areas. Specify this value in points (1 point = $^1/_{72}$ inch). The default `LineWidth` is 0.5 points.

`Position`
four-element vector [x, y, width, height]

Size and location of the object. Specify the lower left corner of the object with the first two elements of the vector defining the point *x, y* in units normalized to the figure (when `Units` property is `normalized`). The third and fourth elements specify the object's *dx* and *dy*, respectively, in units normalized to the figure.

`Units`

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

position units. MATLAB uses this property to determine the units used by the `Position` property. All positions are measured from the lower left corner of the figure window. Normalized units interpret `Position` as a fraction of the width and height of the parent axes. When you resize the axes, MATLAB modifies the size of the object accordingly. `pixels`, `inches`, `centimeters`, and `points` are absolute units (1 point = 1/72 inch).

Purpose

Define annotation line properties

Modifying Properties

You can set and query annotation object properties using the `set` and `get` functions and the Property Editor (displayed with the `propertyeditor` command).

Use the `annotation` function to create annotation objects and obtain their handles. For an example of its use, see "Positioning Annotations in Data Space" in the MATLAB Graphics documentation.

Annotation Line Property Descriptions

Properties You Can Modify

This section lists the properties you can modify on an annotation line 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.

`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.

`Position`
: four-element vector [x, y, width, height]

Size and location of the object. Specify the lower left corner of the object with the first two elements of the vector defining the point *x, y* in units normalized to the figure (when `Units` property is `normalized`). The third and fourth elements specify the object's *dx* and *dy*, respectively, in units normalized to the figure.

`Units`
: `{normalized} | inches | centimeters | points | pixels`

position units. MATLAB uses this property to determine the units used by the `Position` property. All positions are measured from the lower left corner of the figure window. Normalized units interpret `Position` as a fraction of the width and height of the parent axes. When you resize the axes, MATLAB modifies the size of the object accordingly. `pixels`, `inches`, `centimeters`, and `points` are absolute units (1 point = 1/72 inch).

X

vector [X_{begin} X_{end}]

X-coordinates of the beginning and ending points for line. Specify this property as a vector of *x*-axis (horizontal) values that specify the beginning and ending points of the line, units normalized to the figure.

Y

vector [Y_{begin} Y_{end}]

Y-coordinates of the beginning and ending points for line. Specify this property as a vector of *y*-axis (vertical) values that specify the beginning and ending points of the line, units normalized to the figure.

Annotation Rectangle Properties

Purpose

Define annotation rectangle properties

Modifying Properties

You can set and query annotation object properties using the `set` and `get` functions and the Property Editor (displayed with the `propertyeditor` command).

Use the `annotation` function to create annotation objects and obtain their handles. For an example of its use, see “Positioning Annotations in Data Space” in the MATLAB Graphics documentation.

Annotation Rectangle Property Descriptions

Properties You Can Modify

This section lists the properties you can modify on an annotation rectangle object.

`EdgeColor`

ColorSpec `{[0 0 0]} | none |`

Color of the object’s edges. A three-element RGB vector or one of the MATLAB predefined names, specifying the edge color.

See the `ColorSpec` reference page for more information on specifying color.

`FaceAlpha`

Scalar alpha value in range [0 1]

Transparency of object background. This property defines the degree to which the object’s background color is transparent. A value of `1` (the default) makes to color opaque, a value of `0` makes the background completely transparent (i.e., invisible). The default FaceAlpha is `1`.

`FaceColor`

`{flat} | none | ColorSpec`

Color of filled areas. This property can be any of the following:

- `ColorSpec` — A three-element RGB vector or one of the MATLAB predefined names, specifying a single color for all filled areas. See `ColorSpec` for more information on specifying color.
- `none` — Do not draw faces. Note that `EdgeColor` is drawn independently of `FaceColor`
- `flat` — The color of the filled areas is determined by the figure colormap. See `colormap` for information on setting the colormap.

  See the `ColorSpec` reference page for more information on specifying color.

`LineStyle`

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

Line style. This property specifies the line style of the object. Available line styles are shown in the following table.

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

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

`LineWidth`

scalar

The width of linear objects and edges of filled areas. Specify this value in points (1 point = $^1/_{72}$ inch). The default `LineWidth` is 0.5 points.

`Position`
four-element vector [x, y, width, height]

Size and location of the object. Specify the lower left corner of the object with the first two elements of the vector defining the point *x, y* in units normalized to the figure (when `Units` property is `normalized`). The third and fourth elements specify the object's *dx* and *dy*, respectively, in units normalized to the figure.

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

position units. MATLAB uses this property to determine the units used by the `Position` property. All positions are measured from the lower left corner of the figure window. Normalized units interpret `Position` as a fraction of the width and height of the parent axes. When you resize the axes, MATLAB modifies the size of the object accordingly. `pixels`, `inches`, `centimeters`, and `points` are absolute units (1 point = 1/72 inch).

Purpose

Define annotation textarrow properties

Modifying Properties

You can set and query annotation object properties using the `set` and `get` functions and the Property Editor (displayed with the `propertyeditor` command).

Use the `annotation` function to create annotation objects and obtain their handles. For an example of its use, see “Positioning Annotations in Data Space” in the MATLAB Graphics documentation.

Annotation Textarrow Property Descriptions

Properties You Can Modify

This section lists the properties you can modify on an annotation textarrow object.

`Color`

ColorSpec Default: [0 0 0]

Color of the arrow, text and text border. A three-element RGB vector or one of the MATLAB predefined names, specifying the color of the arrow, the color of the text (`TextColor` property), and the rectangle enclosing the text (`TextEdgeColor` property).

Setting the `Color` property also sets the `TextColor` and `TextEdgeColor` properties to the same color. However, if the value of the `TextEdgeColor` is `none`, it remains `none` and the text box is not displayed. You can set `TextColor` or `TextEdgeColor` independently without affecting other properties.

For example, if you want to create a textarrow with a red arrow and black text in a black box, you must

1. Set the `Color` property to red — `set(h,'Color','r')`
2. Set the `TextColor` to black — `set(h,'TextColor','k')`
3. Set the `TextEdgeColor` to black .— `set(h,'TextEdgeColor','k')`

If you do not want display the text box, set the `TextEdgeColor` to `none`.

See the `ColorSpec` reference page for more information on specifying color.

`FontAngle`

`{normal} | italic | oblique`

Character slant. MATLAB uses this property to select a font from those available on your particular system. Generally, setting this property to `italic` or `oblique` selects a slanted font.

`FontName`

A name, such as `Helvetica`

Font family. A string specifying the name of the font to use for the text. To display and print properly, this font must be supported on your system. The default font is `Helvetica`.

`FontSize`

size in points

Approximate size of text characters. A value specifying the font size to use in points. The default size is 10 (1 point = 1/72 inch).

`FontUnits`

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

Font size units. MATLAB uses this property to determine the units used by the `FontSize` property. Normalized units interpret `FontSize` as a fraction of the height of the parent axes. When you resize the axes, MATLAB modifies the screen `FontSize` accordingly. `pixels`, `inches`, `centimeters`, and `points` are absolute units (1 point = 1/72 inch).

`FontWeight`

`light | {normal} | demi | bold`

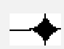
Weight of text characters. MATLAB uses this property to select a font from those available on your system. Generally, setting this property to `bold` or `demi` causes MATLAB to use a bold font.

`HeadLength`
scalar value in points

Length of the arrowhead. Specify this property in points (1 point = 1/72 inch). See also `HeadWidth`.

`HeadStyle`
select string from list

Style of the arrowhead. Specify this property as one of the strings from the following table.

Head Style String	Head	Head Style String	Head
none		star4	
plain		rectangle	
ellipse		diamond	
vback1		rose	
vback2 (Default)		hypocycloid	
vback3		astroid	
cback1		deltoid	

Head Style String	Head	Head Style String	Head
`cback2`			
`cback3`			

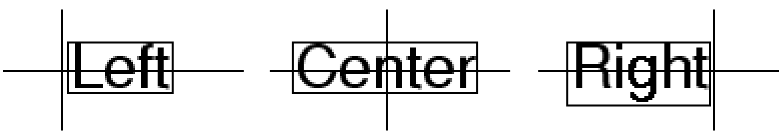
`HeadWidth`
scalar value in points

Width of the arrowhead. Specify this property in points (1 point = 1/72 inch). See also `HeadLength`.

`HorizontalAlignment`
`{left} | center | right`

Horizontal alignment of text. This property specifies the horizontal justification of the text string. It determines where MATLAB places the string with regard to the point specified by the `Position` property. The following picture illustrates the alignment options.

`HorizontalAlignment` viewed with the `VerticalAlignment` set to middle (the default).



See the `Extent` property for related information.

`Interpreter`
latex | `{tex} | none`

Interpret T_EX instructions. This property controls whether MATLAB interprets certain characters in the `String` property as T_EX instructions (default) or displays all characters literally. The options are:

- `latex` — Supports the full L_AT_EX markup language.
- `tex` — Supports a subset of plain T_EX markup language. See the `String` property for a list of supported T_EX instructions.
- `none` — Displays literal characters.

`LineStyle`
`{-} | -- | : | -. | none`

Line style. This property specifies the line style of the object. Available line styles are shown in the following table.

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

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

`LineWidth`
scalar

The width of linear objects and edges of filled areas. Specify this value in points (1 point = $^1/_{72}$ inch). The default `LineWidth` is 0.5 points.

`Position`

four-element vector [x, y, width, height]

Size and location of the object. Specify the lower left corner of the object with the first two elements of the vector defining the point *x, y* in units normalized to the figure (when `Units` property is `normalized`). The third and fourth elements specify the object's *dx* and *dy*, respectively, in units normalized to the figure.

`String`

string

The text string. Specify this property as a quoted string for single-line strings, or as a cell array of strings, or a padded string matrix for multiline strings. MATLAB displays this string at the specified location. Vertical slash characters are not interpreted as line breaks in text strings, and are drawn as part of the text string. See Mathematical Symbols, Greek Letters, and TeX Characters for an example.

When the text `Interpreter` property is set to `Tex` (the default), you can use a subset of TeX commands embedded in the string to produce special characters such as Greek letters and mathematical symbols. The following table lists these characters and the character sequences used to define them.

Character Sequence	Symbol	Character Sequence	Symbol	Character Sequence	Symbol
`\alpha`	α	`\upsilon`	υ	`\sim`	~
`\beta`	β	`\phi`	Φ	`\leq`	≤
`\gamma`	γ	`\chi`	χ	`\infty`	∞
`\delta`	δ	`\psi`	ψ	`\clubsuit`	♣
`\epsilon`	ε	`\omega`	ω	`\diamondsuit`	♦
`\zeta`	ζ	`\Gamma`	Γ	`\heartsuit`	♥

Character Sequence	Symbol	Character Sequence	Symbol	Character Sequence	Symbol
\eta	η	\Delta	Δ	\spadesuit	♠
\theta	Θ	\Theta	Θ	\leftrightarrow	↔
\vartheta	ϑ	\Lambda	Λ	\leftarrow	→
\iota	ι	\Xi	Ξ	\uparrow	↑
\kappa	κ	\Pi	Π	\rightarrow	↔
\lambda	λ	\Sigma	Σ	\downarrow	↓
\mu	µ	\Upsilon	ϒ	\circ	º
\nu	ν	\Phi	Φ	\pm	±
\xi	ξ	\Psi	Ψ	\geq	≥
\pi	π	\Omega	Ω	\propto	∝
\rho	ρ	\forall	∀	\partial	∂
\sigma	σ	\exists	∃	\bullet	•
\varsigma	ς	\ni	∍	\div	÷
\tau	τ	\cong	≅	\neq	≠
\equiv	≡	\approx	~	\aleph	
\Im	ℑ	\Re	ℜ	\wp	℘
\otimes	⊗	\oplus	⊕	\oslash	∅
\cap	∩	\cup	∪	\supseteq	⊇
\supset	⊃	\subseteq	⊆	\subset	⊂
\int	∫	\in		\o	ο
\rfloor	�	\lceil	�	\nabla	∇
\lfloor	�	\cdot	·	\ldots	...

Character Sequence	Symbol	Character Sequence	Symbol	Character Sequence	Symbol
\perp	⊥	\neg	¬	\prime	´
\wedge	∧	\times	x	\0	∅
\rceil	�	\surd	√	\mid	|
\vee	∨	\varpi	ϖ	\copyright	©
\langle	∠	\rangle	∠		

You can also specify stream modifiers that control font type and color. The first four modifiers are mutually exclusive. However, you can use `\fontname` in combination with one of the other modifiers:

`TextBackgroundColor`
`ColorSpec` Default: `none`

Color of text background rectangle. A three-element RGB vector or one of the MATLAB predefined names, specifying the arrow color.

See the `ColorSpec` reference page for more information on specifying color.

`TextColor`
`ColorSpec` Default: `[0 0 0]`

Color of text. A three-element RGB vector or one of the MATLAB predefined names, specifying the arrow color.

See the `ColorSpec` reference page for more information on specifying color. Setting the `Color` property also sets this property.

`TextEdgeColor`
`ColorSpec` or `none` Default: `none`

Color of edge of text rectangle. A three-element RGB vector or one of the MATLAB predefined names, specifying the color of the rectangle that encloses the text.

See the `ColorSpec` reference page for more information on specifying color. Setting the `Color` property also sets this property.

`TextLineWidth`
width in points

The width of the text rectangle edge. Specify this value in points (1 point = $^1/_{72}$ inch). The default `TextLineWidth` is 0.5 points.

`TextMargin`
dimension in pixels default: 5

Space around text. Specify a value in pixels that defines the space around the text string, but within the rectangle.

`TextRotation`
rotation angle in degrees (default = 0)

Text orientation. This property determines the orientation of the text string. Specify values of rotation in degrees (positive angles cause counterclockwise rotation). Angles are absolute and not relative to previous rotations; a rotation of 0 degrees is always horizontal.

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

position units. MATLAB uses this property to determine the units used by the `Position` property. All positions are measured from the lower left corner of the figure window. Normalized units interpret `Position` as a fraction of the width and height of the parent axes. When you resize the axes, MATLAB modifies the size of the object accordingly. `pixels`, `inches`, `centimeters`, and `points` are absolute units (1 point = 1/72 inch).

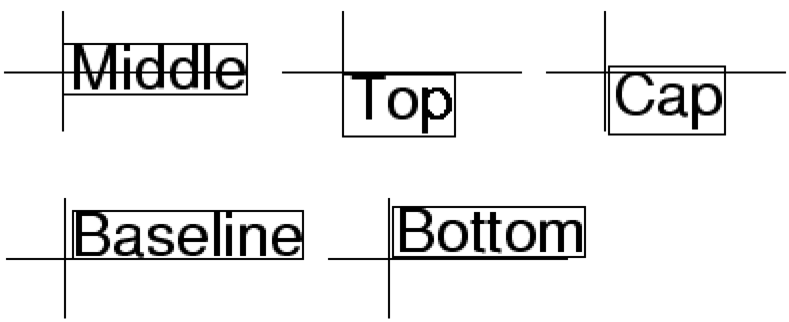
`VerticalAlignment`
`top | cap | {middle} | baseline | bottom`

Vertical alignment of text. This property specifies the vertical justification of the text string. It determines where MATLAB places the string with regard to the value of the `Position` property. The possible values mean

- top — Place the top of the string' s `Extent` rectangle at the specified *y*-position.
- `cap` — Place the string so that the top of a capital letter is at the specified *y*-position.
- `middle` — Place the middle of the string at the specified *y*-position.
- `baseline` — Place font baseline at the specified *y*-position.
- `bottom` — Place the bottom of the string's `Extent` rectangle at the specified *y*-position.

The following picture illustrates the alignment options.

Text `VerticalAlignment` property viewed with the `HorizontalAlignment` property set to `left` (the default).



`X`

vector [X_{begin} X_{end}]

X-coordinates of the beginning and ending points for line. Specify this property as a vector of *x*-axis (horizontal) values that specify the beginning and ending points of the line, units normalized to the figure.

`Y`

vector [Y_{begin} Y_{end}]

Y-coordinates of the beginning and ending points for line. Specify this property as a vector of *y*-axis (vertical) values that specify the beginning and ending points of the line, units normalized to the figure.

Annotation Textbox Properties

Purpose

Define annotation textbox properties

Modifying Properties

You can set and query annotation object properties using the `set` and `get` functions and the Property Editor (displayed with the `propertyeditor` command).

Use the `annotation` function to create annotation objects and obtain their handles. For an example of its use, see “Positioning Annotations in Data Space” in the MATLAB Graphics documentation.

Annotation Textbox Property Descriptions

Properties You Can Modify

This section lists the properties you can modify on an annotation textbox object.

`BackgroundColor`

`ColorSpec` Default: `none`

Color of text background rectangle. A three-element RGB vector or one of the MATLAB predefined names, specifying the arrow color.

See the `ColorSpec` reference page for more information on specifying color.

`Color`

`ColorSpec` Default: `[0 0 0]`

Color of text. A three-element RGB vector or one of the MATLAB predefined names, specifying the arrow color.

See the `ColorSpec` reference page for more information on specifying color. Setting the `Color` property also sets this property.

`EdgeColor`

`ColorSpec` or `none` Default: `none`

Color of edge of text rectangle. A three-element RGB vector or one of the MATLAB predefined names, specifying the color of the rectangle that encloses the text.

See the `ColorSpec` reference page for more information on specifying color. Setting the `Color` property also sets this property.

`FaceAlpha`

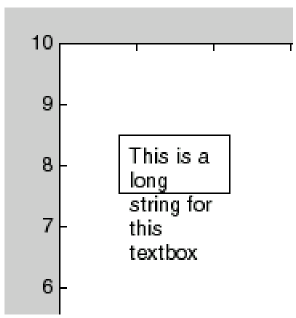
Scalar alpha value in range [0 1]

Transparency of object background. This property defines the degree to which the object's background color is transparent. A value of `1` (the default) makes to color opaque, a value of `0` makes the background completely transparent (i.e., invisible). The default FaceAlpha is `1`.

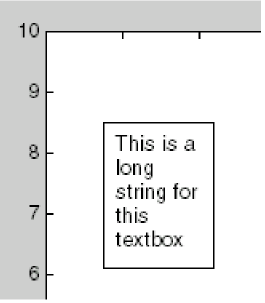
`FitHeightToText`

`on | {off}`

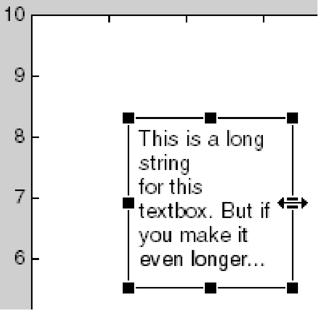
Automatically adjust text box height to fit text. MATLAB automatically wraps text strings to fit the width of the text box. However, if the text string is long enough, it extends beyond the bottom of the text box.



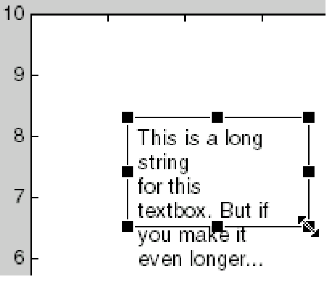
When you set this mode to `on`, MATLAB automatically adjusts the height of the text box to accommodate the string.



The fit-height-to-text behavior continues to apply if you resize the text box from the two side handles.



However, if you resize the text box from any other handles, the position you set is honored without regard to how the text fits the box.



`FontAngle`
  `{normal} | italic | oblique`

  Character slant. MATLAB uses this property to select a font from those available on your particular system. Generally, setting this property to `italic` or `oblique` selects a slanted font.

`FontName`
  A name, such as `Helvetica`

  Font family. A string specifying the name of the font to use for the text. To display and print properly, this font must be supported on your system. The default font is `Helvetica`.

`FontSize`
  size in points

  Approximate size of text characters. A value specifying the font size to use in points. The default size is 10 (1 point = 1/72 inch).

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

  Font size units. MATLAB uses this property to determine the units used by the `FontSize` property. Normalized units interpret `FontSize` as a fraction of the height of the parent axes. When you resize the axes, MATLAB modifies the screen `FontSize` accordingly. `pixels`, `inches`, `centimeters`, and `points` are absolute units (1 point = 1/72 inch).

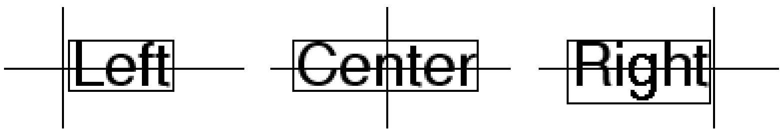
`FontWeight`
  `light | {normal} | demi | bold`

  Weight of text characters. MATLAB uses this property to select a font from those available on your system. Generally, setting this property to `bold` or `demi` causes MATLAB to use a bold font.

`HorizontalAlignment`
  `{left} | center | right`

Horizontal alignment of text. This property specifies the horizontal justification of the text string. It determines where MATLAB places the string with regard to the point specified by the `Position` property. The following picture illustrates the alignment options.

`HorizontalAlignment` viewed with the `VerticalAlignment` set to middle (the default).



See the `Extent` property for related information.

`Interpreter`
`latex | {tex} | none`

Interpret TeX instructions. This property controls whether MATLAB interprets certain characters in the `String` property as TeX instructions (default) or displays all characters literally. The options are:

- `latex` — Supports the full LaTeX markup language.
- `tex` — Supports a subset of plain TeX markup language. See the `String` property for a list of supported TeX instructions.
- `none` — Displays literal characters.

`LineStyle`
`{-} | -- | : | -. | none`

Line style. This property specifies the line style of the object. Available line styles are shown in the following table.

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

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

`LineWidth`
scalar

The width of linear objects and edges of filled areas. Specify this value in points (1 point = $^1/_{72}$ inch). The default `LineWidth` is 0.5 points.

`Margin`
dimension in pixels default: 5

Space around text. Specify a value in pixels that defines the space around the text string, but within the rectangle.

`Position`
four-element vector [x, y, width, height]

Size and location of the object. Specify the lower left corner of the object with the first two elements of the vector defining the point *x, y* in units normalized to the figure (when `Units` property is `normalized`). The third and fourth elements specify the object's *dx* and *dy*, respectively, in units normalized to the figure.

`String`
string

The text string. Specify this property as a quoted string for single-line strings, or as a cell array of strings, or a padded string matrix for multiline strings. MATLAB displays this string at the specified location. Vertical slash characters are not interpreted as line breaks in text strings, and are drawn as part of the text string. See Mathematical Symbols, Greek Letters, and TeX Characters for an example.

When the text `Interpreter` property is set to `Tex` (the default), you can use a subset of TeX commands embedded in the string to produce special characters such as Greek letters and mathematical symbols. The following table lists these characters and the character sequences used to define them.

Character Sequence	Symbol	Character Sequence	Symbol	Character Sequence	Symbol
\alpha	α	\upsilon	υ	\sim	~
\beta	β	\phi	Φ	\leq	≤
\gamma	γ	\chi	χ	\infty	∞
\delta	δ	\psi	ψ	\clubsuit	♣
\epsilon	ε	\omega	ω	\diamondsuit	♦
\zeta	ζ	\Gamma	Γ	\heartsuit	♥
\eta	η	\Delta	Δ	\spadesuit	♠
\theta	Θ	\Theta	Θ	\leftrightarrow	↔
\vartheta	ϑ	\Lambda	Λ	\leftarrow	→
\iota	ι	\Xi	Ξ	\uparrow	↑
\kappa	κ	\Pi	Π	\rightarrow	↔
\lambda	λ	\Sigma	Σ	\downarrow	↓

Character Sequence	Symbol	Character Sequence	Symbol	Character Sequence	Symbol
\mu	µ	\Upsilon	ϒ	\circ	º
\nu	ν	\Phi	Φ	\pm	±
\xi	ξ	\Psi	Ψ	\geq	≥
\pi	π	\Omega	Ω	\propto	∝
\rho	ρ	\forall	∀	\partial	∂
\sigma	σ	\exists	∃	\bullet	•
\varsigma	ς	\ni	∍	\div	÷
\tau	τ	\cong	≅	\neq	≠
\equiv	≡	\approx	~	\aleph	
\Im	ℑ	\Re	ℜ	\wp	℘
\otimes	⊗	\oplus	⊕	\oslash	∅
\cap	∩	\cup	∪	\supseteq	⊇
\supset	⊃	\subseteq	⊆	\subset	⊂
\int	∫	\in		\o	ο
\rfloor	�	\lceil	�	\nabla	∇
\lfloor	�	\cdot	·	\ldots	...
\perp	⊥	\neg	¬	\prime	´
\wedge	∧	\times	x	\0	∅
\rceil	�	\surd	√	\mid	|
\vee	∨	\varpi	ϖ	\copyright	©
\langle	∠	\rangle	∠		

You can also specify stream modifiers that control font type and color. The first four modifiers are mutually exclusive. However, you can use `\fontname` in combination with one of the other modifiers:

`Units`

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

position units. MATLAB uses this property to determine the units used by the `Position` property. All positions are measured from the lower left corner of the figure window. Normalized units interpret `Position` as a fraction of the width and height of the parent axes. When you resize the axes, MATLAB modifies the size of the object accordingly. `pixels`, `inches`, `centimeters`, and `points` are absolute units (1 point = 1/72 inch).

`VerticalAlignment`

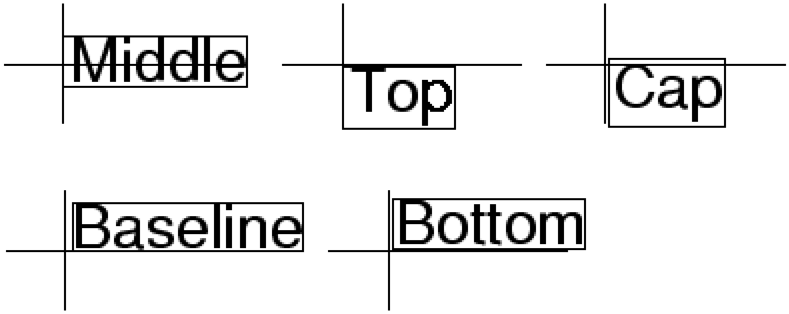
`top | cap | {middle} | baseline |`
`bottom`

Vertical alignment of text. This property specifies the vertical justification of the text string. It determines where MATLAB places the string with regard to the value of the `Position` property. The possible values mean

- top — Place the top of the string' s `Extent` rectangle at the specified *y*-position.
- `cap` — Place the string so that the top of a capital letter is at the specified *y*-position.
- `middle` — Place the middle of the string at the specified *y*-position.
- `baseline` — Place font baseline at the specified *y*-position.
- `bottom` — Place the bottom of the string's `Extent` rectangle at the specified *y*-position.

The following picture illustrates the alignment options.

Text `VerticalAlignment` **property viewed with the** `HorizontalAlignment` **property set to** `left` **(the default).**



Purpose Most recent answer

Syntax

```
ans
```

Description MATLAB creates the ans variable automatically when you specify no output argument.

Examples The statement

```
2+2
```

is the same as

```
ans = 2+2
```

See Also display

Purpose

Determine whether any array elements are nonzero

Syntax

```
B = any(A)
B = any(A,dim)
```

Description

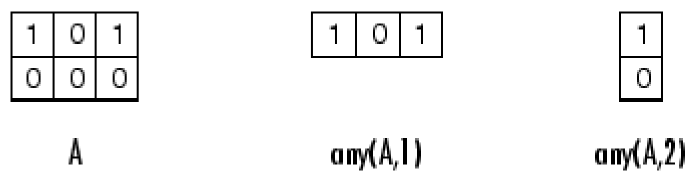
`B = any(A)` tests whether *any* of the elements along various dimensions of an array is a nonzero number or is logical `1` (`true`). `any` ignores entries that are `NaN` (Not a Number).

If `A` is a vector, `any(A)` returns logical `1` (`true`) if any of the elements of `A` is a nonzero number or is logical `1` (`true`), and returns logical `0` (`false`) if all the elements are zero.

If `A` is a matrix, `any(A)` treats the columns of `A` as vectors, returning a row vector of logical `1`'s and `0`'s.

If `A` is a multidimensional array, `any(A)` treats the values along the first nonsingleton dimension as vectors, returning a logical condition for each vector.

`B = any(A,dim)` tests along the dimension of `A` specified by scalar *`dim`*.



Examples

Example 1 – Reducing a Logical Vector to a Scalar Condition

Given

```
A = [0.53 0.67 0.01 0.38 0.07 0.42 0.69]
```

then `B = (A < 0.5)` returns logical `1` (`true`) only where `A` is less than one half:

```
0    0    1    1    1    1    0
```

The any function reduces such a vector of logical conditions to a single condition. In this case, any(B) yields logical 1.

This makes any particularly useful in if statements:

```
if any(A < 0.5)do something
end
```

where code is executed depending on a single condition, not a vector of possibly conflicting conditions.

Example 2– Reducing a Logical Matrix to a Scalar Condition

Applying the any function twice to a matrix, as in any(any(A)), always reduces it to a scalar condition.

```
any(any(eye(3)))
ans =
   1
```

Example 3 – Testing Arrays of Any Dimension

You can use the following type of statement on an array of any dimensions. This example tests a 3-D array to see if any of its elements are greater than 3:

```
x = rand(3,7,5) * 5;

any(x(:) > 3)
ans =
     1
```

or less than zero:

```
any(x(:) < 0)
ans =
     0
```

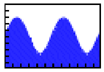
See Also

all, logical operators (elementwise and short-circuit), relational operators, colon

Other functions that collapse an array's dimensions include max, mean, median, min, prod, std, sum, and trapz.

Purpose

Filled area 2-D 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

```
area(Y)
area(X,Y)
area(...,basevalue)
area(...,'PropertyName',PropertyValue,...)
area(axes_handle,...)
h = area(...)
hpatches = area('v6',...)
```

Description

An area graph displays elements in `Y` as one or more curves and fills the area beneath each curve. When `Y` is a matrix, the curves are stacked showing the relative contribution of each row element to the total height of the curve at each x interval.

`area(Y)` plots the vector `Y` or the sum of each column in matrix `Y`. The *x*-axis automatically scales to `1:size(Y,1)`.

`area(X,Y)` For vectors `X` and `Y`, `area(X,Y)` is the same as `plot(X,Y)` except that the area between `0` and `Y` is filled. When `Y` is a matrix, `area(X,Y)` plots the columns of `Y` as filled areas. For each `X`, the net result is the sum of corresponding values from the columns of `Y`.

If `X` is a vector, `length(X)` must equal `length(Y)`. If `X` is a matrix, `size(X)` must equal `size(Y)`.

`area(...,basevalue)` specifies the base value for the area fill. The default `basevalue` is `0`. See the `BaseValue` property for more information.

`area(...,'PropertyName',PropertyValue,...)` specifies property name and property value pairs for the patch graphics object created by `area`.

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

`h = area(...)` returns handles of `areaseries` graphics objects.

Backward-Compatible Version

`hpatches = area('v6',...)` returns the handles of patch objects instead of areaseries objects for compatibility with MATLAB 6.5 and earlier. See patch object properties for a discussion of the properties you can set to control the appearance of these area graphs.

See "Plot Objects and Backward Compatibility" for more information.

Areaseries Objects

Creating an area graph of an *m*-by-*n* matrix creates *n* areaseries objects (i.e., one per column), whereas a 1-by-*n* vector creates one area object.

Some areaseries object properties that you set on an individual areaseries object set the values for all areaseries objects in the graph. See the property descriptions for information on specific properties.

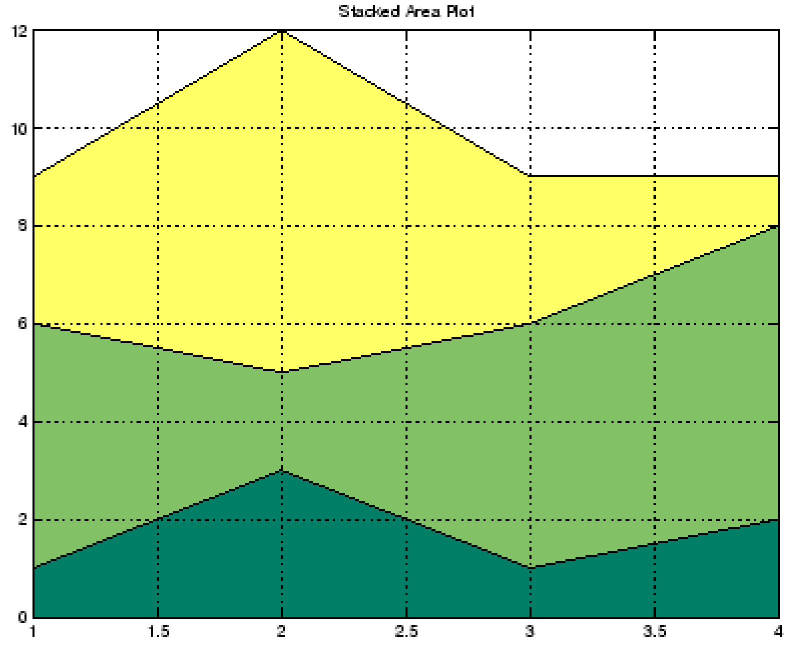
Examples

Stacked Area Graph

This example plots the data in the variable `Y` as an area graph. Each subsequent column of `Y` is stacked on top of the previous data. The figure colormap controls the coloring of the individual areas. You can explicitly set the color of an area using the `EdgeColor` and `FaceColor` properties.

```
Y = [1, 5, 3;
 3, 2, 7;
 1, 5, 3;
 2, 6, 1];
area(Y)
```

```
grid on
colormap summer
set(gca,'Layer','top')
title 'Stacked Area Plot'
```

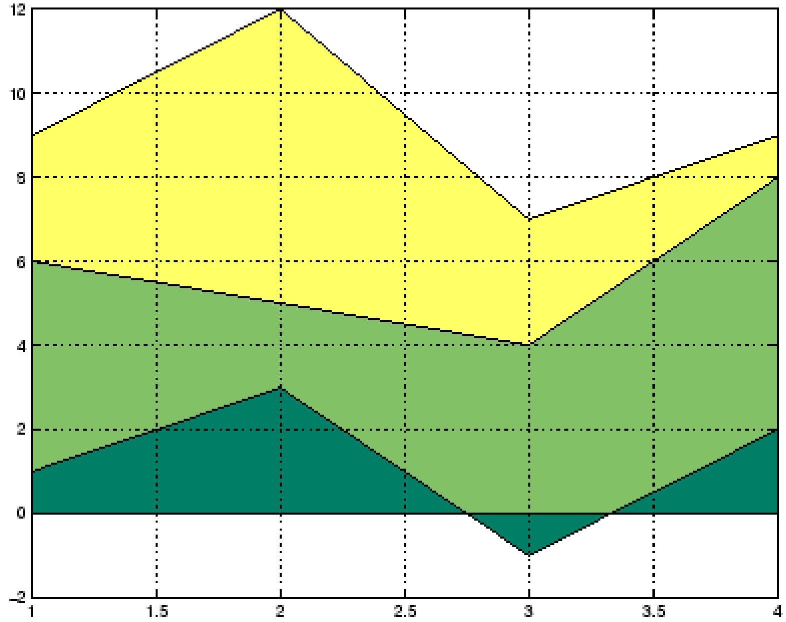


Adjusting the Base Value

The area function uses a y-axis value of 0 as the base of the filled areas. You can change this value by setting the area `BaseValue` property. For example, negate one of the values of Y from the previous example and replot the data.

```
Y(3,1) = -1; % Was 1
h = area(Y);
set(gca,'Layer','top')
grid on
colormap summer
```

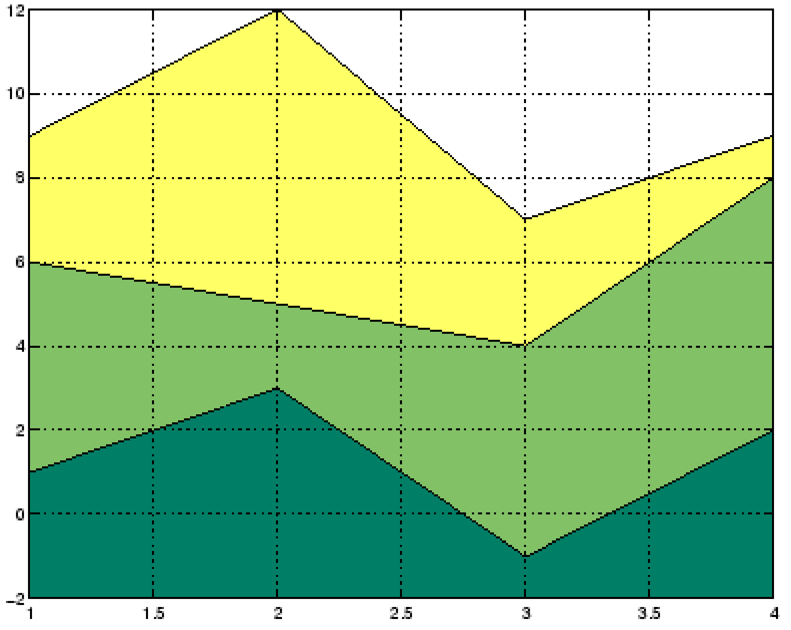
The area graph now looks like this:



Adjusting the BaseValue property improves the appearance of the graph:

```
set(h,'BaseValue',-2)
```

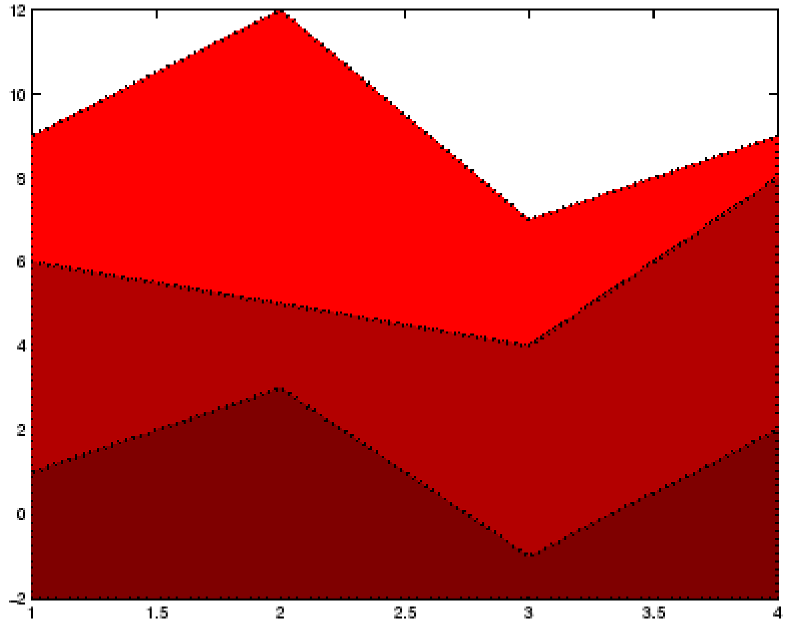
Setting the BaseValue property on one areaseries object sets the values of all objects.



Specifying Colors and Line Styles

You can specify the colors of the filled areas and the type of lines used to separate them.

```
h = area(Y,-2); % Set BaseValue via argument
set(h(1),'FaceColor',[.5 0 0])
set(h(2),'FaceColor',[.7 0 0])
set(h(3),'FaceColor',[1 0 0])
set(h,'LineStyle',':','LineWidth',2) % Set
all to same value
```



See Also

`bar`, `plot`, `sort`

"Area, Bar, and Pie Plots" on page 1-87 for related functions

"Area Graphs" for more examples

`Areaseries Properties` for property descriptions

Areaseries Properties

Purpose

Define areaseries properties

Modifying Properties

You can set and query graphics object properties using the `set` and `get` commands or with the property editor (`propertyeditor`).

Note that you cannot define default properties for areaseries objects.

See "Plot Objects" for more information on areaseries objects.

Areaseries Property Descriptions

This section provides a description of properties. Curly braces { } enclose default values.

`BaseValue`

double: *y*-axis value

Value where filled area base is drawn. Specify the value along the *y*-axis at which MATLAB draws the baseline of the bottommost filled area.

`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`
array of graphics object handles

Children of this object. The handle of a patch object that is the child of this object (whether visible or not).

Note that if a child object's `HandleVisibility` property is set to `callback` or `off`, its handle does not show up in this object's `Children` property unless you set the root `ShowHiddenHandles` property to `on`:

```
set(0,'ShowHiddenHandles','on')
```

`Clipping`
`{on} | off`

Clipping mode. MATLAB clips graphs to the axes plot box by default. If you set `Clipping` to `off`, portions of graphs can be displayed outside the axes plot box. This can occur if you create a plot object, set `hold` to `on`, freeze axis scaling (`axis manual`), and then create a larger plot object.

`CreateFcn`
string or function handle

Callback routine executed during object creation. This property defines a callback that executes when MATLAB creates an object. You must specify the callback during the creation of the object. For example,

```
area(y,'CreateFcn',@CallbackFcn)
```

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.

`EdgeColor`
`{[0 0 0]} | none | ColorSpec`

Color of line that separates filled areas. You can set the color of the edges of filled areas to a three-element RGB vector or one of the MATLAB predefined names, including the string `none`. The default edge color is black. See `ColorSpec` for more information on specifying color.

`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.

`FaceColor`
`{flat} | none | ColorSpec`

Color of filled areas. This property can be any of the following:

- `ColorSpec` — A three-element RGB vector or one of the MATLAB predefined names, specifying a single color for all filled areas. See `ColorSpec` for more information on specifying color.
- `none` — Do not draw faces. Note that `EdgeColor` is drawn independently of `FaceColor`

- `flat` — The color of the filled areas is determined by the figure colormap. See `colormap` for information on setting the colormap.

  See the `ColorSpec` reference page for more information on specifying color.

`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).

`HitTestArea`

`on | {off}`

Select areaseries object on filled area or extent of graph. This property enables you to select areaseries objects in two ways:

- Select by clicking bars (default).
- Select by clicking anywhere in the extent of the area plot.

  When `HitTestArea` is `off`, you must click the bars to select the bar object. When `HitTestArea` is `on`, you can select the bar object by clicking anywhere within the extent of the bar graph (i.e., anywhere within a rectangle that encloses all the bars).

`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
`-.`	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.

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

Parent of this object. This property contains the handle of the object's parent. The parent is normally the axes, hggroup, or hgtransform object that contains the object.

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

`Selected`
`on | {off}`

Is object selected? When you set this property to `on`, MATLAB displays selection "handles" at the corners and midpoints if the `SelectionHighlight` property is also `on` (the default). You can, for example, define the ButtonDownFcn callback to set this property to on, thereby indicating that this particular object is selected. This property is also set to on when an object is manually selected in plot edit mode.

SelectionHighlight
{on} | off

Objects are highlighted when selected. When the Selected property is on, MATLAB indicates the selected state by drawing four edge handles and four corner handles. When SelectionHighlight is off, MATLAB does not draw the handles except when in plot edit mode and objects are selected manually.

Tag
string

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

For example, you might create an areaseries object and set the Tag property.

```
t = area(Y,'Tag','area1')
```

When you want to access objects of a given type, you can use findobj to find the object's handle. The following statement changes the FaceColor property of the object whose Tag is area1.

```
set(findobj('Tag','area1'),'FaceColor','red')
```

Type
string (read only)

Type of graphics object. This property contains a string that identifies the class of the graphics object. For areaseries objects, `Type` is '`hggroup`'.

The following statement finds all the hggroup objects in the current axes.

```
t = findobj(gca,'Type','hggroup');
```

`UIContextMenu`
handle of a uicontextmenu object

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

`UserData`
array

User-specified data. This property can be any data you want to associate with this object (including cell arrays and structures). The object does not set values for this property, but you can access it using the `set` and `get` functions.

`Visible`
`{on} | off`

Visibility of this object and its children. By default, a new object's visibility is `on`. This means all children of the object are visible unless the child object's `Visible` property is set to `off`. Setting an object's `Visible` property to `off` prevents the object from being displayed. However, the object still exists and you can set and query its properties.

`XData`
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

Area plot data. `YData` contains the data plotted as filled areas (the `Y` input argument). If `YData` is a vector, `area` creates a single filled area whose upper boundary is defined by the elements of `YData`. If `YData` is a matrix, `area` creates one filled area per column, stacking each on the previous plot.

The input argument `Y` in the `area` function calling syntax assigns values to `YData`.

`YDataSource`

string (MATLAB variable)

Link `YData` to MATLAB variable. Set this property to a MATLAB variable that is evaluated in the base workspace to generate the `YData`.

MATLAB reevaluates this property only when you set it. Therefore, a change to workspace variables appearing in an expression does not change `YData`.

You can use the `refreshdata` function to force an update of the object's data. `refreshdata` also enables you to specify that the

data source variable be evaluated in the workspace of a function from which you call `refreshdata`.

See the `refreshdata` reference page for more information.

Note If you change one data source property to a variable that contains data of a different dimension, you might cause the function to generate a warning and not render the graph until you have changed all data source properties to appropriate values.

Purpose Apply function to each element of array

Syntax

```
A = arrayfun(fun, S)
A = arrayfun(fun, S, T, ...)
[A, B, ...] = arrayfun(fun, S, ...)
[A, ...] = arrayfun(fun, S, ..., 'param1', value1, ...)
```

Description

`A = arrayfun(fun, S)` applies the function specified by `fun` to each element of array `S`, and returns the results in array `A`. The value `A` returned by `arrayfun` is the same size as `S`, and the `(I,J,...)`th element of `A` is equal to `fun(S(I,J,...))`. The first input argument `fun` is a function handle to a function that takes one input argument and returns a scalar value. `fun` must return values of the same class each time it is called.

If `fun` is bound to more than one built-in or M-file (that is, if it represents a set of overloaded functions), then the class of the values that `arrayfun` actually provides as input arguments to `fun` determines which functions are executed.

The order in which `arrayfun` computes elements of `A` is not specified and should not be relied upon.

`A = arrayfun(fun, S, T, ...)` evaluates `fun` using elements of the arrays `S`, `T`, `...` as input arguments. The `(I,J,...)`th element of `A` is equal to `fun(S(I,J,...), T(I,J,...), ...)`. All input arguments must be of the same size.

`[A, B, ...]  = arrayfun(fun, S, ...)` evaluates `fun`, which is a function handle to a function that returns multiple outputs, and returns arrays `A`, `B`, `...`, each corresponding to one of the output arguments of `fun`. `arrayfun` calls `fun` each time with as many outputs as there are in the call to `arrayfun`. `fun` can return output arguments having different classes, but the class of each output must be the same each time `fun` is called.

`[A, ...]  = arrayfun(fun, S, ..., 'param1', value1, ...)` enables you to specify optional parameter name and value pairs.

Parameters recognized by arrayfun are shown below. Enclose each parameter name with single quotes.

Parameter Name	Parameter Value
UniformOutput	A logical 1 (true) or 0 (false), indicating whether or not the outputs of fun can be returned without encapsulation in a cell array. If true (the default), fun must return scalar values that can be concatenated into an array. These values can also be a cell array. If false, arrayfun returns a cell array (or multiple cell arrays), where the (I,J,...)th cell contains the value fun(S(I,J,...), ...).
ErrorHandler	A function handle, specifying the function that arrayfun is to call if the call to fun fails. If an error handler is not specified, arrayfun rethrows the error from the call to fun.

Remarks

MATLAB provides two functions that are similar to arrayfun; these are structfun and cellfun. With structfun, you can apply a given function to all fields of one or more structures. With cellfun, you apply the function to all cells of one or more cell arrays.

Examples

Example 1 — Operating on a Single Input.

Create a 1-by-15 structure array with fields f1 and f2, each field containing an array of a different size. Make each f1 field be unequal to the f2 field at that same array index:

```
for k=1:15
   s(k).f1 = rand(k+3,k+7) * 10;
   s(k).f2 = rand(k+3,k+7) * 10;
```

```
end
```

Set three f1 fields to be equal to the f2 field at that array index:

```
s(3).f2 = s(3).f1;
s(9).f2 = s(9).f1;
s(12).f2 = s(12).f1;
```

Use arrayfun to compare the fields at each array index. This compares the array of s(1).f1 with that of s(1).f2, the array of s(2).f1 with that of s(2).f2, and so on through the entire structure array.

The first argument in the call to arrayfun is an anonymous function. Anonymous functions return a function handle, which is the required first input to arrayfun:

```
z = arrayfun(@(x)isequal(x.f1, x.f2), s)
z =
   0   0   1   0   0   0   0   0   1   0   0   1   0   0   0
```

Example 2 — Operating on Multiple Inputs.

This example performs the same array comparison as in the previous example, except that it compares the some field of more than one structure array rather than different fields of the same structure array. This shows how you can use more than one array input with arrayfun.

Make copies of array s, created in the last example, to arrays t and u.

```
t = s;   u = s;
```

Make one element of structure array t unequal to the same element of s. Do the same with structure array u:

```
t(4).f1(12)=0;
u(14).f1(6)=0;
```

Compare field f1 of the three arrays s, t, and u:

```
z = arrayfun(@(a,b,c)isequal(a.f1, b.f1, c.f1), s, t, u)
z =
```

```
     1   1   1   0   1   1   1   1   1   1   1   1   1   0   1
```

Example 3 — Generating Nonuniform Output.

Generate a 1-by-3 structure array `s` having random matrices in field `f1`:

```
rand('state', 0);
s(1).f1 = rand(7,4) * 10;
s(2).f1 = rand(3,7) * 10;
s(3).f1 = rand(5,5) * 10;
```

Find the maximum for each `f1` vector. Because the output is nonscalar, specify the `UniformOutput` option as `false`:

```
sMax = arrayfun(@(x) max(x.f1), s, 'UniformOutput', false)
sMax =
    [1x4 double]    [1x7 double]    [1x5 double]

sMax{:}
ans =
  9.5013  9.2181  9.3547  8.1317
ans =
  2.7219  9.3181  8.4622  6.7214  8.3812   8.318  7.0947
ans =
  6.8222  8.6001  8.9977  8.1797  8.385
```

Find the mean for each `f1` vector:

```
sMean = arrayfun(@(x) mean(x.f1), s, ...
                'UniformOutput', false)
sMean =
    [1x4 double]    [1x7 double]    [1x5 double]

sMean{:}
ans =
  6.2628  6.2171  5.4231  3.3144
ans =
  1.6209   7.079  5.7696  4.6665  5.1301  5.7136  4.8099
ans =
```

```
   3.8195  5.8816  6.9128  4.9022  5.9541
```

Example 4 — Assigning to More Than One Output Variable.

The next example uses the `lu` function on the same structure array, returning three outputs from `arrayfun`:

```
[l u p] = arrayfun(@(x)lu(x.f1), s, 'UniformOutput', false)
l =
    [7x4 double]    [3x3 double]    [5x5 double]
u =
    [4x4 double]    [3x7 double]    [5x5 double]
p =
    [7x7 double]    [3x3 double]    [5x5 double]

l{3}
ans =
          1          0          0          0          0
    0.44379          1          0          0          0
    0.79398    0.79936          1          0          0
    0.27799   0.066014   -0.77517          1          0
    0.28353    0.85338    0.29223    0.67036          1

u{3}
ans =
     6.8222     3.7837     8.9977     3.4197     3.0929
          0     6.9209     4.2232     1.3796     7.0124
          0          0    -4.0708   -0.40607    -2.3804
          0          0          0     6.8232     2.1729
          0          0          0          0   -0.35098

p{3}
ans =
     0     0     1     0     0
     0     0     0     1     0
     0     0     0     0     1
     1     0     0     0     0
     0     1     0     0     0
```

See Also `structfun`, `cellfun`, `spfun`, `function_handle`, `cell2mat`

Purpose

Set FTP transfer type to ASCII

Syntax

```
ascii(f)
```

Description

`ascii(f)` sets the download and upload FTP mode to ASCII, which converts new lines, where `f` was created using `ftp`. Use this function for text files only, including HTML pages and Rich Text Format (RTF) files.

Examples

Connect to the MathWorks FTP server, and display the FTP object.

```
tmw=ftp('ftp.mathworks.com');
disp(tmw)
FTP Object
  host: ftp.mathworks.com
  user: anonymous
   dir: /
  mode: binary
```

Note that the FTP object defaults to binary mode.

Use the `ascii` function to set the FTP mode to ASCII, and use the `disp` function to display the FTP object.

```
ascii(tmw)
disp(tmw)
FTP Object
  host: ftp.mathworks.com
  user: anonymous
   dir: /
  mode: ascii
```

Note that the FTP object is now set to ASCII mode.

See Also

`ftp`, `binary`

Purpose Inverse secant; result in radians

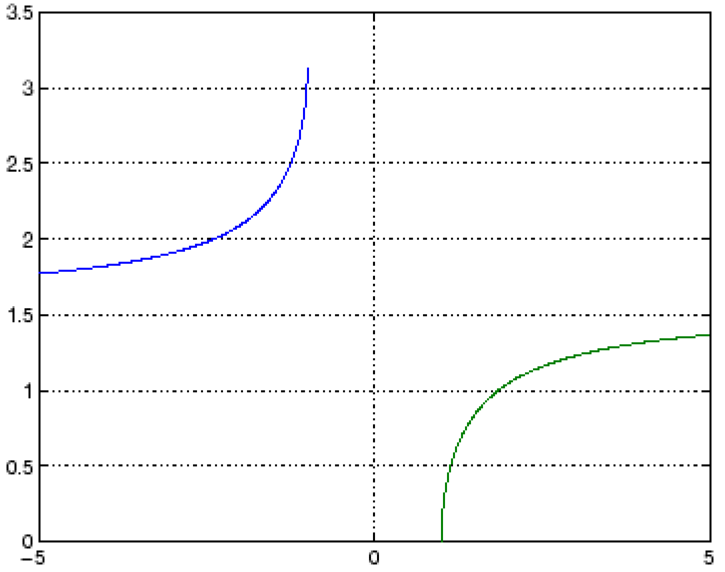
Syntax `Y = asec(X)`

Description `Y = asec(X)` returns the inverse secant (arcsecant) for each element of `X`.

The `asec` function operates element-wise on arrays. The function's domains and ranges include complex values. All angles are in radians.

Examples Graph the inverse secant over the domains $1 \le x \le 5$ and $-5 \le x \le -1$.

```
x1 = -5:0.01:-1;
x2 = 1:0.01:5;
plot(x1,asec(x1),x2,asec(x2)), grid on
```



Definition

The inverse secant can be defined as

$$\sec^{-1}(z) = \cos^{-1}\left(\frac{1}{z}\right)$$

Algorithm

`asec` 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

`asecd`, `asech`, `sec`

asecd

Purpose Inverse secant; result in degrees

Syntax

```
Y = asecd(X)
```

Description `Y = asecd(X)` is the inverse secant, expressed in degrees, of the elements of `X`.

See Also `secd`, `asec`

Purpose

Inverse hyperbolic secant

Syntax

```
Y = asech(X)
```

Description

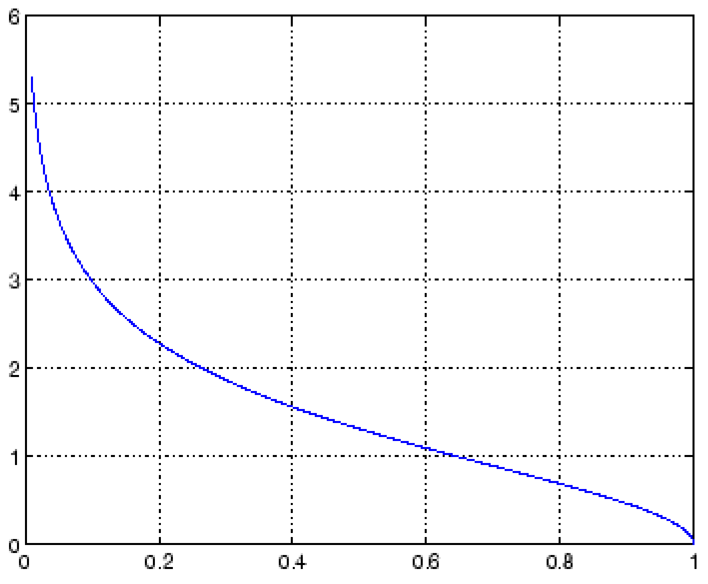
`Y = asech(X)` returns the inverse hyperbolic secant for each element of `X`.

The `asech` function operates element-wise on arrays. The function's domains and ranges include complex values. All angles are in radians.

Examples

Graph the inverse hyperbolic secant over the domain $0.01 \le x \le 1$.

```
x = 0.01:0.001:1;
plot(x,asech(x)), grid on
```



Definition

The hyperbolic inverse secant can be defined as

$$\operatorname{sech}^{-1}(z) = \cosh^{-1}\left(\frac{1}{z}\right)$$

Algorithm

asech uses FDLIBM, which was developed at SunSoft, a Sun Microsystems, Inc. business, by Kwok C. Ng, and others. For information about FDLIBM, see http://www.netlib.org.

See Also

asec, sech

Purpose Inverse sine; result in radians

Syntax

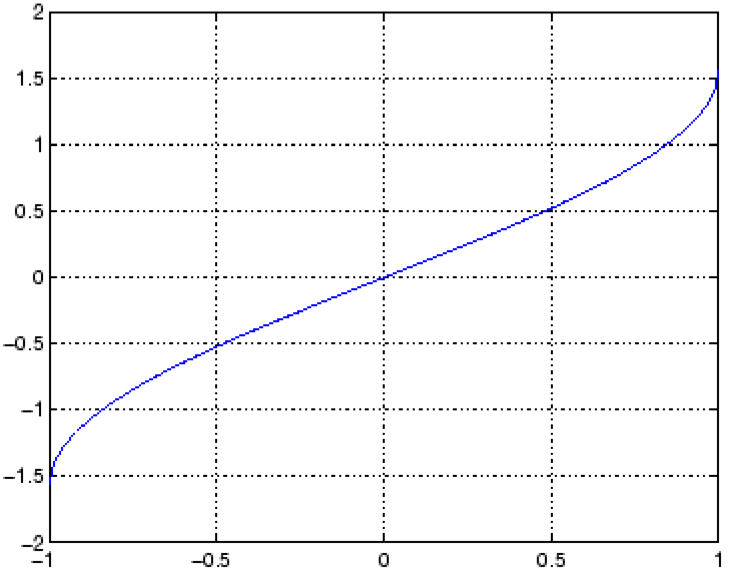
```
Y = asin(X)
```

Description `Y = asin(X)` returns the inverse sine (arcsine) for each element of `X`. For real elements of `X` in the domain $[-1, 1]$, `asin(X)` is in the range $[-\pi/2, \pi/2]$. For real elements of `x` outside the range $[-1, 1]$, `asin(X)` is complex.

The `asin` function operates element-wise on arrays. The function's domains and ranges include complex values. All angles are in radians.

Examples Graph the inverse sine function over the domain $-1 \le x \le 1$.

```
x = -1:.01:1;
plot(x,asin(x)), grid on
```



Definition

The inverse sine can be defined as

$$\sin^{-1}(z) \quad = \; -i \log\left[iz + (1 - z^2)^{\frac{1}{2}} \right]$$

Algorithm

`asin` 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

`asind`, `asinh`, `sin`, `sind`, `sinh`

Purpose Inverse sine; result in degrees

Syntax

Description `Y = asind(X)` is the inverse sine, expressed in degrees, of the elements of `X`.

See Also `asin`, `asinh`, `sin`, `sind`, `sinh`

asinh

Purpose Inverse hyperbolic sine

Syntax

```
Y = asinh(X)
```

Description

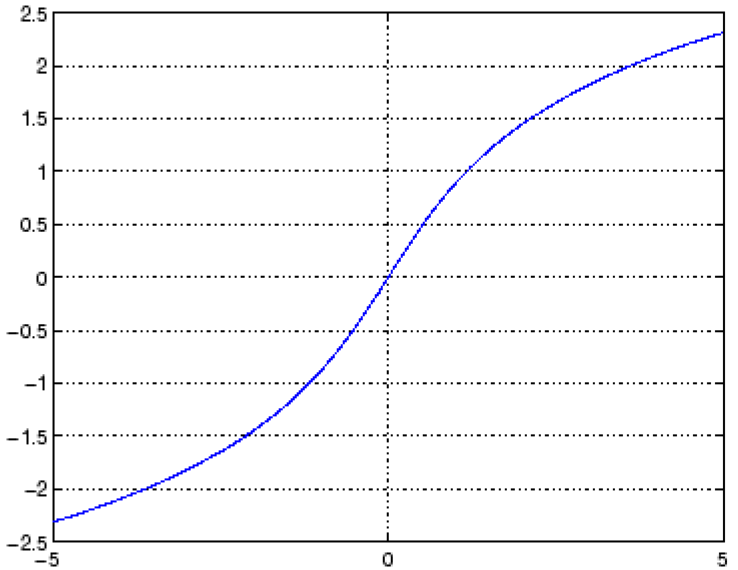
`Y = asinh(X)` returns the inverse hyperbolic sine for each element of `X`.

The `asinh` function operates element-wise on arrays. The function's domains and ranges include complex values. All angles are in radians.

Examples

Graph the inverse hyperbolic sine function over the domain $-5 \leq x \leq 5$.

```
x = -5:.01:5;
plot(x,asinh(x)), grid on
```



Definition

The hyperbolic inverse sine can be defined as

$$\sinh^{-1}(z) = \log\left[z + (z^2+1)^{\frac{1}{2}}\right]$$

Algorithm

`asinh` 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

`asin`, `asind`, `sin`, `sinh`, `sind`

assert

Purpose

Generate error when condition is violated

Syntax

```
assert(expression)
assert(expression, 'errmsg')
assert(expression, 'errmsg', value1, value2, ...)
assert(expression, 'msg_id', 'errmsg', value1, value2, ...)
```

Description

`assert(expression)` evaluates `expression` and, if it is `false`, displays the error message: `Assertion Failed`.

`assert(expression, 'errmsg')` evaluates `expression` and, if it is `false`, displays the string contained in `errmsg`. This string must be enclosed in single quotation marks. When `errmsg` is the last input to `assert`, MATLAB displays it literally, without performing any substitutions on the characters in `errmsg`.

`assert(expression, 'errmsg', value1, value2, ...)` evaluates `expression` and, if it is `false`, displays the formatted string contained in `errmsg`. The `errmsg` string can include escape sequences such as `\t` or `\n`, as well as any of the C language conversion operators supported by the `sprintf` function (e.g., `%s` or `%d`). Additional arguments `value1`, `value2`, etc. provide values that correspond to and replace the conversion operators.

See "Formatting Strings"in the MATLAB Programming documentation for more detailed information on using string formatting commands.

MATLAB makes substitutions for escape sequences and conversion operators in `errmsg` in the same way that it does for the `sprintf` function.

`assert(expression, 'msg_id', 'errmsg', value1, value2, ...)` evaluates `expression` and, if it is `false`, displays the formatted string `errmsg`, also tagging the error with the message identifier `msg_id`. See "Message Identifiers" in the MATLAB Programming documentation for information.

Examples

This function tests input arguments using `assert`:

```
function write2file(varargin)
min_inputs = 3;
assert(nargin >= min_inputs, ...
  'You must call function %s with at least %d inputs', ...
  mfilename, min_inputs)

infile = varargin{1};
assert(ischar(infile), ...
      'First argument must be a filename.')
assert(exist(infile)~=0, 'File %s not found.', infile)

fid = fopen(infile, 'w');
assert(fid > 0, 'Cannot open file %s for writing', infile)

fwrite(fid, varargin{2}, varargin{3});
```

See Also

`error`, `eval`, `sprintf`

assignin

Purpose

Assign value to variable in specified workspace

Syntax

`assignin(ws, 'var', val)`

Description

`assignin(ws, 'var', val)` assigns the value `val` to the variable *`var`* in the workspace `ws`. *`var`* is created if it doesn't exist. `ws` can have a value of `'base'` or `'caller'` to denote the MATLAB base workspace or the workspace of the caller function.

The `assignin` function is particularly useful for these tasks:

- Exporting data from a function to the MATLAB workspace
- Within a function, changing the value of a variable that is defined in the workspace of the caller function (such as a variable in the function argument list)

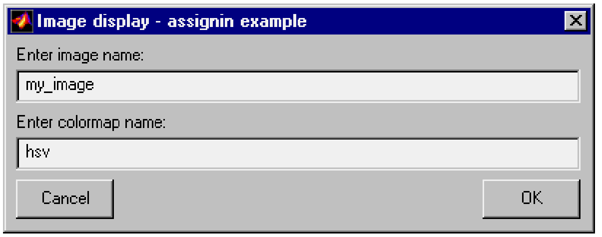
Remarks

The MATLAB base workspace is the workspace that is seen from the MATLAB command line (when not in the debugger). The caller workspace is the workspace of the function that called the M-file. Note that the base and caller workspaces are equivalent in the context of an M-file that is invoked from the MATLAB command line.

Examples

This example creates a dialog box for the image display function, prompting a user for an image name and a colormap name. The `assignin` function is used to export the user-entered values to the MATLAB workspace variables `imfile` and `cmap`.

```
prompt = {'Enter image name:','Enter colormap name:'};
title = 'Image display - assignin example';
lines = 1;
def = {'my_image','hsv'};
answer = inputdlg(prompt,title,lines,def);
assignin('base','imfile',answer{1});
assignin('base','cmap',answer{2});
```



See Also

`evalin`

Purpose Inverse tangent; result in radians

Syntax

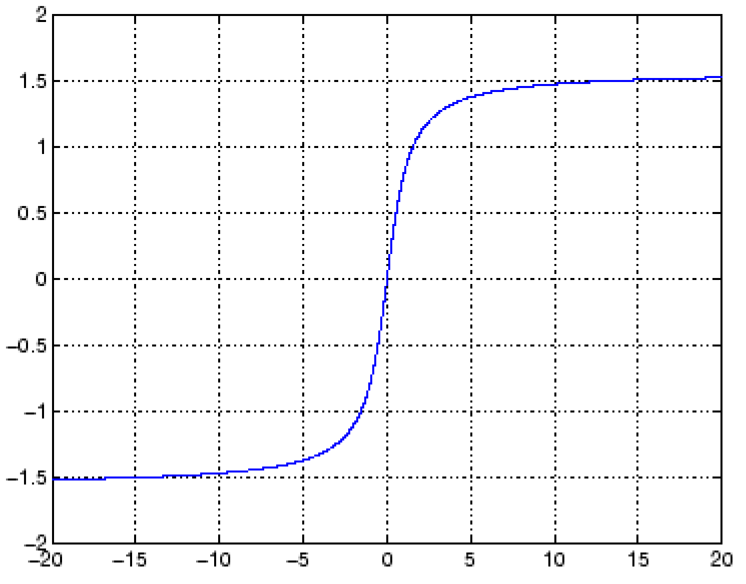
```
Y = atan(X)
```

Description `Y = atan(X)` returns the inverse tangent (arctangent) for each element of `X`. For real elements of `X`, `atan(X)` is in the range $[-\pi/2, \pi/2]$.

The `atan` function operates element-wise on arrays. The function's domains and ranges include complex values. All angles are in radians.

Examples Graph the inverse tangent function over the domain $-20 \le x \le 20$.

```
x = -20:0.01:20;
plot(x,atan(x)), grid on
```



Definition The inverse tangent can be defined as

$$\tan^{-1}(z) = \frac{i}{2}\log\left(\frac{i+z}{i-z}\right)$$

Algorithm

atan 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

atan2, tan, atand, atanh

atan2

Purpose

Four-quadrant inverse tangent

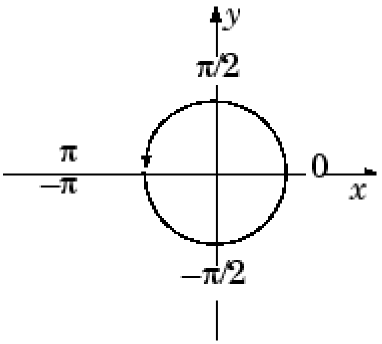
Syntax

```
P = atan2(Y,X)
```

Description

`P = atan2(Y,X)` returns an array `P` the same size as `X` and `Y` containing the element-by-element, four-quadrant inverse tangent (arctangent) of the real parts of `Y` and `X`. Any imaginary parts of the inputs are ignored.

Elements of `P` lie in the closed interval `[-pi,pi]`, where `pi` is the MATLAB floating-point representation of π. `atan` uses `sign(Y)` and `sign(X)` to determine the specific quadrant.



`atan2(Y,X)` contrasts with `atan(Y/X)`, whose results are limited to the interval $[-\pi/2, \pi/2]$, or the right side of this diagram.

Examples

Any complex number $z = x + iy$ is converted to polar coordinates with

```
r = abs(z)
theta = atan2(imag(z),real(z))
```

For example,

```
z = 4 + 3i;
r = abs(z)
theta = atan2(imag(z),real(z))
```

```
r =
     5

theta =
    0.6435
```

This is a common operation, so MATLAB provides a function, `angle(z)`, that computes `theta = atan2(imag(z),real(z))`.

To convert back to the original complex number

```
z = r *exp(i *theta)
z =

   4.0000 + 3.0000i
```

Algorithm

`atan2` 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

`angle`, `atan`, `atanh`

Purpose Inverse tangent; result in degrees

Syntax

```
Y = atand(X)
```

Description `Y = atand(X)` is the inverse tangent, expressed in degrees, of the elements of `X`.

See Also `tand`, `atan`

Purpose Inverse hyperbolic tangent

Syntax

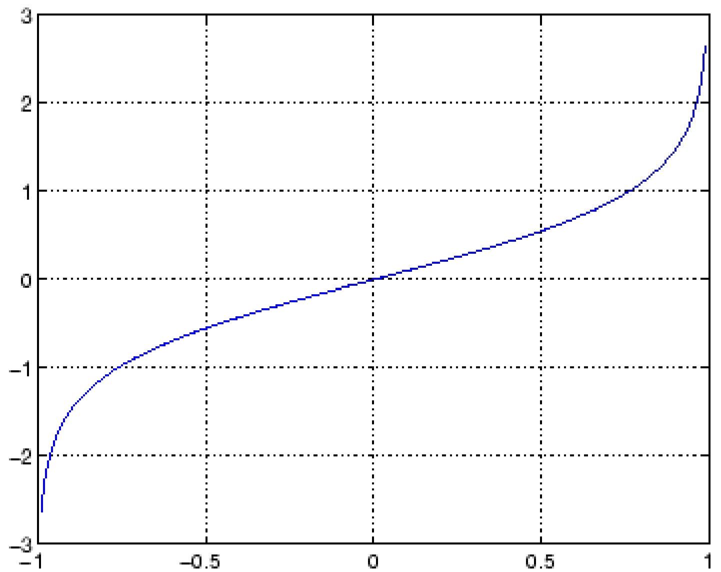
```
Y = atanh(X)
```

Description The `atanh` function operates element-wise on arrays. The function's domains and ranges include complex values. All angles are in radians.

`Y = atanh(X)` returns the inverse hyperbolic tangent for each element of `X`.

Examples Graph the inverse hyperbolic tangent function over the domain $-1 < x < 1$.

```
x = -0.99:0.01:0.99;
plot(x,atanh(x)), grid on
```



Definition The hyperbolic inverse tangent can be defined as

$$\tanh^{-1}(z) = \frac{1}{2}\log\left(\frac{1+z}{1-z}\right)$$

Algorithm atanh 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 atan2, atan, tanh

Purpose

Create audio player object

Syntax

```
player = audioplayer(Y, Fs)
player = audioplayer(Y, Fs, nBits)
player = audioplayer(Y, Fs, nBits, ID)
player = audioplayer(R)
player = audioplayer(R, ID)
```

Description

Note To use all of the features of the audio player object, your system needs a properly installed and configured sound card with 8- and 16-bit I/O, two channels, and support for sampling rates of up to 48 kHz.

`player = audioplayer(Y, Fs)` creates an audio player object for signal `Y`, using sample rate `Fs`. The function returns `player`, a handle to the audio player object. The audio player object supports methods and properties that you can use to control how the audio data is played.

The input signal `Y` can be a vector or two-dimensional array containing `single`, `double`, `int8`, `uint8`, or `int16` MATLAB data types. `Fs` is the sampling rate in Hz to use for playback. Valid values for `Fs` depend on the specific audio hardware installed. Typical values supported by most sound cards are 8000, 11025, 22050, and 44100 Hz.

`player = audioplayer(Y, Fs, nBits)` creates an audio player object and uses `nBits` bits per sample for floating point signal `Y`. Valid values for `nBits` are 8, 16, and 24 on Windows, 8 and 16 on UNIX. The default number of bits per sample for floating point signals is 16.

`player = audioplayer(Y, Fs, nBits, ID)` creates an audio player object using audio device identifier `ID` for output. If `ID` equals -1, the default output device will be used. This option is only available on Windows.

`player = audioplayer(R)` creates an audio player object using audio recorder object `R`.

`player = audioplayer(R, ID)` creates an audio player object from audio recorder object `R` using audio device identifier `ID` for output. This option is only available on Windows.

Remarks

The value range of the input sample depends on the MATLAB data type. The following table lists these ranges.

Data Type	Input Sample Value Range
`int8`	-128 to 127
`uint8`	0 to 255
`int16`	-32768 to 32767
`single`	-1 to 1
`double`	-1 to 1

Example

Load a sample audio file of Handel's Hallelujah Chorus, create an audio player object, and play back only the first three seconds. `y` contains the audio samples and `Fs` is the sampling rate. You can use any of the `audioplayer` functions listed above on the player:

```
load handel;
player = audioplayer(y, Fs);
play(player,[1 (get(player, 'SampleRate')*3)]);
```

To stop the playback, use this command:

```
stop(player); % Equivalent to player.stop
```

Methods

After you create an audio player object, you can use the methods listed below on that object. `player` represents a handle to the audio player object.

Method	Description

`play(player)`
`play(player, start)`
`play(player, [start stop])`
`play(player, range)`
	Starts playback from the beginning and plays to the end of audio player object `player`. Play audio from the sample indicated by `start` to the end, or from the sample indicated by `start` up to the sample indicated by `stop`. The values of `start` and `stop` can also be specified in a two-element vector `range`.

`playblocking(player)`
`playblocking(player, start)`
`playblocking(player, [start stop])`
`playblocking(player, range)`
	Same as play, but does not return control until playback completes.

`stop(player)`	Stops playback.
`pause(player)`	Pauses playback.
`resume(player)`	Restarts playback from where playback was paused.
`isplaying(player)`	Indicates whether playback is in progress. If `0`, playback is not in progress. If `1`, playback is in progress.

`display(player)`
`disp(player)`
`get(player)`
	Displays all property information about audio player `player`.

Properties

Audio player objects have the properties listed below. To set a user-settable property, use this syntax:

```
set(player, 'property1', value,'property2',value,...)
```

To view a read-only property,

```
get(player,'property')  % Displays 'property' setting.
```

Property	Description	Type
`Type`	Name of the object's class.	Read-only
`SampleRate`	Sampling frequency in Hz.	User-settable
`BitsPerSample`	Number of bits per sample.	Read-only
`NumberOfChannels`	Number of channels.	Read-only
`TotalSamples`	Total length, in samples, of the audio data.	Read-only
`Running`	Status of the audio player (`'on'` or `'off'`).	Read-only
`CurrentSample`	Current sample being played by the audio output device (if it is not playing, `CurrentSample` is the next sample to be played with `play` or `resume`).	Read-only
`UserData`	User data of any type.	User-settable
`Tag`	User-specified object label string.	User-settable
For information on using the following four properties, see Creating Timer Callback Functions in the MATLAB documentation. Note that for audio player object callbacks, `eventStruct (event)` is currently empty (`[]`).		

Property	Description	Type
`TimerFcn`	Handle to a user-specified callback function that is executed repeatedly (at `TimerPeriod` intervals) during playback.	User-settable
`TimerPeriod`	Time, in seconds, between `TimerFcn` callbacks.	User-settable
`StartFcn`	Handle to a user-specified callback function that is executed once when playback starts.	User-settable
`StopFcn`	Handle to a user-specified callback function that is executed once when playback stops.	User-settable

See Also

`audiorecorder`, `sound`, `wavplay`, `wavwrite`, `wavread`, `get`, `set`, `methods`

audiorecorder

Purpose

Create audio recorder object

Syntax

```
y = audiorecorder
y = audiorecorder(Fs, nbits, nchans)
y = audiorecorder(Fs, nbits, channels, id)
```

Description

Note To use all of the features of the audiorecorder object, your system must have a properly installed and configured sound card with 8- and 16-bit I/O and support for sampling rates of up to 48 kHz.

`y = audiorecorder` creates an 8000 Hz, 8-bit, 1 channel audiorecorder object. `y` is a handle to the object. The audiorecorder object supports methods and properties that you can use to record audio data.

`y = audiorecorder(Fs, nbits, nchans)` creates an audiorecorder object using the sampling rate `Fs` (in Hz), the sample size `nbits`, and the number of channels`nchans`. `Fs` can be any sampling rate supported by the audio hardware. Common sampling rates are 8000, 11025, 22050, and 44100. The value of `nbits` must be `8`, `16`, or `24`, on Windows, and `8` or `16` on UNIX. The number of channels, `nchans` must be `1` (mono) or `2` (stereo).

`y = audiorecorder(Fs, nbits, channels, id)` creates an audiorecorder object using the audio device specified by its `id` for input. If `id` equals -1, the default input device will be used. This option is only available on Windows.

Examples

Example 1

Using a microphone, record your voice, using a sample rate of 22050 Hz, 16 bits per sample, and one channel. Speak into the microphone, then pause the recording. Play back what you've recorded so far. Record some more, then stop the recording. Finally, return the recorded data to MATLAB as an int16 array.

```
r = audiorecorder(22050, 16, 1);
```

```
record(r);     % speak into microphone...
pause(r);
p = play(r);   % listen
resume(r);     % speak again
stop(r);
p = play(r);   % listen to complete recording
mySpeech = getaudiodata(r, 'int16'); % get data as int16 array
```

Remarks

The current implementation of `audiorecorder` is not intended for long, high-sample-rate recording because it uses system memory for storage and does not use disk buffering. When large recordings are attempted, MATLAB performance may degrade.

Methods

After you create an audiorecorder object, you can use the methods listed below on that object. `y` represents the name of the returned audiorecorder object

Method	Description

`record(y)`
 	
`record(y,length)`
	Starts recording.
	
	Records for `length` number of seconds.

`recordblocking(y,length)`	Same as record, but does not return control until recording completes.
`stop(y)`	Stops recording.
`pause(y)`	Pauses recording.
`resume(y)`	Restarts recording from where recording was paused.
`isrecording(y)`	Indicates the status of recording. If `0`, recording is not in progress. If `1`, recording is in progress.
`play(y)`	Creates an `audioplayer`, plays the recorded audio data, and returns a handle to the created `audioplayer`.

Method	Description
`getplayer(y)`	Creates an `audioplayer` and returns a handle to the created `audioplayer`.
`getaudiodata(y)` `getaudiodata(y,'type')`	Returns the recorded audio data to the MATLAB workspace. `type` is a string containing the desired data type. Supported data types are `double`, `single`, `int16`, `int8`, or `uint8`. If `type` is omitted, it defaults to `'double'`. For `double` and `single`, the array contains values between -1 and 1. For `int8`, values are between -128 to 127. For `uint8`, values are from 0 to 255. For `int16`, values are from -32768 to 32767. If the recording is in mono, the returned array has one column. If it is in stereo, the array has two columns, one for each channel.

`display(y)`
`disp(y)`
`get(y)`
	Displays all property information about audio recorder `y`.

Properties

Audio recorder objects have the properties listed below. To set a user-settable property, use this syntax:

```
set(y, 'property1', value,'property2',value,...)
```

To view a read-only property,

```
get(y,'property')  %displays 'property' setting.
```

Property	Description	Type
`Type`	Name of the object's class.	Read-only
`SampleRate`	Sampling frequency in Hz.	Read-only
`BitsPerSample`	Number of bits per recorded sample.	Read-only
`NumberOfChannels`	Number of channels of recorded audio.	Read-only
`TotalSamples`	Total length, in samples, of the recording.	Read-only
`Running`	Status of the audio recorder (`'on'` or `'off'`).	Read-only
`CurrentSample`	Current sample being recorded by the audio output device (if it is not recording, `currentsample` is the next sample to be recorded with `record` or `resume`).	Read-only
`UserData`	User data of any type.	User-settable
For information on using the following four properties, see Creating Timer Callback Functions in the MATLAB documentation. Note that for audio object callbacks, `eventStruct` (`event`) is currently empty (`[]`).		
`TimerFcn`	Handle to a user-specified callback function that is executed repeatedly (at TimerPeriod intervals) during recording.	User-settable
`TimerPeriod`	Time, in seconds, between `TimerFcn` callbacks.	User-settable

Property	Description	Type
`StartFcn`	Handle to a user-specified callback function that is executed once when recording starts.	User-settable
`StopFcn`	Handle to a user-specified callback function that is executed once when recording stops.	User-settable
`NumberOfBuffers`	Number of buffers used for recording (you should adjust this only if you have skips, dropouts, etc., in your recording).	User-settable
`BufferLength`	Length in seconds of buffer (you should adjust this only if you have skips, dropouts, etc., in your recording).	User-settable
`Tag`	User-specified object label string.	User-settable

See Also

`audioplayer`, `wavread`, `wavrecord`, `wavwrite`, `get`, `set`, `methods`

Purpose Information about NeXT/SUN (`.au`) sound file

Syntax

```
[m d] = aufinfo(aufile)
```

Description `[m d] = aufinfo(aufile)` returns information about the contents of the AU sound file specified by the string `aufile`.

`m` is the string `'Sound (AU) file'`, if `filename` is an AU file. Otherwise, it contains an empty string (`''`).

`d` is a string that reports the number of samples in the file and the number of channels of audio data. If `filename` is not an AU file, it contains the string `'Not an AU file'`.

See Also `auread`

auread

Purpose

Read NeXT/SUN (`.au`) sound file

Graphical Interface

As an alternative to `auread`, use the Import Wizard. To activate the Import Wizard, select **Import data** from the **File** menu.

Syntax

```
y = auread('aufile')
[y,Fs,bits] = auread('aufile')
[...] = auread('aufile',N)
[...] = auread('aufile',[N1 N2])
siz = auread('aufile','size')
```

Description

`y = auread('aufile')` loads a sound file specified by the string `aufile`, returning the sampled data in `y`. The `.au` extension is appended if no extension is given. Amplitude values are in the range `[-1,+1]`. `auread` supports multichannel data in the following formats:

- 8-bit mu-law
- 8-, 16-, and 32-bit linear
- Floating-point

`[y,Fs,bits] = auread('aufile')` returns the sample rate (`Fs`) in Hertz and the number of bits per sample (`bits`) used to encode the data in the file.

`[...] = auread('aufile',N)` returns only the first `N` samples from each channel in the file.

`[...] = auread('aufile',[N1 N2])` returns only samples `N1` through `N2` from each channel in the file.

`siz = auread('aufile','size')` returns the size of the audio data contained in the file in place of the actual audio data, returning the vector `siz = [samples channels]`.

See Also

`auwrite`, `wavread`

Purpose Write NeXT/SUN (`.au`) sound file

Syntax

```
auwrite(y,'aufile')
auwrite(y,Fs,'aufile')
auwrite(y,Fs,N,'aufile')
auwrite(y,Fs,N,'method','aufile')
```

Description

`auwrite(y,'aufile')` writes a sound file specified by the string `aufile`. The data should be arranged with one channel per column. Amplitude values outside the range `[-1,+1]` are clipped prior to writing. `auwrite` supports multichannel data for 8-bit mu-law and 8- and 16-bit linear formats.

`auwrite(y,Fs,'aufile')` specifies the sample rate of the data in Hertz.

`auwrite(y,Fs,N,'aufile')` selects the number of bits in the encoder. Allowable settings are `N = 8` and `N = 16`.

`auwrite(y,Fs,N,'method','aufile')` allows selection of the encoding method, which can be either `mu` or `linear`. Note that mu-law files must be 8-bit. By default, `method = 'mu'`.

See Also `auread`, `wavwrite`

Purpose Create new Audio/Video Interleaved (AVI) file

Syntax

```
aviobj = avifile(filename)
aviobj = avifile(filename, 'Param1', Val1, 'Param2', Val2,
   ...)
```

Description

`aviobj = avifile(filename)` creates an `avifile` object, giving it the name specified in `filename`, using default values for all `avifile` object properties. AVI is a file format for storing audio and video data. If `filename` does not include an extension, `avifile` appends `.avi` to the filename. To close all open AVI files, use the `clear mex` command.

`avifile` returns a handle to an AVI file object `aviobj`. You use this object to refer to the AVI file in other functions. An AVI file object supports properties and methods that control aspects of the AVI file created.

`aviobj = avifile(filename, 'Param1', Val1, 'Param2', Val2,...)` creates an `avifile` object with the property values specified by parameter/value pairs. This table lists available parameters.

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). You must set this parameter before calling `addframe`, unless you are using `addframe` with the MATLAB movie syntax.	There is no default colormap.
`'compression'`	A text string specifying the compression codec to use.	

Parameter	Value		Default

	On Windows:
	`'Indeo3'`
	`'Indeo5'`
	`'Cinepak'`
	`'MSVC'`
	`'RLE'`
	`'None'`
		On UNIX:
		`'None'`
			`'Indeo5'` on Windows.
			`'None'` on UNIX.

	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 cannot find the specified custom compressor. You must set this parameter before calling `addframe`.		
`'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.		2.1429 key frames per second.

Parameter	Value	Default
`'quality'`	A number between 0 and 100. This parameter has no effect on uncompressed movies. Higher quality numbers result in higher video quality and larger file sizes. Lower quality numbers result in lower video quality and smaller file sizes. You must set this parameter before calling `addframe`.	75
`'videoname'`	A descriptive name for the video stream. This parameter must be no greater than 64 characters long and must be set before using `addframe`.	The default is the `filename`.

You can also use structure syntax (also called dot notation) to set `avifile` object properties. The property name must be typed in full, however it is not case sensitive. For example, to set the `quality` property to 100, use the following syntax:

```
aviobj = avifile('myavifile');
aviobj.quality = 100;
```

All the field names of an `avifile` object are the same as the parameter names listed in the table, except for the `keyframe` parameter. To set this property using dot notation, specify the `KeyFramePerSec` property. For example, to change the value of `keyframe` to `2.5`, type

```
aviobj.KeyFramePerSec = 2.5;
```

Example

This example shows how to use the `avifile` function to create the AVI file `example.avi`.

```
fig=figure;
set(fig,'DoubleBuffer','on');
```

```
set(gca,'xlim',[-80 80],'ylim',[-80 80],...
    'NextPlot','replace','Visible','off')
mov = avifile('example.avi')
x = -pi:.1:pi;
radius = 0:length(x);
for k=1:length(x)
 h = patch(sin(x)*radius(k),cos(x)*radius(k),...
    [abs(cos(x(k))) 0 0]);
 set(h,'EraseMode','xor');
 F = getframe(gca);
 mov = addframe(mov,F);
end
mov = close(mov);
```

See Also

addframe, close, movie2avi

Purpose

Information about Audio/Video Interleaved (AVI) file

Syntax

```
fileinfo = aviinfo(filename)
```

Description

`fileinfo = aviinfo(filename)` returns a structure whose fields contain information about the AVI file specified in the string `filename`. If `filename` does not include an extension, then `.avi` is used. The file must be in the current working directory or in a directory on the MATLAB path.

The set of fields in the `fileinfo` structure is shown below.

Field Name	Description
`AudioFormat`	String containing the name of the format used to store the audio data, if audio data is present
`AudioRate`	Integer indicating the sample rate in Hertz of the audio stream, if audio data is present
`Filename`	String specifying the name of the file
`FileModDate`	String containing the modification date of the file
FileSize	Integer indicating the size of the file in bytes
`FramesPerSecond`	Integer indicating the desired frames per second
`Height`	Integer indicating the height of the AVI movie in pixels
`ImageType`	String indicating the type of image. Either `'truecolor'` for a truecolor (RGB) image, or `'indexed'` for an indexed image.

Field Name	Description
NumAudioChannels	Integer indicating the number of channels in the audio stream, if audio data is present
NumFrames	Integer indicating the total number of frames in the movie
NumColormapEntries	Integer specifying the number of colormap entries. For a truecolor image, this value is 0 (zero).
Quality	Number between 0 and 100 indicating the video quality in the AVI file. Higher quality numbers indicate higher video quality; lower quality numbers indicate lower video quality. This value is not always set in AVI files and therefore can be inaccurate.
VideoCompression	String containing the compressor used to compress the AVI file. If the compressor is not Microsoft Video 1, Run Length Encoding (RLE), Cinepak, or Intel Indeo, `aviinfo` returns the four-character code that identifies the compressor.
Width	Integer indicating the width of the AVI movie in pixels

See also

`avifile`, `aviread`

aviread

Purpose

Read Audio/Video Interleaved (AVI) file

Syntax

```
mov = aviread(filename)
mov = aviread(filename, index)
```

Description

`mov = aviread(filename)` reads the AVI movie `filename` into the MATLAB movie structure `mov`. If `filename` does not include an extension, then `.avi` is used. Use the `movie` function to view the movie `mov`. On UNIX, `filename` must be an uncompressed AVI file.

`mov` has two fields, `cdata` and `colormap`. The content of these fields varies depending on the type of image.

Image Type	cdata Field	colormap Field
`Truecolor`	Height-by-width-by-3 array of `uint8` values	Empty
`Indexed`	Height-by-width array of `uint8` values	m-by-3 array of `double` values

`aviread` supports 8-bit frames, for indexed and grayscale images, 16-bit grayscale images, or 24-bit truecolor images. Note, however, that `movie` only accepts 8-bit image frames; it does not accept 16-bit grayscale image frames.

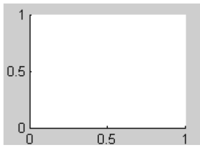
`mov = aviread(filename, index)` reads only the frames specified by `index`. `index` can be a single index or an array of indices into the video stream. In AVI files, the first frame has the index value 1, the second frame has the index value 2, and so on.

See also

`avifile`, `aviinfo`, `movie`

Purpose

Create axes graphics object



GUI Alternatives

To create a figure select **New > Figure** from the MATLAB Desktop or a figure's **File** menu. To add an axes to a figure, click one of the *New Subplots* icons in the Figure Palette, and slide right to select an arrangement of new axes. For details, see "Plotting Tools — Interactive Plotting" in the MATLAB Graphics documentation.

Syntax

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

Description

`axes` is the low-level function for creating axes graphics objects.

`axes` creates an axes graphics object in the current figure using default property values.

`axes('PropertyName',propertyvalue,...)` creates an axes object having the specified property values. MATLAB uses default values for any properties that you do not explicitly define as arguments.

`axes(h)` makes existing axes `h` the current axes and brings the figure containing it into focus. It also makes `h` the first axes listed in the figure's `Children` property and sets the figure's `CurrentAxes` property to `h`. The current axes is the target for functions that draw image, line, patch, rectangle, surface, and text graphics objects.

If you want to make an axes the current axes without changing the state of the parent figure, set the `CurrentAxes` property of the figure containing the axes:

```
set(figure_handle,'CurrentAxes',axes_handle)
```

This is useful if you want a figure to remain minimized or stacked below other figures, but want to specify the current axes.

`h = axes(...)` returns the handle of the created axes object.

Remarks

MATLAB automatically creates an axes, if one does not already exist, when you issue a command that creates a graph.

The `axes` function accepts property name/property value pairs, structure arrays, and cell arrays as input arguments (see the `set` and `get` commands for examples of how to specify these data types). These properties, which control various aspects of the axes object, are described in the `Axes Properties` section.

Use the `set` function to modify the properties of an existing axes or the `get` function to query the current values of axes properties. Use the `gca` command to obtain the handle of the current axes.

The `axis` (not `axes`) function provides simplified access to commonly used properties that control the scaling and appearance of axes.

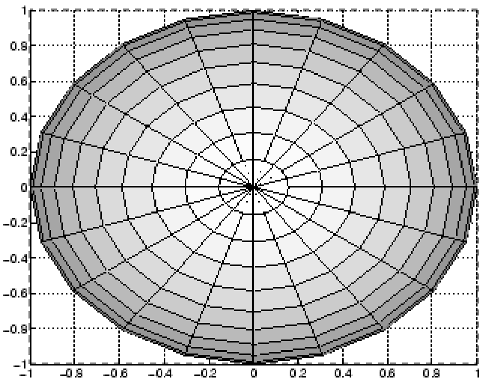
While the basic purpose of an axes object is to provide a coordinate system for plotted data, axes properties provide considerable control over the way MATLAB displays data.

Stretch-to-Fill

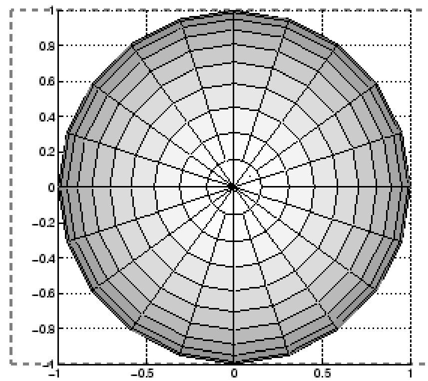
By default, MATLAB stretches the axes to fill the axes position rectangle (the rectangle defined by the last two elements in the `Position` property). This results in graphs that use the available space in the rectangle. However, some 3-D graphs (such as a sphere) appear distorted because of this stretching, and are better viewed with a specific three-dimensional aspect ratio.

Stretch-to-fill is active when the `DataAspectRatioMode`, `PlotBoxAspectRatioMode`, and `CameraViewAngleMode` are all auto (the default). However, stretch-to-fill is turned off when the `DataAspectRatio`, `PlotBoxAspectRatio`, or `CameraViewAngle` is user-specified, or when one or more of the corresponding modes is set to manual (which happens automatically when you set the corresponding property value).

This picture shows the same sphere displayed both with and without the stretch-to-fill. The dotted lines show the axes rectangle.



Stretch-to-fill active



Stretch-to-fill disabled

When stretch-to-fill is disabled, MATLAB sets the size of the axes to be as large as possible within the constraints imposed by the `Position` rectangle without introducing distortion. In the picture above, the height of the rectangle constrains the axes size.

Examples

Zooming

Zoom in using aspect ratio and limits:

```
sphere
set(gca,'DataAspectRatio',[1 1 1],...
        'PlotBoxAspectRatio',[1 1 1],'ZLim',[-0.6 0.6])
```

Zoom in and out using the `CameraViewAngle`:

```
sphere
set(gca,'CameraViewAngle',get(gca,'CameraViewAngle')-5)
set(gca,'CameraViewAngle',get(gca,'CameraViewAngle')+5)
```

Note that both examples disable the MATLAB stretch-to-fill behavior.

Positioning the Axes

The axes Position property enables you to define the location of the axes within the figure window. For example,

```
h = axes('Position',position_rectangle)
```

creates an axes object at the specified position within the current figure and returns a handle to it. Specify the location and size of the axes with a rectangle defined by a four-element vector,

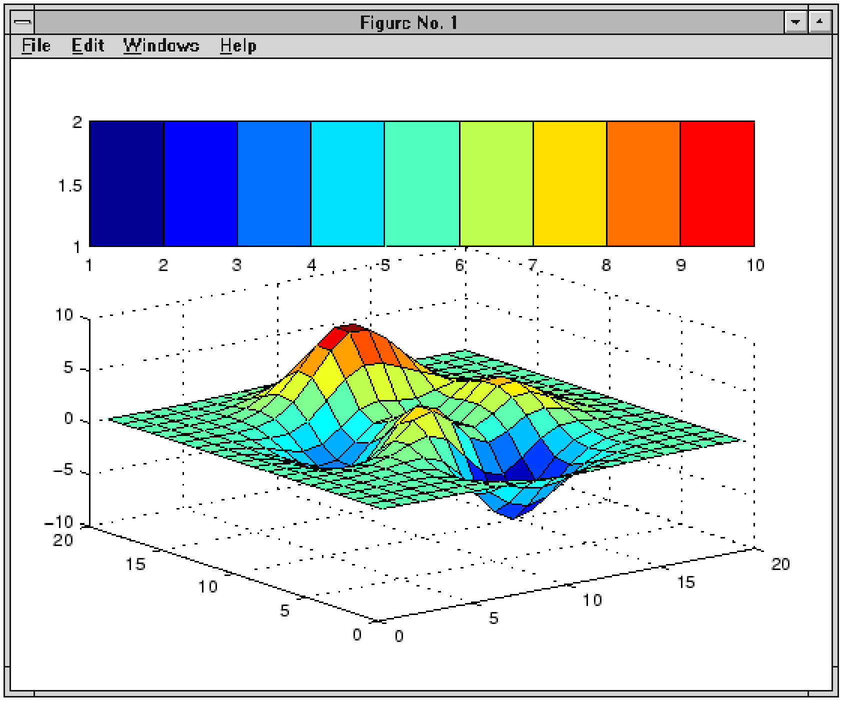
```
position_rectangle = [left, bottom, width, height];
```

The left and bottom elements of this vector define the distance from the lower left corner of the figure to the lower left corner of the rectangle. The width and height elements define the dimensions of the rectangle. You specify these values in units determined by the Units property. By default, MATLAB uses normalized units where (0,0) is the lower left corner and (1.0,1.0) is the upper right corner of the figure window.

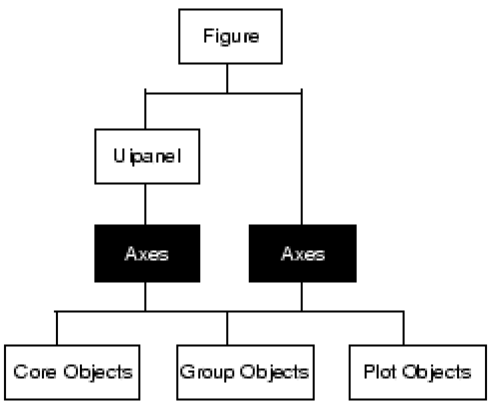
You can define multiple axes in a single figure window:

```
axes('position',[.1  .1  .8  .6])
mesh(peaks(20));
axes('position',[.1  .7  .8  .2])
pcolor([1:10;1:10]);
```

In this example, the first plot occupies the bottom two-thirds of the figure, and the second occupies the top third.



Object Hierarchy



Setting Default Properties

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

```
set(0,'DefaultAxesPropertyName',PropertyValue,...)
set(gcf,'DefaultAxesPropertyName',PropertyValue,...)
```

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

See Also

`axis`, `cla`, `clf`, `figure`, `gca`, `grid`, `subplot`, `title`, `xlabel`, `ylabel`, `zlabel`, `view`

"Axes Operations" on page 1-95 for related functions

"Axes Properties" for more examples

See "Types of Graphics Objects" for information on core, group, plot, and annotation objects.

Purpose

Axes 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.

Axes Property Descriptions

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

`ActivePositionProperty`
: `{outerposition} | position`

  Use `OuterPosition` or `Position` property for resize. `ActivePositionProperty` specifies which property MATLAB uses to determine the size of the axes when the figure is resized (interactively or during a printing or exporting operation).

  See `OuterPosition` and `Position` for related properties.

  See Automatic Axes Resize for a discussion of how to use axes positioning properties.

`ALim`
: `[amin, amax]`

  Alpha axis limits. A two-element vector that determines how MATLAB maps the `AlphaData` values of surface, patch, and image objects to the figure's alphamap. `amin` is the value of the data mapped to the first alpha value in the alphamap, and `amax` is the value of the data mapped to the last alpha value in the alphamap. Data values in between are linearly interpolated across the alphamap, while data values outside are clamped to either the first or last alphamap value, whichever is closest.

When `ALimMode` is `auto` (the default), MATLAB assigns `amin` the minimum data value and `amax` the maximum data value in the graphics object's `AlphaData`. This maps `AlphaData` elements with minimum data values to the first alphamap entry and those with maximum data values to the last alphamap entry. Data values in between are mapped linearly to the values

If the axes contains multiple graphics objects, MATLAB sets `ALim` to span the range of all objects' `AlphaData` (or `FaceVertexAlphaData` for patch objects).

See the `alpha` function reference page for additional information.

`ALimMode`
`{auto} | manual`

Alpha axis limits mode. In `auto` mode, MATLAB sets the `ALim` property to span the `AlphaData` limits of the graphics objects displayed in the axes. If `ALimMode` is `manual`, MATLAB does not change the value of `ALim` when the `AlphaData` limits of axes children change. Setting the `ALim` property sets `ALimMode` to `manual`.

`AmbientLightColor`
`ColorSpec`

The background light in a scene. Ambient light is a directionless light that shines uniformly on all objects in the axes. However, if there are no visible light objects in the axes, MATLAB does not use `AmbientLightColor`. If there are light objects in the axes, the `AmbientLightColor` is added to the other light sources.

`AspectRatio`
(Obsolete)

This property produces a warning message when queried or changed. It has been superseded by the DataAspectRatio[Mode] and PlotBoxAspectRatio[Mode] properties.

BeingDeleted

on | {off}

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.

See the close and delete function reference pages for related information.

Box

on | {off}

Axes box mode. This property specifies whether to enclose the axes extent in a box for 2-D views or a cube for 3-D views. The default is to not display the box.

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 executing, callback 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 that executes whenever you press a mouse button while the pointer is within the axes, but not over another graphics object parented to the axes. For 3-D views, the active area is defined by a rectangle that encloses the axes.

See the figure's SelectionType property to determine whether 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 axes associated with the button down event and an event structure, which is empty for this property)

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

Some Plotting Functions Reset the ButtonDownFcn

Most MATLAB plotting functions clear the axes and reset a number of axes properties, including the ButtonDownFcn before plotting data. If you want to create an interface that enables users to plot data interactively, consider using a control device such as a push button (`uicontrol`), which is not affected by plotting functions. See "Example — Using Function Handles in GUIs" for an example.

If you must use the axes `ButtonDownFcn` to plot data, then you should use low-level functions such as `line` `patch`, and `surface` and manage the process with the figure and axes `NextPlot` properties.

See "High-Level Versus Low-Level" for information on how plotting functions behave.

See "Preparing Figures and Axes for Graphics" for more information.

Camera Properties

See View Control with the Camera Toolbar for information related to the Camera properties

`CameraPosition`

`[x, y, z]` axes coordinates

The location of the camera. This property defines the position from which the camera views the scene. Specify the point in axes coordinates.

If you fix `CameraViewAngle`, you can zoom in and out on the scene by changing the `CameraPosition`, moving the camera closer to the `CameraTarget` to zoom in and farther away from the `CameraTarget` to zoom out. As you change the `CameraPosition`, the amount of perspective also changes, if `Projection` is `perspective`. You can also zoom by changing the `CameraViewAngle`; however, this does not change the amount of perspective in the scene.

`CameraPositionMode`
`{auto} | manual`

Auto or manual `CameraPosition`. When set to `auto`, MATLAB automatically calculates the `CameraPosition` such that the camera lies a fixed distance from the `CameraTarget` along the azimuth and elevation specified by `view`. Setting a value for `CameraPosition` sets this property to manual.

`CameraTarget`
`[x, y, z]` axes coordinates

Camera aiming point. This property specifies the location in the axes that the camera points to. The `CameraTarget` and the `CameraPosition` define the vector (the view axis) along which the camera looks.

`CameraTargetMode`
`{auto} | manual`

Auto or manual `CameraTarget` *placement*. When this property is `auto`, MATLAB automatically positions the `CameraTarget` at the centroid of the axes plot box. Specifying a value for `CameraTarget` sets this property to `manual`.

`CameraUpVector`
`[x, y, z]` axes coordinates

Camera rotation. This property specifies the rotation of the camera around the viewing axis defined by the `CameraTarget` and the `CameraPosition` properties. Specify `CameraUpVector` as a three-element array containing the x, y, and z components of the vector. For example, `[0 1 0]` specifies the positive y-axis as the up direction.

The default `CameraUpVector` is `[0 0 1]`, which defines the positive z-axis as the up direction.

`CameraUpVectorMode`
`auto} | manual`

Default or user-specified up vector. When `CameraUpVectorMode` is `auto`, MATLAB uses a value of `[0 0 1]` (positive *z*-direction is up) for 3-D views and `[0 1 0]` (positive *y*-direction is up) for 2-D views. Setting a value for `CameraUpVector` sets this property to `manual`.

`CameraViewAngle`
scalar greater than 0 and less than or equal to 180 (angle in degrees)

The field of view. This property determines the camera field of view. Changing this value affects the size of graphics objects displayed in the axes, but does not affect the degree of perspective distortion. The greater the angle, the larger the field of view, and the smaller objects appear in the scene.

`CameraViewAngleMode`
`{auto} | manual`

Auto or manual `CameraViewAngle`. When in `auto` mode, MATLAB sets `CameraViewAngle` to the minimum angle that captures the entire scene (up to 180°).

The following table summarizes MATLAB automatic camera behavior.

CameraViewAngle	Camera Target	Camera Position	Behavior
auto	auto	auto	CameraTarget is set to plot box centroid, CameraViewAngle is set to capture entire scene, CameraPosition is set along the view axis.
auto	auto	manual	CameraTarget is set to plot box centroid, CameraViewAngle is set to capture entire scene.
auto	manual	auto	CameraViewAngle is set to capture entire scene, CameraPosition is set along the view axis.
auto	manual	manual	CameraViewAngle is set to capture entire scene.
manual	auto	auto	CameraTarget is set to plot box centroid, CameraPosition is set along the view axis.
manual	auto	manual	CameraTarget is set to plot box centroid

CameraViewAngle	Camera Target	Camera Position	Behavior
manual	manual	auto	CameraPosition is set along the view axis.
manual	manual	manual	All camera properties are user-specified.

Children
    vector of graphics object handles

    . A vector containing the handles of all graphics objects rendered within the axes (whether visible or not). The graphics objects that can be children of axes are image, light, line, patch, rectangle, surface, and text. You can change the order of the handles and thereby change the stacking of the objects on the display.

    The text objects used to label the *x*-, *y*-, and *z*-axes are also children of axes, but their HandleVisibility properties are set to callback. This means their handles do not show up in the axes Children property unless you set the Root ShowHiddenHandles property to on.

    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.

CLim
    [cmin, cmax]

    Color axis limits. A two-element vector that determines how MATLAB maps the CData values of surface and patch objects to the figure's colormap. cmin is the value of the data mapped to the first color in the colormap, and cmax is the value of the data mapped to the last color in the colormap. Data values in between are linearly interpolated across the colormap, while data values outside are clamped to either the first or last colormap color, whichever is closest.

When `CLimMode` is `auto` (the default), MATLAB assigns `cmin` the minimum data value and `cmax` the maximum data value in the graphics object's `CData`. This maps `CData` elements with minimum data value to the first colormap entry and with maximum data value to the last colormap entry.

If the axes contains multiple graphics objects, MATLAB sets `CLim` to span the range of all objects' `CData`.

See the `caxis` function reference page for related information.

`CLimMode`
: `{auto} | manual`

Color axis limits mode. In `auto` mode, MATLAB sets the `CLim` property to span the `CData` limits of the graphics objects displayed in the axes. If `CLimMode` is `manual`, MATLAB does not change the value of `CLim` when the `CData` limits of axes children change. Setting the `CLim` property sets this property to `manual`.

`Clipping`
: `{on} | off`

This property has no effect on axes.

`Color`
: `{none} | ColorSpec`

Color of the axes back planes. Setting this property to `none` means the axes is transparent and the figure color shows through. A `ColorSpec` is a three-element RGB vector or one of the MATLAB predefined names. Note that while the default value is `none`, the `matlabrc.m` file may set the axes `color` to a specific color.

`ColorOrder`
: m-by-3 matrix of RGB values

Colors to use for multiline plots. ColorOrder is an *m*-by-3 matrix of RGB values that define the colors used by the plot and plot3 functions to color each line plotted. If you do not specify a line color with plot and plot3, these functions cycle through the ColorOrder to obtain the color for each line plotted. To obtain the current ColorOrder, which may be set during startup, get the property value:

```
get(gca,'ColorOrder')
```

Note that if the axes NextPlot property is set to replace (the default), high-level functions like plot reset the ColorOrder property before determining the colors to use. If you want MATLAB to use a ColorOrder that is different from the default, set NextPlot to replacechildren. You can also specify your own default ColorOrder.

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 an axes object. You must define this property as a default value for axes. For example, the statement

```
set(0,'DefaultAxesCreateFcn',@ax_create)
```

defines a default value on the Root level that sets axes properties whenever you (or MATLAB) create an axes.

```
function ax_create(src,evnt)
 set(src,'Color','b',...
 'XLim',[1 10],...
 'YLim',[0 100])
end
```

MATLAB executes this function after setting all properties for the axes. Setting the `CreateFcn` property on an existing axes 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 can be queried using `gcbo`.

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

`CurrentPoint`

2-by-3 matrix

Location of last button click, in axes data units. A 2-by-3 matrix containing the coordinates of two points defined by the location of the pointer when the mouse was last clicked. MATLAB returns the coordinates with respect to the requested axes.

Clicking Within the Axes — Orthogonal Projection

The two points lie on the line that is perpendicular to the plane of the screen and passes through the pointer. This is true for both 2-D and 3-D views.

The 3-D coordinates are the points, in the axes coordinate system, where this line intersects the front and back surfaces of the axes volume (which is defined by the axes *x*, *y*, and *z* limits).

The returned matrix is of the form:

$$\begin{bmatrix} x_{front} & y_{front} & z_{front} \\ x_{back} & y_{back} & z_{back} \end{bmatrix}$$

where *front* defines the point nearest to the camera position. Therefore, if `cp` is the matrix returned by the `CurrentPoint` property, then the first row,

```
cp(1,:)
```

specifies the point nearest the viewer and the second row,

```
cp(2,:)
```

specifies the point furthest from the viewer.

Clicking Outside the Axes — Orthogonal Projection

When you click outside the axes volume, but within the figure, the values returned are:

- Back point — a point in the plane of the camera target (which is perpendicular to the viewing axis).
- Front point — a point in the camera position plane (which is perpendicular to the viewing axis).

These points lie on a line that passes through the pointer and is perpendicular to the camera target and camera position planes.

Clicking Within the Axes — Perspective Projection

The values of the current point when using perspective project can be different from the same point in orthographic projection because the shape of the axes volume can be different.

Clicking Outside the Axes — Perspective Projection

Clicking outside of the axes volume causes the front point to be returned as the current camera position at all times. Only the back point updates with the coordinates of a point that lies on a line extending from the camera position through the pointer and intersecting the camera target at the point.

Related Information

See Defining Scenes with Camera Graphics for information on the camera properties.

See View Projection Types for information on orthogonal and perspective projections.

`DataAspectRatio`
`[dx dy dz]`

Relative scaling of data units. A three-element vector controlling the relative scaling of data units in the *x*, *y*, and *z* directions. For example, setting this property t o `[1 2 1]` causes the length of one unit of data in the *x* direction to be the same length as two units of data in the *y* direction and one unit of data in the *z* direction.

Note that the `DataAspectRatio` property interacts with the `PlotBoxAspectRatio`, `XLimMode`, `YLimMode`, and `ZLimMode` properties to control how MATLAB scales the *x*-, *y*-, and *z*-axis. Setting the `DataAspectRatio` will disable the stretch-to-fill behavior if `DataAspectRatioMode`, `PlotBoxAspectRatioMode`, and `CameraViewAngleMode` are all `auto`. The following table describes the interaction between properties when `stretch-to-fill` behavior is disabled.

X-, Y-, Z-Limits	DataAspect Ratio	PlotBox AspectRatio	Behavior
`auto`	`auto`	`auto`	Limits chosen to span data range in all dimensions.

X-, Y-, Z-Limits	DataAspect Ratio	PlotBox AspectRatio	Behavior
auto	auto	manual	Limits chosen to span data range in all dimensions. DataAspectRatio is modified to achieve the requested PlotBoxAspectRatio within the limits selected by MATLAB.
auto	manual	auto	Limits chosen to span data range in all dimensions. PlotBoxAspectRatio is modified to achieve the requested DataAspectRatio within the limits selected by MATLAB.
auto	manual	manual	Limits chosen to completely fit and center the plot within the requested PlotBoxAspectRatio given the requested DataAspectRatio (this may produce empty space around 2 of the 3 dimensions).

X-, Y-, Z-Limits	DataAspect Ratio	PlotBox AspectRatio	Behavior
`manual`	`auto`	`auto`	Limits are honored. The `DataAspectRatio` and `PlotBoxAspectRatio` are modified as necessary.
`manual`	`auto`	`manual`	Limits and `PlotBoxAspectRatio` are honored. The `DataAspectRatio` is modified as necessary.
`manual`	`manual`	`auto`	Limits and `DataAspectRatio` are honored. The `PlotBoxAspectRatio` is modified as necessary.
`1 manual` `2 auto`	`manual`	`manual`	The 2 automatic limits are selected to honor the specified aspect ratios and limit. See "Examples."
`2 or 3 manual`	`manual`	`manual`	Limits and `DataAspectRatio` are honored; the `PlotBoxAspectRatio` is ignored.

See "Understanding Axes Aspect Ratio" for more information.

`DataAspectRatioMode`
`{auto} | manual`

User or MATLAB controlled data scaling. This property controls whether the values of the `DataAspectRatio` property are user defined or selected automatically by MATLAB. Setting values for the `DataAspectRatio` property automatically sets this property to `manual`. Changing `DataAspectRatioMode` to `manual` disables the stretch-to-fill behavior if `DataAspectRatioMode`, `PlotBoxAspectRatioMode`, and `CameraViewAngleMode` are all auto.

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

Delete axes callback function. A callback function that executes when the axes object is deleted (e.g., when you issue a `delete` or `clf` command). MATLAB executes the routine before destroying the object's properties so the callback 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 also 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.

`DrawMode`
`{normal} | fast`

Rendering mode. This property controls the way MATLAB renders graphics objects displayed in the axes when the figure `Renderer` property is `painters`.

- `normal` mode draws objects in back to front ordering based on the current view in order to handle hidden surface elimination and object intersections.
- `fast` mode draws objects in the order in which you specify the drawing commands, without considering the relationships of the objects in three dimensions. This results in faster rendering because it requires no sorting of objects according to location in the view, but can produce undesirable results because it bypasses the hidden surface elimination and object intersection handling provided by `normal DrawMode`.

When the figure `Renderer` is `zbuffer`, `DrawMode` is ignored, and hidden surface elimination and object intersection handling are always provided.

`FontAngle`

`{normal} | italic | oblique`

Select italic or normal font. This property selects the character slant for axes text. `normal` specifies a nonitalic font. `italic` and `oblique` specify italic font.

`FontName`

A name such as `Courier` or the string `FixedWidth`

Font family name. The font family name specifying the font to use for axes labels. To display and print properly, `FontName` must be a font that your system supports. Note that the *x*-, *y*-, and *z*-axis labels are not displayed in a new font until you manually reset them (by setting the `XLabel`, `YLabel`, and `ZLabel` properties or by using the `xlabel`, `ylabel`, or `zlabel` command). Tick mark labels change immediately.

Specifying a Fixed-Width Font

If you want an axes to use a fixed-width font that looks good in any locale, you should set `FontName` to the string `FixedWidth`:

```
set(axes_handle,'FontName','FixedWidth')
```

This eliminates the need to hardcode the name of a fixed-width font, which might not display text properly on systems that do not use ASCII character encoding (such as in Japan, where multibyte character sets are used). A properly written MATLAB application that needs to use a fixed-width font should set `FontName` to `FixedWidth` (note that this string is case sensitive) and rely on `FixedWidthFontName` to be set correctly in the end user's environment.

End users can adapt a MATLAB application to different locales or personal environments by setting the root `FixedWidthFontName` property to the appropriate value for that locale from `startup.m`.

Note that setting the root `FixedWidthFontName` property causes an immediate update of the display to use the new font.

`FontSize`

Font size specified in `FontUnits`

Font size. An integer specifying the font size to use for axes labels and titles, in units determined by the `FontUnits` property. The default point size is 12. The *x*-, *y*-, and *z*-axis text labels are not displayed in a new font size until you manually reset them (by setting the `XLabel`, `YLabel`, or `ZLabel` properties or by using the `xlabel`, `ylabel`, or `zlabel` command). Tick mark labels change immediately.

`FontUnits`

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

Units used to interpret the `FontSize` property. When set to `normalized`, MATLAB interprets the value of `FontSize` as a fraction of the height of the axes. For example, a `normalized` `FontSize` of 0.1 sets the text characters to a font whose height is one tenth of the axes' height. The default units (`points`), are equal to 1/72 of an inch.

Note that if you are setting both the `FontSize` and the `FontUnits` in one function call, you must set the `FontUnits` property first so that MATLAB can correctly interpret the specified `FontSize`.

`FontWeight`
`{normal} | bold | light | demi`

Select bold or normal font. The character weight for axes text. The *x*-, *y*-, and *z*-axis text labels are not displayed in bold until you manually reset them (by setting the `XLabel`, `YLabel`, and `ZLabel` properties or by using the `xlabel`, `ylabel`, or `zlabel` commands). Tick mark labels change immediately.

`GridLineStyle`
`- | --| {:} | -.  | none`

Line style used to draw grid lines. The line style is a string consisting of a character, in quotes, specifying solid lines (-), dashed lines (--), dotted lines(`:`), or dash-dot lines (-.). The default grid line style is dotted. To turn on grid lines, use the `grid` command.

`HandleVisibility`
`{on} | callback | off`

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

Handles are always visible when `HandleVisibility` is `on`.

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

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

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

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

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

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

`HitTest`

`{on} | off`

Selectable by mouse click. `HitTest` determines if the axes 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 axes. If `HitTest` is `off`, clicking the axes selects the object below it (which is usually the figure containing it).

`Interruptible`
`{on} | off`

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

Setting `Interruptible` to `on` allows any graphics object's callback routine to interrupt callback routines originating from an axes 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.

`Layer`
`{bottom} | top`

Draw axis lines below or above graphics objects. This property determines if axis lines and tick marks are drawn on top or below axes children objects for any 2-D view (i.e., when you are looking along the *x*-, *y*-, or *z*-axis). This is useful for placing grid lines and tick marks on top of images.

`LineStyleOrder`
`LineSpec` (default: a solid line '-')

Order of line styles and markers used in a plot. This property specifies which line styles and markers to use and in what order when creating multiple-line plots. For example,

```
set(gca,'LineStyleOrder', '-*|:|o')
```

sets `LineStyleOrder` to solid line with asterisk marker, dotted line, and hollow circle marker. The default is (-), which specifies a solid line for all data plotted. Alternatively, you can create a cell array of character strings to define the line styles:

```
set(gca,'LineStyleOrder',{'-*',':','o'})
```

MATLAB supports four line styles, which you can specify any number of times in any order. MATLAB cycles through the line styles only after using all colors defined by the `ColorOrder` property. For example, the first eight lines plotted use the different colors defined by `ColorOrder` with the first line style. MATLAB then cycles through the colors again, using the second line style specified, and so on.

You can also specify line style and color directly with the `plot` and `plot3` functions or by altering the properties of the`line` or lineseries objects after creating the graph.

High-Level Functions and LineStyleOrder

Note that, if the axes `NextPlot` property is set to `replace` (the default), high-level functions like `plot` reset the `LineStyleOrder` property before determining the line style to use. If you want MATLAB to use a `LineStyleOrder` that is different from the default, set `NextPlot` to `replacechildren`.

Specifying a Default LineStyleOrder

You can also specify your own default `LineStyleOrder`. For example, this statement

```
set(0,'DefaultAxesLineStyleOrder',{'-*',':','o'})
```

creates a default value for the axes `LineStyleOrder` that is not reset by high-level plotting functions.

`LineWidth`
line width in points

Width of axis lines. This property specifies the width, in points, of the *x*-, *y*-, and *z*-axis lines. The default line width is 0.5 points (1 point = $^1/_{72}$ inch).

`MinorGridLineStyle`
`- | --| {:} | -.  | none`

Line style used to draw minor grid lines. The line style is a string consisting of one or more characters, in quotes, specifying solid lines (-), dashed lines (--), dotted lines (`:`), or dash-dot lines (-.). The default minor grid line style is dotted. To turn on minor grid lines, use the `grid minor` command.

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

Where to draw the next plot. This property determines how high-level plotting functions draw into an existing axes.

- `add` — Use the existing axes to draw graphics objects.
- `replace` — Reset all axes properties except `Position` to their defaults and delete all axes children before displaying graphics (equivalent to `cla reset`).
- `replacechildren` — Remove all child objects, but do not reset axes properties (equivalent to `cla`).

The `newplot` function simplifies the use of the `NextPlot` property and is used by M-file functions that draw graphs using only low-level object creation routines. See the M-file `pcolor.m` for an example. Note that figure graphics objects also have a `NextPlot` property.

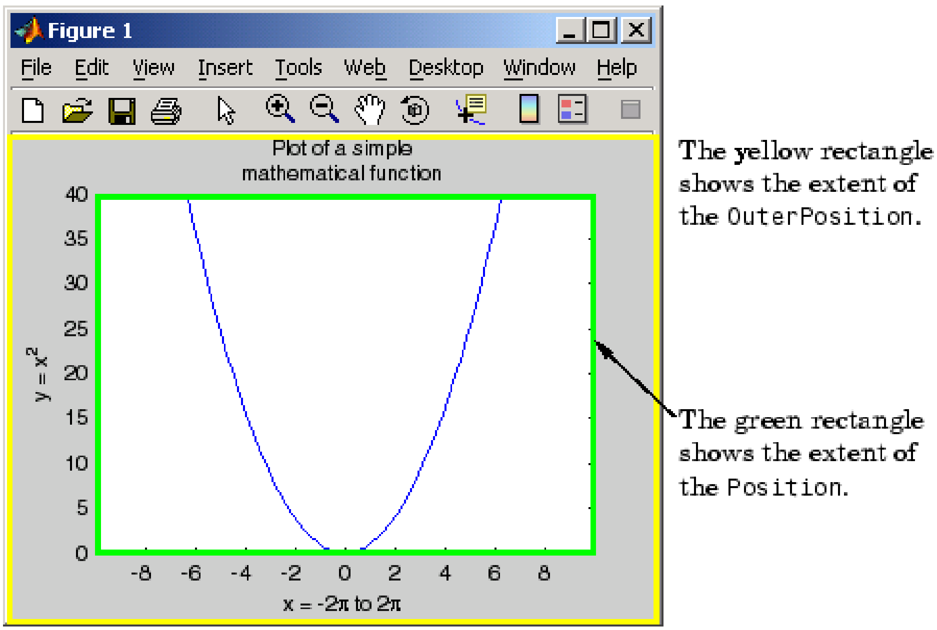
`OuterPosition`
four-element vector

Position of axes including labels, title, and a margin. A four-element vector specifying a rectangle that locates the outer bounds of the axes, including axis labels, the title, and a margin. The vector is defined as follows:

```
[left bottom width height]
```

where `left` and `bottom` define the distance from the lower-left corner of the figure window to the lower-left corner of the rectangle. `width` and `height` are the dimensions of the rectangle

The following picture shows the region defined by the `OuterPosition` enclosed in a yellow rectangle.



When `ActivePositionProperty` is set to `OuterPosition` (the default), none of the text is clipped when you resize the figure.

The default value of `[0 0 1 1]` (normalized units) includes the interior of the figure.

All measurements are in units specified by the `Units` property.

See the `TightInset` property for related information.

See "Automatic Axes Resize" for a discussion of how to use axes positioning properties.

`Parent`
figure or uipanel handle

Axes parent. The handle of the axes' parent object. The parent of an axes object is the figure in which it is displayed or the uipanel object that contains it. The utility function `gcf` returns the handle of the current axes `Parent`. You can reparent axes to other figure or uipanel objects.

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

`PlotBoxAspectRatio`
`[px py pz]`

Relative scaling of axes plot box. A three-element vector controlling the relative scaling of the plot box in the x, y, and z directions. The plot box is a box enclosing the axes data region as defined by the x-, y-, and z-axis limits.

Note that the `PlotBoxAspectRatio` property interacts with the `DataAspectRatio`, `XLimMode`, `YLimMode`, and `ZLimMode` properties to control the way graphics objects are displayed in the axes. Setting the `PlotBoxAspectRatio` disables stretch-to-fill behavior, if `DataAspectRatioMode`, `PlotBoxAspectRatioMode`, and `CameraViewAngleMode` are all `auto`.

`PlotBoxAspectRatioMode`
`{auto} | manual`

User or MATLAB controlled axis scaling. This property controls whether the values of the `PlotBoxAspectRatio` property are user defined or selected automatically by MATLAB. Setting values for the `PlotBoxAspectRatio` property automatically sets this property to `manual`. Changing the `PlotBoxAspectRatioMode` to `manual` disables stretch-to-fill behavior if `DataAspectRatioMode`, `PlotBoxAspectRatioMode`, and `CameraViewAngleMode` are all `auto`.

`Position`
four-element vector

Position of axes. A four-element vector specifying a rectangle that locates the axes within its parent container (figure or uipanel). The vector is of the form

```
[left bottom width height]
```

where `left` and `bottom` define the distance from the lower-left corner of the container to the lower-left corner of the rectangle. `width` and `height` are the dimensions of the rectangle. All measurements are in units specified by the `Units` property.

When axes stretch-to-fill behavior is enabled (when `DataAspectRatioMode`, `PlotBoxAspectRatioMode`, and `CameraViewAngleMode` are all `auto`), the axes are stretched to fill the `Position` rectangle. When stretch-to-fill is disabled, the axes are made as large as possible, while obeying all other properties, without extending outside the `Position` rectangle.

See the `OuterPosition` poperty for related information.

See "Automatic Axes Resize" for a discussion of how to use axes positioning properties.

`Projection`
    `{orthographic} | perspective`

Type of projection. This property selects between two projection types:

- `orthographic` — This projection maintains the correct relative dimensions of graphics objects with regard to the distance a given point is from the viewer. Parallel lines in the data are drawn parallel on the screen.
- `perspective` — This projection incorporates foreshortening, which allows you to perceive depth in 2-D representations of 3-D objects. Perspective projection does not preserve the relative dimensions of objects; a distant line segment is displayed smaller than a nearer line segment of the same length. Parallel lines in the data may not appear parallel on screen.

`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 the axes has been selected.

`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.

`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 axes, regardless of user actions that may have changed the current axes. To do this, identify the axes with a Tag:

```
axes('Tag','Special Axes')
```

Then make that axes the current axes before drawing by searching for the Tag with findobj:

```
axes(findobj('Tag','Special Axes'))
```

TickDir
: in | out

Direction of tick marks. For 2-D views, the default is to direct tick marks inward from the axis lines; 3-D views direct tick marks outward from the axis line.

TickDirMode
: {auto} | manual

Automatic tick direction control. In auto mode, MATLAB directs tick marks inward for 2-D views and outward for 3-D views. When you specify a setting for TickDir, MATLAB sets TickDirMode to manual. In manual mode, MATLAB does not change the specified tick direction.

TickLength
: [2DLength 3DLength]

Length of tick marks. A two-element vector specifying the length of axes tick marks. The first element is the length of tick marks used for 2-D views and the second element is the length of tick marks used for 3-D views. Specify tick mark lengths in units normalized relative to the longest of the visible X-, Y-, or Z-axis annotation lines.

`TightInset`
[left bottom right top] Read only

Margins added to Position to include text labels. The values of this property are the distances between the bounds of the `Position` property and the extent of the axes text labels and title. When added to the `Position` width and height values, the `TightInset` defines the tightest bounding box that encloses the axes and it's labels and title.

See "Automatic Axes Resize" for more information.

`Title`
handle of text object

Axes title. The handle of the `text` object that is used for the axes title. You can use this handle to change the properties of the title text or you can set `Title` to the handle of an existing text object. For example, the following statement changes the color of the current title to red:

```
set(get(gca,'Title'),'Color','r')
```

To create a new title, set this property to the handle of the text object you want to use:

```
set(gca,'Title',text('String','New Title','Color','r'))
```

However, it is generally simpler to use the `title` command to create or replace an axes title:

```
title('New Title','Color','r') % Make text color red
```

```
title({'This title','has 2 lines'}) % Two line title
```

`Type`

string (read only)

Type of graphics object. This property contains a string that identifies the class of graphics object. For axes objects, `Type` is always set to `'axes'`.

`UIContextMenu`

handle of a uicontextmenu object

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

`Units`

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

Axes position units. The units used to interpret the `Position` property. All units are measured from the lower left corner of the figure window.

Note The `Units` property controls the positioning of the axes within the figure. This property does not affect the data units used for graphing. See the axes XLim, YLim, and ZLim properties to set the limits of each axis data units.

- `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).

- `Character` units are defined by characters from the default system font; the width of one character is the width of the letter x, and the height of one character is the distance between the baselines of two lines of text.

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. This property can be any data you want to associate with the axes object. The axes does not use this property, but you can access it using the `set` and `get` functions.

`View`
Obsolete

The functionality provided by the `View` property is now controlled by the axes camera properties — `CameraPosition`, `CameraTarget`, `CameraUpVector`, and `CameraViewAngle`. See the `view` command.

`Visible`
`{on} | off`

Visibility of axes. By default, axes are visible. Setting this property to `off` prevents axis lines, tick marks, and labels from being displayed. The `Visible` property does not affect children of axes.

`XAxisLocation`
`top | {bottom}`

Location of x-axis tick marks and labels. This property controls where MATLAB displays the x-axis tick marks and labels. Setting this property to `top` moves the x-axis to the top of the plot from its default position at the bottom. This property applies to 2–D views only.

`YAxisLocation`
`right | {left}`

Location of y-axis tick marks and labels. This property controls where MATLAB displays the *y*-axis tick marks and labels. Setting this property to `right` moves the *y*-axis to the right side of the plot from its default position on the left side. This property applies to 2–D views only. See the `plotyy` function for a simple way to use two *y*-axes.

Properties That Control the X-, Y-, or Z-Axis

`XColor`
`YColor`
`ZColor`
`ColorSpec`

Color of axis lines. A three-element vector specifying an RGB triple, or a predefined MATLAB color string. This property determines the color of the axis lines, tick marks, tick mark labels, and the axis grid lines of the respective *x*-, *y*-, and *z*-axis. The default color axis color is black. See`ColorSpec` for details on specifying colors.

`XDir`
`YDir`
`ZDir`
`{normal} | reverse`

Direction of increasing values. A mode controlling the direction of increasing axis values. Axes form a right-hand coordinate system. By default,

- *x*-axis values increase from left to right. To reverse the direction of increasing *x* values, set this property to `reverse`.

```
set(gca,'XDir','reverse')
```

- y-axis values increase from bottom to top (2-D view) or front to back (3-D view). To reverse the direction of increasing y values, set this property to `reverse`.

  ```
  set(gca,'YDir','reverse')
  ```

- z-axis values increase pointing out of the screen (2-D view) or from bottom to top (3-D view). To reverse the direction of increasing z values, set this property to `reverse`.

  ```
  set(gca,'ZDir','reverse')
  ```

`XGrid`
`YGrid`
`ZGrid`
`on | {off}`

Axis gridline mode. When you set any of these properties to `on`, MATLAB draws grid lines perpendicular to the respective axis (i.e., along lines of constant x, y, or z values). Use the `grid` command to set all three properties `on` or `off` at once.

```
set(gca,'XGrid','on')
```

`XLabel`
`YLabel`
`ZLabel`
handle of text object

Axis labels. The handle of the `text` object used to label the x-, y-, or z-axis, respectively. To assign values to any of these properties, you must obtain the handle to the text string you want to use as a label. This statement defines a text object and assigns its handle to the `XLabel` property:

```
set(get(gca,'XLabel'),'String','axis label')
```

MATLAB places the string `'axis label'` appropriately for an *x*-axis label. Any text object whose handle you specify as an `XLabel`, `YLabel`, or `ZLabel` property is moved to the appropriate location for the respective label.

Alternatively, you can use the `xlabel`, `ylabel`, and `zlabel` functions, which generally provide a simpler means to label axis lines.

Note that using a bitmapped font (e.g., Courier is usually a bitmapped font) might cause the labels to be rotated improperly. As a workaround, use a TrueType font (e.g., Courier New) for axis labels. See your system documentation to determine the types of fonts installed on your system.

`XLim`
`YLim`
`ZLim`

`[minimum maximum]`

Axis limits. A two-element vector specifying the minimum and maximum values of the respective axis. These values are determined by the data you are plotting.

Changing these properties affects the scale of the *x*-, *y*-, or *z*-dimension as well as the placement of labels and tick marks on the axis. The default values for these properties are [0 1].

See the `axis`, `datetick`, `xlim`, `ylim`, and `zlim` commands to set these properties.

`XLimMode`
`YLimMode`
`ZLimMode`

`{auto} | manual`

MATLAB or user-controlled limits. The axis limits mode determines whether MATLAB calculates axis limits based on the data plotted (i.e., the `XData`, `YData`, or `ZData` of the axes children) or uses the values explicitly set with the `XLim`, `YLim`, or `ZLim` property, in which case, the respective limits mode is set to `manual`.

`XMinorGrid`
`YMinorGrid`
`ZMinorGrid`
`on | {off}`

Enable or disable minor gridlines. When set to `on`, MATLAB draws gridlines aligned with the minor tick marks of the respective axis. Note that you do not have to enable minor ticks to display minor grids.

`XMinorTick`
`YMinorTick`
`ZMinorTick`
`on | {off}`

Enable or disable minor tick marks. When set to `on`, MATLAB draws tick marks between the major tick marks of the respective axis. MATLAB automatically determines the number of minor ticks based on the space between the major ticks.

`XScale`
`YScale`
`ZScale`
`{linear} | log`

Axis scaling. Linear or logarithmic scaling for the respective axis. See also `loglog`, `semilogx`, and `semilogy`.

`XTick`
`YTick`
`ZTick`
vector of data values locating tick marks

Tick spacing. A vector of *x*-, *y*-, or *z*-data values that determine the location of tick marks along the respective axis. If you do not want tick marks displayed, set the respective property to the empty vector, [ ]. These vectors must contain monotonically increasing values.

XTickLabel
YTickLabel
ZTickLabel
string

Tick labels. A matrix of strings to use as labels for tick marks along the respective axis. These labels replace the numeric labels generated by MATLAB. If you do not specify enough text labels for all the tick marks, MATLAB uses all of the labels specified, then reuses the specified labels.

For example, the statement

```
set(gca,'XTickLabel',{'One';'Two';'Three';'Four'})
```

labels the first four tick marks on the *x*-axis and then reuses the labels until all ticks are labeled.

Labels can be specified as cell arrays of strings, padded string matrices, string vectors separated by vertical slash characters, or as numeric vectors (where each number is implicitly converted to the equivalent string using num2str). All of the following are equivalent:

```
set(gca,'XTickLabel',{'1';'10';'100'})
set(gca,'XTickLabel','1|10|100')
set(gca,'XTickLabel',[1;10;100])
set(gca,'XTickLabel',['1  ';'10 ';'100'])
```

Note that tick labels do not interpret TeX character sequences (however, the Title, XLabel, YLabel, and ZLabel properties do).

`XTickMode`
`YTickMode`
`ZTickMode`
  `{auto} | manual`

  MATLAB or user-controlled tick spacing. The axis tick modes determine whether MATLAB calculates the tick mark spacing based on the range of data for the respective axis (`auto` mode) or uses the values explicitly set for any of the `XTick`, `YTick`, and `ZTick` properties (`manual` mode). Setting values for the `XTick`, `YTick`, or `ZTick` properties sets the respective axis tick mode to `manual`.

`XTickLabelMode`
`YTickLabelMode`
`ZTickLabelMode`
  `{auto} | manual`

  MATLAB or user-determined tick labels. The axis tick mark labeling mode determines whether MATLAB uses numeric tick mark labels that span the range of the plotted data (`auto` mode) or uses the tick mark labels specified with the `XTickLabel`, `YTickLabel`, or `ZTickLabel` property (`manual` mode). Setting values for the `XTickLabel`, `YTickLabel`, or `ZTickLabel` property sets the respective axis tick label mode to `manual`.

Purpose

Axis scaling and appearance

Syntax

```
axis([xmin xmax ymin ymax])
axis([xmin xmax ymin ymax zmin zmax cmin cmax])
v = axis
axis auto
axis manual
axis tight
axis fill
axis ij
axis xy
axis equal
axis image
axis square
axis vis3d
axis normal
axis off
axis on
axis(axes_handles,...)
[mode,visibility,direction] = axis('state')
```

Description

`axis` manipulates commonly used axes properties. (See Algorithm section.)

`axis([xmin xmax ymin ymax])` sets the limits for the *x*- and *y*-axis of the current axes.

`axis([xmin xmax ymin ymax zmin zmax cmin cmax])` sets the *x*-, *y*-, and *z*-axis limits and the color scaling limits (see `caxis`) of the current axes.

`v = axis` returns a row vector containing scaling factors for the *x*-, *y*-, and *z*-axis. `v` has four or six components depending on whether the current axes is 2-D or 3-D, respectively. The returned values are the current axes `XLim`, `Ylim`, and `ZLim` properties.

`axis auto` sets MATLAB to its default behavior of computing the current axes limits automatically, based on the minimum and maximum values of *x*, *y*, and *z* data. You can restrict this automatic behavior to a specific axis. For example, `axis 'auto x'` computes only the *x*-axis limits automatically; `axis 'auto yz'` computes the *y*- and *z*-axis limits automatically.

`axis manual` and axis(axis) freezes the scaling at the current limits, so that if `hold` is `on`, subsequent plots use the same limits. This sets the `XLimMode`, `YLimMode`, and `ZLimMode` properties to `manual`.

`axis tight` sets the axis limits to the range of the data.

`axis fill` sets the axis limits and `PlotBoxAspectRatio` so that the axes fill the position rectangle. This option has an effect only if `PlotBoxAspectRatioMode` or `DataAspectRatioMode` is `manual`.

`axis ij` places the coordinate system origin in the upper left corner. The *i*-axis is vertical, with values increasing from top to bottom. The *j*-axis is horizontal with values increasing from left to right.

`axis xy` draws the graph in the default Cartesian axes format with the coordinate system origin in the lower left corner. The *x*-axis is horizontal with values increasing from left to right. The *y*-axis is vertical with values increasing from bottom to top.

`axis equal` sets the aspect ratio so that the data units are the same in every direction. The aspect ratio of the *x*-, *y*-, and *z*-axis is adjusted automatically according to the range of data units in the *x*, *y*, and *z* directions.

`axis image` is the same as `axis equal` except that the plot box fits tightly around the data.

`axis square` makes the current axes region square (or cubed when three-dimensional). MATLAB adjusts the *x*-axis, *y*-axis, and *z*-axis so that they have equal lengths and adjusts the increments between data units accordingly.

`axis vis3d` freezes aspect ratio properties to enable rotation of 3-D objects and overrides stretch-to-fill.

`axis normal` automatically adjusts the aspect ratio of the axes and the relative scaling of the data units so that the plot fits the figure's shape as well as possible.

`axis off` turns off all axis lines, tick marks, and labels.

`axis on` turns on all axis lines, tick marks, and labels.

`axis(axes_handles,...)` applies the `axis` command to the specified axes. For example, the following statements

```
h1 = subplot(221);
h2 = subplot(222);
axis([h1 h2],'square')
```

set both axes to `square`.

`[mode,visibility,direction] = axis('state')` returns three strings indicating the current setting of axes properties:

Output Argument	Strings Returned
mode	'auto' | 'manual'
visibility	'on' | 'off'
direction	'xy' | 'ij'

`mode` is `auto` if `XLimMode`, `YLimMode`, and `ZLimMode` are all set to `auto`. If `XLimMode`, `YLimMode`, or `ZLimMode` is `manual`, `mode` is `manual`.

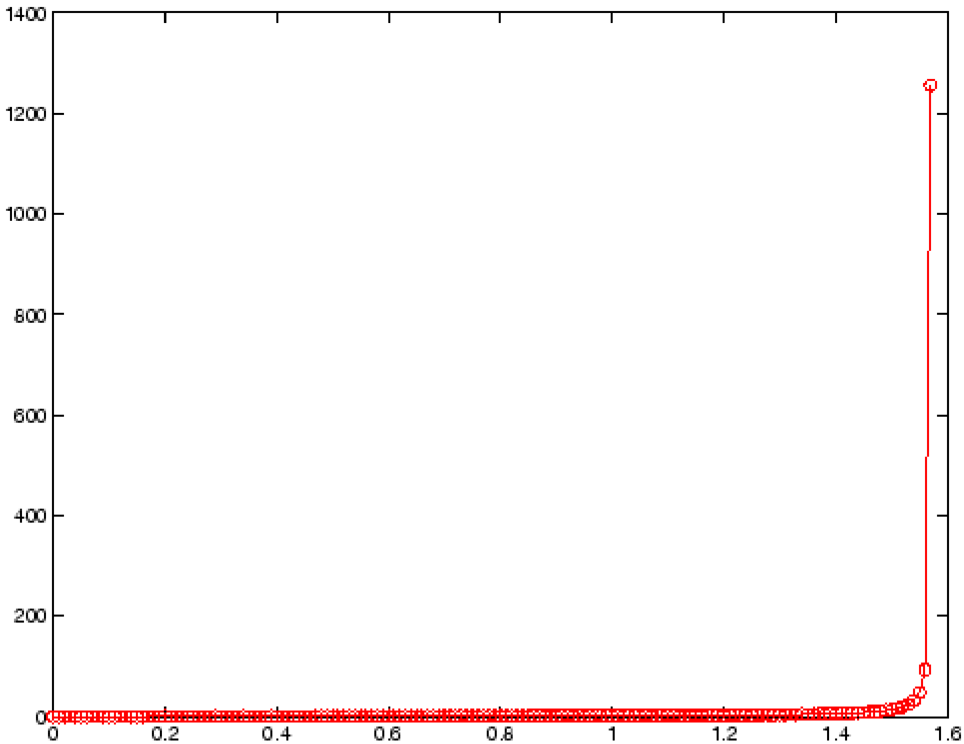
Keywords to `axis` can be combined, separated by a space (e.g., `axis tight equal`). These are evaluated from left to right, so subsequent keywords can overwrite properties set by prior ones.

Examples

The statements

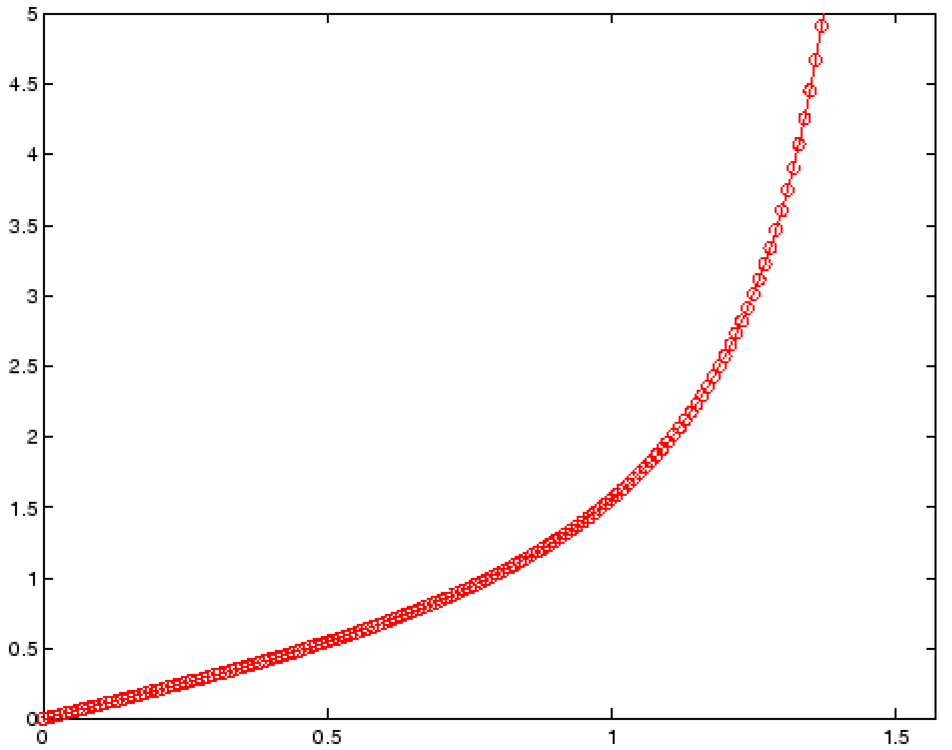
```
x = 0:.025:pi/2;
plot(x,tan(x),'-ro')
```

use the automatic scaling of the *y*-axis based on `ymax = tan(1.57)`, which is well over 1000:



The right figure shows a more satisfactory plot after typing

```
axis([0  pi/2  0  5])
```



Algorithm

When you specify minimum and maximum values for the *x*-, *y*-, and *z*-axes, `axis` sets the `XLim`, `Ylim`, and `ZLim` properties for the current axes to the respective minimum and maximum values in the argument list. Additionally, the `XLimMode`, `YLimMode`, and `ZLimMode` properties for the current axes are set to `manual`.

`axis auto` sets the current axes `XLimMode`, `YLimMode`, and `ZLimMode` properties to `'auto'`.

`axis manual` sets the current axes `XLimMode`, `YLimMode`, and `ZLimMode` properties to `'manual'`.

The following table shows the values of the axes properties set by `axis equal`, `axis normal`, `axis square`, and `axis image`.

Axes Property or Behavior	axis equal	axis normal	axis square	axis image
DataAspectRatio property	[1 1 1]	not set	not set	[1 1 1]
DataAspectRatioMode property	manual	auto	auto	manual
PlotBoxAspectRatio property	[3 4 4]	not set	[1 1 1]	auto
PlotBoxAspectRatioMode property	manual	auto	manual	auto
Stretch-to-fill behavior;	disabled	active	disabled	disabled

See Also

axes, grid, subplot, xlim, ylim, zlim

Properties of axes graphics objects

"Axes Operations" on page 1-95 for related functions

For aspect ratio behavior, see in the axes properties reference page.

Purpose

Diagonal scaling to improve eigenvalue accuracy

Syntax

```
[T,B] = balance(A)
[S,P,B] = balance(A)
B = balance(A)
B = balance(A,'noperm')
```

Description

`[T,B] = balance(A)` returns a similarity transformation `T` such that `B = T\A*T`, and `B` has, as nearly as possible, approximately equal row and column norms. `T` is a permutation of a diagonal matrix whose elements are integer powers of two to prevent the introduction of roundoff error. If `A` is symmetric, then `B == A` and `T` is the identity matrix.

`[S,P,B] = balance(A)` returns the scaling vector `S` and the permutation vector `P` separately. The transformation `T` and balanced matrix `B` are obtained from `A`, `S`, and `P` by `T(:,P) = diag(S)` and `B(P,P) = diag(1./S)*A*diag(S)`.

`B = balance(A)` returns just the balanced matrix `B`.

`B = balance(A,'noperm')` scales `A` without permuting its rows and columns.

Remarks

Nonsymmetric matrices can have poorly conditioned eigenvalues. Small perturbations in the matrix, such as roundoff errors, can lead to large perturbations in the eigenvalues. The condition number of the eigenvector matrix,

```
cond(V) = norm(V)*norm(inv(V))
```

where

```
[V,T] = eig(A)
```

relates the size of the matrix perturbation to the size of the eigenvalue perturbation. Note that the condition number of `A` itself is irrelevant to the eigenvalue problem.

Balancing is an attempt to concentrate any ill conditioning of the eigenvector matrix into a diagonal scaling. Balancing usually cannot turn a nonsymmetric matrix into a symmetric matrix; it only attempts to make the norm of each row equal to the norm of the corresponding column.

Note The MATLAB eigenvalue function, `eig(A)`, automatically balances `A` before computing its eigenvalues. Turn off the balancing with `eig(A,'nobalance')`.

Examples

This example shows the basic idea. The matrix `A` has large elements in the upper right and small elements in the lower left. It is far from being symmetric.

```
A = [1  100  10000; .01  1  100; .0001  .01  1]
A =
   1.0e+04 *
    0.0001    0.0100    1.0000
    0.0000    0.0001    0.0100
    0.0000    0.0000    0.0001
```

Balancing produces a diagonal matrix `T` with elements that are powers of two and a balanced matrix `B` that is closer to symmetric than `A`.

```
[T,B] = balance(A)
T =
   1.0e+03 *
    2.0480         0         0
         0    0.0320         0
         0         0    0.0003
B =
    1.0000    1.5625    1.2207
    0.6400    1.0000    0.7813
    0.8192    1.2800    1.0000
```

To see the effect on eigenvectors, first compute the eigenvectors of A, shown here as the columns of V.

```
[V,E] = eig(A); V
V =
   -1.0000    0.9999    0.9937
    0.0050    0.0100   -0.1120
    0.0000    0.0001    0.0010
```

Note that all three vectors have the first component the largest. This indicates V is badly conditioned; in fact cond(V) is 8.7766e+003. Next, look at the eigenvectors of B.

```
[V,E] = eig(B); V
V =
   -0.8873    0.6933    0.0898
    0.2839    0.4437   -0.6482
    0.3634    0.5679   -0.7561
```

Now the eigenvectors are well behaved and cond(V) is 1.4421. The ill conditioning is concentrated in the scaling matrix; cond(T) is 8192.

This example is small and not really badly scaled, so the computed eigenvalues of A and B agree within roundoff error; balancing has little effect on the computed results.

Algorithm

Inputs of Type Double

For inputs of type double, balance uses the linear algebra package (LAPACK) routines DGEBAL (real) and ZGEBAL (complex). If you request the output T, balance also uses the LAPACK routines DGEBAK (real) and ZGEBAK (complex).

Inputs of Type Single

For inputs of type single, balance uses the LAPACK routines SGEBAL (real) and CGEBAL (complex). If you request the output T, balance also uses the LAPACK routines SGEBAK (real) and CGEBAK (complex).

Limitations

Balancing can destroy the properties of certain matrices; use it with some care. If a matrix contains small elements that are due to roundoff error, balancing might scale them up to make them as significant as the other elements of the original matrix.

See Also

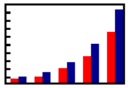
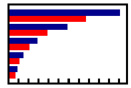
`eig`

References

[1] Anderson, E., Z. Bai, C. Bischof, S. Blackford, J. Demmel, J. Dongarra, J. Du Croz, A. Greenbaum, S. Hammarling, A. McKenney, and D. Sorensen, *LAPACK User's Guide* (`http://www.netlib.org/lapack/lug/lapack_lug.html`), Third Edition, SIAM, Philadelphia, 1999.

Purpose

Plot bar graph (vertical and horizontal)

GUI Alternatives

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

Syntax

```
bar(Y)
bar(x,Y)
bar(...,width)
bar(...,'style')
bar(...,'bar_color')
bar(axes_handle,...)
barh(axes_handle,...)
h = bar(...)
barh(...)
h = barh(...)
hpatches = bar('v6',...)
hpatches = barh('v6',...)
```

Description

A bar graph displays the values in a vector or matrix as horizontal or vertical bars.

`bar(Y)` draws one bar for each element in `Y`. If `Y` is a matrix, `bar` groups the bars produced by the elements in each row. The *x*-axis scale ranges from 1 up to `length(Y)` when `Y` is a vector, and `1` to `size(Y,1)`, which is the number of rows, when `Y` is a matrix. The default is to scale the *x*-axis to the highest x-tick on the plot, (a multiple of 10, 100, etc.). If you want the *x*-axis scale to end exactly at the last bar, you can use the default, and then, for example, type

```
set(gca,'xlim',[1 length(Y)])
```

at the MATLAB prompt.

`bar(x,Y)` draws a bar for each element in `Y` at locations specified in `x`, where `x` is a vector defining the *x*-axis intervals for the vertical bars. The *x*-values can be nonmonotonic, but cannot contain duplicate values. If `Y` is a matrix, `bar` groups the elements of each row in `Y` at corresponding locations in `x`.

`bar(...,width)` sets the relative bar width and controls the separation of bars within a group. The default `width` is `0.8`, so if you do not specify `x`, the bars within a group have a slight separation. If `width` is `1`, the bars within a group touch one another.

`bar(...,'style')` specifies the style of the bars. `'style'` is `'grouped'` or `'stacked'`. `'group'` is the default mode of display.

- `'grouped'` displays *m* groups of *n* vertical bars, where *m* is the number of rows and *n* is the number of columns in `Y`. The group contains one bar per column in `Y`.
- `'stacked'` displays one bar for each row in `Y`. The bar height is the sum of the elements in the row. Each bar is multicolored, with colors corresponding to distinct elements and showing the relative contribution each row element makes to the total sum.

`bar(...,'bar_color')` displays all bars using the color specified by the single-letter abbreviation `'r'`, `'g'`, `'b'`, `'c'`, `'m'`, `'y'`, `'k'`, or `'w'`.

`bar(axes_handle,...)` and `barh(axes_handle,...)` plot into the axes with the handle `axes_handle` instead of into the current axes (`gca`).

`h = bar(...)` returns a vector of handles to barseries graphics objects, one for each created. When `Y` is a matrix, `bar` creates one barseries graphics object per column in `Y`.

`barh(...)` and `h = barh(...)` create horizontal bars. `Y` determines the bar length. The vector `x` is a vector defining the *y*-axis intervals for horizontal bars. The *x*-values can be nonmonotonic, but cannot contain duplicate values.

Backward-Compatible Versions

`hpatches = bar('v6',...)` and `hpatches = barh('v6',...)` return the handles of patch objects instead of barseries objects for compatibility with MATLAB 6.5 and earlier. See patch object properties for a discussion of the properties you can set to control the appearance of these bar graphs.

See "Plot Objects and Backward Compatibility" for more information.

Barseries Objects

Creating a bar graph of an m-by-n matrix creates m groups of n barseries objects. Each barseries object contains the data for corresponding `x` values of each bar group (as indicated by the coloring of the bars).

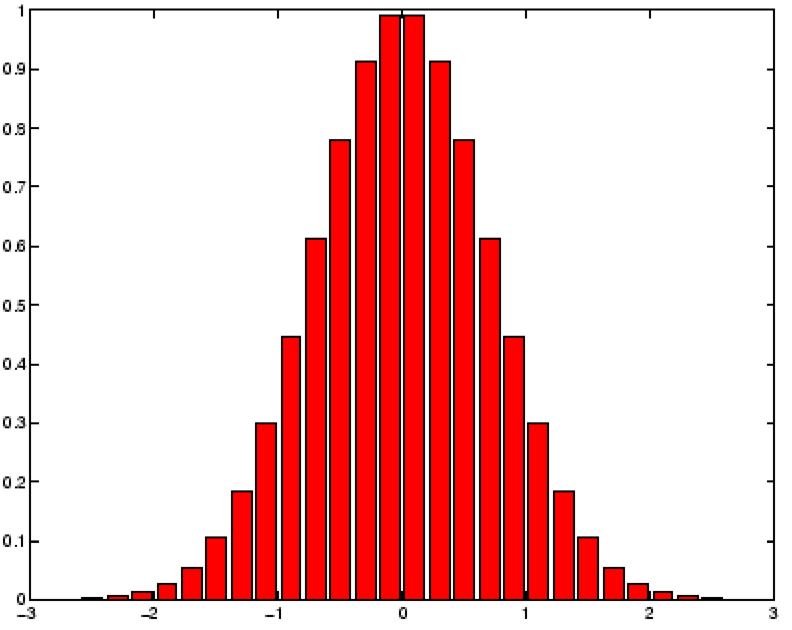
Note that some barseries object properties set on an individual barseries object set the values for all barseries objects in the graph. See the barseries property descriptions for information on specific properties.

Examples

Single Series of Data

This example plots a bell-shaped curve as a bar graph and sets the colors of the bars to red.

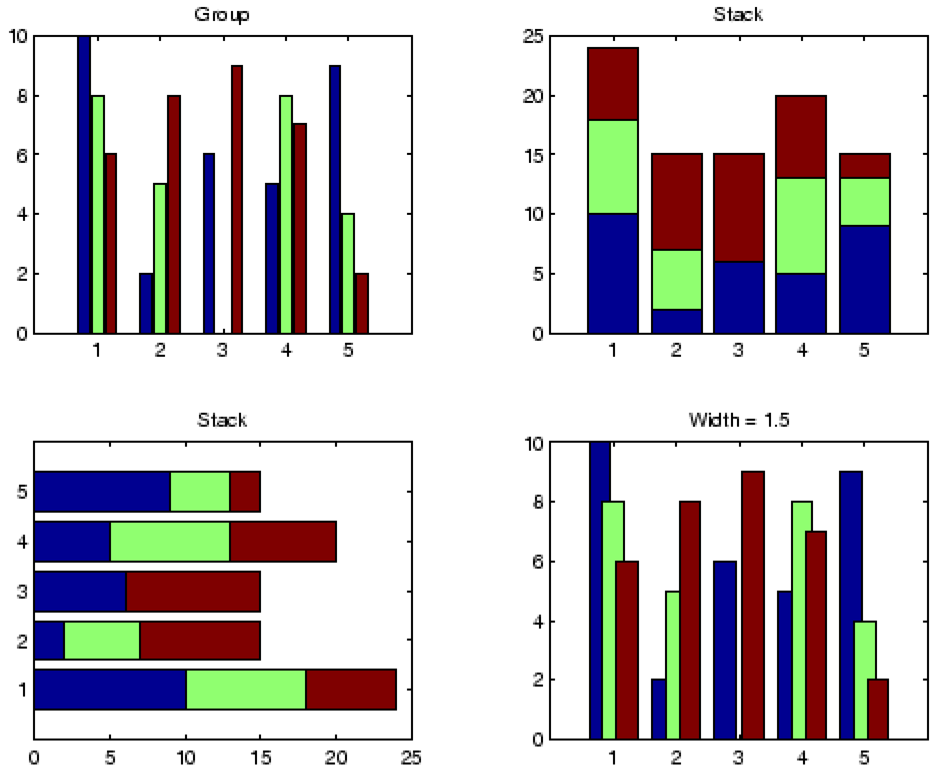
```
x = -2.9:0.2:2.9;
bar(x,exp(-x.*x),'r')
```



Bar Graph Options

This example illustrates some bar graph options.

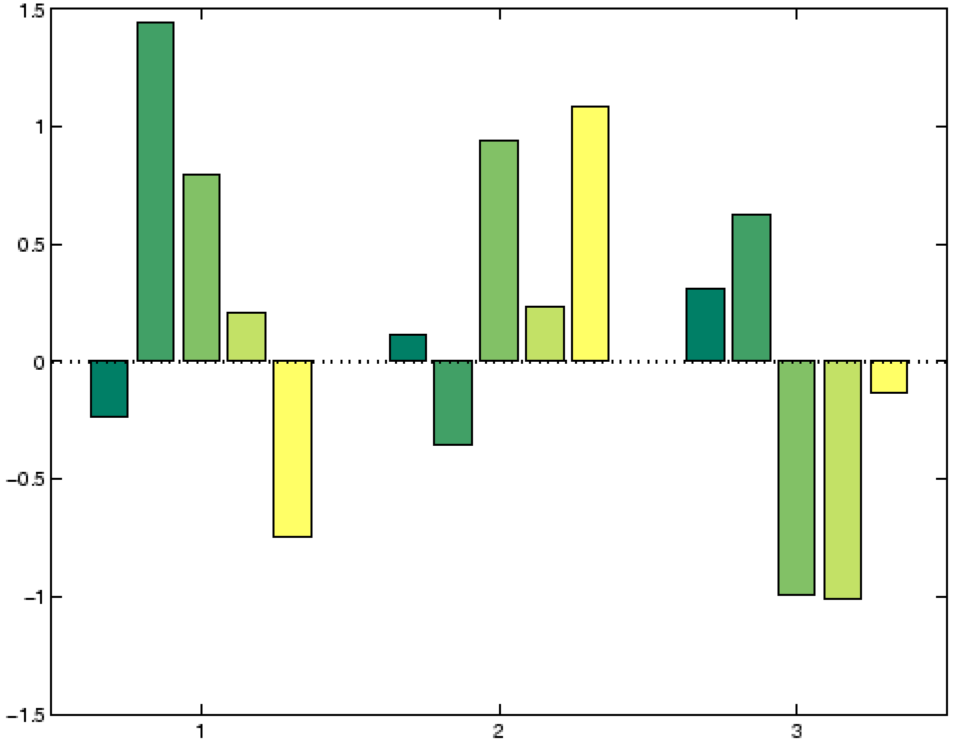
```
Y = round(rand(5,3)*10);
subplot(2,2,1)
bar(Y,'group')
title 'Group'
subplot(2,2,2)
bar(Y,'stack')
title 'Stack'
subplot(2,2,3)
barh(Y,'stack')
title 'Stack'
subplot(2,2,4)
bar(Y,1.5)
title 'Width = 1.5'
```



Setting Properties with Multiobject Graphs

This example creates a graph that displays three groups of bars and contains five barseries objects. Since all barseries objects in a graph share the same baseline, you can set values using any barseries object's `BaseLine` property. This example uses the first handle returned in `h`.

```
Y = randn(3,5);
h = bar(Y);
set(get(h(1),'BaseLine'),'LineWidth',2,'LineStyle',':')
colormap summer % Change the color scheme
```



See Also

`bar3`, `ColorSpec`, `patch`, `stairs`, `hist`

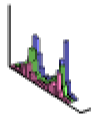
"Area, Bar, and Pie Plots" on page 1-87 for related functions

`Barseries Properties`

"Bar and Area Graphs" for more examples

Purpose

Plot 3-D bar chart



GUI Alternatives

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

Syntax

```
bar3(Y)
bar3(x,Y)
bar3(...,width)
bar3(...,'style')
bar3(...,LineSpec)
bar3(axes_handle,...)
h = bar3(...)
bar3h(...)
h = bar3h(...)
```

Description

`bar3` and `bar3h` draw three-dimensional vertical and horizontal bar charts.

`bar3(Y)` draws a three-dimensional bar chart, where each element in `Y` corresponds to one bar. When `Y` is a vector, the *x*-axis scale ranges from `1` to `length(Y)`. When `Y` is a matrix, the *x*-axis scale ranges from `1` to `size(Y,2)`, which is the number of columns, and the elements in each row are grouped together.

`bar3(x,Y)` draws a bar chart of the elements in `Y` at the locations specified in `x`, where `x` is a vector defining the *y*-axis intervals for vertical bars. The *x*-values can be nonmonotonic, but cannot contain duplicate values. If `Y` is a matrix, `bar3` clusters elements from the same row in Y at locations corresponding to an element in x. Values of elements in each row are grouped together.

bar3(...,width) sets the width of the bars and controls the separation of bars within a group. The default width is 0.8, so if you do not specify x, bars within a group have a slight separation. If width is 1, the bars within a group touch one another.

bar3(...,'*style*') specifies the style of the bars. '*style*' is 'detached', 'grouped', or 'stacked'. 'detached' is the default mode of display.

- 'detached' displays the elements of each row in Y as separate blocks behind one another in the *x* direction.
- 'grouped' displays *n* groups of *m* vertical bars, where *n* is the number of rows and *m* is the number of columns in Y. The group contains one bar per column in Y.
- 'stacked' displays one bar for each row in Y. The bar height is the sum of the elements in the row. Each bar is multicolored, with colors corresponding to distinct elements and showing the relative contribution each row element makes to the total sum.

bar3(...,LineSpec) displays all bars using the color specified by LineSpec.

bar3(axes_handle,...) plots into the axes with the handle axes_handle instead of into the current axes (gca).

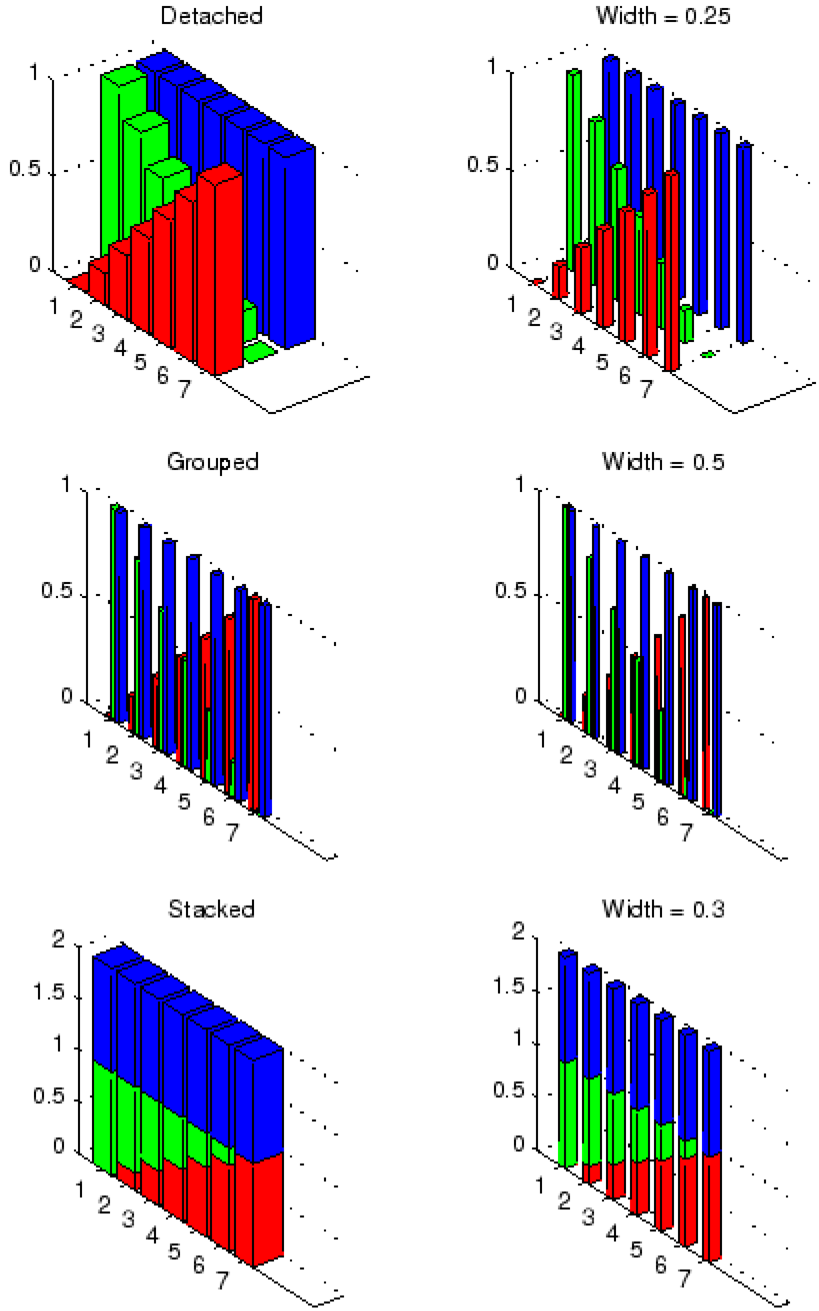
h = bar3(...) returns a vector of handles to patch graphics objects, one for each created. bar3 creates one patch object per column in Y. When Y is a matrix, bar3 creates one patch graphics object per column in Y.

bar3h(...) and h = bar3h(...) create horizontal bars. Y determines the bar length. The vector x is a vector defining the *y*-axis intervals for horizontal bars.

Examples

This example creates six subplots showing the effects of different arguments for `bar3`. The data `Y` is a 7-by-3 matrix generated using the `cool` colormap:

```
Y = cool(7);
subplot(3,2,1)
bar3(Y,'detached')
title('Detached')
subplot(3,2,2)
bar3(Y,0.25,'detached')
title('Width = 0.25')
subplot(3,2,3)
bar3(Y,'grouped')
title('Grouped')
subplot(3,2,4)
bar3(Y,0.5,'grouped')
title('Width = 0.5')
subplot(3,2,5)
bar3(Y,'stacked')
title('Stacked')
subplot(3,2,6)
bar3(Y,0.3,'stacked')
title('Width = 0.3')
colormap([1 0 0;0 1 0;0 0 1])
```


Detached
Width = 0.25
Grouped
Width = 0.5
Stacked
Width = 0.3

See Also

`bar`, `LineSpec`, `patch`

"Area, Bar, and Pie Plots" on page 1-87 for related functions

"Bar and Area Graphs" for more examples

Barseries Properties

Purpose Define barseries properties

Modifying Properties

You can set and query graphics object properties using the `set` and `get` commands or the Property Editor (`propertyeditor`).

Note that you cannot define default properties for barseries objects.

See "Plot Objects" for more information on barseries objects.

Barseries Property Descriptions

This section provides a description of properties. Curly braces { } enclose default values.

`BarLayout`

`{grouped} | stacked`

Specify grouped or stacked bars. Grouped bars display *m* groups of *n* vertical bars, where *m* is the number of rows and *n* is the number of columns in the input argument `Y`. The group contains one bar per column in `Y`.

Stacked bars display one bar for each row in the input argument `Y`. The bar height is the sum of the elements in the row. Each bar is multicolored, with colors corresponding to distinct elements and showing the relative contribution each row element makes to the total sum.

`BarWidth`

scalar in range [0 1]

Width of individual bars. `BarWidth` specifies the relative bar width and controls the separation of bars within a group. The default `width` is `0.8`, so if you do not specify `x`, the bars within a group have a slight separation. If `width` is `1`, the bars within a group touch one another.

`BaseLine`

handle of baseline

Handle of the baseline object. This property contains the handle of the line object used as the baseline. You can set the properties of this line using its handle. For example, the following statements create a bar graph, obtain the handle of the baseline from the barseries object, and then set line properties that make the baseline a dashed, red line.

```
bar_handle = bar(randn(10,1));
baseline_handle = get(bar_handle,'BaseLine');
set(baseline_handle,'LineStyle','--','Color','red')
```

`BaseValue`

double: *y*-axis value

Value where baseline is drawn. You can specify the value along the *y*-axis (vertical bars) or *x*-axis (horizontal bars) at which MATLAB draws the baseline.

`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`
array of graphics object handles

Children of this object. The handle of a patch object that is the child of this object (whether visible or not).

Note that if a child object's `HandleVisibility` property is set to `callback` or `off`, its handle does not show up in this object's `Children` property unless you set the root `ShowHiddenHandles` property to `on`:

```
set(0,'ShowHiddenHandles','on')
```

`Clipping`
`{on} | off`

Clipping mode. MATLAB clips graphs to the axes plot box by default. If you set `Clipping` to `off`, portions of graphs can be displayed outside the axes plot box. This can occur if you create a plot object, set `hold` to `on`, freeze axis scaling (`axis manual`), and then create a larger plot object.

`CreateFcn`
string or function handle

Callback routine executed during object creation. This property defines a callback that executes when MATLAB creates an object. You must specify the callback during the creation of the object. For example,

```
area(y,'CreateFcn',@CallbackFcn)
```

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.

`EdgeColor`
`{[0 0 0]} | none | ColorSpec`

Color of line that separates filled areas. You can set the color of the edges of filled areas to a three-element RGB vector or one of the MATLAB predefined names, including the string `none`. The default edge color is black. See `ColorSpec` for more information on specifying color.

`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.

`FaceColor`

`{flat} | none | ColorSpec`

Color of filled areas. This property can be any of the following:

- `ColorSpec` — A three-element RGB vector or one of the MATLAB predefined names, specifying a single color for all filled areas. See `ColorSpec` for more information on specifying color.
- `none` — Do not draw faces. Note that `EdgeColor` is drawn independently of `FaceColor`

- `flat` — The color of the filled areas is determined by the figure colormap. See `colormap` for information on setting the colormap.

  See the `ColorSpec` reference page for more information on specifying color.

`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).

`HitTestArea`
    `on | {off}`

Select barseries object on bars or area of extent. This property enables you to select barseries objects in two ways:

- Select by clicking bars (default).
- Select by clicking anywhere in the extent of the bar graph.

When `HitTestArea` is `off`, you must click the bars to select the barseries object. When `HitTestArea` is `on`, you can select the barseries object by clicking anywhere within the extent of the bar graph (i.e., anywhere within a rectangle that encloses all the bars).

`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
-.	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.

`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.

`ShowBaseLine`
`{on} | off`

Turn baseline display on or off. This property determines whether bar plots display a baseline from which the bars are drawn. By default, the baseline is displayed.

`Tag`
string

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

For example, you might create a barseries object and set the `Tag` property:

```
t = bar(Y,'Tag','bar1')
```

When you want to access the barseries object, you can use `findobj` to find the barseries object's handle. The following statement changes the `FaceColor` property of the object whose `Tag` is `bar1`.

```
set(findobj('Tag','bar1'),'FaceColor','red')
```

`Type`

string (read only)

Type of graphics object. This property contains a string that identifies the class of the graphics object. For barseries objects, `Type` is `hggroup`.

The following statement finds all the hggroup objects in the current axes.

```
t = findobj(gca,'Type','hggroup');
```

`UIContextMenu`

handle of a uicontextmenu object

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

`UserData`

array

User-specified data. This property can be any data you want to associate with this object (including cell arrays and structures). The object does not set values for this property, but you can access it using the `set` and `get` functions.

`Visible`

`{on} | off`

Visibility of this object and its children. By default, a new object's visibility is `on`. This means all children of the object are visible unless the child object's `Visible` property is set to `off`. Setting an object's `Visible` property to `off` prevents the object from being displayed. However, the object still exists and you can set and query its properties.

`XData`

array

Location of bars. The *x*-axis intervals for the vertical bars or *y*-axis intervals for horizontal bars (as specified by the `x` input argument). If `YData` is a vector, `XData` must be the same size. If `YData` is a matrix, the length of `XData` must be equal to the number of rows in `YData`.

`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`

scalar, vector, or matrix

Bar plot data. `YData` contains the data plotted as bars (the `Y` input argument). Each value in `YData` is represented by a bar in the bar graph. If `XYData` is a matrix, the `bar` function creates a "group" or a "stack" of bars for each column in the matrix. See “Bar Graph Options” on page 2-316 for examples of grouped and stacked bar graphs.

The input argument `Y` in the `bar` function calling syntax assigns values to `YData`.

`YDataSource`

string (MATLAB variable)

Link `YData` to MATLAB variable. Set this property to a MATLAB variable that is evaluated in the base workspace to generate the `YData`.

MATLAB reevaluates this property only when you set it. Therefore, a change to workspace variables appearing in an expression does not change `YData`.

You can use the `refreshdata` function to force an update of the object's data. `refreshdata` also enables you to specify that the data source variable be evaluated in the workspace of a function from which you call `refreshdata`.

See the `refreshdata` reference page for more information.

Note If you change one data source property to a variable that contains data of a different dimension, you might cause the function to generate a warning and not render the graph until you have changed all data source properties to appropriate values.

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

Convert base N number string to decimal number

Syntax

```
d = base2dec('strn', base)
```

Description

`d = base2dec('strn', base)` converts the string number *`strn`* of the specified `base` into its decimal (base 10) equivalent. `base` must be an integer between 2 and 36. If *`'strn'`* is a character array, each row is interpreted as a string in the specified `base`.

Examples

The expression `base2dec('212',3)` converts 212_3 to decimal, returning 23.

See Also

`dec2base`

Purpose Produce beep sound

Syntax

```
beep
beep on
beep off
s = beep
```

Description

`beep` produces your computer's default beep sound.

`beep on` turns the beep on.

`beep off` turns the beep off.

`s = beep` returns the current beep mode (`on` or `off`).

besselh

Purpose Bessel function of third kind (Hankel function)

Syntax

```
H = besselh(nu,K,Z)
H = besselh(nu,Z)
H = besselh(nu,K,Z,1)
[H,ierr] = besselh(...)
```

Definitions The differential equation

$$z^2 \frac{d^2 y}{dz^2} + z \frac{dy}{dz} + (z^2 - \nu^2) y = 0$$

where ν is a nonnegative constant, is called *Bessel's equation*, and its solutions are known as *Bessel functions*. $J_\nu(z)$ and $J_{-\nu}(z)$ form a fundamental set of solutions of Bessel's equation for noninteger ν. $Y_\nu(z)$ is a second solution of Bessel's equation – linearly independent of $J_\nu(z)$ – defined by

$$Y_\nu(z) = \frac{J_\nu(z)\cos(\nu\pi) - J_{-\nu}(z)}{\sin(\nu\pi)}$$

The relationship between the Hankel and Bessel functions is

$$H_\nu^{(1)}(z) = J_\nu(z) + i\ Y_\nu(z)$$
$$H_\nu^{(2)}(z) = J_\nu(z) - i\ Y_\nu(z)$$

where $J_\nu(z)$ is `besselj`, and $Y_\nu(z)$ is `bessely`.

Description `H = besselh(nu,K,Z)` computes the Hankel function $H_\nu^{(K)}(z)$, where `K` = 1 or 2, for each element of the complex array `Z`. If `nu` and `Z` are arrays of the same size, the result is also that size. If either input is a scalar, `besselh` expands it to the other input's size. If one input is a row vector and the other is a column vector, the result is a two-dimensional table of function values.

`H = besselh(nu,Z)` uses `K` = 1.

`H = besselh(nu,K,Z,1)` scales $H_{\nu}^{(K)}(z)$ by `exp(-i*Z)` if `K` = 1, and by `exp(+i*Z)` if `K` = 2.

`[H,ierr] = besselh(...)` also returns completion flags in an array the same size as `H`.

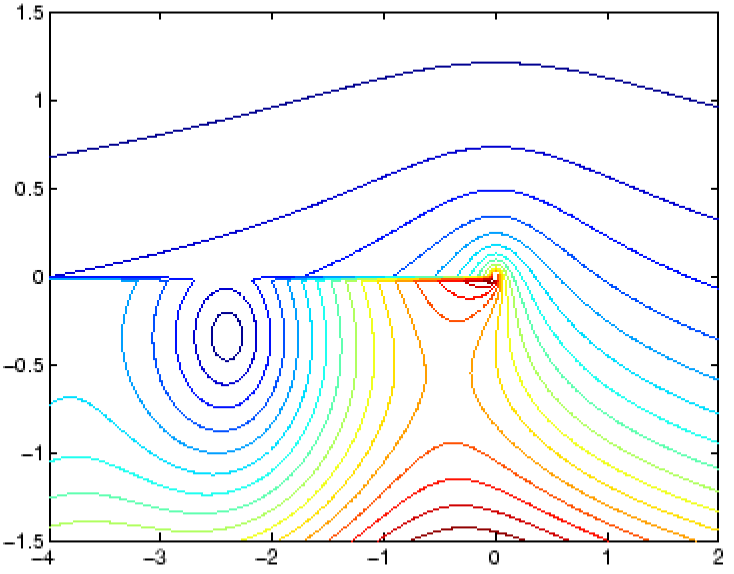
ierr	Description
0	`besselh` successfully computed the Hankel function for this element.
1	Illegal arguments.
2	Overflow. Returns `Inf`.
3	Some loss of accuracy in argument reduction.
4	Unacceptable loss of accuracy, `Z` or `nu` too large.
5	No convergence. Returns `NaN`.

Examples

This example generates the contour plots of the modulus and phase of the Hankel function $H_0^{(1)}(z)$ shown on page 359 of [1] Abramowitz and Stegun, *Handbook of Mathematical Functions*.

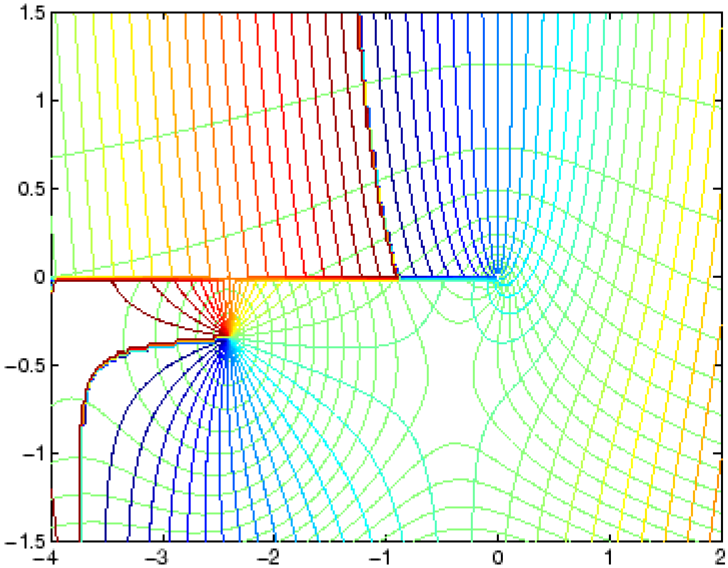
It first generates the modulus contour plot

```
[X,Y] = meshgrid(-4:0.025:2,-1.5:0.025:1.5);
H = besselh(0,1,X+i*Y);
contour(X,Y,abs(H),0:0.2:3.2), hold on
```



then adds the contour plot of the phase of the same function.

```
contour(X,Y,(180/pi)*angle(H),-180:10:180); hold off
```



See Also

`besselj`, `bessely`, `besseli`, `besselk`

References

[1] Abramowitz, M., and I.A. Stegun, *Handbook of Mathematical Functions*, National Bureau of Standards, Applied Math. Series #55, Dover Publications, 1965.

Purpose

Modified Bessel function of first kind

Syntax

```
I = besseli(nu,Z)
I = besseli(nu,Z,1)
[I,ierr] = besseli(...)
```

Definitions

The differential equation

$$z^2\frac{d^2y}{dz^2} + z\frac{dy}{dz} - (z^2 + \nu^2)y = 0$$

where ν is a real constant, is called the *modified Bessel's equation*, and its solutions are known as *modified Bessel functions*.

$I_\nu(z)$ and $I_{-\nu}(z)$ form a fundamental set of solutions of the modified Bessel's equation for noninteger ν. $I_\nu(z)$ is defined by

$$I_\nu(z) = \left(\frac{z}{2}\right)^\nu \sum_{k=0}^{\infty} \frac{\left(\frac{z^2}{4}\right)^k}{k!\ \Gamma(\nu + k + 1)}$$

where $\Gamma(a)$ is the gamma function.

$K_\nu(z)$ is a second solution, independent of $I_\nu(z)$. It can be computed using `besselk`.

Description

`I = besseli(nu,Z)` computes the modified Bessel function of the first kind, $I_\nu(z)$, for each element of the array `Z`. The order `nu` need not be an integer, but must be real. The argument `Z` can be complex. The result is real where `Z` is positive.

If `nu` and `Z` are arrays of the same size, the result is also that size. If either input is a scalar, it is expanded to the other input's size. If one input is a row vector and the other is a column vector, the result is a two-dimensional table of function values.

`I = besseli(nu,Z,1)` computes `besseli(nu,Z).*exp(-abs(real(Z)))`.

`[I,ierr] = besseli(...)` also returns completion flags in an array the same size as `I`.

ierr	Description
0	`besseli` successfully computed the modified Bessel function for this element.
1	Illegal arguments.
2	Overflow. Returns `Inf`.
3	Some loss of accuracy in argument reduction.
4	Unacceptable loss of accuracy, `Z` or `nu` too large.
5	No convergence. Returns `NaN`.

Examples

Example 1

```
format long
z = (0:0.2:1)';

besseli(1,z)

ans =
                   0
   0.10050083402813
   0.20402675573357
   0.31370402560492
   0.43286480262064
   0.56515910399249
```

Example 2

`besseli(3:9,(0:.2,10)',1)` generates the entire table on page 423 of [1] Abramowitz and Stegun, *Handbook of Mathematical Functions*

Algorithm The `besseli` functions use a Fortran MEX-file to call a library developed by D.E. Amos [3] [4].

See Also `airy`, `besselh`, `besselj`, `besselk`, `bessely`

References

[1] Abramowitz, M., and I.A. Stegun, *Handbook of Mathematical Functions*, National Bureau of Standards, Applied Math. Series #55, Dover Publications, 1965, sections 9.1.1, 9.1.89, and 9.12, formulas 9.1.10 and 9.2.5.

[2] Carrier, Krook, and Pearson, *Functions of a Complex Variable: Theory and Technique*, Hod Books, 1983, section 5.5.

[3] Amos, D.E., "A Subroutine Package for Bessel Functions of a Complex Argument and Nonnegative Order," *Sandia National Laboratory Report*, SAND85-1018, May, 1985.

[4] Amos, D.E., "A Portable Package for Bessel Functions of a Complex Argument and Nonnegative Order," *Trans. Math. Software*, 1986.

Purpose

Bessel function of first kind

Syntax

```
J = besselj(nu,Z)
J = besselj(nu,Z,1)
[J,ierr] = besselj(nu,Z)
```

Definition

The differential equation

$$z^2 \frac{d^2y}{dz^2} + z\frac{dy}{dz} + (z^2 - \nu^2)y = 0$$

where ν is a real constant, is called *Bessel's equation*, and its solutions are known as *Bessel functions*.

$J_\nu(z)$ and $J_{-\nu}(z)$ form a fundamental set of solutions of Bessel's equation for noninteger ν. $J_\nu(z)$ is defined by

$$J_\nu(z) = \left(\frac{z}{2}\right)^\nu \sum_{k=0}^{\infty} \frac{\left(-\frac{z^2}{4}\right)^k}{k!\ \Gamma(\nu+k+1)}$$

where $\Gamma(a)$ is the gamma function.

$Y_\nu(z)$ is a second solution of Bessel's equation that is linearly independent of $J_\nu(z)$. It can be computed using `bessely`.

Description

`J = besselj(nu,Z)` computes the Bessel function of the first kind, $J_\nu(z)$, for each element of the array `Z`. The order `nu` need not be an integer, but must be real. The argument `Z` can be complex. The result is real where `Z` is positive.

If `nu` and `Z` are arrays of the same size, the result is also that size. If either input is a scalar, it is expanded to the other input's size. If one input is a row vector and the other is a column vector, the result is a two-dimensional table of function values.

`J = besselj(nu,Z,1)` computes `besselj(nu,Z).*exp(-abs(imag(Z)))`.

`[J,ierr] = besselj(nu,Z)` also returns completion flags in an array the same size as `J`.

ierr	Description
0	`besselj` successfully computed the Bessel function for this element.
1	Illegal arguments.
2	Overflow. Returns `Inf`.
3	Some loss of accuracy in argument reduction.
4	Unacceptable loss of accuracy, `Z` or `nu` too large.
5	No convergence. Returns `NaN`.

Remarks

The Bessel functions are related to the Hankel functions, also called Bessel functions of the third kind,

$$H_\nu^{(1)}(z) = J_\nu(z) + i\ Y_\nu(z)$$

$$H_\nu^{(2)}(z) = J_\nu(z) - i\ Y_\nu(z)$$

where $H_\nu^{(K)}(z)$ is `besselh`, $J_\nu(z)$ is `besselj`, and $Y_\nu(z)$ is `bessely`. The Hankel functions also form a fundamental set of solutions to Bessel's equation (see `besselh`).

Examples

Example 1

```
format long
z = (0:0.2:1)';

besselj(1,z)
```

```
ans =
                     0
   0.09950083263924
   0.19602657795532
   0.28670098806392
   0.36884204609417
   0.44005058574493
```

Example 2

`besselj(3:9,(0:.2:10)')` generates the entire table on page 398 of [1] Abramowitz and Stegun, *Handbook of Mathematical Functions*.

Algorithm

The `besselj` function uses a Fortran MEX-file to call a library developed by D.E. Amos [3] [4].

References

[1] Abramowitz, M., and I.A. Stegun, *Handbook of Mathematical Functions*, National Bureau of Standards, Applied Math. Series #55, Dover Publications, 1965, sections 9.1.1, 9.1.89, and 9.12, formulas 9.1.10 and 9.2.5.

[2] Carrier, Krook, and Pearson, *Functions of a Complex Variable: Theory and Technique*, Hod Books, 1983, section 5.5.

[3] Amos, D.E., "A Subroutine Package for Bessel Functions of a Complex Argument and Nonnegative Order," *Sandia National Laboratory Report*, SAND85-1018, May, 1985.

[4] Amos, D.E., "A Portable Package for Bessel Functions of a Complex Argument and Nonnegative Order," *Trans. Math. Software*, 1986.

See Also

`besselh`, `besseli`, `besselk`, `bessely`

besselk

Purpose

Modified Bessel function of second kind

Syntax

```
K = besselk(nu,Z)
K = besselk(nu,Z,1)
[K,ierr] = besselk(...)
```

Definitions

The differential equation

$$z^2 \frac{d^2 y}{dz^2} + z \frac{dy}{dz} - (z^2 + \nu^2) y = 0$$

where ν is a real constant, is called the *modified Bessel's equation*, and its solutions are known as *modified Bessel functions*.

A solution $K_\nu(z)$ of the second kind can be expressed as

$$K_\nu(z) = \left(\frac{\pi}{2}\right) \frac{I_{-\nu}(z) - I_\nu(z)}{\sin(\nu\pi)}$$

where $I_\nu(z)$ and $I_{-\nu}(z)$ form a fundamental set of solutions of the modified Bessel's equation for noninteger ν

$$I_\nu(z) = \left(\frac{z}{2}\right)^\nu \sum_{k=0}^{\infty} \frac{\left(\frac{z^2}{4}\right)^k}{k!\ \Gamma(\nu + k + 1)}$$

and $\Gamma(a)$ is the gamma function. $K_\nu(z)$ is independent of $I_\nu(z)$.

$I_\nu(z)$ can be computed using `besseli`.

Description

`K = besselk(nu,Z)` computes the modified Bessel function of the second kind, $K_\nu(z)$, for each element of the array `Z`. The order `nu` need not be an integer, but must be real. The argument `Z` can be complex. The result is real where `Z` is positive.

If nu and Z are arrays of the same size, the result is also that size. If either input is a scalar, it is expanded to the other input's size. If one input is a row vector and the other is a column vector, the result is a two-dimensional table of function values.

`K = besselk(nu,Z,1)` computes `besselk(nu,Z).*exp(Z)`.

`[K,ierr] = besselk(...)` also returns completion flags in an array the same size as K.

ierr	Description
0	besselk successfully computed the modified Bessel function for this element.
1	Illegal arguments.
2	Overflow. Returns Inf.
3	Some loss of accuracy in argument reduction.
4	Unacceptable loss of accuracy, Z or nu too large.
5	No convergence. Returns NaN.

Examples

Example 1

```
format long
z = (0:0.2:1)';

besselk(1,z)

ans =
                   Inf
    4.77597254322047
    2.18435442473269
    1.30283493976350
    0.86178163447218
    0.60190723019723
```

Example 2

`besselk(3:9,(0:.2:10)',1)` generates part of the table on page 424 of [1] Abramowitz and Stegun, *Handbook of Mathematical Functions*.

Algorithm

The `besselk` function uses a Fortran MEX-file to call a library developed by D.E. Amos [3][4].

References

[1] Abramowitz, M., and I.A. Stegun, *Handbook of Mathematical Functions*, National Bureau of Standards, Applied Math. Series #55, Dover Publications, 1965, sections 9.1.1, 9.1.89, and 9.12, formulas 9.1.10 and 9.2.5.

[2] Carrier, Krook, and Pearson, *Functions of a Complex Variable: Theory and Technique*, Hod Books, 1983, section 5.5.

[3] Amos, D.E., "A Subroutine Package for Bessel Functions of a Complex Argument and Nonnegative Order," *Sandia National Laboratory Report*, SAND85-1018, May, 1985.

[4] Amos, D.E., "A Portable Package for Bessel Functions of a Complex Argument and Nonnegative Order," *Trans. Math. Software*, 1986.

See Also

`airy`, `besselh`, `besseli`, `besselj`, `bessely`

Purpose

Bessel function of second kind

Syntax

```
Y = bessely(nu,Z)
Y = bessely(nu,Z,1)
[Y,ierr] = bessely(nu,Z)
```

Definition

The differential equation

$$z^2 \frac{d^2 y}{dz^2} + z \frac{dy}{dz} + (z^2 - \nu^2) y = 0$$

where ν is a real constant, is called *Bessel's equation*, and its solutions are known as *Bessel functions*.

A solution $Y_\nu(z)$ of the second kind can be expressed as

$$Y_\nu(z) = \frac{J_\nu(z)\cos(\nu\pi) - J_{-\nu}(z)}{\sin(\nu\pi)}$$

where $J_\nu(z)$ and $J_{-\nu}(z)$ form a fundamental set of solutions of Bessel's equation for noninteger ν

$$J_\nu(z) = \left(\frac{z}{2}\right)^\nu \sum_{k=0}^{\infty} \frac{\left(-\frac{z^2}{4}\right)^k}{k!\ \Gamma(\nu + k + 1)}$$

and $\Gamma(a)$ is the gamma function. $Y_\nu(z)$ is linearly independent of $J_\nu(z)$.

$J_\nu(z)$ can be computed using `besselj`.

Description

`Y = bessely(nu,Z)` computes Bessel functions of the second kind, $Y_\nu(z)$, for each element of the array `Z`. The order `nu` need not be an integer, but must be real. The argument `Z` can be complex. The result is real where `Z` is positive.

If `nu` and `Z` are arrays of the same size, the result is also that size. If either input is a scalar, it is expanded to the other input's size. If one input is a row vector and the other is a column vector, the result is a two-dimensional table of function values.

`Y = bessely(nu,Z,1)` computes `bessely(nu,Z).*exp(-abs(imag(Z)))`.

`[Y,ierr] = bessely(nu,Z)` also returns completion flags in an array the same size as `Y`.

ierr	Description
0	`bessely` successfully computed the Bessel function for this element.
1	Illegal arguments.
2	Overflow. Returns `Inf`.
3	Some loss of accuracy in argument reduction.
4	Unacceptable loss of accuracy, `Z` or `nu` too large.
5	No convergence. Returns `NaN`.

Remarks

The Bessel functions are related to the Hankel functions, also called Bessel functions of the third kind,

$$H_\nu^{(1)}(z) = J_\nu(z) + i\ Y_\nu(z)$$

$$H_\nu^{(2)}(z) = J_\nu(z) - i\ Y_\nu(z)$$

where $H_\nu^{(K)}(z)$ is `besselh`, $J_\nu(z)$ is `besselj`, and $Y_\nu(z)$ is `bessely`. The Hankel functions also form a fundamental set of solutions to Bessel's equation (see `besselh`).

Examples

Example 1

```
format long
z = (0:0.2:1)';

bessely(1,z)

ans =
                  -Inf
   -3.32382498811185
   -1.78087204427005
   -1.26039134717739
   -0.97814417668336
   -0.78121282130029
```

Example 2

`bessely(3:9,(0:.2:10)')` generates the entire table on page 399 of [1] Abramowitz and Stegun, *Handbook of Mathematical Functions*.

Algorithm

The `bessely` function uses a Fortran MEX-file to call a library developed by D. E Amos [3] [4].

References

[1] Abramowitz, M., and I.A. Stegun, *Handbook of Mathematical Functions*, National Bureau of Standards, Applied Math. Series #55, Dover Publications, 1965, sections 9.1.1, 9.1.89, and 9.12, formulas 9.1.10 and 9.2.5.

[2] Carrier, Krook, and Pearson, *Functions of a Complex Variable: Theory and Technique*, Hod Books, 1983, section 5.5.

[3] Amos, D.E., "A Subroutine Package for Bessel Functions of a Complex Argument and Nonnegative Order," *Sandia National Laboratory Report*, SAND85-1018, May, 1985.

[4] Amos, D.E., "A Portable Package for Bessel Functions of a Complex Argument and Nonnegative Order," *Trans. Math. Software*, 1986.

See Also

besselh, besseli, besselj, besselk

Purpose

Beta function

Syntax

```
B = beta(Z,W)
```

Definition

The beta function is

$$B(z, w) = \int_0^1 t^{z-1}(1-t)^{w-1}\,dt = \frac{\Gamma(z)\Gamma(w)}{\Gamma(z+w)}$$

where $\Gamma(z)$ is the gamma function.

Description

`B = beta(Z,W)` computes the beta function for corresponding elements of arrays `Z` and `W`. The arrays must be real and nonnegative. They must be the same size, or either can be scalar.

Examples

In this example, which uses integer arguments,

```
beta(n,3)
   = (n-1)!*2!/(n+2)!
   = 2/(n*(n+1)*(n+2))
```

is the ratio of fairly small integers, and the rational format is able to recover the exact result.

```
format rat
beta((0:10)',3)

ans =

     1/0
     1/3
     1/12
     1/30
     1/60
     1/105
     1/168
     1/252
```

```
1/360
1/495
1/660
```

Algorithm

```
beta(z,w) = exp(gammaln(z)+gammaln(w)-gammaln(z+w))
```

See Also

`betainc`, `betaln`, `gammaln`

Purpose

Incomplete beta function

Syntax

```
I = betainc(X,Z,W)
```

Definition

The incomplete beta function is

$$I_x(z, w) = \frac{1}{B(z, w)} \int_0^x t^{z-1}(1-t)^{w-1}\, dt$$

where $B(z, w)$, the beta function, is defined as

$$B(z, w) = \int_0^1 t^{z-1}(1-t)^{w-1}\, dt = \frac{\Gamma(z)\Gamma(w)}{\Gamma(z+w)}$$

and $\Gamma(z)$ is the gamma function.

Description

`I = betainc(X,Z,W)` computes the incomplete beta function for corresponding elements of the arrays `X`, `Z`, and `W`. The elements of `X` must be in the closed interval $[0,1]$. The arrays `Z` and `W` must be nonnegative and real. All arrays must be the same size, or any of them can be scalar.

Examples

```
format long
betainc(.5,(0:10)',3)

ans =
    1.00000000000000
    0.87500000000000
    0.68750000000000
    0.50000000000000
    0.34375000000000
    0.22656250000000
    0.14453125000000
    0.08984375000000
    0.05468750000000
    0.03271484375000
    0.01928710937500
```

See Also

`beta`, `betaln`

Purpose

Logarithm of beta function

Syntax

`L = betaln(Z,W)`

Description

`L = betaln(Z,W)` computes the natural logarithm of the `beta` function `log(beta(Z,W))`, for corresponding elements of arrays `Z` and `W`, without computing `beta(Z,W)`. Since the beta function can range over very large or very small values, its logarithm is sometimes more useful.

`Z` and `W` must be real and nonnegative. They must be the same size, or either can be scalar.

Examples

```
x = 510
betaln(x,x)

ans =
      -708.8616
```

`-708.8616` is slightly less than `log(realmin)`. Computing `beta(x,x)` directly would underflow (or be denormal).

Algorithm

```
betaln(z,w) = gammaln(z)+gammaln(w)-gammaln(z+w)
```

See Also

`beta`, `betainc`, `gammaln`

Purpose

Biconjugate gradients method

Syntax

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

Description

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

"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 `bicg` converges, it displays a message to that effect. If `bicg` fails to converge after the maximum number of iterations or halts for any reason, it prints a warning message that includes the relative residual `norm(b-A*x)/norm(b)` and the iteration number at which the method stopped or failed.

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

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

`bicg(A,b,tol,maxit,M)` and `bicg(A,b,tol,maxit,M1,M2)` use the preconditioner `M` or `M = M1*M2` and effectively solve the system `inv(M)*A*x = inv(M)*b` for `x`. If `M` is `[]` then `bicg` applies no preconditioner. `M` can be a function handle `mfun` such that `mfun(x,'notransp')` returns `M\x` and `mfun(x,'transp')` returns `M'\x`.

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

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

Flag	Convergence
0	`bicg` converged to the desired tolerance `tol` within `maxit` iterations.
1	`bicg` iterated `maxit` times but did not converge.
2	Preconditioner `M` was ill-conditioned.
3	`bicg` stagnated. (Two consecutive iterates were the same.)
4	One of the scalar quantities calculated during `bicg` 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] = bicg(A,b,...)` also returns the relative residual `norm(b-A*x)/norm(b)`. If `flag` is `0`, `relres <= tol`.

`[x,flag,relres,iter] = bicg(A,b,...)` also returns the iteration number at which `x` was computed, where `0 <= iter <= maxit`.

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

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 = bicg(A,b,tol,maxit,M1,M2);
```

displays this message:

```
bicg converged at iteration 9 to a solution with relative
residual 5.3e-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_bicg` that

- Calls `bicg` with the function handle `@afun` as its first argument.
- Contains `afun` as a nested function, so that all variables in `run_bicg` are available to `afun`.

The following shows the code for `run_bicg`:

```
function x1 = run_bicg
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 = bicg(@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_bicg;
```

MATLAB displays the message

```
bicg converged at iteration 9 to a solution with ...
relative residual
5.3e-009
```

Example 3

This example demonstrates the use of a preconditioner. Start with `A = west0479`, a real 479-by-479 sparse matrix, and define `b` so that the true solution is a vector of all ones.

```
load west0479;
A = west0479;
b = sum(A,2);
```

You can accurately solve `A*x = b` using backslash since `A` is not so large.

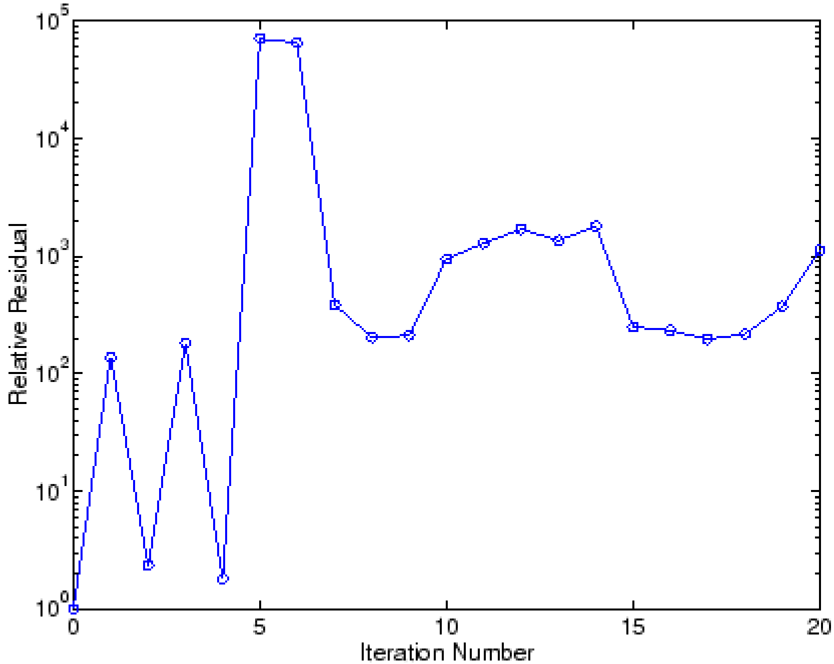
```
x = A \ b;
norm(b-A*x) / norm(b)

ans =
    8.3154e-017
```

Now try to solve `A*x = b` with `bicg`.

```
[x,flag,relres,iter,resvec] = bicg(A,b)

flag =
          1
relres =
          1
iter =
          0
```

The value of `flag` indicates that `bicg` iterated the default 20 times without converging. The value of `iter` shows that the method behaved so badly that the initial all-zero guess was better than all the subsequent iterates. The value of `relres` supports this: `relres = norm(b-A*x)/norm(b) = norm(b)/norm(b) = 1`. You can confirm that the unpreconditioned method oscillates rather wildly by plotting the relative residuals at each iteration.

```
semilogy(0:20,resvec/norm(b),'-o')
xlabel('Iteration Number')
ylabel('Relative Residual')
```



Now, try an incomplete LU factorization with a drop tolerance of `1e-5` for the preconditioner.

```
[L1,U1] = luinc(A,1e-5);
Warning: Incomplete upper triangular factor has 1 zero diagonal.
         It cannot be used as a preconditioner for an iterative
         method.

nnz(A), nnz(L1), nnz(U1)

ans =
         1887
ans =
         5562
ans =
         4320
```

The zero on the main diagonal of the upper triangular U1 indicates that U1 is singular. If you try to use it as a preconditioner,

```
[x,flag,relres,iter,resvec] = bicg(A,b,1e-6,20,L1,U1)

flag =
         2
relres =
         1
iter =
         0
resvec =
         7.0557e+005
```

the method fails in the very first iteration when it tries to solve a system of equations involving the singular U1 using backslash. bicg is forced to return the initial estimate since no other iterates were produced.

Try again with a slightly less sparse preconditioner.

```
[L2,U2] = luinc(A,1e-6);

nnz(L2), nnz(U2)

ans =
         6231
ans =
         4559
```

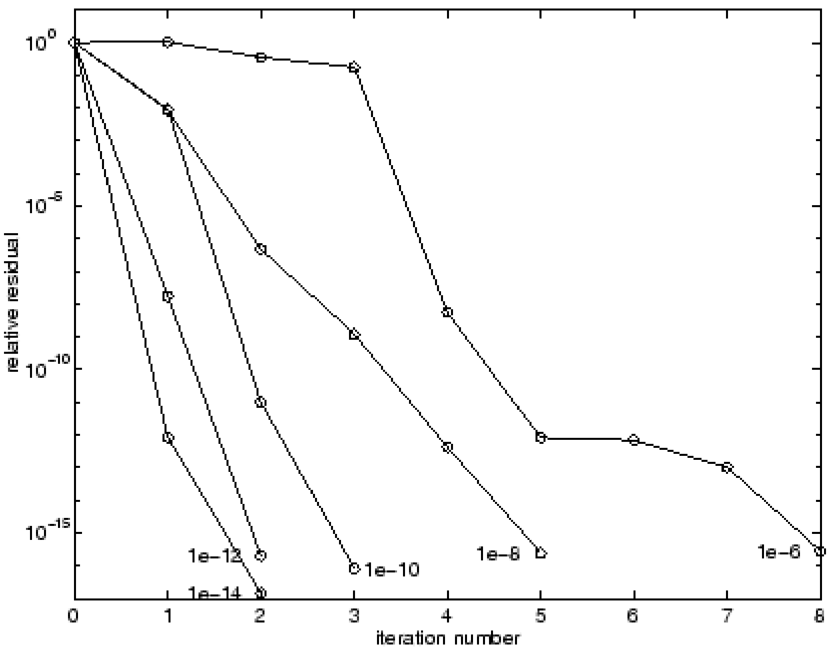
This time U2 is nonsingular and may be an appropriate preconditioner.

```
[x,flag,relres,iter,resvec] = bicg(A,b,1e-15,10,L2,U2)

flag =
         0
relres =
         2.8664e-016
iter =
```

8

and bicg converges to within the desired tolerance at iteration number 8. Decreasing the value of the drop tolerance increases the fill-in of the incomplete factors but also increases the accuracy of the approximation to the original matrix. Thus, the preconditioned system becomes closer to inv(U)*inv(L)*L*U*x = inv(U)*inv(L)*b, where L and U are the true LU factors, and closer to being solved within a single iteration.

The next graph shows the progress of bicg using six different incomplete LU factors as preconditioners. Each line in the graph is labeled with the drop tolerance of the preconditioner used in bicg.



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.

See Also

bicgstab, cgs, gmres, ilu, lsqr, luinc, minres, pcg, qmr, symmlq, function_handle (@), mldivide (\)

Purpose

Biconjugate gradients stabilized method

Syntax

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

Description

`x = bicgstab(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.

“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 `bicgstab` converges, a message to that effect is displayed. If `bicgstab` 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.

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

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

`bicgstab(A,b,tol,maxit,M)` and `bicgstab(A,b,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 `bicgstab` applies no preconditioner. `M` can be a function handle `mfun` such that `mfun(x)` returns `M\x`.

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

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

Flag	Convergence
0	`bicgstab` converged to the desired tolerance `tol` within `maxit` iterations.
1	`bicgstab` iterated `maxit` times but did not converge.
2	Preconditioner `M` was ill-conditioned.
3	`bicgstab` stagnated. (Two consecutive iterates were the same.)
4	One of the scalar quantities calculated during `bicgstab` 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] = bicgstab(A,b,...)` also returns the relative residual `norm(b-A*x)/norm(b)`. If `flag` is `0`, `relres <= tol`.

`[x,flag,relres,iter] = bicgstab(A,b,...)` also returns the iteration number at which `x` was computed, where `0 <= iter <= maxit`. `iter` can be an integer + 0.5, indicating convergence halfway through an iteration.

`[x,flag,relres,iter,resvec] = bicgstab(A,b,...)` also returns a vector of the residual norms at each half iteration, including `norm(b-A*x0)`.

Example

Example 1

This example first solves `Ax = b` by providing `A` and the preconditioner `M1` directly as arguments.

```
A = gallery('wilk',21);
b = sum(A,2);
tol = 1e-12;
maxit = 15;
M1 = diag([10:-1:1 1 1:10]);

x = bicgstab(A,b,tol,maxit,M1);
```

displays the message

```
bicgstab converged at iteration 12.5 to a solution with relative
residual 6.7e-014
```

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_bicgstab` that

- Calls `bicgstab` with the function handle `@afun` as its first argument.
- Contains `afun` and `mfun` as nested functions, so that all variables in `run_bicgstab` are available to `afun` and `mfun`.

The following shows the code for `run_bicgstab`:

```
function x1 = run_bicgstab
n = 21;
A = gallery('wilk',n);
b = sum(A,2);
tol = 1e-12;
maxit = 15;
M1 = diag([10:-1:1 1 1:10]);
x1 = bicgstab(@afun,b,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_bicgstab;
```

MATLAB displays the message

```
bicgstab converged at iteration 12.5 to a solution with relative
residual 6.7e-014
```

Example 3

This examples demonstrates the use of a preconditioner. Start with `A = west0479`, a real 479-by-479 sparse matrix, and define `b` so that the true solution is a vector of all ones.

```
load west0479;
A = west0479;
b = sum(A,2);
[x,flag] = bicgstab(A,b)
```

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

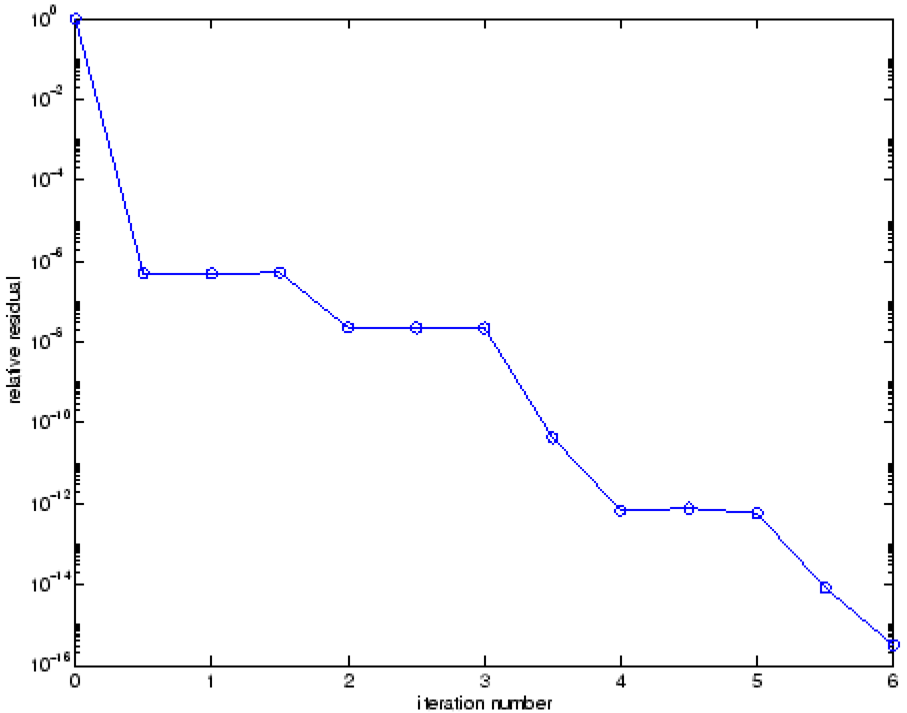
```
[L1,U1] = luinc(A,1e-5);
[x1,flag1] = bicgstab(A,b,1e-6,20,L1,U1)
```

flag1 is 2 because the upper triangular U1 has a zero on its diagonal. This causes bicgstab to fail in the first iteration when it tries to solve a system such as U1*y = r using backslash.

```
[L2,U2] = luinc(A,1e-6);
[x2,flag2,relres2,iter2,resvec2] = bicgstab(A,b,1e-15,10,L2,U2)
```

flag2 is 0 because bicgstab converges to the tolerance of 3.1757e-016 (the value of relres2) at the sixth iteration (the value of iter2) when preconditioned by the incomplete LU factorization with a drop tolerance of 1e-6. resvec2(1) = norm(b) and resvec2(13) = norm(b-A*x2). You can follow the progress of bicgstab by plotting the relative residuals at the halfway point and end of each iteration starting from the initial estimate (iterate number 0).

```
semilogy(0:0.5:iter2,resvec2/norm(b),'-o')
xlabel('iteration number')
ylabel('relative residual')
```



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] van der Vorst, H.A., "BI-CGSTAB: A fast and smoothly converging variant of BI-CG for the solution of nonsymmetric linear systems," *SIAM J. Sci. Stat. Comput.*, March 1992, Vol. 13, No. 2, pp. 631-644.

See Also

`bicg`, `cgs`, `gmres`, `lsqr`, `luinc`, `minres`, `pcg`, `qmr`, `symmlq`, `function_handle` (`@`), `mldivide` (`\`)

Purpose

Convert binary number string to decimal number

Syntax

`bin2dec(`*`binarystr`*`)`

Description

`bin2dec(`*`binarystr`*`)` interprets the binary string *`binarystr`* and returns the equivalent decimal number.

`bin2dec` ignores any space (`' '`) characters in the input string.

Examples

Binary `010111` converts to decimal `23`:

```
bin2dec('010111')
ans =
    23
```

Because space characters are ignored, this string yields the same result:

```
bin2dec(' 010   111 ')
ans =
    23
```

See Also

`dec2bin`

binary

Purpose

Set FTP transfer type to binary

Syntax

```
binary(f)
```

Description

`binary(f)` sets the FTP download and upload mode to binary, which does not convert new lines, where `f` was created using `ftp`. Use this function when downloading or uploading any nontext file, such as an executable or ZIP archive.

Examples

Connect to the MathWorks FTP server, and display the FTP object.

```
tmw=ftp('ftp.mathworks.com');
disp(tmw)
FTP Object
  host: ftp.mathworks.com
  user: anonymous
   dir: /
  mode: binary
```

Note that the FTP object defaults to binary mode.

Use the `ascii` function to set the FTP mode to ASCII, and use the `disp` function to display the FTP object.

```
ascii(tmw)
disp(tmw)
FTP Object
  host: ftp.mathworks.com
  user: anonymous
   dir: /
  mode: ascii
```

Note that the FTP object is now set to ASCII mode.

Use the `binary` function to set the FTP mode to binary, and use the `disp` function to display the FTP object.

```
binary(tmw)
```

```
disp(tmw)
FTP Object
  host: ftp.mathworks.com
  user: anonymous
   dir: /
  mode: binary
```

Note that the FTP object's mode is again set to binary.

See Also

`ftp`, `ascii`

bitand

Purpose

Bitwise AND

Syntax

```
C = bitand(A, B)
```

Description

`C = bitand(A, B)` returns the bitwise AND of arguments `A` and `B`, where `A` and `B` are unsigned integers or arrays of unsigned integers.

Examples

Example 1

The five-bit binary representations of the integers 13 and 27 are 01101 and 11011, respectively. Performing a bitwise AND on these numbers yields 01001, or 9:

```
C = bitand(uint8(13), uint8(27))
C =
    9
```

Example 2

Create a truth table for a logical AND operation:

```
A = uint8([0 1; 0 1]);
B = uint8([0 0; 1 1]);

TT = bitand(A, B)
TT =
    0    0
    0    1
```

See Also

`bitcmp`, `bitget`, `bitmax`, `bitor`, `bitset`, `bitshift`, `bitxor`

Purpose

Bitwise complement

Syntax

```
C = bitcmp(A)
C = bitcmp(A, n)
```

Description

`C = bitcmp(A)` returns the bitwise complement of `A`, where `A` is an unsigned integer or an array of unsigned integers.

`C = bitcmp(A, n)` returns the bitwise complement of `A` as an `n`-bit unsigned integer `C`. Input `A` may not have any bits set higher than `n` (that is, `A` may not have a value greater than `2^n-1`). The value of `n` can be no greater than the number of bits in the unsigned integer class of `A`. For example, if the class of `A` is `uint32`, then `n` must be a positive integer less than 32.

Examples

Example 1

With eight-bit arithmetic, the one's complement of 01100011 (decimal 99) is 10011100 (decimal 156):

```
C = bitcmp(uint8(99))
C =
   156
```

Example 2

The complement of hexadecimal A5 (decimal 165) is 5A:

```
x = hex2dec('A5')
x =
   165

dec2hex(bitcmp(x, 8))
ans =
5A
```

Next, find the complement of hexadecimal 000000A5:

```
dec2hex(bitcmp(x, 32))
```

```
ans =
FFFFFF5A
```

See Also

`bitand`, `bitget`, `bitmax`, `bitor`, `bitset`, `bitshift`, `bitxor`

Purpose Bit at specified position

Syntax `C = bitget(A, bit)`

Description `C = bitget(A, bit)` returns the value of the bit at position *`bit`* in `A`. Operand `A` must be an unsigned integer or an array of unsigned integers, and *`bit`* must be a number between 1 and the number of bits in the unsigned integer class of `A` (e.g., 32 for the `uint32` class).

Examples

Example 1

The `dec2bin` function converts decimal numbers to binary. However, you can also use the `bitget` function to show the binary representation of a decimal number. Just test successive bits from most to least significant:

```
disp(dec2bin(13))
1101

C = bitget(uint8(13), 4:-1:1)
C =
     1     1     0     1
```

Example 2

Prove that `intmax` sets all the bits to 1:

```
a = intmax('uint8');
if all(bitget(a, 1:8))
   disp('All the bits have value 1.')
   end

All the bits have value 1.
```

See Also `bitand`, `bitcmp`, `bitmax`, `bitor`, `bitset`, `bitshift`, `bitxor`

bitmax

Purpose

Maximum double-precision floating-point integer

Syntax

```
bitmax
```

Description

`bitmax` returns the maximum unsigned double-precision floating-point integer for your computer. It is the value when all bits are set, namely the value $2^{53} - 1$.

Note Instead of integer-valued double-precision variables, use unsigned integers for bit manipulations and replace `bitmax` with `intmax`.

Examples

Display in different formats the largest floating point integer and the largest 32 bit unsigned integer:

```
format long e
bitmax
ans =
   9.007199254740991e+015

intmax('uint32')
ans =
   4294967295

format hex
bitmax
ans =
   433fffffffffffff

intmax('uint32')
ans =
   ffffffff
```

In the second bitmax statement, the last 13 hex digits of `bitmax` are `f`, corresponding to 52 1's (all 1's) in the mantissa of the binary representation. The first 3 hex digits correspond to the sign bit 0 and the 11 bit biased exponent `10000110011` in binary (`1075` in decimal), and the actual exponent is (`1075-1023`) = `52`. Thus the binary value of `bitmax` is `1.111...111 x 2^52` with 52 trailing 1's, or `2^53-1`.

See Also

`bitand`, `bitcmp`, `bitget`, `bitor`, `bitset`, `bitshift`, `bitxor`

Purpose Bitwise OR

Syntax

```
C = bitor(A, B)
```

Description `C = bitor(A, B)` returns the bitwise OR of arguments `A` and `B`, where `A` and `B` are unsigned integers or arrays of unsigned integers.

Examples

Example 1

The five-bit binary representations of the integers 13 and 27 are 01101 and 11011, respectively. Performing a bitwise OR on these numbers yields 11111, or 31.

```
C = bitor(uint8(13), uint8(27))
C =
    31
```

Example 2

Create a truth table for a logical OR operation:

```
A = uint8([0 1; 0 1]);
B = uint8([0 0; 1 1]);

TT = bitor(A, B)
TT =
    0    1
    1    1
```

See Also `bitand`, `bitcmp`, `bitget`, `bitmax`, `bitset`, `bitshift`, `bitxor`

Purpose

Set bit at specified position

Syntax

```
C = bitset(A, bit)
C = bitset(A, bit, v)
```

Description

`C = bitset(A, bit)` sets bit position *`bit`* in `A` to 1 (on). `A` must be an unsigned integer or an array of unsigned integers, and *`bit`* must be a number between 1 and the number of bits in the unsigned integer class of `A` (e.g., 32 for the `uint32` class).

`C = bitset(A, bit, v)` sets the bit at position *`bit`* to the value `v`, which must be either 0 or 1.

Examples

Example 1

Setting the fifth bit in the five-bit binary representation of the integer 9 (01001) yields 11001, or 25:

```
C = bitset(uint8(9), 5)
C =
    25
```

Example 2

Repeatedly subtract powers of 2 from the largest `uint32` value:

```
a = intmax('uint32')
for k = 1:32
   a = bitset(a, 32-k+1, 0)
   end
```

See Also

`bitand`, `bitcmp`, `bitget`, `bitmax`, `bitor`, `bitshift`, `bitxor`

bitshift

Purpose Shift bits specified number of places

Syntax

```
C = bitshift(A, k)
C = bitshift(A, k, n)
```

Description

`C = bitshift(A, k)` returns the value of `A` shifted by `k` bits. Input argument `A` must be an unsigned integer or an array of unsigned integers. Shifting by `k` is the same as multiplication by `2^k`. Negative values of `k` are allowed and this corresponds to shifting to the right, or dividing by `2^abs(k)` and truncating to an integer. If the shift causes `C` to overflow the number of bits in the unsigned integer class of `A`, then the overflowing bits are dropped.

`C = bitshift(A, k, n)` causes any bits that overflow `n` bits to be dropped. The value of `n` must be less than or equal to the length in bits of the unsigned integer class of `A` (e.g., `n <= 32` for `uint32`).

Instead of using `bitshift(A, k, 8)` or another power of 2 for `n`, consider using `bitshift(uint8(A), k)` or the appropriate unsigned integer class for `A`.

Examples

Example 1

Shifting 1100 (12, decimal) to the left two bits yields 110000 (48, decimal).

```
C = bitshift(12, 2)
C =
    48
```

Example 2

Repeatedly shift the bits of an unsigned 16 bit value to the left until all the nonzero bits overflow. Track the progress in binary:

```
a = intmax('uint16');
disp(sprintf( ...
   'Initial uint16 value %5d is %16s in binary', ...
   a, dec2bin(a)))
```

```
for k = 1:16
   a = bitshift(a, 1);
   disp(sprintf( ...
      'Shifted uint16 value %5d is %16s in binary',...
      a, dec2bin(a)))
end
```

See Also

bitand, bitcmp, bitget, bitmax, bitor, bitset, bitxor, fix

bitxor

Purpose

Bitwise XOR

Syntax

```
C = bitxor(A, B)
```

Description

`C = bitxor(A, B)` returns the bitwise XOR of arguments `A` and `B`, where `A` and `B` are unsigned integers or arrays of unsigned integers.

Examples

Example 1

The five-bit binary representations of the integers 13 and 27 are 01101 and 11011, respectively. Performing a bitwise XOR on these numbers yields 10110, or 22.

```
C = bitxor(uint8(13), uint8(27))
C =
    22
```

Example 2

Create a truth table for a logical XOR operation:

```
A = uint8([0 1; 0 1]);
B = uint8([0 0; 1 1]);

TT = bitxor(A, B)
TT =
    0    1
    1    0
```

See Also

`bitand`, `bitcmp`, `bitget`, `bitmax`, `bitor`, `bitset`, `bitshift`

Purpose Create string of blank characters

Syntax

```
blanks(n)
```

Description `blanks(n)` is a string of `n` blanks.

Examples `blanks` is useful with the `display` function. For example,

```
disp(['xxx' blanks(20) 'yyy'])
```

displays twenty blanks between the strings `'xxx'` and `'yyy'`.

`disp(blanks(n)')` moves the cursor down `n` lines.

See Also `clc`, `format`, `home`

blkdiag

Purpose

Construct block diagonal matrix from input arguments

Syntax

```
out = blkdiag(a,b,c,d,...)
```

Description

`out = blkdiag(a,b,c,d,...)`, where `a`, `b`, `c`, `d`, `...` are matrices, outputs a block diagonal matrix of the form

$$\begin{bmatrix} a & 0 & 0 & 0 & 0 \\ 0 & b & 0 & 0 & 0 \\ 0 & 0 & c & 0 & 0 \\ 0 & 0 & 0 & d & 0 \\ 0 & 0 & 0 & 0 & \ldots \end{bmatrix}$$

The input matrices do not have to be square, nor do they have to be of equal size.

See Also

`diag`, `horzcat`, `vertcat`

Purpose

Axes border

Syntax

```
box on
box off
box
box(axes_handle,...)
```

Description

`box on` displays the boundary of the current axes.

`box off` does not display the boundary of the current axes.

`box` toggles the visible state of the current axes boundary.

`box(axes_handle,...)` uses the axes specified by `axes_handle` instead of the current axes.

Algorithm

The `box` function sets the axes `Box` property to `on` or `off`.

See Also

`axes`, `grid`

"Axes Operations" on page 1-95 for related functions

break

Purpose

Terminate execution of `for` or `while` loop

Syntax

`break`

Description

`break` terminates the execution of a `for` or `while` loop. Statements in the loop that appear after the `break` statement are not executed.

In nested loops, `break` exits only from the loop in which it occurs. Control passes to the statement that follows the `end` of that loop.

Remarks

`break` is not defined outside a `for` or `while` loop. Use `return` in this context instead.

Examples

The example below shows a `while` loop that reads the contents of the file `fft.m` into a MATLAB character array. A `break` statement is used to exit the `while` loop when the first empty line is encountered. The resulting character array contains the M-file help for the `fft` program.

```
fid = fopen('fft.m','r');
s = '';
while ~feof(fid)
   line = fgetl(fid);
   if isempty(line), break, end
   s = strvcat(s,line);
end
disp(s)
```

See Also

`for`, `while`, `end`, `continue`, `return`

Purpose

Brighten or darken colormap

Syntax

```
brighten(beta)
brighten(h,beta)
newmap = brighten(beta)
newmap = brighten(cmap,beta)
```

Description

`brighten` increases or decreases the color intensities in a colormap. The modified colormap is brighter if `0 < beta < 1` and darker if `1 < beta < 0`.

`brighten(beta)` replaces the current colormap with a brighter or darker colormap of essentially the same colors. `brighten(beta)`, followed by `brighten(-beta)`, where `beta < 1`, restores the original map.

`brighten(h,beta)` brightens all objects that are children of the figure having the handle `h`.

`newmap = brighten(beta)` returns a brighter or darker version of the current colormap without changing the display.

`newmap = brighten(cmap,beta)` returns a brighter or darker version of the colormap `cmap` without changing the display.

Examples

Brighten and then darken the current colormap:

```
beta = .5; brighten(beta);
beta = -.5; brighten(beta);
```

Algorithm

The values in the colormap are raised to the power of gamma, where gamma is

$$\gamma = \begin{cases} 1 - \beta, & \beta > 0 \\ \dfrac{1}{1+\beta}, & \beta \le 0 \end{cases}$$

`brighten` has no effect on graphics objects defined with true color.

See Also `colormap`, `rgbplot`

“Color Operations” on page 1-97 for related functions

“Altering Colormaps” for more information

Purpose Build searchable documentation database

Syntax

```
builddocsearchdb help_location
```

Description `builddocsearchdb help_location` builds a searchable database of user-added HTML and related help files in the specified help location. The `help_location` argument is the full path to the directory containing the help files. The database enables the Help browser to search for content within the help files.

`builddocsearchdb` creates a directory named `helpsearch` under `help_location`. The `helpsearch` directory contains the search database files. Add the location of the `helpsearch` directory to your `info.xml` file.

The `helpsearch` directory works only with the version of MATLAB used to create it.

For a full discussion of this process, refer to "Adding Your Own Help Files in the Help Browser".

Examples Build a search database for the documentation files found at `D:\work\mytoolbox\help`.

```
builddocsearchdb D:\work\mytoolbox\help
```

See Also `doc`, `help`

builtin

Purpose Execute built-in function from overloaded method

Syntax

```
builtin(function, x1, ..., xn)
[y1, ..., yn] = builtin(function, x1, ..., xn)
```

Description `builtin` is used in methods that overload built-in functions to execute the original built-in function. If *`function`* is a string containing the name of a built-in function, then

`builtin(`*`function`*`, x1, ..., xn)` evaluates the specified `function` at the given arguments `x1` through `xn`. The `function` argument must be a string containing a valid function name. `function` cannot be a function handle.

`[y1, ..., yn] = builtin(`*`function`*`, x1, ..., xn)` returns multiple output arguments.

Remarks `builtin(...)` is the same as `feval(...)` except that it calls the original built-in version of the function even if an overloaded one exists. (For this to work you must never overload `builtin`.)

See Also `feval`

Purpose

Applies element-by-element binary operation to two arrays with singleton expansion enabled

Syntax

`C = bsxfun(fun,A,B)`

Description

`C = bsxfun(fun,A,B)` applies an element-by-element binary operation to arrays `A` and `B`, with singleton expansion enabled. `fun` is a function handle, and can either be an M-file function or one of the following built-in functions:

`@plus`	Plus
`@minus`	Minus
`@times`	Array multiply
`@rdivide`	Right array divide
`@ldivide`	Left array divide
`@power`	Array power
`@max`	Binary maximum
`@min`	Binary minimum
`@rem`	Remainder after division
`@mod`	Modulus after division
`@atan2`	Four quadrant inverse tangent
`@hypot`	Square root of sum of squares
`@eq`	Equal
`@ne`	Not equal
`@lt`	Less than
`@le`	Less than or equal to
`@gt`	Greater than
`@ge`	Greater than or equal to

`@and`	Element-wise logical AND
`@or`	Element-wise logical OR
`@xor`	Logical exclusive OR

If an M-file function is specified, it must be able to accept either two column vectors of the same size, or one column vector and one scalar, and return as output a column vector of the size as the input values.

Each dimension of `A` and `B` must either be equal to each other, or equal to `1`. Whenever a dimension of `A` or `B` is singleton (equal to `1`), the array is virtually replicated along the dimension to match the other array. The array may be diminished if the corresponding dimension of the other array is `0`.

The size of the output array `C` is equal to: `max(size(A),size(B)).*(size(A)>0 & size(B)>0)`.

Examples

In this example, `bsxfun` is used to subtract the column means from the matrix `A`.

```
A = magic(5);
A = bsxfun(@minus, A, mean(A))
A =

 4  11 -12  -5  2
10  -8  -6   1  3
-9  -7  0   7  9
-3  -1  6   8 -10
-2   5  12  -11   -4
```

See Also

`repmat`, `arrayfun`

Purpose

Solve boundary value problems for ordinary differential equations

Syntax

```
sol = bvp4c(odefun,bcfun,solinit)
sol = bvp4c(odefun,bcfun,solinit,options)
solinit = bvpinit(x, yinit, params)
```

Arguments

odefun	A function handle that evaluates the differential equations $f(x, y)$. It can have the form
	
	`dydx = odefun(x,y)`
	`dydx = odefun(x,y,parameters)`
	
	where x is a scalar corresponding to x, and y is a column vector corresponding to y. parameters is a vector of unknown parameters. The output dydx is a column vector.

bcfun	A function handle that computes the residual in the boundary conditions. For two-point boundary value conditions of the form $bc(y(a), y(b))$, bcfun can have the form
	
	`res = bcfun(ya,yb)`
	`res = bcfun(ya,yb,parameters)`
	
	where ya and yb are column vectors corresponding to $y(a)$ and $y(b)$. parameters is a vector of unknown parameters. The output res is a column vector.
	
	See "Multipoint Boundary Value Problems" on page 2-406 for a description of bcfun for multipoint boundary value problems.

solinit	A structure containing the initial guess for a solution. You create solinit using the function bvpinit. solinit has the following fields.

	x	Ordered nodes of the initial mesh. Boundary conditions are imposed at a = solinit.x(1) and b = solinit.x(end).
	y	Initial guess for the solution such that solinit.y(:,i) is a guess for the solution at the node solinit.x(i).
	parameters	Optional. A vector that provides an initial guess for unknown parameters.
	The structure can have any name, but the fields must be named x, y, and parameters. You can form solinit with the helper function bvpinit. See bvpinit for details.	
options	Optional integration argument. A structure you create using the bvpset function. See bvpset for details.	

Description

sol = bvp4c(odefun,bcfun,solinit) integrates a system of ordinary differential equations of the form

$$y' = f(x, y)$$

on the interval [a,b] subject to two-point boundary value conditions

$$bc(y(a), y(b)) = 0$$

odefun and bcfun are function handles. 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 odefun, as well as the boundary condition function bcfun, if necessary.

bvp4c can also solve multipoint boundary value problems. See “Multipoint Boundary Value Problems” on page 2-406. You can use the function bvpinit to specify the boundary points, which are stored in the input argument solinit. See the reference page for bvpinit for more information.

The bvp4c solver can also find unknown parameters p for problems of the form

$$y' = f(x, y, p)$$
$$0 = bc(y(a), y(b), p)$$

where p corresponds to parameters. You provide bvp4c an initial guess for any unknown parameters in solinit.parameters. The bvp4c solver returns the final values of these unknown parameters in sol.parameters.

bvp4c produces a solution that is continuous on [a,b] and has a continuous first derivative there. Use the function deval and the output sol of bvp4c to evaluate the solution at specific points xint in the interval [a,b].

```
sxint = deval(sol,xint)
```

The structure sol returned by bvp4c has the following fields:

sol.x	Mesh selected by bvp4c
sol.y	Approximation to $y(x)$ at the mesh points of sol.x
sol.yp	Approximation to $y'(x)$ at the mesh points of sol.x
sol.parameters	Values returned by bvp4c for the unknown parameters, if any
sol.solver	'bvp4c'

The structure sol can have any name, and bvp4c creates the fields x, y, yp, parameters, and solver.

sol = bvp4c(odefun,bcfun,solinit,options) solves as above with default integration properties replaced by the values in options, a structure created with the bvpset function. See bvpset for details.

`solinit = bvpinit(x, yinit, params)` forms the initial guess `solinit` with the vector `params` of guesses for the unknown parameters.

Singular Boundary Value Problems

`bvp4c` solves a class of singular boundary value problems, including problems with unknown parameters `p`, of the form

$$y' = S \cdot y/x + f(x, y, p)$$
$$0 = bc(y(0), y(b), p)$$

The interval is required to be [0, *b*] with b > 0. Often such problems arise when computing a smooth solution of ODEs that result from partial differential equations (PDEs) due to cylindrical or spherical symmetry. For singular problems, you specify the (constant) matrix `S` as the value of the `'SingularTerm'` option of `bvpset`, and `odefun` evaluates only $f(x, y, p)$. The boundary conditions must be consistent with the necessary condition $S \cdot y(0) = 0$ and the initial guess should satisfy this condition.

Multipoint Boundary Value Problems

`bvp4c` can solve multipoint boundary value problems where $a = a_0 < a_1 < a_2 < \ldots < a_n = b$ are boundary points in the interval $[a, b]$. The points $a_1, a_2, \ldots, a_{n-1}$ represent interfaces that divide $[a, b]$ into regions. `bvp4c` enumerates the regions from left to right (from *a* to *b*), with indices starting from 1. In region *k*, $[a_{k-1}, a_k]$, `bvp4c` evaluates the derivative as

```
yp = odefun(x, y, k)
```

In the boundary conditions function

```
bcfun(yleft, yright)
```

yleft(:, k) is the solution at the left boundary of $[a_{k-1}, a_k]$. Similarly, `yright(:, k)` is the solution at the right boundary of region *k*. In particular,

```
yleft(:, 1) = y(a)
```

and

```
yright(:, end) = y(b)
```

When you create an initial guess with

```
solinit = bvpinit(xinit, yinit),
```

use double entries in `xinit` for each interface point. See the reference page for `bvpinit` for more information.

If `yinit` is a function, `bvpinit` calls `y = yinit(x, k)` to get an initial guess for the solution at `x` in region `k`. In the solution structure `sol` returned by `bpv4c`, `sol.x` has double entries for each interface point. The corresponding columns of `sol.y` contain the left and right solution at the interface, respectively.

For an example of solving a three-point boundary value problem, type `threebvp` at the MATLAB command prompt to run a demonstration.

Examples

Example 1

Boundary value problems can have multiple solutions and one purpose of the initial guess is to indicate which solution you want. The second-order differential equation

$$y'' + |y| = 0$$

has exactly two solutions that satisfy the boundary conditions

$$y(0) = 0$$
$$y(4) = -2$$

Prior to solving this problem with `bvp4c`, you must write the differential equation as a system of two first-order ODEs

$$y_1' = y_2$$
$$y_2' = -|y_1|$$

Here $y_1 = y$ and $y_2 = y'$. This system has the required form

$$y' = f(x, y)$$
$$bc(y(a), y(b)) = 0$$

The function f and the boundary conditions bc are coded in MATLAB as functions `twoode` and `twobc`.

```
function dydx = twoode(x,y)
  dydx = [ y(2)
           -abs(y(1))];

function res = twobc(ya,yb)
  res = [ ya(1)
          yb(1) + 2];
```

Form a guess structure consisting of an initial mesh of five equally spaced points in [0,4] and a guess of constant values $y_1(x) \equiv 1$ and $y_2(x) \equiv 0$ with the command

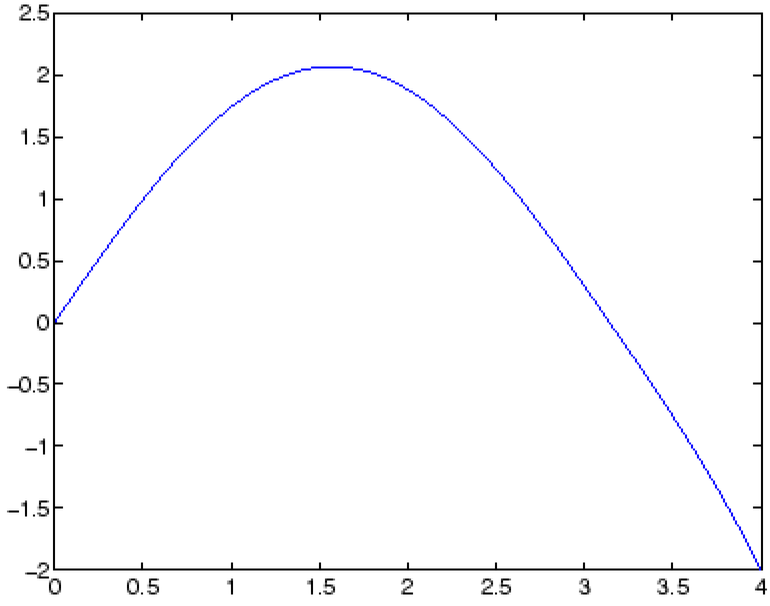
```
solinit = bvpinit(linspace(0,4,5),[1 0]);
```

Now solve the problem with

```
sol = bvp4c(@twoode,@twobc,solinit);
```

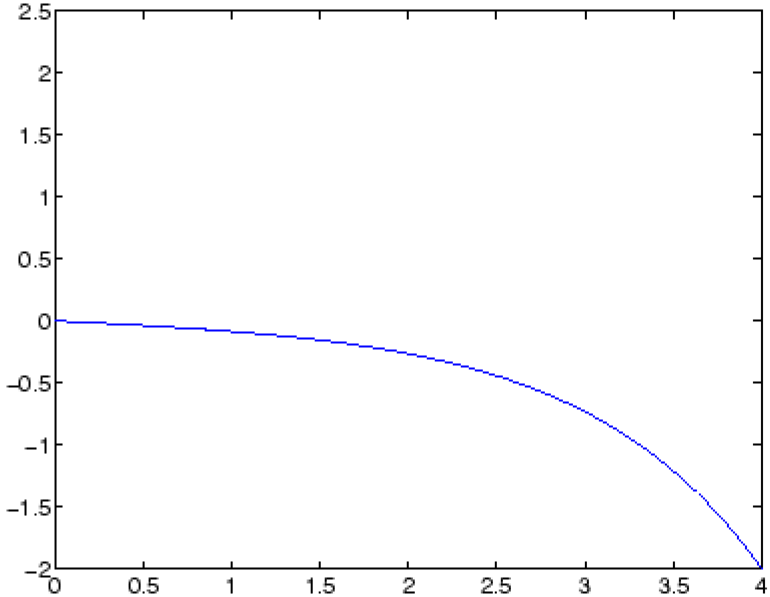
Evaluate the numerical solution at 100 equally spaced points and plot $y(x)$ with

```
x = linspace(0,4);
y = deval(sol,x);
plot(x,y(1,:));
```



You can obtain the other solution of this problem with the initial guess

```
solinit = bvpinit(linspace(0,4,5),[-1 0]);
```



Example 2

This boundary value problem involves an unknown parameter. The task is to compute the fourth ($q = 5$) eigenvalue λ of Mathieu's equation

$$y'' + (\lambda - 2\,q\cos 2x)\,y = 0$$

Because the unknown parameter λ is present, this second-order differential equation is subject to *three* boundary conditions

$$y'(0) = 0$$
$$y'(\pi) = 0$$
$$y(0) = 1$$

It is convenient to use subfunctions to place all the functions required by `bvp4c` in a single M-file.

```
function mat4bvp
```

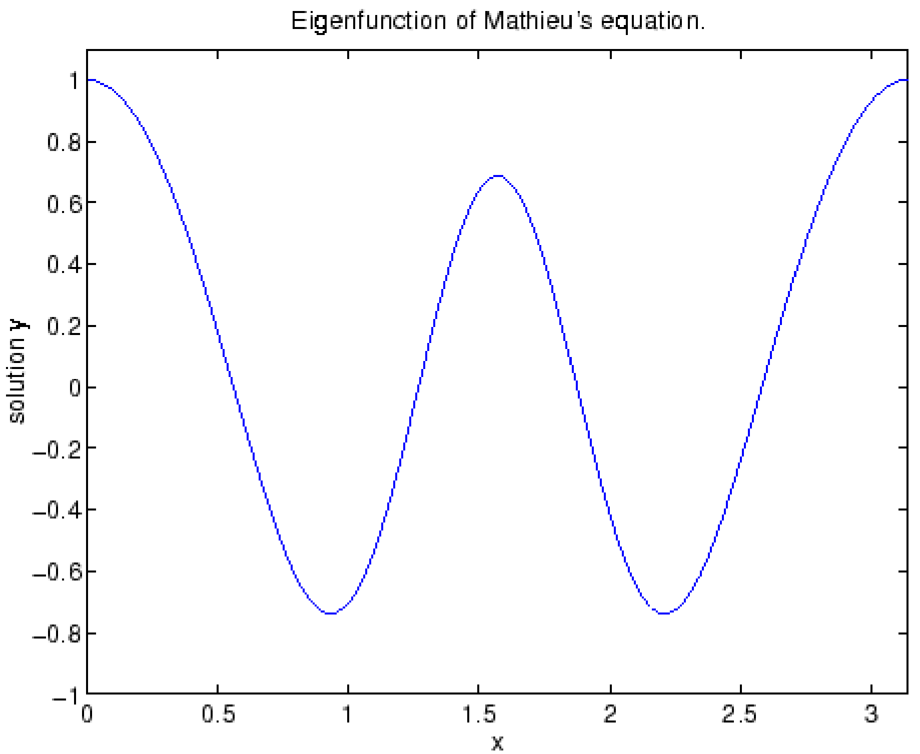
```
lambda = 15;
solinit = bvpinit(linspace(0,pi,10),@mat4init,lambda);
sol = bvp4c(@mat4ode,@mat4bc,solinit);

fprintf('The fourth eigenvalue is approximately %7.3f.\n',...
        sol.parameters)

xint = linspace(0,pi);
Sxint = deval(sol,xint);
plot(xint,Sxint(1,:))
axis([0 pi -1 1.1])
title('Eigenfunction of Mathieu''s equation.')
xlabel('x')
ylabel('solution y')
% ------------------------------------------------------------
function dydx = mat4ode(x,y,lambda)
q = 5;
dydx = [  y(2)
         -(lambda - 2*q*cos(2*x))*y(1) ];
% ------------------------------------------------------------
function res = mat4bc(ya,yb,lambda)
res = [  ya(2)
         yb(2)
        ya(1)-1 ];
% ------------------------------------------------------------
function yinit = mat4init(x)
yinit = [  cos(4*x)
          -4*sin(4*x) ];
```

The differential equation (converted to a first-order system) and the boundary conditions are coded as subfunctions `mat4ode` and `mat4bc`, respectively. Because unknown parameters are present, these functions must accept three input arguments, even though some of the arguments are not used.

The guess structure `solinit` is formed with `bvpinit`. An initial guess for the solution is supplied in the form of a function `mat4init`. We chose

$y = \cos 4x$ because it satisfies the boundary conditions and has the correct qualitative behavior (the correct number of sign changes). In the call to `bvpinit`, the third argument (`lambda = 15`) provides an initial guess for the unknown parameter λ.

After the problem is solved with `bvp4c`, the field `sol.parameters` returns the value $\lambda = 17.097$, and the plot shows the eigenfunction associated with this eigenvalue.



Algorithms

`bvp4c` is a finite difference code that implements the three-stage Lobatto IIIa formula. This is a collocation formula and the collocation polynomial provides a C^1-continuous solution that is fourth-order accurate uniformly in [a,b]. Mesh selection and error control are based on the residual of the continuous solution.

References

[1] Shampine, L.F., M.W. Reichelt, and J. Kierzenka, “Solving Boundary Value Problems for Ordinary Differential Equations in MATLAB with bvp4c,” available at http://www.mathworks.com/bvp_tutorial

See Also

function_handle (@), bvpget, bvpinit, bvpset, bvpxtend, deval

bvpget

Purpose

Extract properties from options structure created with `bvpset`

Syntax

```
val = bvpget(options,'name')
val = bvpget(options,'name',default)
```

Description

`val = bvpget(options,'name')` extracts the value of the named property from the structure `options`, returning an empty matrix if the property value is not specified in `options`. It is sufficient to type only the leading characters that uniquely identify the property. Case is ignored for property names. `[]` is a valid `options` argument.

`val = bvpget(options,'name',default)` extracts the named property as above, but returns `val = default` if the named property is not specified in `options`. For example,

```
val = bvpget(opts,'RelTol',1e-4);
```

returns `val = 1e-4` if the `RelTol` is not specified in `opts`.

See Also

`bvp4c`, `bvpinit`, `bvpset`, `deval`

Purpose

Form initial guess for bvp4c

Syntax

```
solinit = bvpinit(x,yinit)
solinit = bvpinit(x,yinit,parameters)
solinit = bvpinit(sol,[anew bnew])
solinit = bvpinit(sol,[anew bnew],parameters)
```

Description

solinit = bvpinit(x,yinit) forms the initial guess for the boundary value problem solver bvp4c.

x is a vector that specifies an initial mesh. If you want to solve the boundary value problem (BVP) on $[a, b]$, then specify x(1) as a and x(end) as b. The function bvp4c adapts this mesh to the solution, so a guess like xb=nlinspace(a,b,10) often suffices. However, in difficult cases, you should place mesh points where the solution changes rapidly. The entries of x must be in

- Increasing order if $a < b$
- Decreasing order if $a > b$

For two-point boundary value problems, the entries of x must be distinct. That is, if $a < b$, the entries must satisfy x(1) < x(2) < ... < x(end). If $a > b$, the entries must satisfy x(1) > x(2) > ... > x(end)

For multipoint boundary value problem, you can specify the points in $[a, b]$ at which the boundary conditions apply, other than the endpoints a and b, by repeating their entries in x. For example, if you set

```
x = [0, 0.5, 1, 1,  1.5, 2];
```

the boundary conditions apply at three points: the endpoints 0 and 2, and the repeated entry 1. In general, repeated entries represent boundary points between regions in $[a, b]$. In the preceding example, the repeated entry 1 divides the interval [0,2] into two regions: [0,1] and [1,2].

yinit is a guess for the solution. It can be either a vector, or a function:

- Vector – For each component of the solution, `bvpinit` replicates the corresponding element of the vector as a constant guess across all mesh points. That is, `yinit(i)` is a constant guess for the `i`th component `yinit(i,:)` of the solution at all the mesh points in `x`.
- Function – For a given mesh point, the guess function must return a vector whose elements are guesses for the corresponding components of the solution. The function must be of the form

  ```
  y = guess(x)
  ```

  where `x` is a mesh point and `y` is a vector whose length is the same as the number of components in the solution. For example, if the guess function is an M-file function, `bvpinit` calls

  ```
  y(:,j) = guess(x(j))
  ```

  at each mesh point.

  For multipoint boundary value problems, the guess function must be of the form

  ```
  y = guess(x, k)
  ```

  where `y` an initial guess for the solution at `x` in region `k`. The function must accept the input argument `k`, which is provided for flexibility in writing the guess function. However, the function is not required to use `k`.

`solinit = bvpinit(x,yinit,parameters)` indicates that the boundary value problem involves unknown parameters. Use the vector `parameters` to provide a guess for all unknown parameters.

`solinit` is a structure with the following fields. The structure can have any name, but the fields must be named `x`, `y`, and `parameters`.

`x`	Ordered nodes of the initial mesh.
`y`	Initial guess for the solution with `solinit.y(:,i)` a guess for the solution at the node `solinit.x(i)`.
`parameters`	Optional. A vector that provides an initial guess for unknown parameters.

`solinit = bvpinit(sol,[anew bnew])` forms an initial guess on the interval `[anew bnew]` from a solution `sol` on an interval $[a, b]$. The new interval must be larger than the previous one, so either `anew <=`a `<`b `<= bnew` or `anew >=`a `>`b `>= bnew`. The solution `sol` is extrapolated to the new interval. If `sol` contains `parameters`, they are copied to `solinit`.

`solinit = bvpinit(sol,[anew bnew],parameters)` forms `solinit` as described above, but uses `parameters` as a guess for unknown parameters in `solinit`.

See Also

`@(function_handle)`, `bvp4c`, `bvpget`, `bvpset`, `bvpxtend`, `deval`

Purpose

Create or alter options structure of boundary value problem

Syntax

```
options = bvpset('name1',value1,'name2',value2,...)
options = bvpset(oldopts,'name1',value1,...)
options = bvpset(oldopts,newopts)
bvpset
```

Description

`options = bvpset('name1',value1,'name2',value2,...)` creates a structure `options` that you can supply to the boundary value problem solver `bvp4c`, in which the named properties have the specified values. Any unspecified properties retain their default values. For all properties, it is sufficient to type only the leading characters that uniquely identify the property. `bvpset` ignores case for property names.

`options = bvpset(oldopts,'name1',value1,...)` alters an existing options structure `oldopts`. This overwrites any values in `oldopts` that are specified using name/value pairs and returns the modified structure as the output argument.

`options = bvpset(oldopts,newopts)` combines an existing options structure `oldopts` with a new options structure `newopts`. Any values set in `newopts` overwrite the corresponding values in `oldopts`.

`bvpset` with no input arguments displays all property names and their possible values, indicating defaults with braces `{}`.

You can use the function `bvpget` to query the `options` structure for the value of a specific property.

BVP Properties

`bvpset` enables you to specify properties for the boundary value problem solver `bvp4c`. There are several categories of properties that you can set:

- “Error Tolerance Properties” on page 2-419
- “Vectorization” on page 2-420
- “Analytical Partial Derivatives” on page 2-421
- “Singular BVPs” on page 2-424

- "Mesh Size Property" on page 2-424
- "Solution Statistic Property" on page 2-425

Error Tolerance Properties

Because bvp4c uses a collocation formula, the numerical solution is based on a mesh of points at which the collocation equations are satisfied. Mesh selection and error control are based on the residual of this solution, such that the computed solution $S(x)$ is the exact solution of a perturbed problem $S'(x) = f(x, S(x)) + res(x)$. On each subinterval of the mesh, a norm of the residual in the ith component of the solution, res(i), is estimated and is required to be less than or equal to a tolerance. This tolerance is a function of the relative and absolute tolerances, RelTol and AbsTol, defined by the user.

$$\|(\mathrm{res(i)/max(abs(f(i)),AbsTol(i)/RelTol)})\| \le \mathrm{RelTol}$$

The following table describes the error tolerance properties.

BVP Error Tolerance Properties

Property	Value	Description
`RelTol`	Positive scalar {`1e-3`}	A relative error tolerance that applies to all components of the residual vector. It is a measure of the residual relative to the size of $f(x, y)$. The default, `1e-3`, corresponds to 0.1% accuracy. The computed solution $S(x)$ is the exact solution of $S'(x) = F(x, S(x)) + \mathrm{res}(x)$. On each subinterval of the mesh, the residual $\mathrm{res}(x)$ satisfies $\|(\mathrm{res(i)/max(abs(F(i)),AbsTol(i)/RelTol)})\| \le \mathrm{RelTol}$
`AbsTol`	Positive scalar or vector {`1e-6`}	Absolute error tolerances that apply to the corresponding components of the residual vector. `AbsTol(i)` is a threshold below which the values of the corresponding components are unimportant. If a scalar value is specified, it applies to all components.

Vectorization

The following table describes the BVP vectorization property. Vectorization of the ODE function used by `bvp4c` differs from the vectorization used by the ODE solvers:

- For `bvp4c`, the ODE function must be vectorized with respect to the first argument as well as the second one, so that `F([x1 x2 ...],[y1 y2 ...])` returns `[F(x1,y1) F(x2,y2)...]`.
- `bvp4c` benefits from vectorization even when analytical Jacobians are provided. For stiff ODE solvers, vectorization is ignored when analytical Jacobians are used.

Vectorization Properties

Property	Value	Description

Vectorized	on | {off}	Set on to inform bvp4c that you have coded the ODE function F so that F([x1 x2 ...],[y1 y2 ...]) returns [F(x1,y1) F(x2,y2) ...]. That is, your ODE function can pass to the solver a whole array of column vectors at once. This enables the solver to reduce the number of function evaluations and may significantly reduce solution time.
		
		With the MATLAB array notation, it is typically an easy matter to vectorize an ODE function. In the shockbvp example shown previously, the shockODE function has been vectorized using colon notation into the subscripts and by using the array multiplication (.*) operator.
		
		`function dydx = shockODE(x,y,e)`
		`pix = pi*x;`
		`dydx = [ y(2,:)...`
		`-x/e.*y(2,:)-pi^2*cos(pix)-`
		`pix/e.*sin(pix)];`

Analytical Partial Derivatives

By default, the bvp4c solver approximates all partial derivatives with finite differences. bvp4c can be more efficient if you provide analytical partial derivatives $\partial f / \partial y$ of the differential equations, and analytical partial derivatives, $\partial bc/\partial ya$ and $\partial bc/\partial yb$, of the boundary conditions. If the problem involves unknown parameters, you must also provide partial derivatives, $\partial f/\partial p$ and $\partial bc/\partial p$, with respect to the parameters.

The following table describes the analytical partial derivatives properties.

BVP Analytical Partial Derivative Properties

Property	Value	Description
`FJacobian`	Function handle	Handle to a function that computes the analytical partial derivatives of $f(x, y)$. When solving $y' = f(x, y)$, set this property to `@fjac` if `dfdy = fjac(x,y)` evaluates the Jacobian $\partial f / \partial y$. If the problem involves unknown parameters p, `[dfdy,dfdp] = fjac(x,y,p)` must also return the partial derivative $\partial f / \partial p$. For problems with constant partial derivatives, set this property to the value of `dfdy` or to a cell array `{dfdy,dfdp}`. See "Function Handles" in the MATLAB Programming documentation for more information.
`BCJacobian`	Function handle	Handle to a function that computes the analytical partial derivatives of $bc(ya, yb)$. For boundary conditions $bc(ya, yb)$, set this property to `@bcjac` if `[dbcdya,dbcdyb] = bcjac(ya,yb)` evaluates the partial derivatives $\partial bc / \partial ya$, and $\partial bc / \partial yb$. If the problem involves unknown parameters p, `[dbcdya,dbcdyb,dbcdp] = bcjac(ya,yb,p)` must also return the partial derivative $\partial bc / \partial p$. For problems with constant partial derivatives, set this property to a cell array `{dbcdya,dbcdyb}` or `{dbcdya,dbcdyb,dbcdp}`.

Singular BVPs

bvp4c can solve singular problems of the form

$$y' = S\frac{y}{x} + f(x, y, p)$$

posed on the interval $[0, b]$ where $b > 0$. For such problems, specify the constant matrix S as the value of SingularTerm. For equations of this form, odefun evaluates only the $f(x, y, p)$ term, where p represents unknown parameters, if any.

Singular BVP Property

Property	Value	Description
SingularTerm	Constant matrix	Singular term of singular BVPs. Set to the constant matrix S for equations of the form $$y' = S\frac{y}{x} + f(x, y, p)$$ posed on the interval $[0, b]$ where $b > 0$.

Mesh Size Property

bvp4c solves a system of algebraic equations to determine the numerical solution to a BVP at each of the mesh points. The size of the algebraic system depends on the number of differential equations (n) and the number of mesh points in the current mesh (N). When the allowed number of mesh points is exhausted, the computation stops, bvp4c displays a warning message and returns the solution it found so far. This solution does not satisfy the error tolerance, but it may provide an excellent initial guess for computations restarted with relaxed error tolerances or an increased value of `NMax`.

The following table describes the mesh size property.

BVP Mesh Size Property

Property	Value	Description
`NMax`	positive integer {`floor(1000/n)`}	Maximum number of mesh points allowed when solving the BVP, where `n` is the number of differential equations in the problem. The default value of `NMax` limits the size of the algebraic system to about 1000 equations. For systems of a few differential equations, the default value of `NMax` should be sufficient to obtain an accurate solution.

Solution Statistic Property

The `Stats` property lets you view solution statistics.

The following table describes the solution statistics property.

BVP Solution Statistic Property

Property	Value	Description
`Stats`	`on` | `{off}`	Specifies whether statistics about the computations are displayed. If the `stats` property is `on`, after solving the problem, `bvp4c` displays: • The number of points in the mesh • The maximum residual of the solution • The number of times it called the differential equation function `odefun` to evaluate $f(x, y)$ • The number of times it called the boundary condition function `bcfun` to evaluate $bc(y(a), y(b))$

Example

To create an options structure that changes the relative error tolerance of `bvp4c` from the default value of `1e-3` to `1e-4`, enter

```
options = bvpset('RelTol', 1e-4);
```

To recover the value of `'RelTol'` from `options`, enter

```
bvpget(options, 'RelTol')

ans =

   1.0000e-004
```

See Also

`@` (function_handle), `bvp4c`, `bvpget`, `bvpinit`, `deval`

Purpose

Form guess structure for extending boundary value solutions

Syntax

```
solinit = bvpxtend(sol,xnew,ynew)
solinit = bvpxtend(sol,xnew,extrap)
solinit = bvpxtend(sol,xnew)
solinit = bvpxtend(sol,xnew,ynew,pnew)
solinit = bvpxtend(sol,xnew,extrap,pnew)
```

Description

`solinit = bvpxtend(sol,xnew,ynew)` uses solution `sol` computed on `[a,b]` to form a solution guess for the interval extended to `xnew`. The extension point `xnew` must be outside the interval `[a,b]`, but on either side. The vector `ynew` provides an initial guess for the solution at `xnew`.

`solinit = bvpxtend(sol,xnew,extrap)` forms the guess at `xnew` by extrapolating the solution `sol`. `extrap` is a string that determines the extrapolation method. `extrap` has three possible values:

- `'constant'` — `ynew` is a value nearer to end point of solution in `sol`.
- `'linear'` — `ynew` is a value at `xnew` of linear interpolant to the value and slope at the nearer end point of solution in `sol`.
- `'solution'` — `ynew` is the value of (cubic) solution in `sol` at `xnew`.

The value of `extrap` is case-insensitive and only the leading, unique portion needs to be specified.

`solinit = bvpxtend(sol,xnew)` uses the extrapolating solution where `extrap` is `'constant'`. If there are unknown parameters, values present in `sol` are used as the initial guess for parameters in `solinit`.

`solinit = bvpxtend(sol,xnew,ynew,pnew)` specifies a different guess `pnew`. `pnew` can be used with extrapolation, using the syntax `solinit = bvpxtend(sol,xnew,extrap,pnew)`. To modify parameters without changing the interval, use `[]` as place holder for `xnew` and `ynew`.

See Also

`bvp4c`, `bvpinit`

calendar

Purpose

Calendar for specified month

Syntax

```
c = calendar
c = calendar(d)
c = calendar(y, m)
```

Description

`c = calendar` returns a 6-by-7 matrix containing a calendar for the current month. The calendar runs Sunday (first column) to Saturday.

`c = calendar(d)`, where `d` is a serial date number or a date string, returns a calendar for the specified month.

`c = calendar(y, m)`, where `y` and `m` are integers, returns a calendar for the specified month of the specified year.

Examples

The command

```
calendar(1957,10)
```

reveals that the Space Age began on a Friday (on October 4, 1957, when Sputnik 1 was launched).

```
                    Oct 1957
    S      M     Tu      W     Th      F      S
    0      0      1      2      3      4      5
    6      7      8      9     10     11     12
   13     14     15     16     17     18     19
   20     21     22     23     24     25     26
   27     28     29     30     31      0      0
    0      0      0      0      0      0      0
```

See Also

`datenum`

Purpose Call function in external library

Syntax

```
[x1, ..., xN] = calllib('libname', 'funcname', arg1, ...,
   argN)
```

Description

[x1, ..., xN] = calllib('libname', 'funcname', arg1, ..., argN) calls the function funcname in library libname, passing input arguments arg1 through argN. calllib returns output values obtained from function funcname in x1 through XN.

If you used an alias when initially loading the library, then you must use that alias for the libname argument.

Ways to Call calllib

The following examples show ways calls to calllib. By using libfunctionsview, you determined that the addStructByRef function in the shared library shrlibsample requires a pointer to a c_struct data type as its argument.

Load the library:

```
addpath([matlabroot '\extern\examples\shrlib'])
loadlibrary shrlibsample shrlibsample.h
```

Create a MATLAB structure and use libstruct to create a C structure of the proper type (c_struct here):

```
struct.p1 = 4; struct.p2 = 7.3; struct.p3 = -290;
[res,st] = calllib('shrlibsample','addStructByRef',...
 libstruct('c_struct',struct));
```

Let MATLAB convert struct to the proper type of C structure:

```
[res,st] = calllib('shrlibsample','addStructByRef',struct);
```

Pass an empty array to libstruct and assign the values from your C function:

```
[res,st] = calllib('shrlibsample','addStructByRef',...
```

```
libstruct('c_struct',[]);
```

Let MATLAB create the proper type of structure and assign values from your C function:

```
[res,st] = calllib('shrlibsample','addStructByRef',[]);
```

Examples

This example calls functions from the `libmx` library to test the value stored in `y`:

```
hfile = [matlabroot '\extern\include\matrix.h'];
loadlibrary('libmx', hfile)

y = rand(4, 7, 2);

calllib('libmx', 'mxGetNumberOfElements', y)
ans =
    56

calllib('libmx', 'mxGetClassID', y)
ans =
   mxDOUBLE_CLASS

unloadlibrary libmx
```

See Also

`loadlibrary`, `libfunctions`, `libfunctionsview`, `libpointer`, `libstruct`, `libisloaded`, `unloadlibrary`

See Passing Arguments for information on defining the correct data types for library function arguments.

Purpose Send SOAP message off to endpoint

Syntax

```
callSoapService(endpoint, soapAction, message)
```

Description `callSoapService(endpoint, soapAction, message)` sends `message`, a Java document object model (DOM), to the `soapAction` service at the `endpoint`.

Example

```
message = createSoapMessage(...
'urn:xmethods-delayed-quotes','getQuote',{'GOOG'},{'symbol'},...
{'{http://www.w3.org/2001/XMLSchema}string'},'rpc')
response = callSoapService('http://64.124.140.30:9090/soap',...
'urn:xmethods-delayed-quotes#getQuote',message)
price = parseSoapResponse(response)
```

See Also `createClassFromWsdl`, `CreateSoapMessage`, `parseSoapResponse`

camdolly

Purpose

Move camera position and target

Syntax

```
camdolly(dx,dy,dz)
camdolly(dx,dy,dz,'targetmode')
camdolly(dx,dy,dz,'targetmode','coordsys')
camdolly(axes_handle,...)
```

Description

`camdolly` moves the camera position and the camera target by the specified amounts.

`camdolly(dx,dy,dz)` moves the camera position and the camera target by the specified amounts (see Coordinate Systems).

`camdolly(dx,dy,dz,'`*`targetmode`*`')` The *`targetmode`* argument can take on two values that determine how MATLAB moves the camera:

- `movetarget` (default) — Move both the camera and the target.
- `fixtarget` — Move only the camera.

`camdolly(dx,dy,dz,'`*`targetmode`*`','`*`coordsys`*`')` The *`coordsys`* argument can take on three values that determine how MATLAB interprets `dx`, `dy`, and `dz`:

Coordinate Systems

- `camera` (default) — Move in the camera's coordinate system. `dx` moves left/right, `dy` moves down/up, and `dz` moves along the viewing axis. The units are normalized to the scene.

  For example, setting `dx` to 1 moves the camera to the right, which pushes the scene to the left edge of the box formed by the axes position rectangle. A negative value moves the scene in the other direction. Setting `dz` to 0.5 moves the camera to a position halfway between the camera position and the camera target.
- `pixels` — Interpret `dx` and `dy` as pixel offsets. `dz` is ignored.
- `data` — Interpret `dx`, `dy`, and `dz` as offsets in axes data coordinates.

`camdolly(axes_handle,...)` operates on the axes identified by the first argument, `axes_handle`. When you do not specify an axes handle, `camdolly` operates on the current axes.

Remarks

`camdolly` sets the axes `CameraPosition` and`CameraTarget` properties, which in turn causes the `CameraPositionMode` and `CameraTargetMode` properties to be set to `manual`.

Examples

This example moves the camera along the *x*- and *y*-axes in a series of steps.

```
surf(peaks)
axis vis3d
t = 0:pi/20:2*pi;
dx = sin(t)./40;
dy = cos(t)./40;
for i = 1:length(t);
    camdolly(dx(i),dy(i),0)
    drawnow
end
```

See Also

`axes`, `campos`, `camproj`, `camtarget`, `camup`, `camva`

The axes properties `CameraPosition`, `CameraTarget`, `CameraUpVector`, `CameraViewAngle`, `Projection`

"Controlling the Camera Viewpoint" on page 1-98 for related functions

See "Defining Scenes with Camera Graphics" for more information on camera properties.

Purpose

Control camera toolbar programmatically

Syntax

```
cameratoolbar
cameratoolbar('NoReset')
cameratoolbar('SetMode',mode)
cameratoolbar('SetCoordSys',coordsys)
cameratoolbar('Show')
cameratoolbar('Hide')
cameratoolbar('Toggle')
cameratoolbar('ResetCameraAndSceneLight')
cameratoolbar('ResetCamera')
cameratoolbar('ResetSceneLight')
cameratoolbar('ResetTarget')
mode = cameratoolbar('GetMode')
paxis = cameratoolbar('GetCoordsys')
vis = cameratoolbar('GetVisible')
cameratoolbar(fig,...)
h = cameratoolbar
cameratoolbar('Close')
```

Description

`cameratoolbar` creates a new toolbar that enables interactive manipulation of the axes camera and light when users drag the mouse on the figure window. Several axes camera properties are set when the toolbar is initialized.

`cameratoolbar('NoReset')` creates the toolbar without setting any camera properties.

`cameratoolbar('SetMode',`*`mode`*`)` sets the toolbar mode (depressed button). *`mode`* can be `'orbit'`, `'orbitscenelight'`, `'pan'`, `'dollyhv'`, `'dollyfb'`, `'zoom'`, `'roll'`, `'nomode'`.

`cameratoolbar('SetCoordSys',`*`coordsys`*`)` sets the principal axis of the camera motion. *`coordsys`* can be: `'x'`, `'y'`, `'z'`, `'none'`.

`cameratoolbar('Show')` shows the toolbar on the current figure.

`cameratoolbar('Hide')` hides the toolbar on the current figure.

`cameratoolbar('Toggle')` toggles the visibility of the toolbar.

`cameratoolbar('ResetCameraAndSceneLight')` resets the current camera and scenelight.

`cameratoolbar('ResetCamera')` resets the current camera.

`cameratoolbar('ResetSceneLight')` resets the current scenelight.

`cameratoolbar('ResetTarget')` resets the current camera target.

`mode = cameratoolbar('GetMode')` returns the current mode.

`paxis = cameratoolbar('GetCoordsys')` returns the current principal axis.

`vis = cameratoolbar('GetVisible')` returns the visibility of the toolbar (`1` if visible, `0` if not visible).

`cameratoolbar(fig,...)` specifies the figure to operate on by passing the figure handle as the first argument.

`h = cameratoolbar` returns the handle to the toolbar.

`cameratoolbar('Close')` removes the toolbar from the current figure.

Note that, in general, the use of OpenGL hardware improves rendering performance.

See Also

`rotate3d`, `zoom`

Purpose

Create or move light object in camera coordinates

Syntax

```
camlight('headlight')
camlight('right')
camlight('left')
camlight
camlight(az,el)
camlight(...,'style')
camlight(light_handle,...)
light_handle = camlight(...)
```

Description

`camlight('headlight')` creates a light at the camera position.

`camlight('right')` creates a light right and up from camera.

`camlight('left')` creates a light left and up from camera.

`camlight` with no arguments is the same as `camlight('right')`.

`camlight(az,el)` creates a light at the specified azimuth (`az`) and elevation (`el`) with respect to the camera position. The camera target is the center of rotation and `az` and `el` are in degrees.

`camlight(...,'style')` The style argument can take on two values:

- `local` (default) — The light is a point source that radiates from the location in all directions.
- `infinite` — The light shines in parallel rays.

`camlight(light_handle,...)` uses the light specified in `light_handle`.

`light_handle = camlight(...)` returns the light's handle.

Remarks

`camlight` sets the light object `Position` and `Style` properties. A light created with `camlight` will not track the camera. In order for the light to stay in a constant position relative to the camera, you must call `camlight` whenever you move the camera.

Examples

This example creates a light positioned to the left of the camera and then repositions the light each time the camera is moved:

```
surf(peaks)
axis vis3d
h = camlight('left');
for i = 1:20;
 camorbit(10,0)
 camlight(h,'left')
 drawnow;
end
```

See Also

`light`, `lightangle`

"Lighting" on page 1-100 for related functions

"Lighting as a Visualization Tool" for more information on using lights

Purpose

Position camera to view object or group of objects

Syntax

```
camlookat(object_handles)
camlookat(axes_handle)
camlookat
```

Description

`camlookat(object_handles)` views the objects identified in the vector `object_handles`. The vector can contain the handles of axes children.

`camlookat(axes_handle)` views the objects that are children of the axes identified by `axes_handle`.

`camlookat` views the objects that are in the current axes.

Remarks

`camlookat` moves the camera position and camera target while preserving the relative view direction and camera view angle. The object (or objects) being viewed roughly fill the axes position rectangle.

`camlookat` sets the axes `CameraPosition` and `CameraTarget` properties.

Examples

This example creates three spheres at different locations and then progressively positions the camera so that each sphere is the object around which the scene is composed:

```
[x y z] = sphere;
s1 = surf(x,y,z);
hold on
s2 = surf(x+3,y,z+3);
s3 = surf(x,y,z+6);
daspect([1 1 1])
view(30,10)
camproj perspective
camlookat(gca) % Compose the scene around the current axes
pause(2)
camlookat(s1)  % Compose the scene around sphere s1
pause(2)
camlookat(s2)  % Compose the scene around sphere s2
pause(2)
```

```
camlookat(s3)  % Compose the scene around sphere s3
pause(2)
camlookat(gca)
```

See Also

campos, camtarget

"Controlling the Camera Viewpoint" on page 1-98 for related functions

"Defining Scenes with Camera Graphics" for more information

Purpose Rotate camera position around camera target

Syntax

```
camorbit(dtheta,dphi)
camorbit(dtheta,dphi,'coordsys')
camorbit(dtheta,dphi,'coordsys','direction')
camorbit(axes_handle,...)
```

Description

`camorbit(dtheta,dphi)` rotates the camera position around the camera target by the amounts specified in `dtheta` and `dphi` (both in degrees). `dtheta` is the horizontal rotation and `dphi` is the vertical rotation.

`camorbit(dtheta,dphi,'`*`coordsys`*`')` The *`coordsys`* argument determines the center of rotation. It can take on two values:

- `data` (default) — Rotate the camera around an axis defined by the camera target and the `direction` (default is the positive *z* direction).
- `camera` — Rotate the camera about the point defined by the camera target.

`camorbit(dtheta,dphi,'`*`coordsys`*`','direction')` The `direction` argument, in conjunction with the camera target, defines the axis of rotation for the data coordinate system. Specify `direction` as a three-element vector containing the x, y, and z components of the direction or one of the characters, `x`, `y`, or `z`, to indicate `[1 0 0]`, `[0 1 0]`, or `[0 0 1]` respectively.

`camorbit(axes_handle,...)` operates on the axes identified by the first argument, `axes_handle`. When you do not specify an axes handle, `camorbit` operates on the current axes.

Examples

Compare rotation in the two coordinate systems with these `for` loops. The first rotates the camera horizontally about a line defined by the camera target point and a direction that is parallel to the *y*-axis. Visualize this rotation as a cone formed with the camera target at the apex and the camera position forming the base:

```
surf(peaks)
```

```
axis vis3d
for i=1:36
 camorbit(10,0,'data',[0 1 0])
 drawnow
end
```

Rotation in the `camera` coordinate system orbits the camera around the axes along a circle while keeping the center of a circle at the camera target.

```
surf(peaks)
axis vis3d
for i=1:36
 camorbit(10,0,'camera')
 drawnow
end
```

See Also

`axes`, `axis('vis3d')`, `camdolly`, `campan`, `camzoom`, `camroll`

"Controlling the Camera Viewpoint" on page 1-98 for related functions

"Defining Scenes with Camera Graphics" for more information

campan

Purpose

Rotate camera target around camera position

Syntax

```
campan(dtheta,dphi)
campan(dtheta,dphi,'coordsys')
campan(dtheta,dphi,'coordsys','direction')
campan(axes_handle,...)
```

Description

`campan(dtheta,dphi)` rotates the camera target around the camera position by the amounts specified in `dtheta` and `dphi` (both in degrees). `dtheta` is the horizontal rotation and `dphi` is the vertical rotation.

`campan(dtheta,dphi,'`*`coordsys`*`')` The `coordsys` argument determines the center of rotation. It can take on two values:

- `data` (default) — Rotate the camera target around an axis defined by the camera position and the `direction` (default is the positive *z* direction)
- `camera` — Rotate the camera about the point defined by the camera target.

`campan(dtheta,dphi,'`*`coordsys`*`','direction')` The `direction` argument, in conjunction with the camera position, defines the axis of rotation for the data coordinate system. Specify `direction` as a three-element vector containing the x, y, and z components of the direction or one of the characters, `x`, `y`, or `z`, to indicate `[1 0 0]`, `[0 1 0]`, or `[0 0 1]` respectively.

`campan(axes_handle,...)` operates on the axes identified by the first argument, `axes_handle`. When you do not specify an axes handle, `campan` operates on the current axes.

See Also

`axes`, `camdolly`, `camorbit`, `camtarget`, `camzoom`, `camroll`

"Controlling the Camera Viewpoint" on page 1-98 for related functions

"Defining Scenes with Camera Graphics" for more information

Purpose

Set or query camera position

Syntax

```
campos
campos([camera_position])
campos('mode')
campos('auto')
campos('manual')
campos(axes_handle,...)
```

Description

`campos` with no arguments returns the camera position in the current axes.

`campos([camera_position])` sets the position of the camera in the current axes to the specified value. Specify the position as a three-element vector containing the *x*-, *y*-, and *z*-coordinates of the desired location in the data units of the axes.

`campos('mode')` returns the value of the camera position mode, which can be either `auto` (the default) or `manual`.

`campos('auto')` sets the camera position mode to `auto`.

`campos('manual')` sets the camera position mode to `manual`.

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

Remarks

`campos` sets or queries values of the axes `CameraPosition` and `CameraPositionMode` properties. The camera position is the point in the Cartesian coordinate system of the axes from which you view the scene.

Examples

This example moves the camera along the *x*-axis in a series of steps:

```
surf(peaks)
axis vis3d off
for x = -200:5:200
    campos([x,5,10])
    drawnow
```

```
end
```

See Also

`axis`, `camproj`, `camtarget`, `camup`, `camva`

The axes properties `CameraPosition`, `CameraTarget`, `CameraUpVector`, `CameraViewAngle`, `Projection`

"Controlling the Camera Viewpoint" on page 1-98 for related functions

"Defining Scenes with Camera Graphics" for more information

Purpose

Set or query projection type

Syntax

```
camproj
camproj('projection_type')
camproj(axes_handle,...)
```

Description

The projection type determines whether MATLAB uses a perspective or orthographic projection for 3-D views.

`camproj` with no arguments returns the projection type setting in the current axes.

`camproj('projection_type')` sets the projection type in the current axes to the specified value. Possible values for *`projection_type`* are `orthographic` and `perspective`.

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

Remarks

`camproj` sets or queries values of the axes object `Projection` property.

See Also

`campos`, `camtarget`, `camup`, `camva`

The axes properties `CameraPosition`, `CameraTarget`, `CameraUpVector`, `CameraViewAngle`, `Projection`

"Controlling the Camera Viewpoint" on page 1-98 for related functions

"Defining Scenes with Camera Graphics" for more information

camroll

Purpose

Rotate camera about view axis

Syntax

```
camroll(dtheta)
camroll(axes_handle,dtheta)
```

Description

`camroll(dtheta)` rotates the camera around the camera viewing axis by the amounts specified in `dtheta` (in degrees). The viewing axis is defined by the line passing through the camera position and the camera target.

`camroll(axes_handle,dtheta)` operates on the axes identified by the first argument, `axes_handle`. When you do not specify an axes handle, `camroll` operates on the current axes.

Remarks

`camroll` sets the axes `CameraUpVector` property and thereby also sets the `CameraUpVectorMode` property to `manual`.

See Also

`axes`, `axis('vis3d')`, `camdolly`, `camorbit`, `camzoom`, `campan`

"Controlling the Camera Viewpoint" on page 1-98 for related functions

"Defining Scenes with Camera Graphics" for more information

Purpose

Set or query location of camera target

Syntax

```
camtarget
camtarget([camera_target])
camtarget('mode')
camtarget('auto')
camtarget('manual')
camtarget(axes_handle,...)
```

Description

The camera target is the location in the axes that the camera points to. The camera remains oriented toward this point regardless of its position.

`camtarget` with no arguments returns the location of the camera target in the current axes.

`camtarget([camera_target])` sets the camera target in the current axes to the specified value. Specify the target as a three-element vector containing the *x*-, *y*-, and *z*-coordinates of the desired location in the data units of the axes.

`camtarget('mode')` returns the value of the camera target mode, which can be either `auto` (the default) or `manual`.

`camtarget('auto')` sets the camera target mode to `auto`.

`camtarget('manual')` sets the camera target mode to `manual`.

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

Remarks

`camtarget` sets or queries values of the axes object `CameraTarget` and `CameraTargetMode` properties.

When the camera target mode is `auto`, MATLAB positions the camera target at the center of the axes plot box.

Examples

This example moves the camera position and the camera target along the *x*-axis in a series of steps:

```
surf(peaks);
axis vis3d
xp = linspace(-150,40,50);
xt = linspace(25,50,50);
for i=1:50
     campos([xp(i),25,5]);
     camtarget([xt(i),30,0])
     drawnow
end
```

See Also

`axis`, `camproj`, `campos`, `camup`, `camva`

The axes properties `CameraPosition`, `CameraTarget`, `CameraUpVector`, `CameraViewAngle`, `Projection`

"Controlling the Camera Viewpoint" on page 1-98 for related functions

"Defining Scenes with Camera Graphics" for more information

Purpose

Set or query camera up vector

Syntax

```
camup
camup([up_vector])
camup('mode')
camup('auto')
camup('manual')
camup(axes_handle,...)
```

Description

The camera up vector specifies the direction that is oriented up in the scene.

`camup` with no arguments returns the camera up vector setting in the current axes.

`camup([up_vector])` sets the up vector in the current axes to the specified value. Specify the up vector as x, y, and z components. See Remarks.

`camup('mode')` returns the current value of the camera up vector mode, which can be either `auto` (the default) or `manual`.

`camup('auto')` sets the camera up vector mode to `auto`. In `auto` mode, MATLAB uses a value for the up vector of `[0 1 0]` for 2-D views. This means the z-axis points up.

`camup('manual')` sets the camera up vector mode to `manual`. In `manual` mode, MATLAB does not change the value of the camera up vector.

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

Remarks

`camup` sets or queries values of the axes object `CameraUpVector` and `CameraUpVectorMode` properties.

Specify the camera up vector as the x-, y-, and z-coordinates of a point in the axes coordinate system that forms the directed line segment PQ, where P is the point (0,0,0) and Q is the specified x-, y-, and z-coordinates. This line always points up. The length of the line PQ has no effect on the orientation of the scene. This means a value of `[0 0 1]` produces the same results as `[0 0 25]`.

See Also

`axis`, `camproj`, `campos`, `camtarget`, `camva`

The axes properties `CameraPosition`, `CameraTarget`, `CameraUpVector`, `CameraViewAngle`, `Projection`

"Controlling the Camera Viewpoint" on page 1-98 for related functions

"Defining Scenes with Camera Graphics" for more information

Purpose

Set or query camera view angle

Syntax

```
camva
camva(view_angle)
camva('mode')
camva('auto')
camva('manual')
camva(axes_handle,...)
```

Description

The camera view angle determines the field of view of the camera. Larger angles produce a smaller view of the scene. You can implement zooming by changing the camera view angle.

`camva` with no arguments returns the camera view angle setting in the current axes.

`camva(view_angle)` sets the view angle in the current axes to the specified value. Specify the view angle in degrees.

`camva('mode')` returns the current value of the camera view angle mode, which can be either `auto` (the default) or `manual`. See Remarks.

`camva('auto')` sets the camera view angle mode to `auto`.

`camva('manual')` sets the camera view angle mode to `manual`. See Remarks.

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

Remarks

`camva` sets or queries values of the axes object `CameraViewAngle` and `CameraViewAngleMode` properties.

When the camera view angle mode is `auto`, MATLAB adjusts the camera view angle so that the scene fills the available space in the window. If you move the camera to a different position, MATLAB changes the camera view angle to maintain a view of the scene that fills the available area in the window.

Setting a camera view angle or setting the camera view angle to `manual` disables the MATLAB stretch-to-fill feature (stretching of the axes to fit the window). This means setting the camera view angle to its current value,

```
camva(camva)
```

can cause a change in the way the graph looks. See the Remarks section of the `axes` reference page for more information.

Examples

This example creates two pushbuttons, one that zooms in and another that zooms out.

```
uicontrol('Style','pushbutton',...
  'String','Zoom In',...
  'Position',[20 20 60 20],...
  'Callback','if camva <= 1;return;else;camva(camva-1);end');
uicontrol('Style','pushbutton',...
  'String','Zoom Out',...
  'Position',[100 20 60 20],...
  'Callback','if camva >= 179;return;else;camva(camva+1);end');
```

Now create a graph to zoom in and out on:

```
surf(peaks);
```

Note the range checking in the callback statements. This keeps the values for the camera view angle in the range greater than zero and less than 180.

See Also

`axis`, `camproj`, `campos`, `camup`, `camtarget`

The axes properties `CameraPosition`, `CameraTarget`, `CameraUpVector`, `CameraViewAngle`, `Projection`

"Controlling the Camera Viewpoint" on page 1-98 for related functions

"Defining Scenes with Camera Graphics" for more information

Purpose

Zoom in and out on scene

Syntax

```
camzoom(zoom_factor)
camzoom(axes_handle,...)
```

Description

`camzoom(zoom_factor)` zooms in or out on the scene depending on the value specified by `zoom_factor`. If `zoom_factor` is greater than 1, the scene appears larger; if `zoom_factor` is greater than zero and less than 1, the scene appears smaller.

`camzoom(axes_handle,...)` operates on the axes identified by the first argument, `axes_handle`. When you do not specify an axes handle, `camzoom` operates on the current axes.

Remarks

`camzoom` sets the axes `CameraViewAngle` property, which in turn causes the `CameraViewAngleMode` property to be set to `manual`. Note that setting the `CameraViewAngle` property disables the MATLAB stretch-to-fill feature (stretching of the axes to fit the window). This may result in a change to the aspect ratio of your graph. See the `axes` function for more information on this behavior.

See Also

`axes`, `camdolly`, `camorbit`, `campan`, `camroll`, `camva`

"Controlling the Camera Viewpoint" on page 1-98 for related functions

"Defining Scenes with Camera Graphics" for more information

cart2pol

Purpose

Transform Cartesian coordinates to polar or cylindrical

Syntax

```
[THETA,RHO,Z] = cart2pol(X,Y,Z)
[THETA,RHO] = cart2pol(X,Y)
```

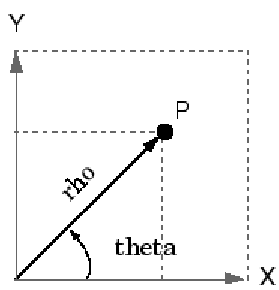
Description

`[THETA,RHO,Z] = cart2pol(X,Y,Z)` transforms three-dimensional Cartesian coordinates stored in corresponding elements of arrays `X`, `Y`, and `Z`, into cylindrical coordinates. `THETA` is a counterclockwise angular displacement in radians from the positive *x*-axis, `RHO` is the distance from the origin to a point in the *x*-*y* plane, and `Z` is the height above the *x*-*y* plane. Arrays `X`, `Y`, and `Z` must be the same size (or any can be scalar).

`[THETA,RHO] = cart2pol(X,Y)` transforms two-dimensional Cartesian coordinates stored in corresponding elements of arrays `X` and `Y` into polar coordinates.

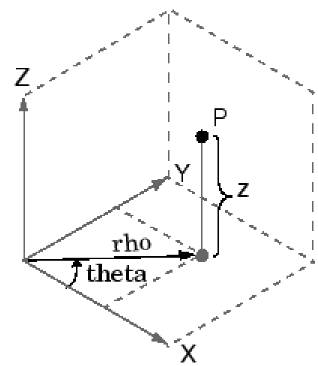
Algorithm

The mapping from two-dimensional Cartesian coordinates to polar coordinates, and from three-dimensional Cartesian coordinates to cylindrical coordinates is



Two-Dimensional Mapping

```
theta = atan2(y,x)
rho = sqrt(x.^2 + y.^2)
```



Three-Dimensional Mapping

```
theta = atan2(y,x)
rho = sqrt(x.^2 + y.^2)
z = z
```

See Also

`cart2sph`, `pol2cart`, `sph2cart`

Purpose

Transform Cartesian coordinates to spherical

Syntax

```
[THETA,PHI,R] = cart2sph(X,Y,Z)
```

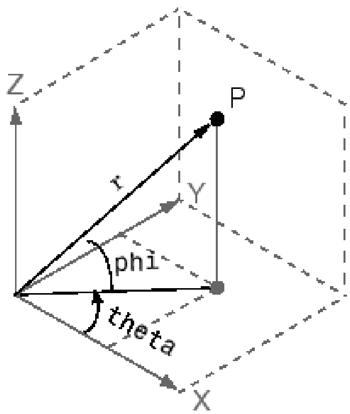
Description

`[THETA,PHI,R] = cart2sph(X,Y,Z)` transforms Cartesian coordinates stored in corresponding elements of arrays `X`, `Y`, and `Z` into spherical coordinates. Azimuth `THETA` and elevation `PHI` are angular displacements in radians measured from the positive *x*-axis, and the *x*-*y* plane, respectively; and `R` is the distance from the origin to a point.

Arrays `X`, `Y`, and `Z` must be the same size.

Algorithm

The mapping from three-dimensional Cartesian coordinates to spherical coordinates is




```
theta = atan2(y,x)
  phi = atan2(z, sqrt(x.^2 + y.^2))
    r = sqrt(x.^2+y.^2+z.^2)
```

The notation for spherical coordinates is not standard. For the `cart2sph` function, the angle PHI is measured from the *x*-*y* plane. Notice that if PHI = 0 then the point is in the *x*-*y* plane and if PHI = pi/2 then the point is on the positive *z*-axis.

See Also

`cart2pol`, `pol2cart`, `sph2cart`

Purpose

Execute block of code if condition is `true`

Syntax

```
switch switch_expr
 case case_expr
    statement, ..., statement
  case {case_expr1, case_expr2, case_expr3, ...}
    statement, ..., statement
  otherwise
    statement, ..., statement
end
```

Description

`case` is part of the `switch` statement syntax which allows for conditional execution. A particular case consists of the `case` statement itself followed by a case expression and one or more statements.

`case case_expr` compares the value of the expression `switch_expr` declared in the preceding `switch` statement with one or more values in `case_expr`, and executes the block of code that follows if any of the comparisons yield a `true` result.

You typically use multiple `case` statements in the evaluation of a single `switch` statement. The block of code associated with a particular `case` statement is executed only if its associated `case` expression (`case_expr`) is the first to match the switch expression (`switch_expr`).

To enter more than one `case` expression in a `switch` statement, put the expressions in a cell array, as shown above.

Examples

To execute a certain block of code based on what the string, `method`, is set to,

```
method = 'Bilinear';

switch lower(method)
   case {'linear','bilinear'}
      disp('Method is linear')
   case 'cubic'
```

```
        disp('Method is cubic')
    case 'nearest'
        disp('Method is nearest')
    otherwise
        disp('Unknown method.')
end

Method is linear
```

See Also

`switch`, `otherwise`, `end`, `if`, `else`, `elseif`, `while`

Purpose

Cast variable to different data type

Syntax

`B = cast(A, newclass)`

Description

`B = cast(A, newclass)` casts `A` to class `newclass`. `A` must be convertible to class `newclass`. `newclass` must be the name of one of the built in data types.

Examples

```
a = int8(5);
b = cast(a,'uint8');
class(b)

ans =

uint8
```

See Also

`class`

Purpose Concatenate arrays along specified dimension

Syntax

```
C = cat(dim, A, B)
C = cat(dim, A1, A2, A3, A4, ...)
```

Description `C = cat(dim, A, B)` concatenates the arrays `A` and `B` along `dim`.

`C = cat(dim, A1, A2, A3, A4, ...)` concatenates all the input arrays (`A1`, `A2`, `A3`, `A4`, and so on) along `dim`.

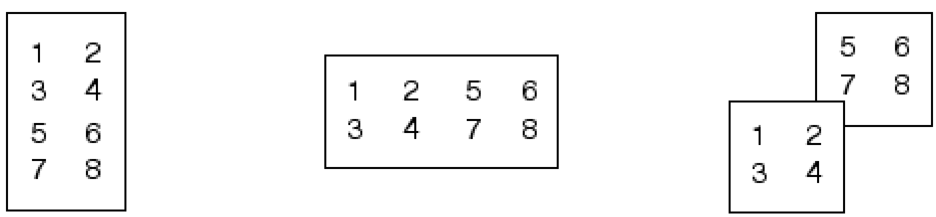
`cat(2, A, B)` is the same as `[A, B]`, and `cat(1, A, B)` is the same as `[A; B]`.

Remarks When used with comma-separated list syntax, `cat(dim, C{:})` or `cat(dim, C.field)` is a convenient way to concatenate a cell or structure array containing numeric matrices into a single matrix.

Examples Given

```
A =                    B =
      1     2                       5     6
      3     4                       7     8
```

concatenating along different dimensions produces



`C = cat(1,A,B)` `C = cat(2,A,B)` `C = cat(3,A,B)`

The commands

```
A = magic(3); B = pascal(3);
C = cat(4, A, B);
```

produce a 3-by-3-by-1-by-2 array.

See Also

`num2cell`

The `special character []`

Purpose

Specify how to respond to error in `try` statement

Description

The general form of a `try` statement is

```
try,
statement,
...,
statement,
catch,
statement,
...,
statement,
end
```

Normally, only the statements between the `try` and `catch` are executed. However, if an error occurs during execution of any of the statements, the error is captured into `lasterror`, and the statements between the `catch` and `end` are executed. If an error occurs within the `catch` statements, execution stops unless caught by another `try`...`catch` block. The error string produced by a failed `try` block can be obtained with `lasterror`.

See Also

`try`, `rethrow`, `end`, `lasterror`, `eval`, `evalin`

caxis

Purpose

Color axis scaling

Syntax

```
caxis([cmin cmax])
caxis auto
caxis manual
caxis(caxis) freeze
v = caxis
caxis(axes_handle,...)
```

Description

`caxis` controls the mapping of data values to the colormap. It affects any surfaces, patches, and images with indexed `CData` and `CDataMapping` set to scaled. It does not affect surfaces, patches, or images with true color `CData` or with `CDataMapping` set to `direct`.

`caxis([cmin cmax])` sets the color limits to specified minimum and maximum values. Data values less than `cmin` or greater than `cmax` map to `cmin` and `cmax`, respectively. Values between `cmin` and `cmax` linearly map to the current colormap.

`caxis auto` lets MATLAB compute the color limits automatically using the minimum and maximum data values. This is the default behavior. Color values set to `Inf` map to the maximum color, and values set to `-Inf` map to the minimum color. Faces or edges with color values set to `NaN` are not drawn.

`caxis manual` and `caxis(caxis) freeze` the color axis scaling at the current limits. This enables subsequent plots to use the same limits when `hold` is `on`.

`v = caxis` returns a two-element row vector containing the `[cmin cmax]` currently in use.

`caxis(axes_handle,...)` uses the axes specified by `axes_handle` instead of the current axes.

Remarks

`caxis` changes the `CLim` and `CLimMode` properties of axes graphics objects.

How Color Axis Scaling Works

Surface, patch, and image graphics objects having indexed CData and CDataMapping set to scaled map CData values to colors in the figure colormap each time they render. CData values equal to or less than cmin map to the first color value in the colormap, and CData values equal to or greater than cmax map to the last color value in the colormap. MATLAB performs the following linear transformation on the intermediate values (referred to as C below) to map them to an entry in the colormap (whose length is m, and whose row index is referred to as index below).

```
index = fix((C-cmin)/(cmax-cmin)*m)+1
```

Examples

Create (X,Y,Z) data for a sphere and view the data as a surface.

```
[X,Y,Z] = sphere;
C = Z;
surf(X,Y,Z,C)
```

Values of C have the range [-1 1]. Values of C near -1 are assigned the lowest values in the colormap; values of C near 1 are assigned the highest values in the colormap.

To map the top half of the surface to the highest value in the color table, use

```
caxis([-1 0])
```

To use only the bottom half of the color table, enter

```
caxis([-1 3])
```

which maps the lowest CData values to the bottom of the colormap, and the highest values to the middle of the colormap (by specifying a cmax whose value is equal to cmin plus twice the range of the CData).

The command

```
caxis auto
```

resets axis scaling back to autoranging and you see all the colors in the surface. In this case, entering

```
caxis
```

returns

```
[-1 1]
```

Adjusting the color axis can be useful when using images with scaled color data. For example, load the image data and colormap for Cape Cod, Massachusetts.

```
load cape
```

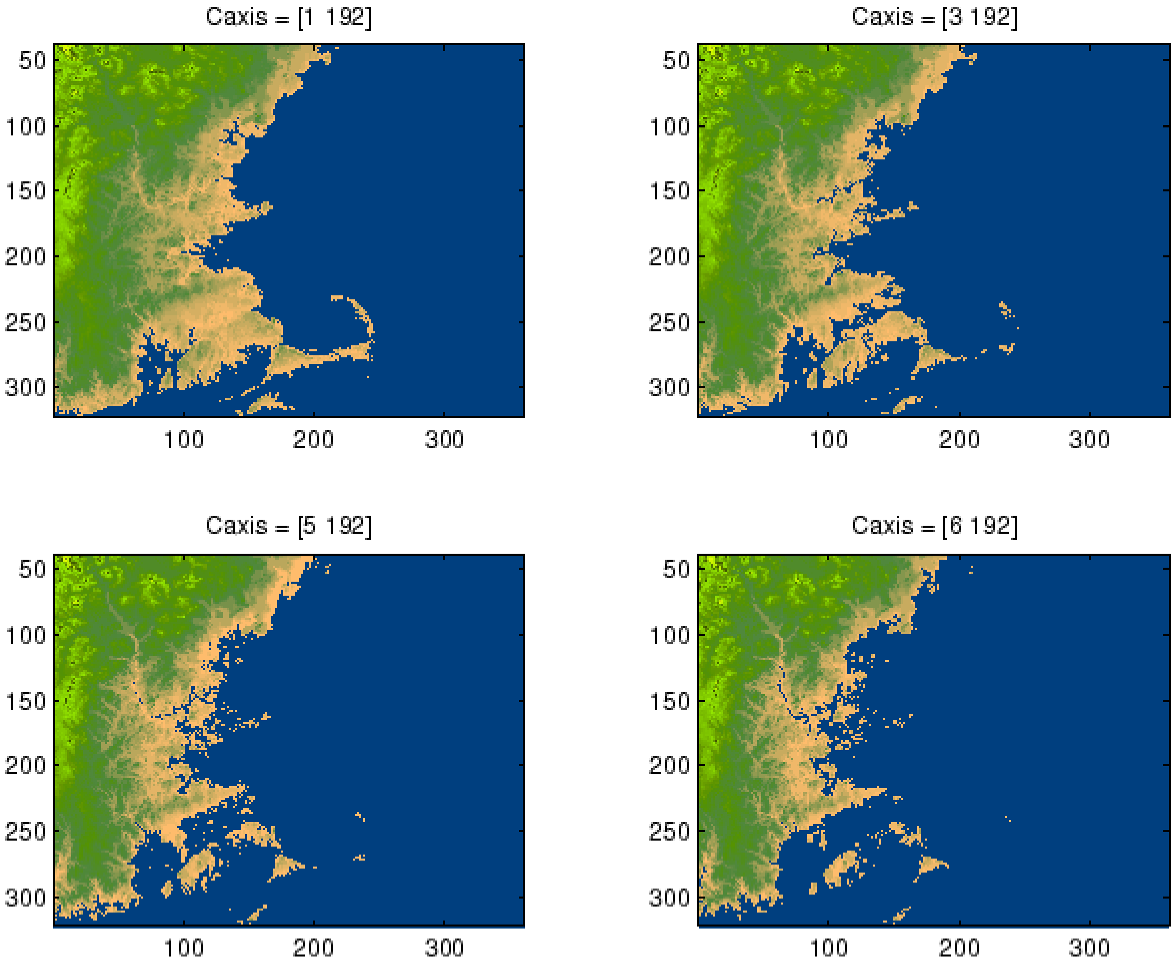
This command loads the image's data `X` and the image's colormap `map` into the workspace. Now display the image with `CDataMapping` set to `scaled` and install the image's colormap.

```
image(X,'CDataMapping','scaled')colormap(map)
```

MATLAB sets the color limits to span the range of the image data, which is 1 to 192:

```
caxis
ans =
     1   192
```

The blue color of the ocean is the first color in the colormap and is mapped to the lowest data value (1). You can effectively move sea level by changing the lower color limit value. For example,



See Also

`axes`, `axis`, `colormap`, `get`, `mesh`, `pcolor`, `set`, `surf`

The `CLim` and `CLimMode` properties of axes graphics objects

The `Colormap` property of figure graphics objects

"Color Operations" on page 1-97 for related functions

"Axes Color Limits — the CLim Property" for more examples

Purpose

Change working directory

Graphical Interface

As an alternative to the cd function, use the current directory field

in the MATLAB desktop toolbar.

Syntax

```
cd
w = cd
cd('directory')
cd('..')
cd directory
```

Description

`cd` displays the current working directory.

`w = cd` assigns the current working directory to `w`.

`cd('directory')` sets the current working directory to `directory`. Use the full pathname for `directory`. On UNIX platforms, the character ~ is interpreted as the user's root directory.

`cd('..')` changes the current working directory to the directory above it.

`cd directory` or cd .. is the unquoted form of the syntax.

Examples

On UNIX

```
cd('/usr/local/matlab/toolbox/control/ctrldemos')
```

changes the current working directory to `ctrldemos` for the Control System Toolbox.

On Windows

```
cd('c:/matlab/toolbox/control/ctrldemos')
```

changes the current working directory to `ctrldemos` for the Control System Toolbox. Then typing

```
cd ..
```

changes the current working directory to `control`, and typing

```
cd ..
```

again, changes the current working directory to `toolbox`.

On any platform, use `cd` with the `matlabroot` function to change to a directory relative to the directory in which MATLAB is installed. For example

```
cd([matlabroot '/toolbox/control/ctrldemos'])
```

changes the current working directory to `ctrldemos` for the Control System Toolbox.

See Also

`dir`, `fileparts`, `mfilename`, `path`, `pwd`, `what`

Purpose

Change current directory on FTP server

Syntax

```
cd(f)
cd(f,'dirname')
cd(f,'..')
```

Description

`cd(f)` Displays the current directory on the FTP server `f`, where `f` was created using `ftp`.

`cd(f,'dirname')` Changes the current directory on the FTP server `f` to `dirname`, where `f` was created using `ftp`. After running cd, the object `f` remembers the current directory on the FTP server. You can then perform file operations functions relative to `f` using the methods `delete`, `dir`, `mget`, `mkdir`, `mput`, `rename`, and `rmdir`.

`cd(f,'..')` changes the current directory on the FTP server `f` to the directory above the current one.

Examples

Connect to the MathWorks FTP server.

```
tmw=ftp('ftp.mathworks.com');
```

View the contents.

```
dir(tmw)
```

Change the current directory to `pub`.

```
cd(tmw,'pub');
```

View the contents of `pub`.

```
dir(tmw)
```

See Also

`dir (ftp)`, `ftp`

cdf2rdf

Purpose

Convert complex diagonal form to real block diagonal form

Syntax

```
[V,D] = cdf2rdf(V,D)
[V,D] = cdf2rdf(V,D)
```

Description

If the eigensystem `[V,D] = eig(X)` has complex eigenvalues appearing in complex-conjugate pairs, `cdf2rdf` transforms the system so `D` is in real diagonal form, with 2-by-2 real blocks along the diagonal replacing the complex pairs originally there. The eigenvectors are transformed so that

```
X = V*D/V
```

continues to hold. The individual columns of `V` are no longer eigenvectors, but each pair of vectors associated with a 2-by-2 block in `D` spans the corresponding invariant vectors.

Examples

The matrix

```
X =
    1     2     3
    0     4     5
    0    -5     4
```

has a pair of complex eigenvalues.

```
[V,D] = eig(X)

V =

    1.0000      -0.0191 - 0.4002i     -0.0191 + 0.4002i
         0            0 - 0.6479i           0 + 0.6479i
         0       0.6479                0.6479

D =

    1.0000            0                     0
```

```
        0        4.0000 + 5.0000i          0
        0             0               4.0000 - 5.0000i
```

Converting this to real block diagonal form produces

```
[V,D] = cdf2rdf(V,D)

V =

    1.0000    -0.0191     -0.4002
         0          0     -0.6479
         0     0.6479           0

D =

    1.0000          0           0
         0     4.0000      5.0000
         0    -5.0000      4.0000
```

Algorithm

The real diagonal form for the eigenvalues is obtained from the complex form using a specially constructed similarity transformation.

See Also

`eig`, `rsf2csf`

cdfepoch

Purpose Construct `cdfepoch` object for Common Data Format (CDF) export

Syntax

```
E = cdfepoch(date)
```

Description

`E = cdfepoch(date)` constructs a `cdfepoch` object, where `date` is a valid string (`datestr`), a number (`datenum`) representing a date, or a `cdfepoch` object.

When writing data to a CDF using `cdfwrite`, use `cdfepoch` to convert MATLAB formatted dates to CDF formatted dates. The MATLAB `cdfepoch` object simulates the `CDFEPOCH` data type in CDF files.

Use the `todatenum` function to convert a `cdfepoch` object into a MATLAB serial date number.

Note A CDF epoch is the number of milliseconds since 1-Jan-0000. MATLAB `datenums` are the number of days since 0-Jan-0000.

See Also `cdfinfo`, `cdfread`, `cdfwrite`, `datenum`

Purpose

Information about Common Data Format (CDF) file

Syntax

```
info = cdfinfo(filename)
```

Description

`info = cdfinfo(filename)` returns information about the Common Data Format (CDF) file specified in the string `filename`.

Note Because `cdfinfo` creates temporary files, the current working directory must be writeable.

The return value, `info`, is a structure that contains the fields listed alphabetically in the following table.

Field	Description
`FileModDate`	Text string indicating the date the file was last modified
`Filename`	Text string specifying the name of the file
`FileSettings`	Structure array containing library settings used to create the file
`FileSize`	Double scalar specifying the size of the file, in bytes
`Format`	Text string specifying the file format
`FormatVersion`	Text string specifying the version of the CDF library used to create the file
`GlobalAttributes`	Structure array that contains one field for each global attribute. The name of each field corresponds to the name of an attribute. The data in each field, contained in a cell array, represents the entry values for that attribute.

Field	Description
`Subfiles`	Filenames containing the CDF file's data, if it is a multifile CDF
`VariableAttributes`	Structure array that contains one field for each variable attribute. The name of each field corresponds to the name of an attribute. The data in each field is contained in a *n*-by-2 cell array, where *n* is the number of variables. The first column of this cell array contains the variable names associated with the entries. The second column contains the entry values.

Field	Description	
`Variables`	N-by-6 cell array, where N is the number of variables, containing information about the variables in the file. The columns present the following information:	
	Column 1	Text string specifying name of variable
	Column 2	Double array specifying the dimensions of the variable, as returned by the `size` function
	Column 3	Double scalar specifying the number of records assigned for the variable
	Column 4	Text string specifying the data type of the variable, as stored in the CDF file

	Column 5	Text string specifying the record and dimension variance settings for the variable. The single `T` or `F` to the left of the slash designates whether values vary by record. The zero or more `T` or `F` letters to the right of the slash designate whether values vary at each dimension. Here are some examples.
		`T/  (scalar variable`
		`F/T (one-dimensional variable)`
		T/TFF (three-dimensional variable)

	Column 6	Text string specifying the sparsity of the variable's records, with these possible values: `'Full' 'Sparse (padded)' 'Sparse (nearest)'`

Note Attribute names returned by `cdfinfo` might not match the names of the attributes in the CDF file exactly. Attribute names can contain characters that are illegal in MATLAB field names. `cdfinfo` removes illegal characters that appear at the beginning of attributes and replaces other illegal characters with underscores ('_'). When `cdfinfo` modifies an attribute name, it appends the attribute's internal number to the end of the field name. For example, the attribute name `Variable%Attribute` becomes `Variable_Attribute_013`.

Examples

```
info = cdfinfo('example.cdf')
info =
              Filename: 'example.cdf'
           FileModDate: '09-Mar-2001 15:45:22'
              FileSize: 1240
                Format: 'CDF'
         FormatVersion: '2.7.0'
          FileSettings: [1x1 struct]
              Subfiles: {}
             Variables: {5x6 cell}
      GlobalAttributes: [1x1 struct]
    VariableAttributes: [1x1 struct]

info.Variables
ans =
  'Time'         [1x2 double] [24] 'epoch'  'T/'     'Full'
  'Longitude'    [1x2 double] [ 1] 'int8'   'F/FT'   'Full'
  'Latitude'     [1x2 double] [ 1] 'int8'   'F/TF'   'Full'
  'Data'         [1x3 double] [ 1] 'double' 'T/TTT'  'Full'
  'multidim'     [1x4 double] [ 1] 'uint8'  'T/TTTT' 'Full'
```

See Also

`cdfread`

Purpose

Read data from Common Data Format (CDF) file

Syntax

```
data = cdfread(filename)
data = cdfread(filename, param1, val1, param2, val2, ...)
[data, info] = cdfread(filename, ...)
```

Description

`data = cdfread(filename)` reads all the data from the Common Data Format (CDF) file specified in the string `filename`. CDF data sets typically contain a set of variables, of a specific data type, each with an associated set of records. The variable might represent time values with each record representing a specific time that an observation was recorded. `cdfread` returns all the data in a cell array where each column represents a variable and each row represents a record associated with a variable. If the variables have varying numbers of associated records, `cdfread` pads the rows to create a rectangular cell array, using pad values defined in the CDF file.

Note Because `cdfread` creates temporary files, the current working directory must be writeable.

`data = cdfread(filename, param1, val1, param2, val2, ...)` reads data from the file, where *param1*, *param2*, and so on, can be any of the following parameters.

Parameter	Value
`'Records'`	A vector specifying which records to read. Record numbers are zero-based. `cdfread` returns a cell array with the same number of rows as the number of records read and as many columns as there are variables.

Parameter	Value
'Variables'	A 1-by-n or n-by-1 cell array specifying the names of the variables to read from the file. n must be less than or equal to the total number of variables in the file. `cdfread` returns a cell array with the same number of columns as the number of variables read, and a row for each record read.
'Slices'	An m-by-3 array, where each row specifies where to start reading along a particular dimension of a variable, the skip interval to use on that dimension (every item, every other item, etc.), and the total number of values to read on that dimension. m must be less than or equal to the number of dimensions of the variable. If m is less than the total number of dimensions, `cdfread` reads every value from the unspecified dimensions (`[0 1 n]`, where n is the total number of elements in the dimension. Note: Because the `'Slices'` parameter describes how to process a single variable, it must be used in conjunction with the `'Variables'` parameter.

Parameter	Value
`'ConvertEpochToDatenum'`	A Boolean value that determines whether `cdfread` automatically converts CDF epoch data types to MATLAB serial date numbers. If set to `false` (the default), `cdfread` wraps epoch values in MATLAB`cdfepoch` objects. Note: For better performance when reading large data sets, set this parameter to `true`.
`'CombineRecords'`	A Boolean value that determines how `cdfread` returns the CDF data sets read from the file. If set to `false` (the default), `cdfread` stores the data in an *m*-by-*n* cell array, where *m* is the number of records and *n* is the number of variables requested. If set to `true`, `cdfread` combines all records for a particular variable into one cell in the output cell array. In this cell, `cdfread` stores scalar data as a column array. `cdfread` extends the dimensionality of nonscalar and string data. For example, instead of creating 1000 elements containing 20-by-30 arrays for each record, `cdfread` stores all the records in one cell as a 1000-by-20-by-30 array Note: If you use the `'Records'` parameter to specify which records to read, you cannot use the `'CombineRecords'` parameter. Note: When using the `'Variable'` parameter to read one variable, if the `'CombineRecords'` parameter is `true`, `cdfread` returns the data as an M-by-N numeric or character array; it does not put the data into a cell array.

`[data, info] = cdfread(`*`filename`*`, ...)` returns details about the CDF file in the `info` structure.

Note To maximize performance, specify both the `'ConvertEpochToDatenum'` and `'CombineRecords'` parameters, setting their values to `'true'`.

Examples

Read all the data from a CDF file.

```
data = cdfread('example.cdf');
```

Read the data from the variable 'Time'.

```
data = cdfread('example.cdf', 'Variable', {'Time'});
```

Read the first value in the first dimension, the second value in the second dimension, the first and third values in the third dimension, and all values in the remaining dimension of the variable 'multidimensional'.

```
data = cdfread('example.cdf', ...
               'Variable', {'multidimensional'}, ...
               'Slices', [0 1 1; 1 1 1; 0 2 2]);
```

This is similar to reading the whole variable into data and then using matrix indexing, as in the following.

```
data{1}(1, 2, [1 3], :)
```

Collapse the records from a data set and convert CDF epoch data types to MATLAB serial date numbers.

```
data = cdfread('example.cdf', ...
               'CombineRecords', true, ...
               'ConvertEpochToDatenum', true);
```

See Also

cdfepoch, cdfinfo, cdfwrite

For more information about using this function, see “Common Data Format (CDF) Files”.

Purpose

Write data to Common Data Format (CDF) file

Syntax

```
cdfwrite(filename,variablelist)
cdfwrite(...,'PadValues',padvals)
cdfwrite(...,'GlobalAttributes',gattrib)
cdfwrite(..., 'VariableAttributes', vattrib)
cdfwrite(...,'WriteMode',mode)
cdfwrite(...,'Format',format)
```

Description

`cdfwrite(filename,variablelist)` writes out a Common Data Format (CDF) file, specified in `filename`. The `filename` input is a string enclosed in single quotes. The `variablelist` argument is a cell array of ordered pairs, each of which comprises a CDF variable name (a string) and the corresponding CDF variable value. To write out multiple records for a variable, put the values in a cell array where each element in the cell array represents a record.

Note Because `cdfwrite` creates temporary files, both the destination directory for the file and the current working directory must be writeable.

`cdfwrite(...,'PadValues',padvals)` writes out pad values for given variable names. `padvals` is a cell array of ordered pairs, each of which comprises a variable name (a string) and a corresponding pad value. Pad values are the default values associated with the variable when an out-of-bounds record is accessed. Variable names that appear in `padvals` must appear in `variablelist`.

`cdfwrite(...,'GlobalAttributes',gattrib)` writes the structure `gattrib` as global metadata for the CDF file. Each field of the structure is the name of a global attribute. The value of each field contains the value of the attribute. To write out multiple values for an attribute, put the values in a cell array where each element in the cell array represents a record.

Note To specify a global attribute name that is illegal in MATLAB, create a field called `'CDFAttributeRename'` in the attribute structure. The value of this field must have a value that is a cell array of ordered pairs. The ordered pair consists of the name of the original attribute, as listed in the `GlobalAttributes` structure, and the corresponding name of the attribute to be written to the CDF file.

`cdfwrite(..., 'VariableAttributes', vattrib)` writes the structure `vattrib` as variable metadata for the CDF. Each field of the struct is the name of a variable attribute. The value of each field should be an M-by-2 cell array where M is the number of variables with attributes. The first element in the cell array should be the name of the variable and the second element should be the value of the attribute for that variable.

Note To specify a variable attribute name that is illegal in MATLAB, create a field called `'CDFAttributeRename'` in the attribute structure. The value of this field must have a value that is a cell array of ordered pairs. The ordered pair consists of the name of the original attribute, as listed in the `VariableAttributes` struct, and the corresponding name of the attribute to be written to the CDF file. If you are specifying a variable attribute of a CDF variable that you are renaming, the name of the variable in the `VariableAttributes` structure must be the same as the renamed variable.

`cdfwrite(...,'WriteMode',`*`mode`*`)`, where *`mode`* is either `'overwrite'` or `'append'`, indicates whether or not the specified variables should be appended to the CDF file if the file already exists. By default, `cdfwrite` overwrites existing variables and attributes.

`cdfwrite(...,'Format',`*`format`*`)`, where *`format`* is either `'multifile'` or `'singlefile'`, indicates whether or not the data is written out as a multifile CDF. In a multifile CDF, each variable is stored in a separate file with the name `*.vN`, where `N` is the number of the variable that is written out to the CDF. By default, `cdfwrite` writes out a single file CDF. When `'WriteMode'` is set to `'Append'`, the `'Format'` option is ignored, and the format of the preexisting CDF is used.

Examples

Write out a file `'example.cdf'` containing a variable `'Longitude'` with the value `[0:360]`.

```
cdfwrite('example', {'Longitude', 0:360});
```

Write out a file `'example.cdf'` containing variables `'Longitude'` and `'Latitude'` with the variable `'Latitude'` having a pad value of 10 for all out-of-bounds records that are accessed.

```
cdfwrite('example', {'Longitude', 0:360, 'Latitude', 10:20}, ...
         'PadValues', {'Latitude', 10});
```

Write out a file `'example.cdf'`, containing a variable `'Longitude'` with the value `[0:360]`, and with a variable attribute of `'validmin'` with the value 10.

```
varAttribStruct.validmin = {'longitude' [10]};
cdfwrite('example', {'Longitude' 0:360}, 'VarAttribStruct', ...
         varAttribStruct);
```

See Also

`cdfread`, `cdfinfo`, `cdfepoch`

Purpose Round toward infinity

Syntax

```
B = ceil(A)
```

Description `B = ceil(A)` rounds the elements of `A` to the nearest integers greater 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, 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

ceil(a)

ans =
  Columns 1 through 4
  -1.0000        0              4.0000        6.0000

  Columns 5 through 6
   7.0000        3.0000 + 4.0000i
```

See Also `fix`, `floor`, `round`

Purpose

Construct cell array

Syntax

```
c = cell(n)
c = cell(m, n)
c = cell([m, n])
c = cell(m, n, p,...)
c = cell([m n p ...])
c = cell(size(A))
c = cell(javaobj)
```

Description

`c = cell(n)` creates an `n`-by-`n` cell array of empty matrices. An error message appears if `n` is not a scalar.

`c = cell(m, n)` or `c = cell([m, n])` creates an `m`-by-`n` cell array of empty matrices. Arguments `m` and `n` must be scalars.

`c = cell(m, n, p,...)` or `c = cell([m n p ...])` creates an `m`-by-`n`-by-`p`-... cell array of empty matrices. Arguments `m`, `n`, `p`,`...` must be scalars.

`c = cell(size(A))` creates a cell array the same size as `A` containing all empty matrices.

`c = cell(javaobj)` converts a Java array or Java object `javaobj` into a MATLAB cell array. Elements of the resulting cell array will be of the MATLAB type (if any) closest to the Java array elements or Java object.

Remarks

This type of cell is not related to “cell mode,” a MATLAB feature used in debugging and publishing.

Examples

This example creates a cell array that is the same size as another array, `A`.

```
A = ones(2,2)

A =
     1     1
     1     1
```

```
c = cell(size(A))

c =
     []     []
     []     []
```

The next example converts an array of `java.lang.String` objects into a MATLAB cell array.

```
strArray = java_array('java.lang.String', 3);
strArray(1) = java.lang.String('one');
strArray(2) = java.lang.String('two');
strArray(3) = java.lang.String('three');

cellArray = cell(strArray)
cellArray =
    'one'
    'two'
    'three'
```

See Also

`num2cell`, `ones`, `rand`, `randn`, `zeros`

Purpose Convert cell array of matrices to single matrix

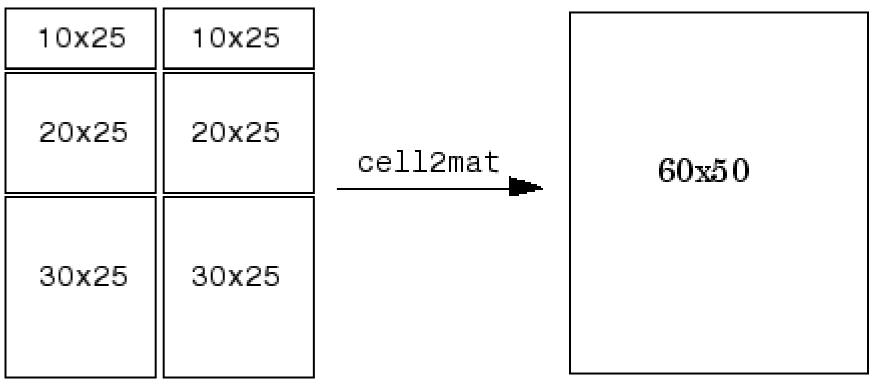
Syntax

```
m = cell2mat(c)
```

Description `m = cell2mat(c)` converts a multidimensional cell array `c` with contents of the same data type into a single matrix, `m`. The contents of `c` must be able to concatenate into a hyperrectangle. Moreover, for each pair of neighboring cells, the dimensions of the cells' contents must match, excluding the dimension in which the cells are neighbors.

The example shown below combines matrices in a 3-by-2 cell array into a single 60-by-50 matrix:

```
cell2mat(c)
```



Remarks The dimensionality (or number of dimensions) of `m` will match the highest dimensionality contained in the cell array.

`cell2mat` is not supported for cell arrays containing cell arrays or objects.

Examples Combine the matrices in four cells of cell array `C` into the single matrix, `M`:

```
C = {[1] [2 3 4]; [5; 9] [6 7 8; 10 11 12]}
```

```
C =
    [         1]    [1x3 double]
    [2x1 double]    [2x3 double]

C{1,1}                         C{1,2}
ans =                          ans =
     1                              2     3     4

C{2,1}                         C{2,2}
ans =                          ans =
     5                              6     7     8
     9                             10    11    12

M = cell2mat(C)
M =
     1     2     3     4
     5     6     7     8
     9    10    11    12
```

See Also

`mat2cell`, `num2cell`

Purpose

Convert cell array to structure array

Syntax

```
s = cell2struct(c, fields, dim)
```

Description

`s = cell2struct(c, fields, dim)` creates a structure array `s` from the information contained within cell array `c`.

The `fields` argument specifies field names for the structure array. `fields` can be a character array or a cell array of strings.

The `dim` argument controls which axis of the cell array is to be used in creating the structure array. The length of `c` along the specified dimension must match the number of fields named in `fields`. In other words, the following must be true.

```
size(c,dim) == length(fields)   % If fields is a cell array
size(c,dim) == size(fields,1)   % If fields is a char array
```

Examples

The cell array `c` in this example contains information on trees. The three columns of the array indicate the common name, genus, and average height of a tree.

```
c = {'birch', 'betula', 65;  'maple', 'acer', 50}
c =
    'birch'    'betula'    [65]
    'maple'    'acer'      [50]
```

To put this information into a structure with the fields `name`, `genus`, and `height`, use `cell2struct` along the second dimension of the 2-by-3 cell array.

```
fields = {'name', 'genus', 'height'};
s = cell2struct(c, fields, 2);
```

This yields the following 2-by-1 structure array.

```
s(1)                          s(2)
ans =                         ans =
      name: 'birch'                 name: 'maple'
```

```
  genus: 'betula'             genus: 'acer'
 height: 65                  height: 50
```

See Also

`struct2cell`, `cell`, `iscell`, `struct`, `isstruct`, `fieldnames`, dynamic field names

Purpose Cell array contents

Syntax

```
celldisp(C)
celldisp(C, name)
```

Description `celldisp(C)` recursively displays the contents of a cell array.

`celldisp(C, name)` uses the string *name* for the display instead of the name of the first input (or `ans`).

Examples Use `celldisp` to display the contents of a 2-by-3 cell array:

```
C = {[1 2] 'Tony' 3+4i; [1 2;3 4] -5 'abc'};
celldisp(C)

C{1,1} =
     1     2

C{2,1} =
     1     2
     3     4

C{1,2} =
Tony

C{2,2} =
    -5

C{1,3} =
   3.0000+ 4.0000i

C{2,3} =
abc
```

See Also `cellplot`

Purpose Apply function to each cell in cell array

Syntax

```
A = cellfun(fun, C)
A = cellfun(fun, C, D, ...)
[A, B, ...] = cellfun(fun, C, ...)
[A, ...] = cellfun(fun, C, ..., 'param1', value1, ...)
A = cellfun('fname', C)
A = cellfun('size', C, k)
A = cellfun('isclass', C, 'classname')
```

Description

`A = cellfun(fun, C)` applies the function specified by `fun` to the contents of each cell of cell array `C`, and returns the results in array `A`. The value `A` returned by `cellfun` is the same size as `C`, and the `(I,J,...)`th element of `A` is equal to `fun(C{I,J,...})`. The first input argument `fun` is a function handle to a function that takes one input argument and returns a scalar value. `fun` must return values of the same class each time it is called. The order in which `cellfun` computes elements of `A` is not specified and should not be relied upon.

If `fun` is bound to more than one built-in or M-file (that is, if it represents a set of overloaded functions), then the class of the values that `cellfun` actually provides as input arguments to `fun` determines which functions are executed.

`A = cellfun(fun, C, D, ...)` evaluates `fun` using the contents of the cells of cell arrays `C`, `D`, `...` as input arguments. The `(I,J,...)`th element of `A` is equal to `fun(C{I,J,...}, D{I,J,...}, ...)`. All input arguments must be of the same size and shape.

`[A, B, ...] = cellfun(fun, C, ...)` evaluates `fun`, which is a function handle to a function that returns multiple outputs, and returns arrays `A`, `B`, `...`, each corresponding to one of the output arguments of `fun`. `cellfun` calls `fun` each time with as many outputs as there are in the call to `cellfun`. `fun` can return output arguments having different classes, but the class of each output must be the same each time `fun` is called.

`[A, ...] = cellfun(fun, C, ..., 'param1', value1, ...)` enables you to specify optional parameter name and value pairs.

Parameters recognized by `cellfun` are shown below. Enclose each parameter name with single quotes.

Parameter Name	Parameter Value
`UniformOutput`	Logical 1 (`true`) or 0 (`false`), indicating whether or not the outputs of `fun` can be returned without encapsulation in a cell array. See "UniformOutput Parameter" on page 2-493 below.
`ErrorHandler`	Function handle, specifying the function that `cellfun` is to call if the call to `fun` fails. See "ErrorHandler Parameter" on page 2-493 below.

UniformOutput Parameter

If you set the `UniformOutput` parameter to `true` (the default), `fun` must return scalar values that can be concatenated into an array. These values can also be a cell array.

If `UniformOutput` is `false`, `cellfun` returns a cell array (or multiple cell arrays), where the `(I,J,...)`th cell contains the value

```
fun(C{I,J,...}, ...)
```

ErrorHandler Parameter

MATLAB calls the function represented by the `ErrorHandler` parameter with two input arguments:

- A structure having three fields, named `identifier`, `message`, and `index`, respectively containing the identifier of the error that occurred, the text of the error message, and a linear index into the input array or arrays for which the error occurred
- The set of input arguments for which the call to the function failed

The error handling function must either rethrow the error that was caught, or it must return the output values from the call to `fun`. Error handling functions that do not rethrow the error must have the same number of outputs as `fun`. MATLAB places these output values in the output variables used in the call to `arrayfun`.

Shown here is an example of a simple error handling function, `errorfun`:

```
function [A, B] = errorfun(S, varargin)
warning(S.identifier, S.message);
A = NaN;  B = NaN;
```

If `'UniformOutput'` is set to logical 1 (`true`), the outputs of the error handler must be scalars and of the same data type as the outputs of function `fun`.

If you do not specify an error handler, `cellfun` rethrows the error.

Backward Compatibility

The following syntaxes are also accepted for backward compatibility:

`A = cellfun('fname', C)` applies the function `fname` to the elements of cell array `C` and returns the results in the double array `A`. Each element of `A` contains the value returned by `fname` for the corresponding element in `C`. The output array `A` is the same size as the cell array `C`.

These functions are supported:

Function	Return Value
`isempty`	`true` for an empty cell element
`islogical`	`true` for a logical cell element
`isreal`	`true` for a real cell element
`length`	Length of the cell element
`ndims`	Number of dimensions of the cell element
`prodofsize`	Number of elements in the cell element

`A = cellfun('size', C, k)` returns the size along the `k`th dimension of each element of `C`.

A = cellfun('isclass', C, 'classname') returns logical 1 (true) for each element of C that matches classname. This function syntax returns logical 0 (false) for objects that are a subclass of classname.

Note For the previous three syntaxes, if C contains objects, cellfun does not call any overloaded versions of MATLAB functions corresponding to the above strings.

Examples

Compute the mean of several data sets:

```
C = {1:10, [2; 4; 6], []};

Cmeans = cellfun(@mean, C)
Cmeans =
    5.5000    4.0000       NaN
```

Compute the size of these data sets:

```
[Cnrows, Cncols] = cellfun(@size, C)
Cnrows =
     1     3     0
Cncols =
    10     1     0
```

Again compute the size, but with UniformOutput set to false:

```
Csize = cellfun(@size, C, 'UniformOutput', false)
Csize =
    [1x2 double]    [1x2 double]    [1x2 double]

Csize{:}
ans =
     1    10
ans =
     3     1
ans =
```

```
     0     0
```

Find the positive values in several data sets.

```
C = {randn(10,1), randn(20,1), randn(30,1)};

Cpositives = cellfun(@(x) x(x>0), C, 'UniformOutput',false)
Cpositives =
    [6x1 double]    [11x1 double]    [15x1 double]

Cpositives{:}
ans =
    0.1253
    0.2877
    1.1909
     etc.
ans =
    0.7258
    2.1832
    0.1139
     etc.
ans =
    0.6900
    0.8156
    0.7119
     etc.
```

Compute the covariance between several pairs of data sets:

```
C = {randn(10,1), randn(20,1), randn(30,1)};
D = {randn(10,1), randn(20,1), randn(30,1)};

CDcovs = cellfun(@cov, C, D, 'UniformOutput', false)
CDcovs =
    [2x2 double]    [2x2 double]    [2x2 double]

CDcovs{:}
ans =
```

```
    0.7353   -0.2148
   -0.2148    0.6080
ans =
    0.5743   -0.2912
   -0.2912    0.8505
ans =
    0.7130    0.1750
    0.1750    0.6910
```

See Also

`arrayfun`, `spfun`, `function_handle`, `cell2mat`

Purpose Graphically display structure of cell array

Syntax

```
cellplot(c)
cellplot(c, 'legend')
handles = cellplot(c)
```

Description `cellplot(c)` displays a figure window that graphically represents the contents of `c`. Filled rectangles represent elements of vectors and arrays, while scalars and short text strings are displayed as text.

`cellplot(c, 'legend')` places a colorbar next to the plot labelled to identify the data types in `c`.

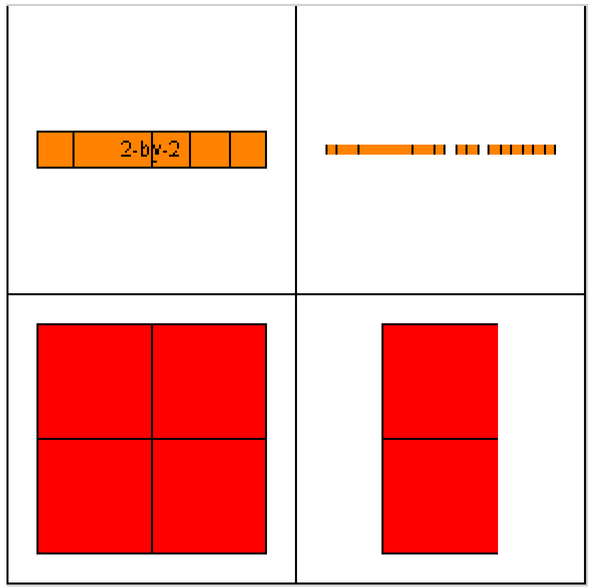
`handles = cellplot(c)` displays a figure window and returns a vector of surface handles.

Limitations The `cellplot` function can display only two-dimensional cell arrays.

Examples Consider a 2-by-2 cell array containing a matrix, a vector, and two text strings:

```
c{1,1} = '2-by-2';
c{1,2} = 'eigenvalues of eye(2)';
c{2,1} = eye(2);
c{2,2} = eig(eye(2));
```

The command `cellplot(c)` produces


2-by-2

Purpose

Create cell array of strings from character array

Syntax

```
c = cellstr(S)
```

Description

`c = cellstr(S)` places each row of the character array `S` into separate cells of `c`. Any trailing spaces in the rows of `S` are removed.

Use the `char` function to convert back to a string matrix.

Examples

Given the string matrix

```
S = ['abc '; 'defg'; 'hi  ']

S =
    abc
    defg
    hi

whos S
  Name      Size         Bytes  Class
  S         3x4             24  char array
```

The following command returns a 3-by-1 cell array.

```
c = cellstr(S)

c =
    'abc'
    'defg'
    'hi'

whos c
  Name      Size         Bytes  Class
  c         3x1            294  cell array
```

See Also

`iscellstr`, `strings`, `char`, `isstrprop`

Purpose

Conjugate gradients squared method

Syntax

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

Description

`x = cgs(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.

"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 `cgs` converges, a message to that effect is displayed. If `cgs` 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.

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

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

`cgs(A,b,tol,maxit,M)` and `cgs(A,b,tol,maxit,M1,M2)` use the preconditioner `M` or `M = M1*M2` and effectively solve the system `inv(M)*A*x = inv(M)*b` for `x`. If `M` is `[]` then `cgs` applies no preconditioner. M can be a function handle mfun such that mfun(x) returns M\x.

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

[x,flag] = cgs(A,b,...) returns a solution x and a flag that describes the convergence of cgs.

Flag	Convergence
0	cgs converged to the desired tolerance tol within maxit iterations.
1	cgs iterated maxit times but did not converge.
2	Preconditioner M was ill-conditioned.
3	cgs stagnated. (Two consecutive iterates were the same.)
4	One of the scalar quantities calculated during cgs 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] = cgs(A,b,...) also returns the relative residual norm(b-A*x)/norm(b). If flag is 0, then relres <= tol.

[x,flag,relres,iter] = cgs(A,b,...) also returns the iteration number at which x was computed, where 0 <= iter <= maxit.

[x,flag,relres,iter,resvec] = cgs(A,b,...) also returns a vector of the residual norms at each iteration, including norm(b-A*x0).

Examples

Example

```
A = gallery('wilk',21);
b = sum(A,2);
```

```
tol = 1e-12;  maxit = 15;
M1 = diag([10:-1:1 1 1:10]);
x = cgs(A,b,tol,maxit,M1);
```

displays the message

```
cgs converged at iteration 13 to a solution with relative residual
1.3e-016
```

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_cgs` that

- Calls `cgs` with the function handle `@afun` as its first argument.
- Contains `afun` as a nested function, so that all variables in `run_cgs` are available to `afun` and `myfun`.

The following shows the code for `run_cgs`:

```
function x1 = run_cgs
n = 21;
A = gallery('wilk',n);
b = sum(A,2);
tol = 1e-12;  maxit = 15;
x1 = cgs(@afun,b,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_cgs
```

MATLAB returns

```
cgs converged at iteration 13 to a solution with relative residual
1.3e-016
```

Example 3

```
load west0479
A = west0479
b = sum(A,2)
[x,flag] = cgs(A,b)
```

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

```
[L1,U1] = luinc(A,1e-5)
[x1,flag1] = cgs(A,b,1e-6,20,L1,U1)
```

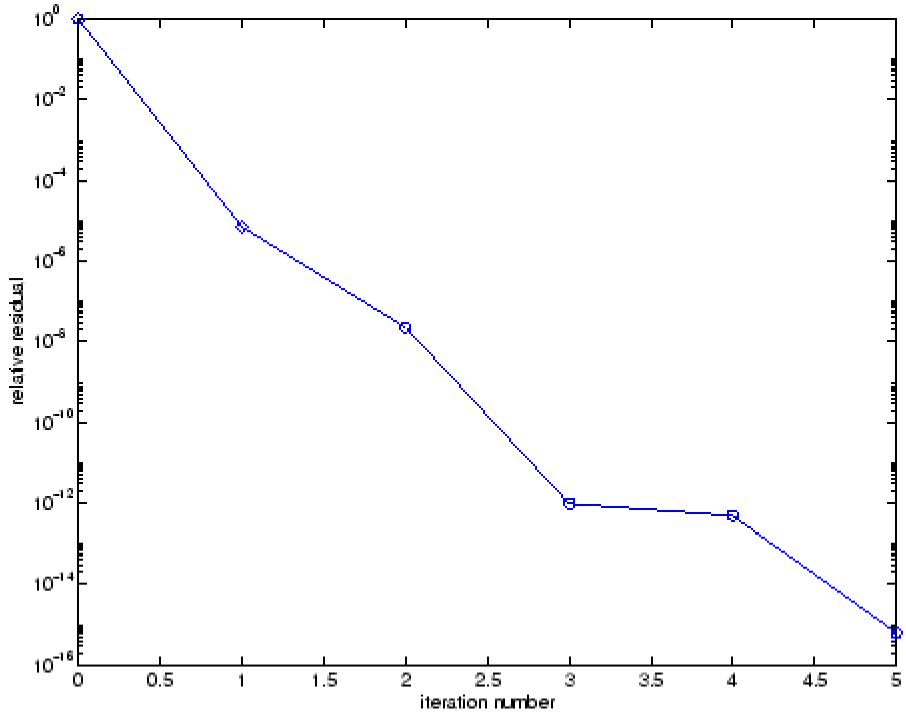
`flag1` is 2 because the upper triangular `U1` has a zero on its diagonal, and `cgs` fails in the first iteration when it tries to solve a system such as `U1*y = r` for `y` with backslash.

```
[L2,U2] = luinc(A,1e-6)
[x2,flag2,relres2,iter2,resvec2] = cgs(A,b,1e-15,10,L2,U2)
```

`flag2` is 0 because `cgs` converges to the tolerance of `6.344e-16` (the value of `relres2`) at the fifth iteration (the value of `iter2`) when preconditioned by the incomplete LU factorization with a drop tolerance of `1e-6`. `resvec2(1) = norm(b)` and `resvec2(6) = norm(b-A*x2)`. You can follow the progress of `cgs` by plotting the relative residuals at each iteration starting from the initial estimate (iterate number 0) with

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

```
ylabel('relative residual')
```



See Also

`bicg`, `bicgstab`, `gmres`, `lsqr`, `luinc`, `minres`, `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] Sonneveld, Peter, "CGS: A fast Lanczos-type solver for nonsymmetric linear systems," *SIAM J. Sci. Stat. Comput.*, January 1989, Vol. 10, No. 1, pp. 36-52.

char

Purpose

Convert to character array (string)

Syntax

```
S = char(X)
S = char(C)
S = char(t1, t2, t3, ...)
```

Description

`S = char(X)` converts the array `X` that contains nonnegative integers representing character codes into a MATLAB character array. The actual characters displayed depend on the character encoding scheme for a given font. The result for any elements of `X` outside the range from 0 to 65535 is not defined (and can vary from platform to platform). Use `double` to convert a character array into its numeric codes.

`S = char(C)`, when `C` is a cell array of strings, places each element of `C` into the rows of the character array `s`. Use `cellstr` to convert back.

`S = char(t1, t2, t3, ...)` forms the character array `S` containing the text strings `T1`, `T2`, `T3`, `...` as rows, automatically padding each string with blanks to form a valid matrix. Each text parameter, `T`*i*, can itself be a character array. This allows the creation of arbitrarily large character arrays. Empty strings are significant.

Examples

To print a 3-by-32 display of the printable ASCII characters,

```
ascii = char(reshape(32:127, 32, 3)')
ascii =
    !"#$%&'()*+,-./0123456789:;<=>?
   @ABCDEFGHIJKLMNOPQRSTUVWXYZ[\]^_
   `abcdefghijklmnopqrstuvwxyz{|}~
```

See Also

`ischar`, `isletter`, `isspace`, `isstrprop`, `cellstr`, `iscellstr`, `get`, `set`, `strings`, `strvcat`, `text`

Purpose

Check files into source control system (UNIX)

GUI Alternatives

As an alternative to the `checkin` function, use **File > Source Control > Check In** in the Editor/Debugger, Simulink, or Stateflow, or in the context menu of the Current Directory browser. For more information, see “Checking Files Into the Source Control System”.

Syntax

```
checkin('filename','comments','comment_text')
checkin({'filename1','filename2'},'comments','comment_text')
checkin('filename','comments', 'comment_text','option',
   'value')
```

Description

`checkin('filename','comments','comment_text')` checks in the file named `filename` to the source control system. Use the full path for `filename` and include the file extension. You must save the file before checking it in, but the file can be open or closed. The comment_text argument is a MATLAB string containing checkin comments for the source control system. You must supply **`comments`** and comment_text.

`checkin({'filename1','filename2'},'comments','comment_text')` checks in the files `filename1` through `filenamen` to the source control system. Use the full paths for the files and include file extensions. Comments apply to all files checked in.

`checkin('filename','comments','comment_text','option','value')` provides additional `checkin` options. For multiple filenames, use an array of strings instead of `filename`, that is, `{'filename1','filename2',...}`. Options apply to all filenames. The *`option`* and *`value`* arguments are shown in the following table.

option Argument	value Argument	Purpose
'force'	'on'	`filename` is checked in even if the file has not changed since it was checked out.
'force'	'off' (default)	`filename` is not checked in if there were no changes since checkout.
'lock'	'on'	`filename` is checked in with comments, and is automatically checked out.
'lock'	'off' (default)	`filename` is checked in with comments but does not remain checked out.

Examples

Check In a File

Typing

```
checkin('/myserver/mymfiles/clock.m','comments',...
'Adjustment for leapyear')
```

checks the file `/myserver/mymfiles/clock.m` into the source control system, with the comment `Adjustment for leapyear`.

Check In Multiple Files

Typing

```
checkin({'/myserver/mymfiles/clock.m', ...
'/myserver/mymfiles/calendar.m'},'comments',...
'Adjustment for leapyear')
```

checks the two files into the source control system, using the same comment for each.

Check In a File and Keep It Checked Out

Typing

```
checkin('/myserver/mymfiles/clock.m','comments',...
'Adjustment for leapyear','lock','on')
```

checks the file `/myserver/mymfiles/clock.m` into the source control system and keeps the file checked out.

See Also

`checkout`, `cmopts`, `undocheckout`

For Windows platforms, use `verctrl`.

checkout

Purpose

Check files out of source control system (UNIX)

GUI Alternatives

As an alternative to the `checkout` function, select **Source Control > Check Out** from the **File** menu in the Editor/Debugger, Simulink, or Stateflow, or in the context menu of the Current Directory browser. For details, see "Checking Files Out of the Source Control System".

Syntax

```
checkout('filename')
checkout({'filename1','filename2', ...})
checkout('filename','option','value',...)
```

Description

`checkout('filename')` checks out the file named `filename` from the source control system. Use the full path for `filename` and include the file extension. The file can be open or closed when you use `checkout`.

`checkout({'filename1','filename2', ...})` checks out the files named `filename1` through `filenamen` from the source control system. Use the full paths for the files and include the file extensions.

`checkout('filename','`*`option`*`','`*`value`*`',...)` provides additional `checkout` options. For multiple filenames, use an array of strings instead of `filename`, that is, `{'filename1','filename2', ...}`. Options apply to all filenames. The *`option`* and *`value`* arguments are shown in the following table.

option Argument	value Argument	Purpose
`'force'`	`'on'`	The checkout is forced, even if you already have the file checked out. This is effectively an `undocheckout` followed by a `checkout`.

option Argument	value Argument	Purpose
'force'	'off' (default)	Prevents you from checking out the file if you already have it checked out.
'lock'	'on' (default)	The checkout gets the file, allows you to write to it, and locks the file so that access to the file for others is read only.
'lock'	'off'	The checkout gets a read-only version of the file, allowing another user to check out the file for updating. You do not have to check the file in after checking it out with this option.
'revision'	'version_num'	Checks out the specified revision of the file.

If you end the MATLAB session, the file remains checked out. You can check in the file from within MATLAB during a later session, or directly from your source control system.

Examples

Check Out a File

Typing

```
checkout('/myserver/mymfiles/clock.m')
```

checks out the file /myserver/mymfiles/clock.m from the source control system.

Check Out Multiple Files

Typing

```
checkout({'/myserver/mymfiles/clock.m',...
'/myserver/mymfiles/calendar.m'})
```

checks out /matlab/mymfiles/clock.m and /matlab/mymfiles/calendar.m from the source control system.

Force a Checkout, Even If File Is Already Checked Out

Typing

```
checkout('/myserver/mymfiles/clock.m','force','on')
```

checks out /matlab/mymfiles/clock.m even if clock.m is already checked out to you.

Check Out Specified Revision of File

Typing

```
checkout('/matlab/mymfiles/clock.m','revision','1.1')
```

checks out revision 1.1 of clock.m.

See Also

checkin, cmopts, undocheckout, customverctrl

For Windows platforms, use verctrl.

Purpose

Cholesky factorization

Syntax

```
R = chol(A)
L = chol(A,'lower')
[R,p] = chol(A)
[L,p] = chol(A,'lower')
[R,p,S] = chol(A)
[R,p,s] = chol(A,'vector')
[L,p,s] = chol(A,'lower','vector')
```

Description

`R = chol(A)` produces an upper triangular matrix `R` from the diagonal and upper triangle of matrix `A`, satisfying the equation `R'*R=A`. The lower triangle is assumed to be the (complex conjugate) transpose of the upper triangle. Matrix `A` must be positive definite; otherwise, MATLAB displays an error message.

`L = chol(A,'lower')` produces a lower triangular matrix `L` from the diagonal and lower triangle of matrix `A`, satisfying the equation `L*L'=A`. When `A` is sparse, this syntax of `chol` is typically faster. Matrix `A` must be positive definite; otherwise MATLAB displays an error message.

`[R,p] = chol(A)` for positive definite `A`, produces an upper triangular matrix `R` from the diagonal and upper triangle of matrix `A`, satisfying the equation `R'*R=A` and `p` is zero. If `A` is not positive definite, then `p` is a positive integer and MATLAB does not generate an error. When `A` is full, `R` is an upper triangular matrix of order `q=p-1` such that `R'*R=A(1:q,1:q)`. When `A` is sparse, `R` is an upper triangular matrix of size `q`-by-`n` so that the `L`-shaped region of the first `q` rows and first `q` columns of `R'*R` agree with those of `A`.

`[L,p] = chol(A,'lower')` for positive definite `A`, produces a lower triangular matrix `L` from the diagonal and lower triangle of matrix `A`, satisfying the equation `L'*L=A` and `p` is zero. If `A` is not positive definite, then `p` is a positive integer and MATLAB does not generate an error. When `A` is full, `L` is a lower triangular matrix of order `q=p-1` such that `L'*L=A(1:q,1:q)`. When `A` is sparse, `L` is a lower triangular matrix of size `q`-by-`n` so that the `L`-shaped region of the first `q` rows and first `q` columns of `L'*L` agree with those of `A`.

`[R,p,S] = chol(A)`, when `A` is sparse, returns a permutation matrix `S`. Note that the preordering `S` may differ from that obtained from `amd` since `chol` will slightly change the ordering for increased performance. When `p=0`, `R` is an upper triangular matrix such that `R'*R=S'*A*S`. When `p` is not zero, `R` is an upper triangular matrix of size `q`-by-`n` so that the `L`-shaped region of the first `q` rows and first `q` columns of `R'*R` agree with those of `S'*A*S`. The factor of `S'*A*S` tends to be sparser than the factor of `A`.

`[R,p,s] = chol(A,'vector')` returns the permutation information as a vector `s` such that `A(s,s)=R'*R`, when `p=0`. You can use the `'matrix'` option in place of `'vector'` to obtain the default behavior.

`[L,p,s] = chol(A,'lower','vector')` uses only the diagonal and the lower triangle of `A` and returns a lower triangular matrix `L` and a permutation vector `s` such that `A(s,s)=L*L'`, when `p=0`. As above, you can use the `'matrix'` option in place of `'vector'` to obtain a permutation matrix.

For sparse `A`, CHOLMOD is used to compute the Cholesky factor.

Note Using `chol` is preferable to using `eig` for determining positive definiteness.

Examples

The binomial coefficients arranged in a symmetric array create an interesting positive definite matrix.

```
n = 5;
X = pascal(n)
X =
     1     1     1     1     1
     1     2     3     4     5
     1     3     6    10    15
     1     4    10    20    35
     1     5    15    35    70
```

It is interesting because its Cholesky factor consists of the same coefficients, arranged in an upper triangular matrix.

```
R = chol(X)
R =
     1     1     1     1     1
     0     1     2     3     4
     0     0     1     3     6
     0     0     0     1     4
     0     0     0     0     1
```

Destroy the positive definiteness (and actually make the matrix singular) by subtracting 1 from the last element.

```
X(n,n) = X(n,n)-1

X =
     1     1     1     1     1
     1     2     3     4     5
     1     3     6    10    15
     1     4    10    20    35
     1     5    15    35    69
```

Now an attempt to find the Cholesky factorization fails.

Algorithm

For full matrices `X`, `chol` uses the LAPACK routines listed in the following table.

	Real	Complex
`X double`	DPOTRF	ZPOTRF
`X single`	SPOTRF	CPOTRF

For sparse matrices, MATLAB uses CHOLMOD to compute the Cholesky factor.

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., *CHOLMOD Version 1.0 User Guide* (`http://www.cise.ufl.edu/research/sparse/cholmod`), Dept. of Computer and Information Science and Engineering, Univ. of Florida, Gainesville, FL, 2005.

See Also

`cholinc`, `cholupdate`

Purpose

Sparse incomplete Cholesky and Cholesky-Infinity factorizations

Syntax

```
R = cholinc(X,droptol)
R = cholinc(X,options)
R = cholinc(X,'0')
[R,p] = cholinc(X,'0')
R = cholinc(X,'inf')
```

Description

`cholinc` produces two different kinds of incomplete Cholesky factorizations: the drop tolerance and the 0 level of fill-in factorizations. These factors may be useful as preconditioners for a symmetric positive definite system of linear equations being solved by an iterative method such as `pcg` (Preconditioned Conjugate Gradients). `cholinc` works only for sparse matrices.

`R = cholinc(X,droptol)` performs the incomplete Cholesky factorization of `X`, with drop tolerance `droptol`.

`R = cholinc(X,options)` allows additional options to the incomplete Cholesky factorization. `options` is a structure with up to three fields:

`droptol`	Drop tolerance of the incomplete factorization
`michol`	Modified incomplete Cholesky
`rdiag`	Replace zeros on the diagonal of `R`

Only the fields of interest need to be set.

`droptol` is a non-negative scalar used as the drop tolerance for the incomplete Cholesky factorization. This factorization is computed by performing the incomplete LU factorization with the pivot threshold option set to `0` (which forces diagonal pivoting) and then scaling the rows of the incomplete upper triangular factor, `U`, by the square root of the diagonal entries in that column. Since the nonzero entries `U(i,j)` are bounded below by `droptol*norm(X(:,j))` (see `luinc`), the nonzero entries `R(i,j)` are bounded below by the local drop tolerance `droptol*norm(X(:,j))/R(i,i)`.

Setting `droptol = 0` produces the complete Cholesky factorization, which is the default.

`michol` stands for modified incomplete Cholesky factorization. Its value is either `0` (unmodified, the default) or `1` (modified). This performs the modified incomplete LU factorization of `X` and scales the returned upper triangular factor as described above.

`rdiag` is either `0` or `1`. If it is `1`, any zero diagonal entries of the upper triangular factor R are replaced by the square root of the local drop tolerance in an attempt to avoid a singular factor. The default is `0`.

`R = cholinc(X,'0')` produces the incomplete Cholesky factor of a real sparse matrix that is symmetric and positive definite using no fill-in. The upper triangular `R` has the same sparsity pattern as `triu(X)`, although `R` may be zero in some positions where `X` is nonzero due to cancellation. The lower triangle of `X` is assumed to be the transpose of the upper. Note that the positive definiteness of `X` does not guarantee the existence of a factor with the required sparsity. An error message results if the factorization is not possible. If the factorization is successful, `R'*R` agrees with `X` over its sparsity pattern.

`[R,p] = cholinc(X,'0')` with two output arguments, never produces an error message. If `R` exists, `p` is `0`. If `R` does not exist, then `p` is a positive integer and `R` is an upper triangular matrix of size `q`-by-`n` where `q = p-1`. In this latter case, the sparsity pattern of `R` is that of the `q`-by-`n` upper triangle of `X`. `R'*R` agrees with `X` over the sparsity pattern of its first `q` rows and first `q` columns.

`R = cholinc(X,'inf')` produces the Cholesky-Infinity factorization. This factorization is based on the Cholesky factorization, and additionally handles real positive semi-definite matrices. It may be useful for finding a solution to systems which arise in interior-point methods. When a zero pivot is encountered in the ordinary Cholesky factorization, the diagonal of the Cholesky-Infinity factor is set to `Inf` and the rest of that row is set to `0`. This forces a `0` in the corresponding entry of the solution vector in the associated system of linear equations. In practice, `X` is assumed to be positive semi-definite so even negative pivots are replaced with a value of `Inf`.

Remarks

The incomplete factorizations may be useful as preconditioners for solving large sparse systems of linear equations. 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 `rdiag` option to replace a zero diagonal only gets rid of the symptoms of the problem, but it does not solve it. The preconditioner may not be singular, but it probably is not useful, and a warning message is printed.

The Cholesky-Infinity factorization is meant to be used within interior-point methods. Otherwise, its use is not recommended.

Examples

Example 1

Start with a symmetric positive definite matrix, `S`.

```
S = delsq(numgrid('C',15));
```

S is the two-dimensional, five-point discrete negative Lapacian on the grid generated by numgrid('C',15).

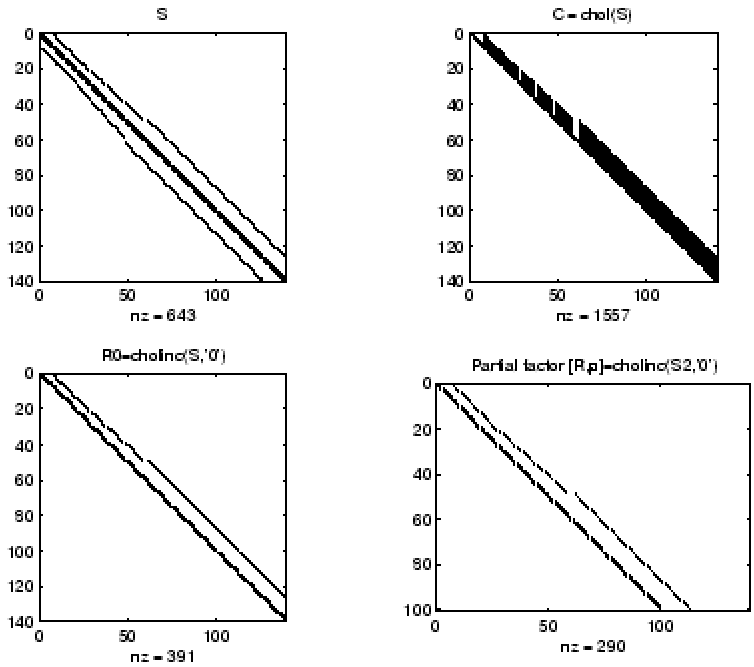
Compute the Cholesky factorization and the incomplete Cholesky factorization of level 0 to compare the fill-in. Make `S` singular by zeroing out a diagonal entry and compute the (partial) incomplete Cholesky factorization of level `0`.

```
C = chol(S);
R0 = cholinc(S,'0');
S2 = S; S2(101,101) = 0;
[R,p] = cholinc(S2,'0');
```

Fill-in occurs within the bands of `S` in the complete Cholesky factor, but none in the incomplete Cholesky factor. The incomplete factorization of the singular `S2` stopped at row `p = 101` resulting in a 100-by-139 partial factor.

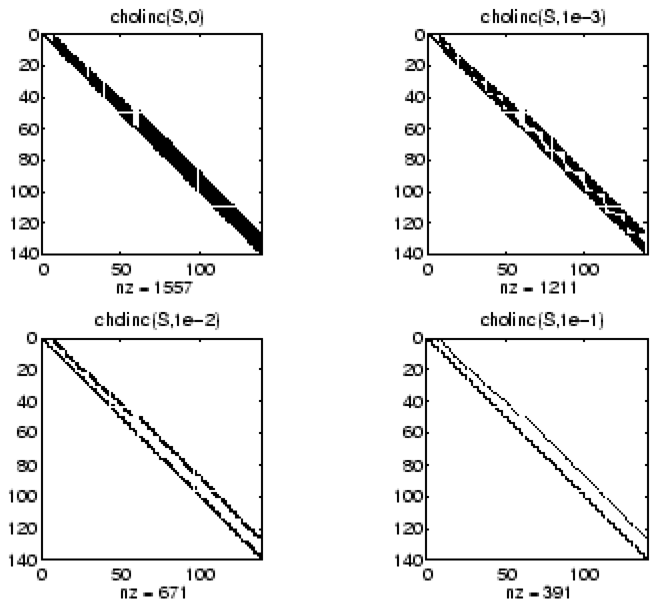
```
D1 = (R0'*R0).*spones(S)-S;
D2 = (R'*R).*spones(S2)-S2;
```

D1 has elements of the order of eps, showing that R0'*R0 agrees with S over its sparsity pattern. D2 has elements of the order of eps over its first 100 rows and first 100 columns, D2(1:100,:) and D2(:,1:100).

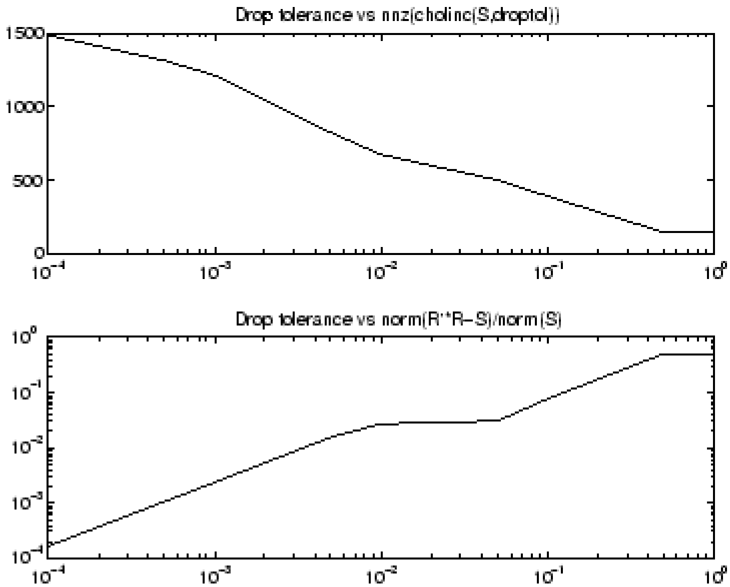


Example 2

The first subplot below shows that cholinc(S,0), the incomplete Cholesky factor with a drop tolerance of 0, is the same as the Cholesky factor of S. Increasing the drop tolerance increases the sparsity of the incomplete factors, as seen below.



Unfortunately, the sparser factors are poor approximations, as is seen by the plot of drop tolerance versus `norm(R'*R-S,1)/norm(S,1)` in the next figure.



Example 3

The Hilbert matrices have (i,j) entries 1/(i+j-1) and are theoretically positive definite:

```
H3 = hilb(3)
H3 =
    1.0000    0.5000    0.3333
    0.5000    0.3333    0.2500
    0.3333    0.2500    0.2000
R3 = chol(H3)
R3 =
    1.0000    0.5000    0.3333
         0    0.2887    0.2887
         0         0    0.0745
```

In practice, the Cholesky factorization breaks down for larger matrices:

```
H20 = sparse(hilb(20));
```

```
[R,p] = chol(H20);
p =
    14
```

For hilb(20), the Cholesky factorization failed in the computation of row 14 because of a numerically zero pivot. You can use the Cholesky-Infinity factorization to avoid this error. When a zero pivot is encountered, cholinc places an Inf on the main diagonal, zeros out the rest of the row, and continues with the computation:

```
Rinf = cholinc(H20,'inf');
```

In this case, all subsequent pivots are also too small, so the remainder of the upper triangular factor is:

```
full(Rinf(14:end,14:end))
ans =
   Inf     0     0     0     0     0     0
     0   Inf     0     0     0     0     0
     0     0   Inf     0     0     0     0
     0     0     0   Inf     0     0     0
     0     0     0     0   Inf     0     0
     0     0     0     0     0   Inf     0
     0     0     0     0     0     0   Inf
```

Limitations

cholinc works on square sparse matrices only. For cholinc(X,'0') and cholinc(X,'inf'), X must be real.

Algorithm

R = cholinc(X,droptol) is obtained from [L,U] = luinc(X,options), where options.droptol = droptol and options.thresh = 0. The rows of the uppertriangular U are scaled by the square root of the diagonal in that row, and this scaled factor becomes R.

R = cholinc(X,options) is produced in a similar manner, except the rdiag option translates into the udiag option and the milu option takes the value of the michol option.

`R = cholinc(X,'0')` is based on the "KJI" variant of the Cholesky factorization. Updates are made only to positions which are nonzero in the upper triangle of `X`.

`R = cholinc(X,'inf')` is based on the algorithm in Zhang [2].

See Also

`chol`, `ilu`, `luinc`, `pcg`

References

[1] Saad, Yousef, *Iterative Methods for Sparse Linear Systems*, PWS Publishing Company, 1996. Chapter 10, "Preconditioning Techniques"

[2] Zhang, Yin, *Solving Large-Scale Linear Programs by Interior-Point Methods Under the MATLAB Environment*, Department of Mathematics and Statistics, University of Maryland Baltimore County, Technical Report TR96-01

Purpose

Rank 1 update to Cholesky factorization

Syntax

```
R1 = cholupdate(R,x)
R1 = cholupdate(R,x,'+')
R1 = cholupdate(R,x,'-')
[R1,p] = cholupdate(R,x,'-')
```

Description

`R1 = cholupdate(R,x)` where `R = chol(A)` is the original Cholesky factorization of `A`, returns the upper triangular Cholesky factor of `A + x*x'`, where `x` is a column vector of appropriate length. `cholupdate` uses only the diagonal and upper triangle of `R`. The lower triangle of `R` is ignored.

`R1 = cholupdate(R,x,'+')` is the same as `R1 = cholupdate(R,x)`.

`R1 = cholupdate(R,x,'-')` returns the Cholesky factor of `A - x*x'`. An error message reports when R is not a valid Cholesky factor or when the downdated matrix is not positive definite and so does not have a Cholesky factorization.

`[R1,p] = cholupdate(R,x,'-')` will not return an error message. If `p` is `0`, `R1` is the Cholesky factor of `A - x*x`'. If `p` is greater than `0`, `R1` is the Cholesky factor of the original `A`. If `p` is `1`, `cholupdate` failed because the downdated matrix is not positive definite. If `p` is `2`, `cholupdate` failed because the upper triangle of `R` was not a valid Cholesky factor.

Remarks

`cholupdate` works only for full matrices.

Example

```
A = pascal(4)
A =

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

R = chol(A)
R =
```

```
        1     1     1     1
        0     1     2     3
        0     0     1     3
        0     0     0     1
  x = [0 0 0 1]';
```

This is called a rank one update to `A` since `rank(x*x')` is `1`:

```
  A + x*x'
  ans =


        1     1     1     1
        1     2     3     4
        1     3     6    10
        1     4    10    21
```

Instead of computing the Cholesky factor with `R1 = chol(A + x*x')`, we can use `cholupdate`:

```
  R1 = cholupdate(R,x)
  R1 =

      1.0000    1.0000    1.0000    1.0000
           0    1.0000    2.0000    3.0000
           0         0    1.0000    3.0000
           0         0         0    1.4142
```

Next destroy the positive definiteness (and actually make the matrix singular) by subtracting `1` from the last element of `A`. The downdated matrix is:

```
  A - x*x'
  ans =

        1     1     1     1
        1     2     3     4
```

```
     1     3     6    10
     1     4    10    19
```

Compare chol with cholupdate:

```
R1 = chol(A-x*x')
??? Error using ==> chol
Matrix must be positive definite.
R1 = cholupdate(R,x,'-')
??? Error using ==> cholupdate
Downdated matrix must be positive definite.
```

However, subtracting 0.5 from the last element of A produces a positive definite matrix, and we can use cholupdate to compute its Cholesky factor:

```
x = [0 0 0 1/sqrt(2)]';
R1 = cholupdate(R,x,'-')
R1 =
    1.0000    1.0000    1.0000    1.0000
         0    1.0000    2.0000    3.0000
         0         0    1.0000    3.0000
         0         0         0    0.7071
```

Algorithm

cholupdate uses the algorithms from the LINPACK subroutines ZCHUD and ZCHDD. cholupdate is useful since computing the new Cholesky factor from scratch is an $O(N^3)$ algorithm, while simply updating the existing factor in this way is an $O(N^2)$ algorithm.

See Also

chol, qrupdate

References

[1] Dongarra, J.J., J.R. Bunch, C.B. Moler, and G.W. Stewart, *LINPACK Users' Guide*, SIAM, Philadelphia, 1979.

circshift

Purpose

Shift array circularly

Syntax

```
B = circshift(A,shiftsize)
```

Description

`B = circshift(A,shiftsize)` circularly shifts the values in the array, `A`, by `shiftsize` elements. `shiftsize` is a vector of integer scalars where the `n`-th element specifies the shift amount for the `n`-th dimension of array `A`. If an element in `shiftsize` is positive, the values of `A` are shifted down (or to the right). If it is negative, the values of `A` are shifted up (or to the left). If it is `0`, the values in that dimension are not shifted.

Example

Circularly shift first dimension values down by 1.

```
A = [ 1 2 3;4 5 6; 7 8 9]
A =
     1     2     3
     4     5     6
     7     8     9

B = circshift(A,1)
B =
     7     8     9
     1     2     3
     4     5     6
```

Circularly shift first dimension values down by 1 and second dimension values to the left by 1.

```
B = circshift(A,[1 -1]);
B =
    8     9     7
    2     3     1
    5     6     4
```

See Also

`fftshift`, `shiftdim`

Purpose

Clear current axes

GUI Alternatives

Remove axes and clear objects from them in *plot edit* mode. For details, see “Using Plot Edit Mode” in the MATLAB Graphics documentation.

Syntax

```
cla
cla reset
cla(ax)
cla(ax,'reset')
```

Description

`cla` deletes from the current axes all graphics objects whose handles are not hidden (i.e., their `HandleVisibility` property is set to `on`).

`cla reset` deletes from the current axes all graphics objects regardless of the setting of their `HandleVisibility` property and resets all axes properties, except `Position` and `Units`, to their default values.

`cla(ax)` or `cla(ax,'reset')` clears the single axes with handle `ax`.

Remarks

The `cla` command behaves the same way when issued on the command line as it does in callback routines — it does not recognize the `HandleVisibility` setting of `callback`. This means that when issued from within a callback routine, `cla` deletes only those objects whose `HandleVisibility` property is set to `on`.

See Also

`clf`, `hold`, `newplot`, `reset`

“Axes Operations” on page 1-95 for related functions

clabel

Purpose

Contour plot elevation labels

Syntax

```
clabel(C,h)
clabel(C,h,v)
clabel(C,h,'manual')
clabel(C)
clabel(C,v)
clabel(C,'manual')
text_handles = clabel(...)
clabel(...,'PropertyName',propertyvalue,...)
clabel(...'LabelSpacing',points)
```

Description

The `clabel` function adds height labels to a 2-D contour plot.

`clabel(C,h)` rotates the labels and inserts them in the contour lines. The function inserts only those labels that fit within the contour, depending on the size of the contour.

`clabel(C,h,v)` creates labels only for those contour levels given in vector `v`, then rotates the labels and inserts them in the contour lines.

`clabel(C,h,'manual')` places contour labels at locations you select with a mouse. Press the left mouse button (the mouse button on a single-button mouse) or the space bar to label a contour at the closest location beneath the center of the cursor. Press the **Return** key while the cursor is within the figure window to terminate labeling. The labels are rotated and inserted in the contour lines.

`clabel(C)` adds labels to the current contour plot using the contour array `C` output from `contour`. The function labels all contours displayed and randomly selects label positions.

`clabel(C,v)` labels only those contour levels given in vector `v`.

`clabel(C,'manual')` places contour labels at locations you select with a mouse.

`text_handles = clabel(...)` returns the handles of text objects created by clabel. The `UserData` properties of the text objects contain the contour values displayed. If you call `clabel` without the `h` argument, `text_handles` also contains the handles of line objects used to create the `'+'` symbols.

`clabel(...,'PropertyName',propertyvalue,...)` enables you to specify text object property/value pairs for the label strings. (See `Text Properties`.)

`clabel(...'LabelSpacing',points)` specifies the spacing between labels on the same contour line, in units of points (72 points equal one inch).

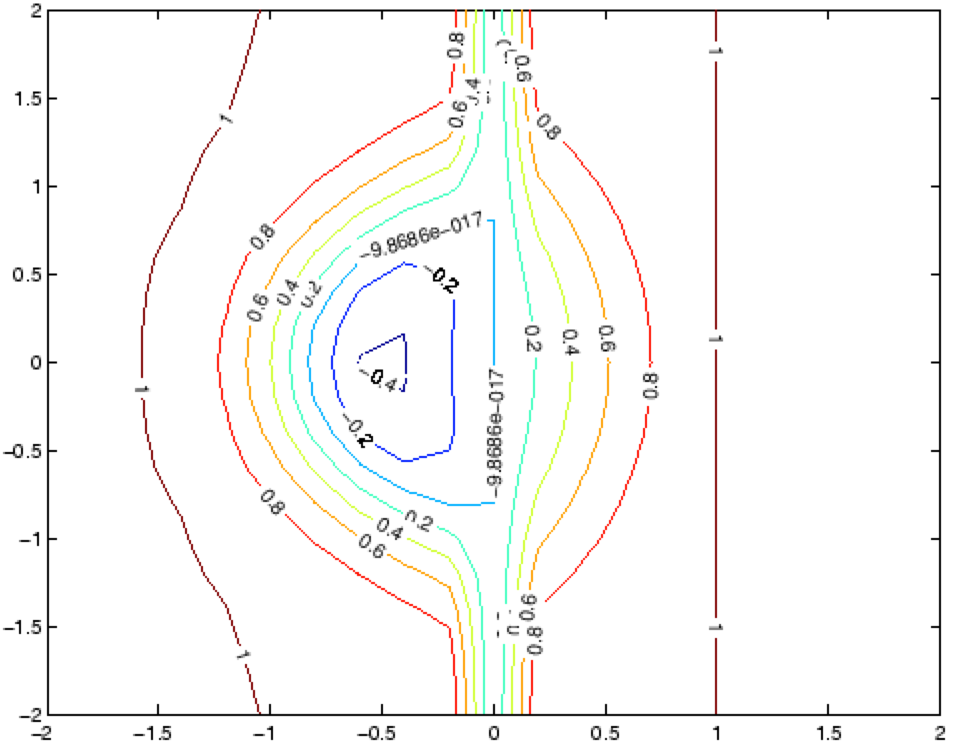
Remarks

When the syntax includes the argument `h`, this function rotates the labels and inserts them in the contour lines (see Examples). Otherwise, the labels are displayed upright and a `'+'` indicates which contour line the label is annotating.

Examples

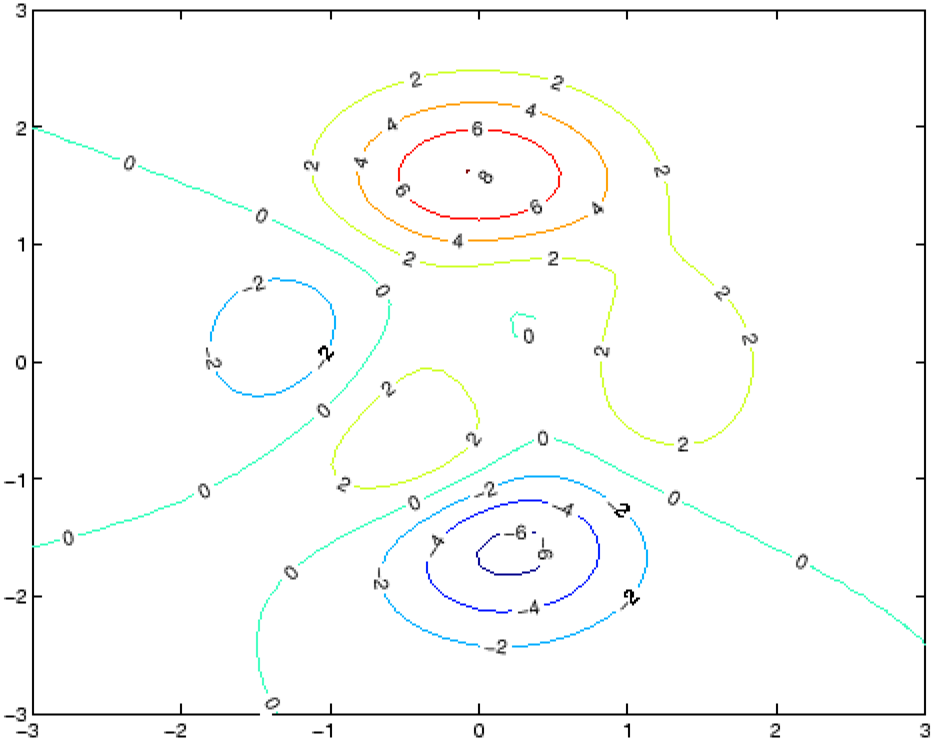
Generate, draw, and label a simple contour plot.

```
[x,y] = meshgrid(-2:.2:2);
z = x.^exp(-x.^2-y.^2);
[C,h] = contour(x,y,z);
clabel(C,h);
```



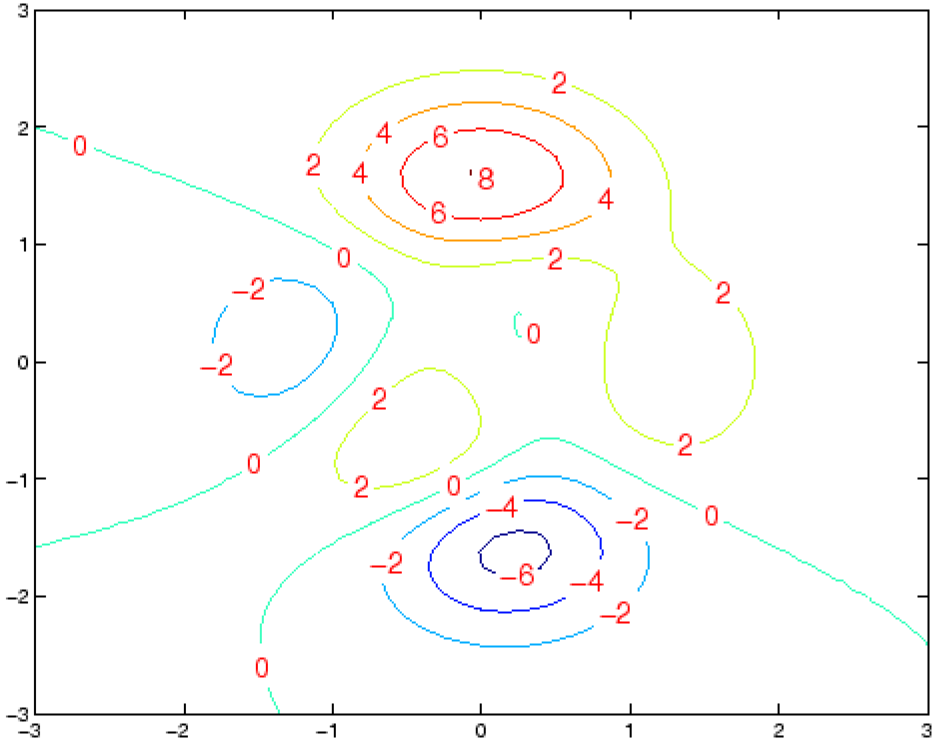
Label a contour plot with label spacing set to 72 points (one inch).

```
[x,y,z] = peaks;
[C,h] = contour(x,y,z);
clabel(C,h,'LabelSpacing',72)
```



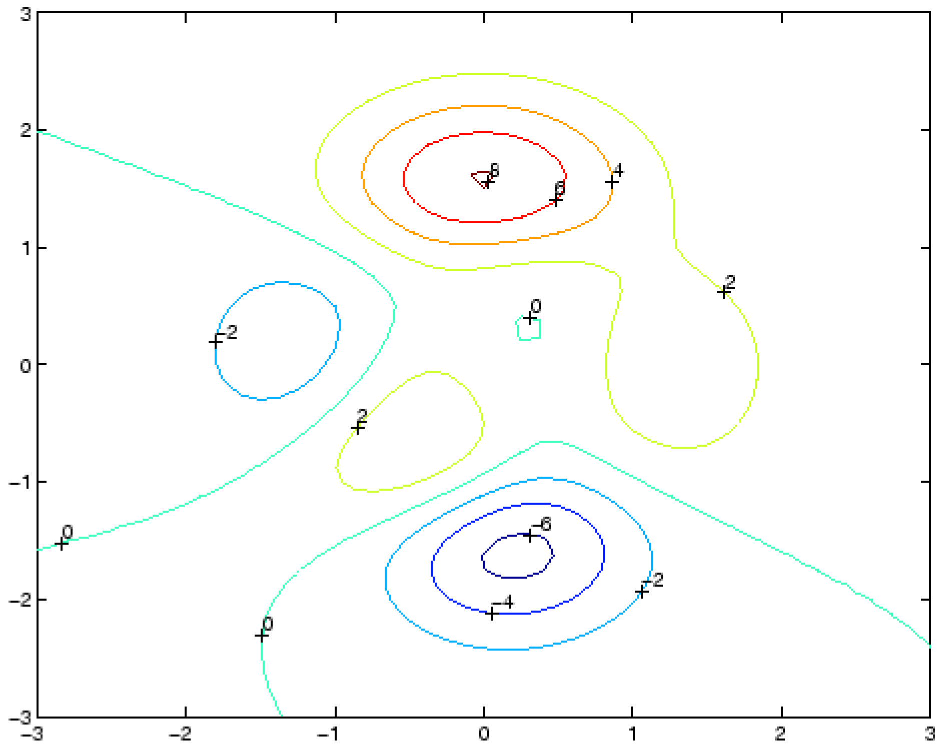
Label a contour plot with 15 point red text.

```
[x,y,z] = peaks;
[C,h] = contour(x,y,z);
clabel(C,h,'FontSize',15,'Color','r','Rotation',0)
```



Label a contour plot with upright text and '+' symbols indicating which contour line each label annotates.

```
[x,y,z] = peaks;
C = contour(x,y,z);
clabel(C)
```



See Also

`contour`, `contourc`, `contourf`

"Annotating Plots" on page 1-86 for related functions

"Drawing Text in a Box" for an example that illustrates the use of contour labels

class

Purpose

Create object or return class of object

Syntax

```
str = class(object)
obj = class(s, 'class_name')
obj = class(s, 'class_name', parent1, parent2, ...)
obj = class(struct([]), 'class_name', parent1, parent2, ...)
```

Description

`str = class(object)` returns a string specifying the class of `object`.

The following table lists the object class names that can be returned. All except the last one are MATLAB classes.

`logical`	Logical array of `true` and `false` values
`char`	Character 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
`single`	Single-precision floating-point number array
`double`	Double-precision floating-point number array
`cell`	Cell array
`struct`	Structure array
`function handle`	Array of values for calling functions indirectly
'*`class_name`*'	Custom MATLAB object class or Java class

`obj = class(s, 'class_name')` creates an object of MATLAB class `'class_name'` using structure `s` as a template. This syntax is valid only in a function named `class_name.m` in a directory named `@class_name` (where `'class_name'` is the same as the string passed in to `class`).

`obj = class(s, 'class_name', parent1, parent2, ...)` creates an object of MATLAB class `'class_name'` that inherits the methods and fields of the parent objects `parent1`, `parent2`, and so on. Structure `s` is used as a template for the object.

`obj = class(struct([]), 'class_name', parent1, parent2, ...)` creates an object of MATLAB class `'class_name'` that inherits the methods and fields of the parent objects `parent1`, `parent2`, and so on. Specifying the empty structure `struct([])` as the first argument ensures that the object created contains no fields other than those that are inherited from the parent objects.

Examples

To return in `nameStr` the name of the class of Java object `j`,

```
nameStr = class(j)
```

To create a user-defined MATLAB object of class `polynom`,

```
p = class(p, 'polynom')
```

See Also

`inferiorto`, `isa`, `superiorto`

The “Classes and Objects” and the “Calling Java from MATLAB” chapters in MATLAB Programming and Data Types documentation.

Purpose

Clear Command Window

GUI Alternatives

As an alternative to the `clc` function, select **Edit > Clear Command Window** in the MATLAB desktop.

Syntax

```
clc
```

Description

`clc` clears all input and output from the Command Window display, giving you a "clean screen."

After using `clc`, you cannot use the scroll bar to see the history of functions, but you still can use the up arrow to recall statements from the command history.

Examples

Use `clc` in an M-file to always display output in the same starting position on the screen.

See Also

`clear`, `clf`, `close`, `home`

Purpose

Remove items from workspace, freeing up system memory

Graphical Interface

As an alternative to the `clear` function, use **Edit > Clear Workspace** in the MATLAB desktop.

Syntax

```
clear
clear name
clear name1 name2 name3 ...
clear global name
clear -regexp expr1 expr2 ...
clear global -regexp expr1 expr2 ...
clear keyword
clear('name1','name2','name3',...)
```

Description

`clear` removes all variables from the workspace. This frees up system memory.

`clear name` removes just the M-file or MEX-file function or variable `name` from the workspace. You can use wildcards (`*`) to remove items selectively. For example, `clear my*` removes any variables whose names begin with the string `my`. It removes debugging breakpoints in M-files and reinitializes persistent variables, since the breakpoints for a function and persistent variables are cleared whenever the M-file is changed or cleared. If `name` is global, it is removed from the current workspace, but left accessible to any functions declaring it global. If `name` has been locked by `mlock`, it remains in memory.

Use a `partial path` to distinguish between different overloaded versions of a function. For example, `clear polynom/display` clears only the `display` method for `polynom` objects, leaving any other implementations in memory.

`clear name1 name2 name3 ...` removes `name1`, `name2`, and `name3` from the workspace.

`clear` **`global`** `name` removes the global variable `name`. If `name` is global, `clear name` removes `name` from the current workspace, but leaves it accessible to any functions declaring it global. Use `clear global name` to completely remove a global variable.

`clear` **`-regexp`** `expr1 expr2 ...` clears all variables that match any of the regular expressions `expr1`, `expr2`, etc. This option only clears variables.

`clear` **`global -regexp`** `expr1 expr2 ...` clears all global variables that match any of the regular expressions `expr1`, `expr2`, etc.

`clear` *`keyword`* clears the items indicated by *`keyword`*.

Keyword	Items Cleared
`all`	Removes all variables, functions, and MEX-files from memory, leaving the workspace empty. Using `clear all` removes debugging breakpoints in M-files and reinitializes persistent variables, since the breakpoints for a function and persistent variables are cleared whenever the M-file is changed or cleared. When issued from the Command Window prompt, also removes the Java packages import list.
`classes`	The same as `clear all`, but also clears MATLAB class definitions. If any objects exist outside the workspace (for example, in user data or persistent variables in a locked M-file), a warning is issued and the class definition is not cleared. Issue a `clear classes` function if the number or names of fields in a class are changed.
`functions`	Clears all the currently compiled M-functions and MEX-functions from memory. Using `clear function` removes debugging breakpoints in the function M-file and reinitializes persistent variables, since the breakpoints for a function and persistent variables are cleared whenever the M-file is changed or cleared.

Keyword	Items Cleared
`global`	Clears all global variables from the workspace.
`import`	Removes the Java packages import list. It can only be issued from the Command Window prompt. It cannot be used in a function.
`java`	The same as `clear all`, but also clears the definitions of all Java classes defined by files on the Java dynamic class path (see "The Java Class Path" in the External Interfaces documentation). If any java objects exist outside the workspace (for example, in user data or persistent variables in a locked M-file), a warning is issued and the Java class definition is not cleared. Issue a `clear java` command after modifying any files on the Java dynamic class path.
`variables`	Clears all variables from the workspace.

`clear('name1','name2','name3',...)` is the function form of the syntax. Use this form when the variable name or function name is stored in a string.

Remarks

When you use `clear` in a function, it has the following effect on items in your function and base workspaces:

- `clear name` — If `name` is the name of a function, the function is cleared in both the function workspace and in your base workspace.
- `clear` **`functions`** — All functions are cleared in both the function workspace and in your base workspace.
- `clear` **`global`** — All global variables are cleared in both the function workspace and in your base workspace.
- `clear` **`all`** — All functions, global variables, and classes are cleared in both the function workspace and in your base workspace.

Limitations

`clear` does not affect the amount of memory allocated to the MATLAB process under UNIX.

The `clear` function does not clear Simulink models. Use `close` instead.

Examples

Given a workspace containing the following variables

```
  Name        Size          Bytes  Class

  c           3x4            1200  cell array
  frame       1x1                  java.awt.Frame
  gbl1        1x1               8  double array (global)
  gbl2        1x1               8  double array (global)
  xint        1x1               1  int8 array
```

you can clear a single variable, `xint`, by typing

```
clear xint
```

To clear all global variables, type

```
clear global
whos
  Name       Size          Bytes  Class

  c          3x4            1200  cell array
  frame      1x1                  java.awt.Frame
```

Using regular expressions, clear those variables with names that begin with `Mon`, `Tue`, or `Wed`:

```
clear('-regexp', '^Mon|^Tue|^Wed');
```

To clear all compiled M- and MEX-functions from memory, type `clear functions`. In the case shown below, `clear functions` was unable to clear one M-file function from memory, `testfun`, because the function is locked.

```
clear functions    % Attempt to clear all functions.
```

```
inmem

ans =
   'testfun'       % One M-file function remains in memory.

mislocked testfun
ans =
    1              % This function is locked in memory.
```

Once you unlock the function from memory, you can clear it.

```
munlock testfun
clear functions

inmem
ans =
   Empty cell array: 0-by-1
```

See Also

`clc`, `close`, `import`, `inmem`, `load`, `mlock`, `munlock`, `pack`, `persistent`, `save`, `who`, `whos`, `workspace`

clear (serial)

Purpose Remove serial port object from MATLAB workspace

Syntax

```
clear obj
```

Arguments

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

Description `clear obj` removes `obj` from the MATLAB workspace.

Remarks If `obj` is connected to the device and it is cleared from the workspace, then `obj` remains connected to the device. You can restore `obj` to the workspace with the `instrfind` function. A serial port object connected to the device has a `Status` property value of `open`.

To disconnect `obj` from the device, use the `fclose` function. To remove `obj` from memory, use the `delete` function. You should remove invalid serial port objects from the workspace with `clear`.

Example This example creates the serial port object `s`, copies `s` to a new variable `scopy`, and clears `s` from the MATLAB workspace. `s` is then restored to the workspace with `instrfind` and is shown to be identical to `scopy`.

```
s = serial('COM1');
scopy = s;
clear s
s = instrfind;
isequal(scopy,s)
ans =
     1
```

See Also

Functions

`delete`, `fclose`, `instrfind`, `isvalid`

Properties

`Status`

Purpose

Clear current figure window

GUI Alternatives

Use **Clear Figure** from the figure window's **File** menu to clear the contents of a figure. You can also create a *desktop shortcut* to clear the current figure with one mouse click. See "Shortcuts for MATLAB — Easily Run a Group of Statements" in the MATLAB Desktop Environment documentation.

Syntax

```
clf('reset')
clf(fig)
clf(fig,'reset')
figure_handle = clf(...)
```

Description

`clf` deletes from the current figure all graphics objects whose handles are not hidden (i.e., their `HandleVisibility` property is set to `on`).

`clf('reset')` deletes from the current figure all graphics objects regardless of the setting of their `HandleVisibility` property and resets all figure properties except `Position`, `Units`, `PaperPosition`, and `PaperUnits` to their default values.

`clf(fig)` or `clf(fig,'reset')` clears the single figure with handle `fig`.

`figure_handle = clf(...)` returns the handle of the figure. This is useful when the figure `IntegerHandle` property is `off` because the noninteger handle becomes invalid when the reset option is used (i.e., `IntegerHandle` is reset to `on`, which is the default).

Remarks

The `clf` command behaves the same way when issued on the command line as it does in callback routines — it does not recognize the `HandleVisibility` setting of `callback`. This means that when issued from within a callback routine, `clf` deletes only those objects whose `HandleVisibility` property is set to `on`.

See Also

`cla`, `clc`, `hold`, `reset`

"Figure Windows" on page 1-94 for related functions

clipboard

Purpose

Copy and paste strings to and from system clipboard

Graphical Interface

As an alternative to `clipboard`, use the Import Wizard. To use the Import Wizard to copy data from the clipboard, select **Paste to Workspace** from the **Edit** menu.

Syntax

```
clipboard('copy', data)
str = clipboard('paste')
data = clipboard('pastespecial')
```

Description

`clipboard('copy', data)` sets the clipboard contents to `data`. If `data` is not a character array, the clipboard uses `mat2str` to convert it to a string.

`str = clipboard('paste')` returns the current contents of the clipboard as a string or as an empty string (`' '`), if the current clipboard contents cannot be converted to a string.

`data = clipboard('pastespecial')` returns the current contents of the clipboard as an array using `uiimport`.

Note Requires an active X display on UNIX, and Java elsewhere.

See Also

`load`, `uiimport`

clock

Purpose

Current time as date vector

Syntax

```
c = clock
```

Description

`c = clock` returns a 6-element date vector containing the current date and time in decimal form:

```
c = [year month day hour minute seconds]
```

The first five elements are integers. The `seconds` element is accurate to several digits beyond the decimal point. The statement `fix(clock)` rounds to integer display format.

Remarks

When timing the duration of an event, use the `tic` and `toc` functions instead of `clock` or `etime`. These latter two functions are based on the system time which can be adjusted periodically by the operating system and thus might not be reliable in time comparison operations.

See Also

`cputime`, `datenum`, `datevec`, `etime`, `tic`, `toc`

close

Purpose

Remove specified figure

Syntax

```
close
close(h)
close name
close all
close all hidden
status = close(...)
```

Description

`close` deletes the current figure or the specified figure(s). It optionally returns the status of the close operation.

`close` deletes the current figure (equivalent to `close(gcf)`).

`close(h)` deletes the figure identified by h. If h is a vector or matrix, `clse` deletes all figures identified by h.

`close name` deletes the figure with the specified name.

`close all` deletes all figures whose handles are not hidden.

`close all hidden` deletes all figures including those with hidden handles.

`status = close(...)` returns `1` if the specified windows have been deleted and `0` otherwise.

Remarks

The `close` function works by evaluating the specified figure's `CloseRequestFcn` property with the statement

```
eval(get(h,'CloseRequestFcn'))
```

The default `CloseRequestFcn`, `closereq`, deletes the current figure using `delete(get(0,'CurrentFigure'))`. If you specify multiple figure handles, `close` executes each figure's `CloseRequestFcn` in turn. If MATLAB encounters an error that terminates the execution of a `CloseRequestFcn`, the figure is not deleted. Note that using your computer's window manager (i.e., the **Close** menu item) also calls the figure's `CloseRequestFcn`.

If a figure’s handle is hidden (i.e., the figure’s `HandleVisibility` property is set to `callback` or `off` and the root `ShowHiddenHandles` property is set to `on`), you must specify the `hidden` option when trying to access a figure using the `all` option.

To delete all figures unconditionally, use the statements

```
set(0,'ShowHiddenHandles','on')
delete(get(0,'Children'))
```

The `delete` function does not execute the figure’s `CloseRequestFcn`; it simply deletes the specified figure.

The figure `CloseRequestFcn` allows you to either delay or abort the closing of a figure once the `close` function has been issued. For example, you can display a dialog box to see if the user really wants to delete the figure or save and clean up before closing.

See Also

`delete`, `figure`, `gcf`

The figure `HandleVisibility` property

The root `ShowHiddenHandles` property

“Figure Windows” on page 1-94 for related functions

close (avifile)

Purpose

Close Audio/Video Interleaved (AVI) file

Syntax

```
aviobj = close(aviobj)
```

Description

`aviobj = close(aviobj)` finishes writing and closes the AVI file associated with `aviobj`, which is an AVI file object created using the `avifile` function.

See Also

`avifile`, `addframe`, `movie2avi`

Purpose

Close connection to FTP server

Syntax

```
close(f)
```

Description

`close(f)` closes the connection to the FTP server, represented by object `f`, which was created using `ftp`. Be sure to use `close` after completing work on the server. If you do not run `close`, the connection will be terminated automatically either because of the server's time-out feature or by exiting MATLAB.

Examples

Connect to the MathWorks FTP server and then disconnect.

```
tmw=ftp('ftp.mathworks.com');
close(tmw)
```

See Also

`ftp`

closereq

Purpose Default figure close request function

Syntax

```
closereq
```

Description `closereq` deletes the current figure.

See Also The figure `CloseRequestFcn` property

"Figure Windows" on page 1-94 for related functions

Purpose

Name of source control system

GUI Alternatives

As an alternative to `cmopts`, select **File > Preferences > General > Source Control** to view the currently selected source control system.

Syntax

```
cmopts
```

Description

`cmopts` displays the name of the source control system you selected using preferences, which is one of the following:

- `clearcase` (UNIX only)
- `customverctrl` (UNIX only)
- `cvs` (UNIX only)
- `pvcs` (UNIX only, used for PVCS and ChangeMan)
- `rcs` (UNIX only)
- `sourcesafe` (Windows only)

If you have not selected a source control system, `cmopts` displays

```
none
```

For more information, see "Specify Source Control System in MATLAB" for PC platforms, and "Specifying the Source Control System" for UNIX platforms in the MATLAB Desktop Tools and Development Environment documentation.

Examples

Type

```
cmopts
```

and MATLAB returns

```
ans =
Microsoft Visual SourceSafe
```

which is the source control system specified in preferences.

See Also

`checkin`, `checkout`, `customverctrl`, `verctrl`

Purpose

Column approximate minimum degree permutation

Syntax

```
p = colamd(S)
```

Description

`p = colamd(S)` returns the column approximate minimum degree permutation vector for the sparse matrix `S`. For a non-symmetric matrix `S`, `S(:,p)` tends to have sparser LU factors than `S`. The Cholesky factorization of `S(:,p)' * S(:,p)` also tends to be sparser than that of `S'*S`.

`knobs` is a two-element vector. If S is `m`-by-`n`, then rows with more than `(knobs(1))*n` entries are ignored. Columns with more than `(knobs(2))*m` entries are removed prior to ordering, and ordered last in the output permutation `p`. If the `knobs` parameter is not present, then `knobs(1)` = `knobs(2)` = `spparms('wh_frac')`.

`stats` is an optional vector that provides data about the ordering and the validity of the matrix `S`.

`stats(1)`	Number of dense or empty rows ignored by `colamd`
`stats(2)`	Number of dense or empty columns ignored by `colamd`
`stats(3)`	Number of garbage collections performed on the internal data structure used by `colamd` (roughly of size `2.2*nnz(S) + 4*m + 7*n` integers)
`stats(4)`	`0` if the matrix is valid, or `1` if invalid
`stats(5)`	Rightmost column index that is unsorted or contains duplicate entries, or `0` if no such column exists

`stats(6)`	Last seen duplicate or out-of-order row index in the column index given by `stats(5)`, or `0` if no such row index exists
`stats(7)`	Number of duplicate and out-of-order row indices

Although, MATLAB built-in functions generate valid sparse matrices, a user may construct an invalid sparse matrix using the MATLAB C or Fortran APIs and pass it to `colamd`. For this reason, `colamd` verifies that `S` is valid:

- If a row index appears two or more times in the same column, `colamd` ignores the duplicate entries, continues processing, and provides information about the duplicate entries in `stats(4:7)`.
- If row indices in a column are out of order, `colamd` sorts each column of its internal copy of the matrix `S` (but does not repair the input matrix `S`), continues processing, and provides information about the out-of-order entries in `stats(4:7)`.
- If `S` is invalid in any other way, `colamd` cannot continue. It prints an error message, and returns no output arguments (`p` or `stats`) .

The ordering is followed by a column elimination tree post-ordering.

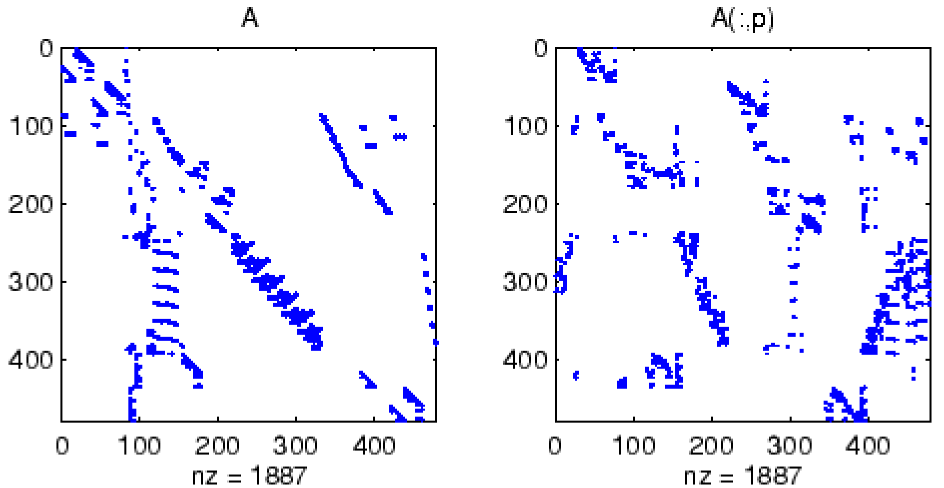
Note `colamd` tends to be faster than `colmmd` and tends to return a better ordering.

Examples

The Harwell-Boeing collection of sparse matrices and the MATLAB demos directory include a test matrix `west0479`. It is a matrix of order 479 resulting from a model due to Westerberg of an eight-stage chemical distillation column. The spy plot shows evidence of the eight stages. The `colamd` ordering scrambles this structure.

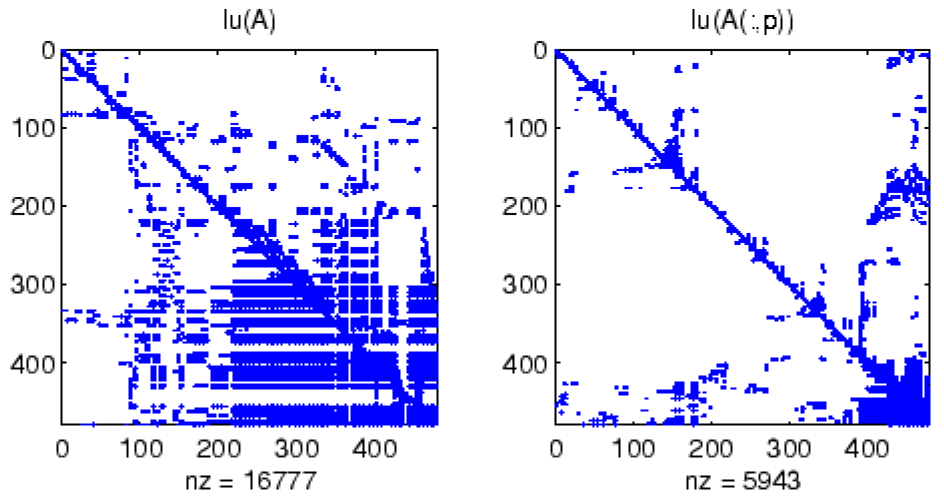
```
load west0479
```

```
A = west0479;
p = colamd(A);
subplot(1,2,1), spy(A,4), title('A')
subplot(1,2,2), spy(A(:,p),4), title('A(:,p)')
```



Comparing the spy plot of the LU factorization of the original matrix with that of the reordered matrix shows that minimum degree reduces the time and storage requirements by better than a factor of 2.8. The nonzero counts are 16777 and 5904, respectively.

```
spy(lu(A),4)
spy(lu(A(:,p)),4)
```



See Also

`colperm`, `spparms`, `symamd`, `symrcm`

References

[1] The authors of the code for "colamd" are Stefan I. Larimore and Timothy A. Davis (davis@cise.ufl.edu), University of Florida. The algorithm was developed in collaboration with John Gilbert, Xerox PARC, and Esmond Ng, Oak Ridge National Laboratory. Sparse Matrix Algorithms Research at the University of Florida: `http://www.cise.ufl.edu/research/sparse/`

Purpose

Sparse column minimum degree permutation

Syntax

```
p = colmmd(S)
```

Note `colmmd` is obsolete and will be removed from a future version of MATLAB. Use `colamd` instead.

Description

`p = colmmd(S)` returns the column minimum degree permutation vector for the sparse matrix `S`. For a nonsymmetric matrix `S`, this is a column permutation `p` such that `S(:,p)` tends to have sparser LU factors than `S`.

The `colmmd` permutation is automatically used by `\` and `/` for the solution of nonsymmetric and symmetric indefinite sparse linear systems.

Use `spparms` to change some options and parameters associated with heuristics in the algorithm.

Algorithm

The minimum degree algorithm for symmetric matrices is described in the review paper by George and Liu [1]. For nonsymmetric matrices, the MATLAB minimum degree algorithm is new and is described in the paper by Gilbert, Moler, and Schreiber [2]. It is roughly like symmetric minimum degree for `A'*A`, but does not actually form `A'*A`.

Each stage of the algorithm chooses a vertex in the graph of `A'*A` of lowest degree (that is, a column of `A` having nonzero elements in common with the fewest other columns), eliminates that vertex, and updates the remainder of the graph by adding fill (that is, merging rows). If the input matrix `S` is of size `m`-by-`n`, the columns are all eliminated and the permutation is complete after `n` stages. To speed up the process, several heuristics are used to carry out multiple stages simultaneously.

See Also

`colamd`, `colperm`, `lu`, `spparms`, `symamd`, `symmmd`, `symrcm`

The arithmetic operator `\`

References

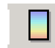
[1] George, Alan and Liu, Joseph, "The Evolution of the Minimum Degree Ordering Algorithm," *SIAM Review*, 1989, 31:1-19.

[2] Gilbert, John R., Cleve Moler, and Robert Schreiber, "Sparse Matrices in MATLAB: Design and Implementation," *SIAM Journal on Matrix Analysis and Applications 13*, 1992, pp. 333-356.

Purpose

Colorbar showing color scale

GUI Alternatives

Add a colorbar to a plot with the colorbar tool  on the figure toolbar, or use **Insert —> Colorbar** 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

```
colorbar
colorbar(...,'peer',axes_handle)
colorbar(...,'location')
colorbar(...,'PropertyName',propertyvalue)
cbar_axes = colorbar(...)
colorbar(axes_handle)
```

Description

The `colorbar` function displays the current colormap in the current figure and resizes the current axes to accommodate the colorbar.

`colorbar` adds a new vertical colorbar on the right side of the current axes. If a colorbar exists in that location, `colorbar` replaces it with a new one. If a colorbar exists at a nondefault location, it is retained along with the new colorbar

`colorbar(...,'peer',axes_handle)` creates a colorbar associated with the axes `axes_handle` instead of the current axes.

`colorbar(...,'`*`location`*`')` adds a colorbar in the specified orientation with respect to the axes. If a colorbar exists at the location specified, it is replaced. Any colorbars not occupying the specified location are retained. Possible values for *`location`* are

`North`	Inside plot box near top
`South`	Inside bottom
`East`	Inside right
`West`	Inside left

NorthOutside	Outside plot box near top
SouthOutside	Outside bottom
EastOutside	Outside right
WestOutside	Outside left

Using one of the `...Outside` values for *`location`* ensures that the colorbar does not overlap the plot, whereas overlaps can occur when you specify any of the other four values.

`colorbar(...,'PropertyName',propertyvalue)` specifies property names and values for the axes object used to create the colorbar. See axes properties for a description of the properties you can set. The *`location`* property applies only to colorbars and legends, not to axes.

`cbar_axes = colorbar(...)` returns a handle to the colorbar, which is an axes graphics object that contains one additional property, `Location`.

Backward-Compatible Version

`h = colorbar('v6',...)` creates a colorbar compatible with MATLAB 6.5 and earlier. It returns the handles of patch objects instead of a colorbar object.

`colorbar(axes_handle)` adds the colorbar to the axes `axes_handle` in the default (`right`) orientation. As in Version 6 and earlier releases, no new axes is created.

Remarks

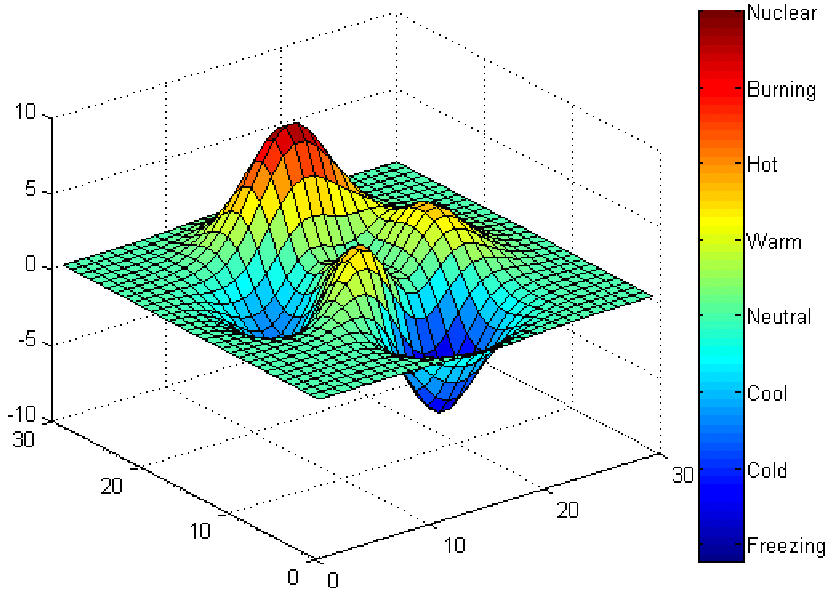
You can use `colorbar` with 2-D and 3-D plots.

Examples

Example 1

Display a colorbar beside the axes and use descriptive text strings as *y*-tick labels. Note that labels will repeat cyclically when the number of *y*-ticks is greater than the number of labels, and not all labels will appear if there are fewer *y*-ticks than labels you have specified. Also note that when colorbars are horizontal, their ticks and labels are governed by the `XTick` property rather than the `YTick` property. For more information, see "Labeling Colorbar Ticks".

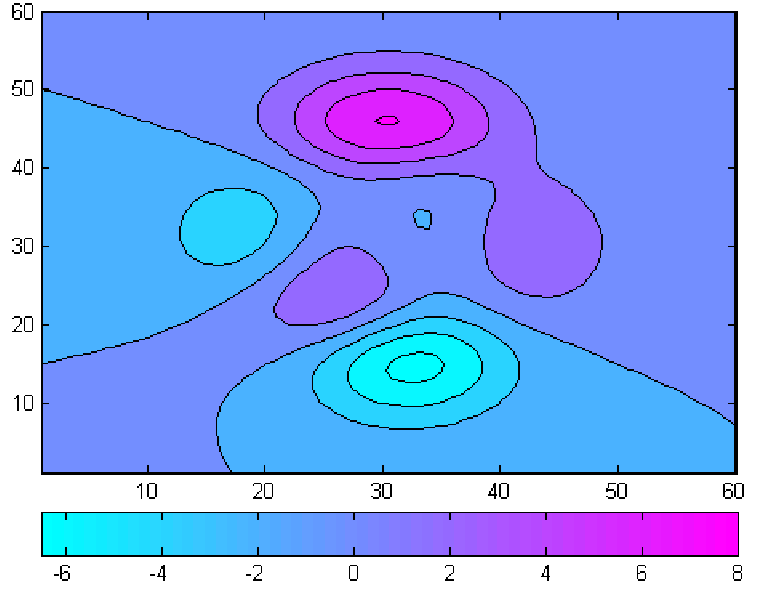
```
surf(peaks(30))
colorbar('YTickLabel',...
    {'Freezing','Cold','Cool','Neutral',...
     'Warm','Hot','Burning','Nuclear'})
```



Example 2

Display a horizontal colorbar beneath the axes of a filled contour plot:

```
contourf(peaks(60))
colormap cool
colorbar('location','southoutside')
```



See Also

`colormap`

"Color Operations" on page 1-97 for related functions

Purpose

Set default property values to display different color schemes

Syntax

```
colordef white
colordef black
colordef none
colordef(fig,color_option)
h = colordef('new',color_option)
```

Description

`colordef` enables you to select either a white or black background for graphics display. It sets axis lines and labels so that they contrast with the background color.

`colordef white` sets the axis background color to white, the axis lines and labels to black, and the figure background color to light gray.

`colordef black` sets the axis background color to black, the axis lines and labels to white, and the figure background color to dark gray.

`colordef none` sets the figure coloring to that used by MATLAB Version 4. The most noticeable difference is that the axis background is set to `'none'`, making the axis background and figure background colors the same. The figure background color is set to black.

`colordef(fig,`*`color_option`*`)` sets the color scheme of the figure identified by the handle `fig` to one of the color options `'white'`, `'black'`, or `'none'`. When you use this syntax to apply `colordef` to an existing figure, the figure must have no graphic content. If it does, you should first clear it (via `clf`) before using this form of the command.

`h = colordef('new',`*`color_option`*`)` returns the handle to a new figure created with the specified color options (i.e., `'white'`, `'black'`, or `'none'`). This form of the command is useful for creating GUIs when you may want to control the default environment. The figure is created with `'visible','off'` to prevent flashing.

Remarks

`colordef` affects only subsequently drawn figures, not those currently on the display. This is because `colordef` works by setting default property values (on the root or figure level). You can list the currently set default values on the root level with the statement

```
get(0,'defaults')
```

You can remove all default values using the `reset` command:

```
reset(0)
```

See the `get` and `reset` references pages for more information.

See Also

`whitebg`, `clf`

"Color Operations" on page 1-97 for related functions

Purpose

Set and get current colormap

GUI Alternatives

Select a built-in colormap with the Property Editor. To modify the current colormap, use the Colormap Editor, accessible from **Edit —> Colormap** on the figure menu.

Syntax

```
colormap(map)
colormap('default')
cmap = colormap
```

Description

A colormap is an m-by-3 matrix of real numbers between 0.0 and 1.0. Each row is an RGB vector that defines one color. The kth row of the colormap defines the kth color, where `map(k,:) = [r(k) g(k) b(k)])` specifies the intensity of red, green, and blue.

`colormap(map)` sets the colormap to the matrix `map`. If any values in `map` are outside the interval [0 1], MATLAB returns the error `Colormap must have values in [0,1].`

`colormap('default')` sets the current colormap to the default colormap.

`cmap = colormap` retrieves the current colormap. The values returned are in the interval [0 1].

Specifying Colormaps

M-files in the `color` directory generate a number of colormaps. Each M-file accepts the colormap size as an argument. For example,

```
colormap(hsv(128))
```

creates an `hsv` colormap with 128 colors. If you do not specify a size, MATLAB creates a colormap the same size as the current colormap.

Supported Colormaps

MATLAB supports a number of built-in colormaps, illustrated and described below. In addition to specifying built-in colormaps programmatically, you can use the **Colormap** menu in the **Figure Properties** pane of the **Plot Tools** GUI to select one interactively.

The named built-in colormaps are the following:

- `autumn` varies smoothly from red, through orange, to yellow.
- `bone` is a grayscale colormap with a higher value for the blue component. This colormap is useful for adding an "electronic" look to grayscale images.
- `colorcube` contains as many regularly spaced colors in RGB colorspace as possible, while attempting to provide more steps of gray, pure red, pure green, and pure blue.
- `cool` consists of colors that are shades of cyan and magenta. It varies smoothly from cyan to magenta.
- `copper` varies smoothly from black to bright copper.

- `flag` consists of the colors red, white, blue, and black. This colormap completely changes color with each index increment.
- `gray` returns a linear grayscale colormap.
- `hot` varies smoothly from black through shades of red, orange, and yellow, to white.
- `hsv` varies the hue component of the hue-saturation-value color model. The colors begin with red, pass through yellow, green, cyan, blue, magenta, and return to red. The colormap is particularly appropriate for displaying periodic functions. `hsv(m)` is the same as `hsv2rgb([h ones(m,2)])` where `h` is the linear ramp, `h = (0:m 1)'/m`.
- `jet` ranges from blue to red, and passes through the colors cyan, yellow, and orange. It is a variation of the `hsv` colormap. The `jet` colormap is associated with an astrophysical fluid jet simulation from the National Center for Supercomputer Applications. See the “Examples” on page 2-569 section.
- `lines` produces a colormap of colors specified by the axes `ColorOrder` property and a shade of gray.
- `pink` contains pastel shades of pink. The pink colormap provides sepia tone colorization of grayscale photographs.
- `prism` repeats the six colors red, orange, yellow, green, blue, and violet.
- `spring` consists of colors that are shades of magenta and yellow.
- `summer` consists of colors that are shades of green and yellow.
- `white` is an all white monochrome colormap.
- `winter` consists of colors that are shades of blue and green.

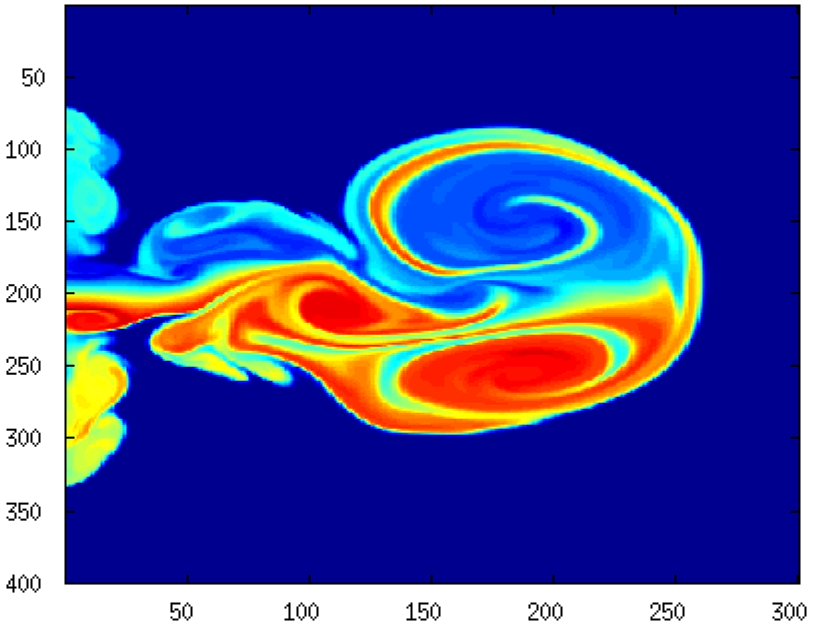
Examples

The images and colormaps demo, `imagedemo`, provides an introduction to colormaps. Select **Color Spiral** from the menu. This uses the `pcolor` function to display a 16-by-16 matrix whose elements vary from 0 to 255 in a rectilinear spiral. The `hsv` colormap starts with red in the center, then passes through yellow, green, cyan, blue, and magenta before returning to red at the outside end of the spiral. Selecting **Colormap Menu** gives access to a number of other colormaps.

The `rgbplot` function plots colormap values. Try `rgbplot(hsv)`, `rgbplot(gray)`, and `rgbplot(hot)`.

The following commands display the `flujet` data using the `jet` colormap.

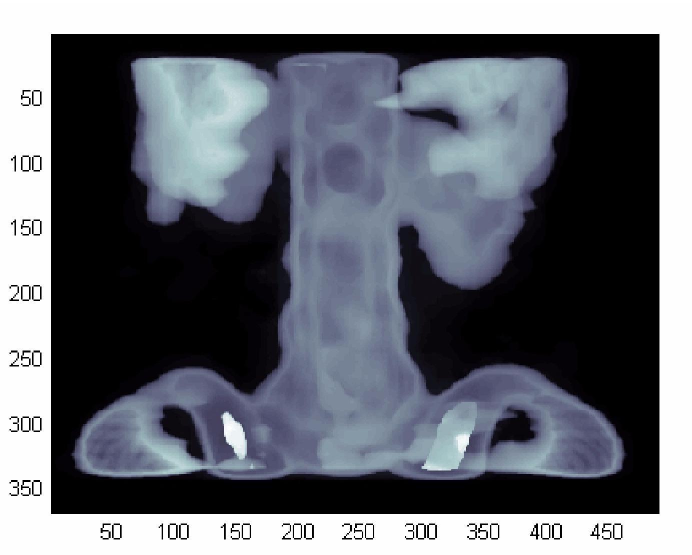
```
load flujet
image(X)
colormap(jet)
```



The `demos` directory contains a CAT scan image of a human spine. To view the image, type the following commands:

```
load spine
image(X)
```

```
colormap bone
```



Algorithm

Each figure has its own `Colormap` property. `colormap` is an M-file that sets and gets this property.

See Also

`brighten`, `caxis`, `colormapeditor`, `colorbar`, `contrast`, `hsv2rgb`, `pcolor`, `rgb2hsv`, `rgbplot`

The `Colormap` property of figure graphics objects

"Color Operations" on page 1-97 for related functions

"Coloring Mesh and Surface Plots" for more information about colormaps and other coloring methods

Purpose

Start colormap editor

Syntax

```
colormapeditor
```

Description

`colormapeditor` displays the current figure's colormap as a strip of rectangular cells in the colormap editor. Node pointers are colored cells below the colormap strip that indicate points in the colormap where the rate of the variation of R, G, and B values changes. You can also work in the HSV colorspace by setting the **Interpolating Colorspace** selector to HSV.

You can also start the colormap editor by selecting **Colormap** from the **Edit** menu.

Node Pointer Operations

You can select and move node pointers to change a range of colors in the colormap. The color of a node pointer remains constant as you move it, but the colormap changes by linearly interpolating the RGB values between nodes.

Change the color at a node by double-clicking the node pointer. MATLAB displays a color picker from which you can select a new color. After you select a new color at a node, MATLAB reinterpolates the colors in between nodes.

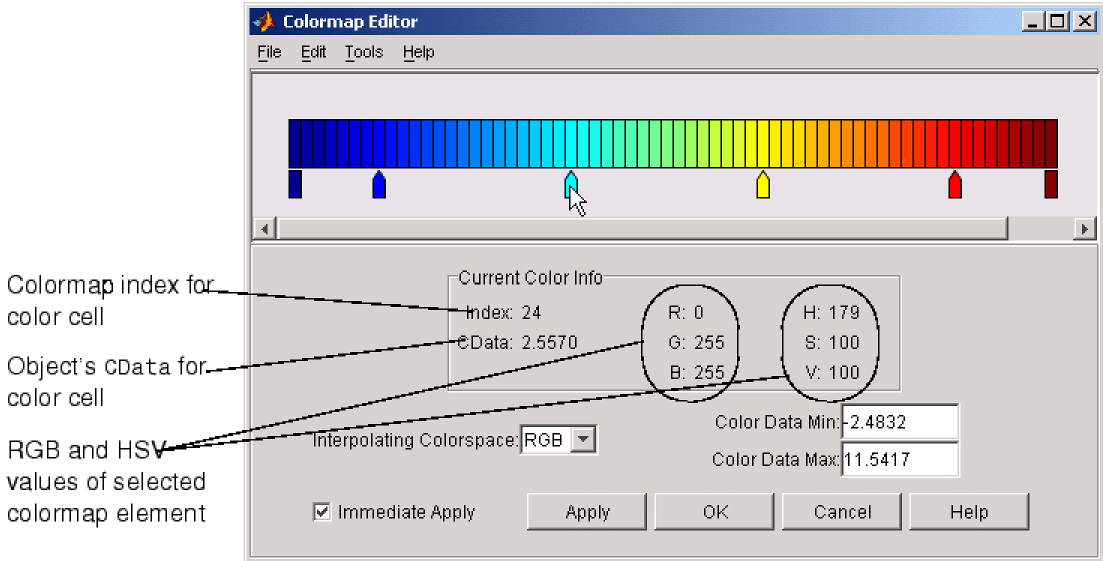
Operation	How to Perform
Add a node	Click below the corresponding cell in the colormap strip.
Select a node	Left-click the node.
Select multiple nodes	Adjacent: left-click first node, **Shift+click** the last node. Nonadjacent: left-click first node, **Ctrl+click** subsequent nodes.

Operation	How to Perform
Move a node	Select and drag with the mouse or select and use the left and right arrow keys.
Move multiple nodes	Select multiple nodes and use the left and right arrow keys to move nodes as a group. Movement stops when one of the selected nodes hits an unselected node or an end node.
Delete a node	Select the node and then press the **Delete** key, or select **Delete** from the **Edit** menu, or type **Ctrl+x**.
Delete multiple nodes	Select the nodes and then press the **Delete** key, or select **Delete** from the **Edit** menu, or type **Ctrl+x**.
Display color picker for a node	Double-click the node pointer.

Current Color Info

When you put the mouse over a color cell or node pointer, the colormap editor displays the following information about that colormap element:

- The element's index in the colormap
- The value from the graphics object color data that is mapped to the node's color (i.e., data from the `CData` property of any image, patch, or surface objects in the figure)
- The color's RGB and HSV color value



Interpolating Colorspace

The colorspace determines what values are used to calculate the colors of cells between nodes. For example, in the RGB colorspace, internode colors are calculated by linearly interpolating the red, green, and blue intensity values from one node to the next. Switching to the HSV colorspace causes the colormap editor to recalculate the colors between nodes using the hue, saturation, and value components of the color definition.

Note that when you switch from one colorspace to another, the color editor preserves the number, color, and location of the node pointers, which can cause the colormap to change.

Interpolating in HSV. Since hue is conceptually mapped about a color circle, the interpolation between hue values can be ambiguous. To minimize this ambiguity, the interpolation uses the shortest distance around the circle. For example, interpolating between two nodes, one with hue of 2 (slightly orange red) and another with a hue of 356 (slightly magenta red), does not result in hues 3,4,5...353,354,355 (orange/red-yellow-green-cyan-blue-magenta/red). Taking the shortest distance around the circle gives 357,358,1,2 (orange/red-red-magenta/red).

Color Data Min and Max

The **Color Data Min** and **Color Data Max** text fields enable you to specify values for the axes `CLim` property. These values change the mapping of object color data (the `CData` property of images, patches, and surfaces) to the colormap. See "Axes Color Limits — the CLim Property" for discussion and examples of how to use this property.

Examples

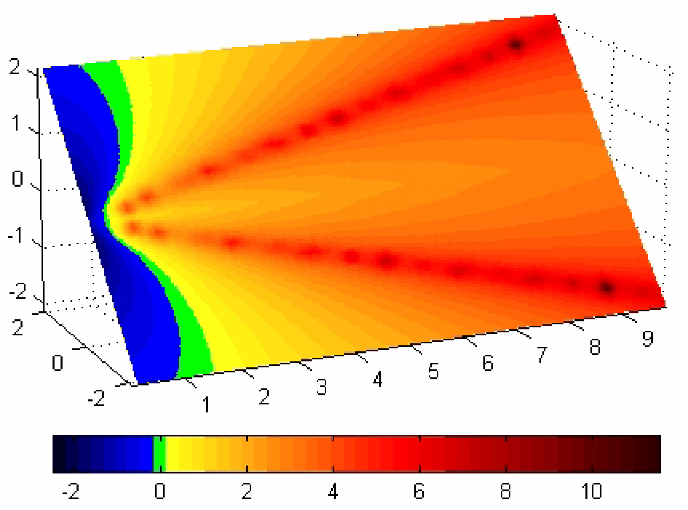
This example modifies a default MATLAB colormap so that ranges of data values are displayed in specific ranges of color. The graph is a slice plane illustrating a cross section of fluid flow through a jet nozzle. See the `slice` reference page for more information on this type of graph.

Example Objectives

The objectives are as follows:

- Regions of flow from left to right (positive data) are mapped to colors from yellow through orange to dark red. Yellow is slowest and dark red is the fastest moving fluid.
- Regions that have a speed close to zero are colored green.
- Regions where the fluid is actually moving right to left (negative data) are shades of blue (darker blue is faster).

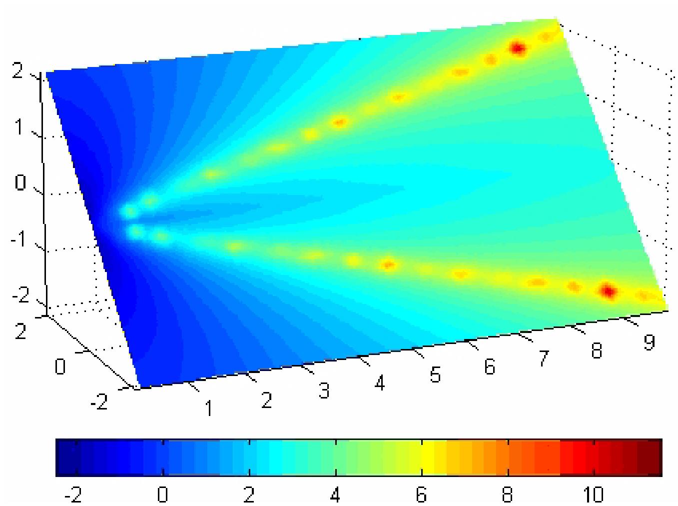
The following picture shows the desired coloring of the slice plane. The colorbar shows the data to color mapping.



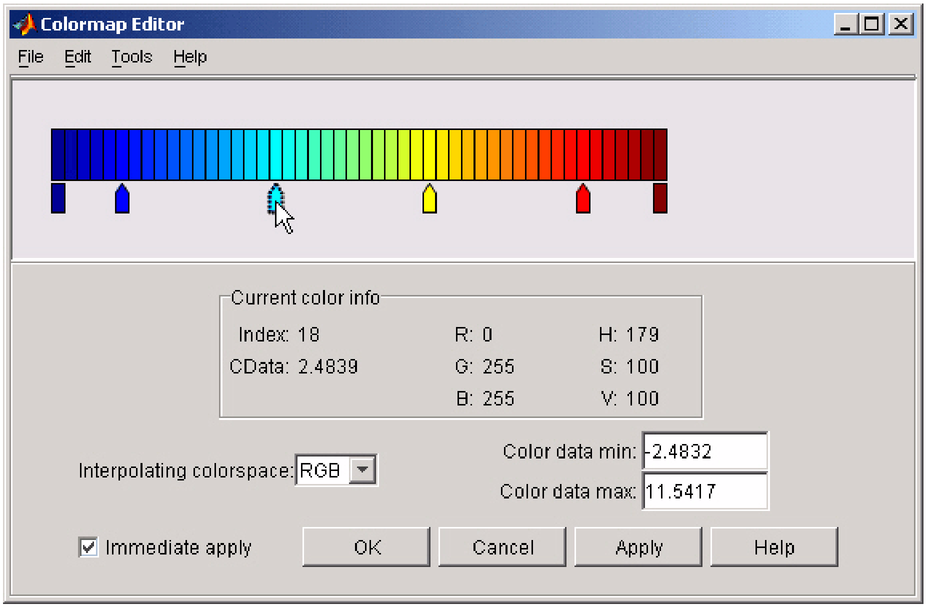
Running the Example

Note If you are viewing this documentation in the MATLAB help browser, you can display the graph used in this example by running this M-file from the MATLAB editor (select **Run** from the **Debug** menu).

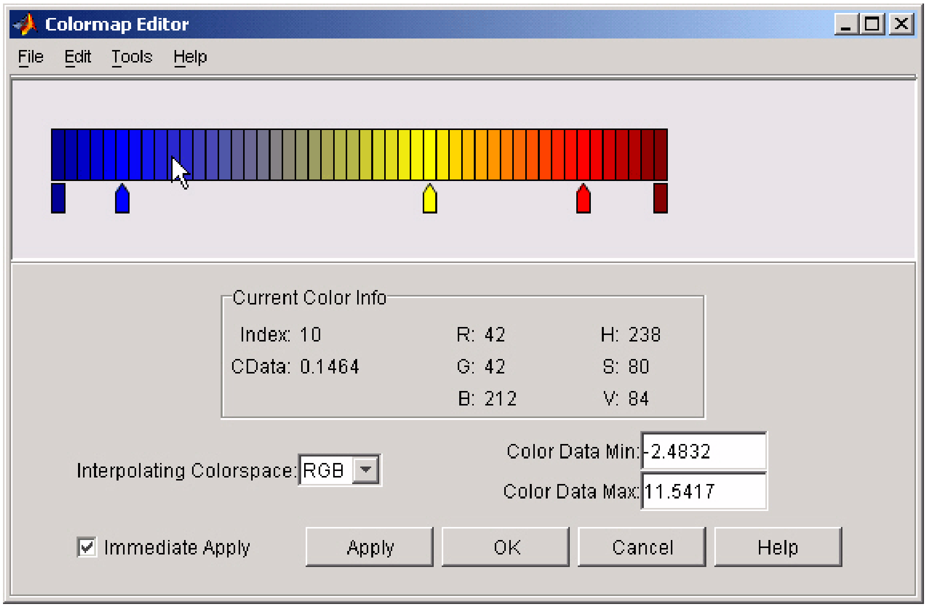
Initially, the default colormap (`jet`) colored the slice plane, as illustrated in the following picture. Note that this example uses a colormap that is 48 elements to display wider bands of color (the default is 64 elements).



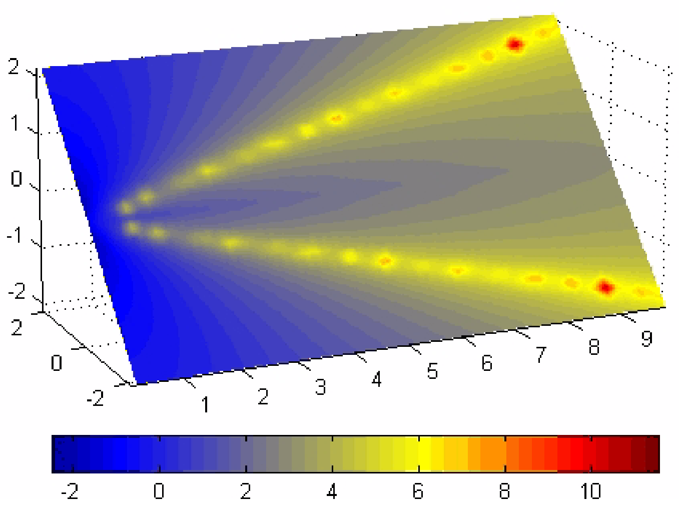
1 Start the colormap editor using the `colormapeditor` command. The color map editor displays the current figure' s colormap, as shown in the following picture.



2 Since we want the regions of left-to-right flow (positive speed) to range from yellow to dark red, we can delete the cyan node pointer. To do this, first select it by clicking with the left mouse button and press **Delete**. The colormap now looks like this.

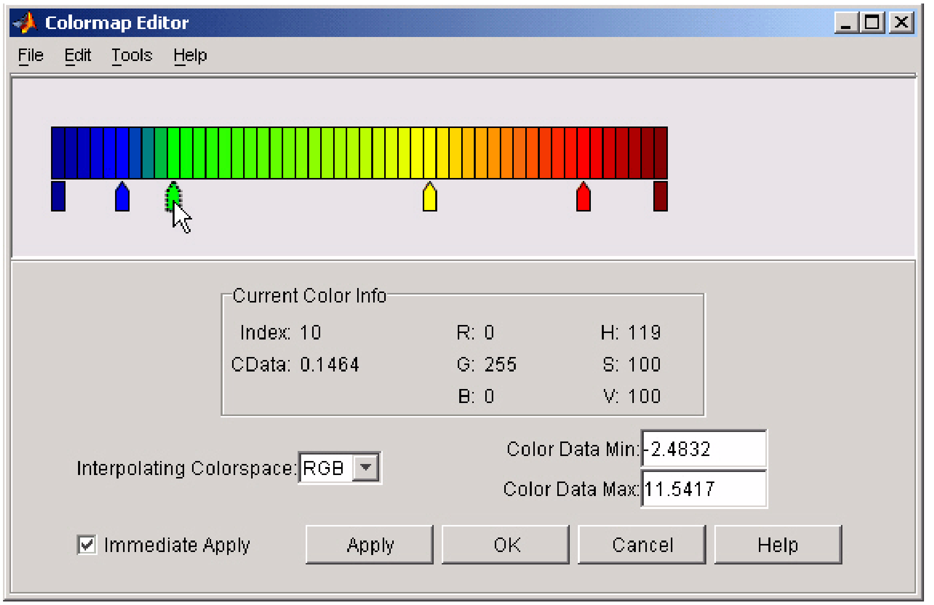


The **Immediate Apply** box is checked, so the graph displays the results of the changes made to the colormap.

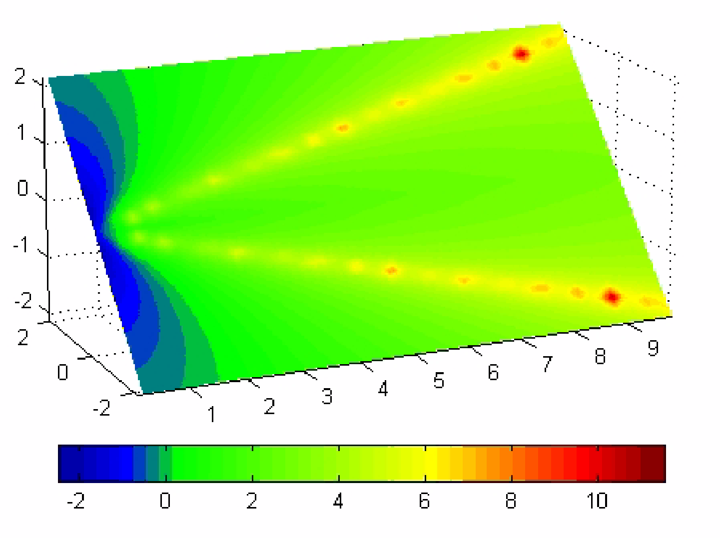


3 We want the fluid speed values around zero to stand out, so we need to find the color cell where the negative-to-positive transition occurs. Dragging the cursor over the color strip enables you to read the data values in the **Current Color Info** panel.

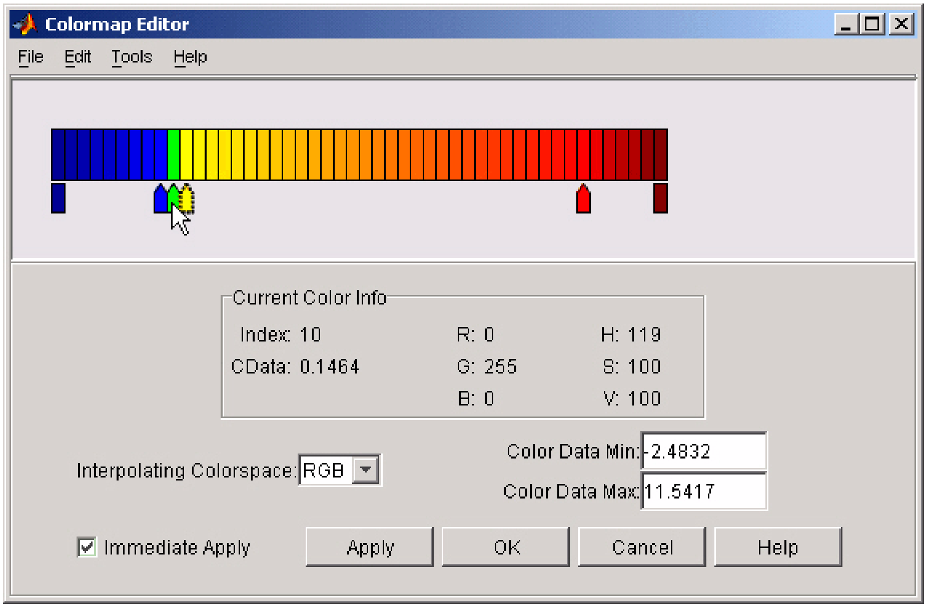
In this case, cell 10 is the first positive value, so we click below that cell and create a node pointer. Double-clicking the node pointer displays the color picker. Set the color of this node to green.



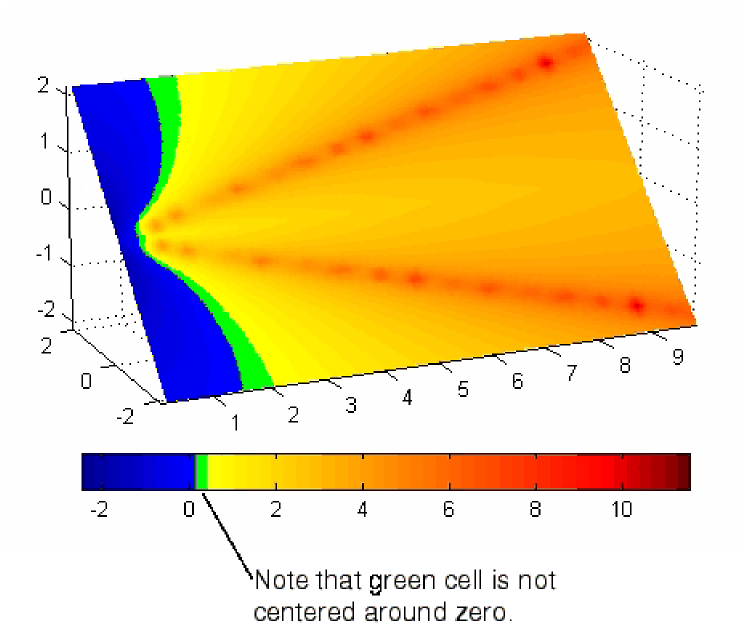
The graph continues to update to the modified colormap.



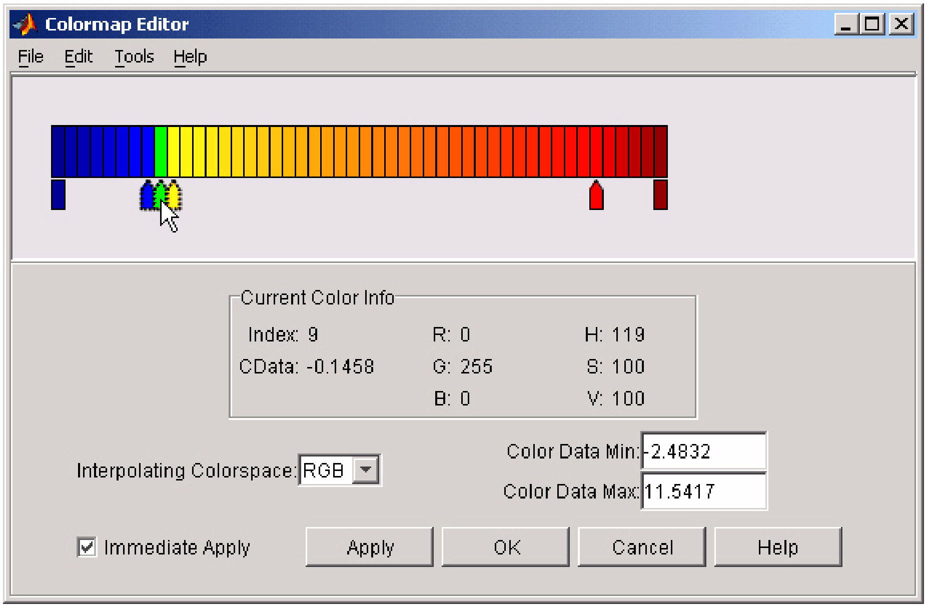
4 In the current state, the colormap colors are interpolated from the green node to the yellowish node about 20 cells away. We actually want only the single cell that is centered around zero to be colored green. To limit the color green to one cell, move the blue and yellow node pointers next to the green pointer.



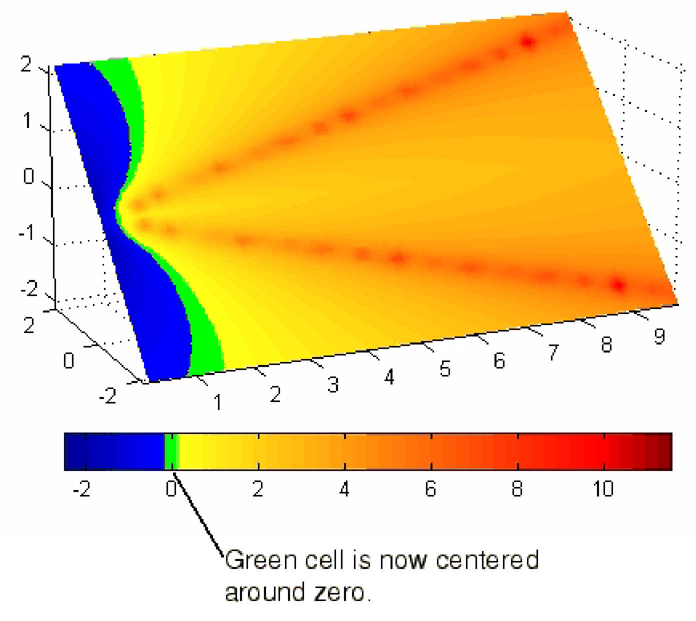
5 Before making further adjustments to the colormap, we need to move the green cell so that it is centered around zero. Use the colorbar to locate the green cell.



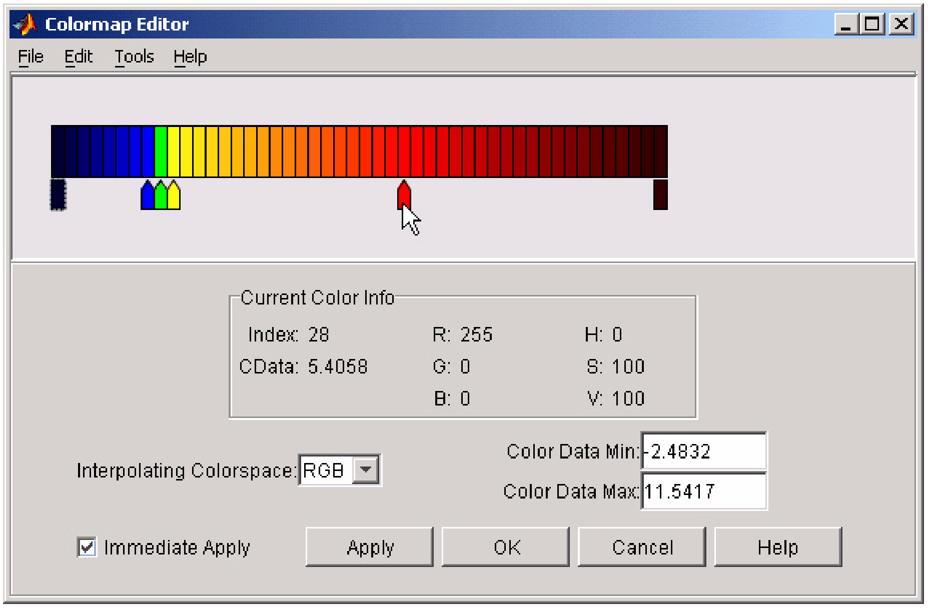
To recenter the green cell around zero, select the blue, green, and yellow node pointers (left-click blue, **Shift+click** yellow) and move them as a group using the left arrow key. Watch the colorbar in the figure window to see when the green color is centered around zero.



The slice plane now has the desired range of colors for negative, zero, and positive data.

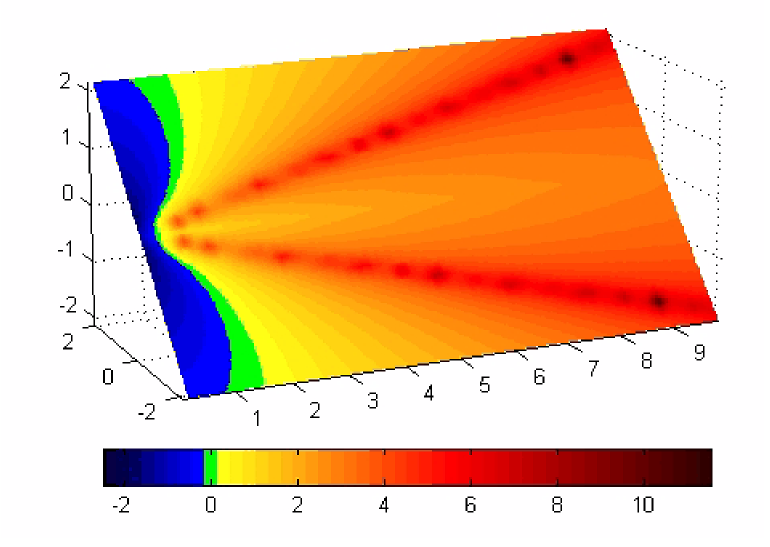


6 Increase the orange-red coloring in the slice by moving the red node pointer toward the yellow node.



7 Darken the endpoints to bring out more detail in the extremes of the data. Double-click the end nodes to display the color picker. Set the red endpoint to the RGB value [50 0 0] and set the blue endpoint to the RGB value [0 0 50].

The slice plane coloring now matches the example objectives.



Saving the Modified Colormap

You can save the modified colormap using the `colormap` function or the figure `Colormap` property.

After you have applied your changes, save the current figure colormap in a variable:

```
mycmap = get(fig,'Colormap'); % fig is figure
handle or use gcf
```

To use this colormap in another figure, set that figure's `Colormap` property:

```
set(new_fig,'Colormap',mycmap)
```

To save your modified colormap in a MAT-file, use the `save` command to save the `mycmap` workspace variable:

```
save('MyColormaps','mycmap')
```

To use your saved colormap in another MATLAB session, `load` the variable into the workspace and assign the colormap to the figure:

```
load('MyColormaps','mycmap')
set(fig,'Colormap',mycmap)
```

See Also

`colormap`, `get`, `load`, `save`, `set`

Color Operations for related functions

See "Colormaps" for more information on using MATLAB colormaps.

ColorSpec

Purpose

Color specification

Description

`ColorSpec` is not a function; it refers to the three ways in which you specify color in MATLAB:

- RGB triple
- Short name
- Long name

The short names and long names are MATLAB strings that specify one of eight predefined colors. The RGB triple is a three-element row vector whose elements specify the intensities of the red, green, and blue components of the color; the intensities must be in the range [0 1]. The following table lists the predefined colors and their RGB equivalents.

RGB Value	Short Name	Long Name
[1 1 0]	y	yellow
[1 0 1]	m	magenta
[0 1 1]	c	cyan
[1 0 0]	r	red
[0 1 0]	g	green
[0 0 1]	b	blue
[1 1 1]	w	white
[0 0 0]	k	black

Remarks

The eight predefined colors and any colors you specify as RGB values are not part of a figure's colormap, nor are they affected by changes to the figure's colormap. They are referred to as *fixed* colors, as opposed to *colormap* colors.

Some high-level functions (for example, `scatter`) accept a colorspec as an input argument and use it to set the `CData` of graphic objects they create. When using such functions, take care not to specify a colorspec in a property/value pair that sets `CData`; values for `CData` are always n-length vectors or n-by-3 matrices, where n is the length of `XData` and `YData`, never strings.

Examples

To change the background color of a figure to green, specify the color with a short name, a long name, or an RGB triple. These statements generate equivalent results:

```
whitebg('g')
whitebg('green')
whitebg([0 1 0]);
```

You can use `ColorSpec` anywhere you need to define a color. For example, this statement changes the figure background color to pink:

```
set(gcf,'Color',[1,0.4,0.6])
```

See Also

`bar`, `bar3`, `colordef`, `colormap`, `fill`, `fill3`, `whitebg`

"Color Operations" on page 1-97 for related functions

colperm

Purpose

Sparse column permutation based on nonzero count

Syntax

```
j = colperm(S)
```

Description

`j = colperm(S)` generates a permutation vector `j` such that the columns of `S(:,j)` are ordered according to increasing count of nonzero entries. This is sometimes useful as a preordering for LU factorization; in this case use `lu(S(:,j))`.

If `S` is symmetric, then `j = colperm(S)` generates a permutation `j` so that both the rows and columns of `S(j,j)` are ordered according to increasing count of nonzero entries. If `S` is positive definite, this is sometimes useful as a preordering for Cholesky factorization; in this case use `chol(S(j,j))`.

Algorithm

The algorithm involves a sort on the counts of nonzeros in each column.

Examples

The `n`-by-`n` *arrowhead* matrix

```
A = [ones(1,n); ones(n-1,1) speye(n-1,n-1)]
```

has a full first row and column. Its LU factorization, `lu(A)`, is almost completely full. The statement

```
j = colperm(A)
```

returns `j = [2:n 1]`. So `A(j,j)` sends the full row and column to the bottom and the rear, and `lu(A(j,j))` has the same nonzero structure as `A` itself.

On the other hand, the Bucky ball example,

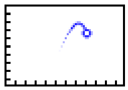
```
B = bucky
```

has exactly three nonzero elements in each row and column, so `j = colperm(B)` is the identity permutation and is no help at all for reducing fill-in with subsequent factorizations.

See Also `chol`, `colamd`, `lu`, `spparms`, `symamd`, `symrcm`

Purpose

2-D comet 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

```
comet(y)
comet(x,y)
comet(x,y,p)
comet(axes_handle,...)
```

Description

A comet graph is an animated graph in which a circle (the comet *head*) traces the data points on the screen. The comet *body* is a trailing segment that follows the head. The *tail* is a solid line that traces the entire function.

`comet(y)` displays a comet graph of the vector `y`.

`comet(x,y)` displays a comet graph of vector `y` versus vector `x`.

`comet(x,y,p)` specifies a comet body of length `p*length(y)`. `p` defaults to `0.1`.

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

Remarks

The trace left by `comet` is created by using an `EraseMode` of `none`, which means you cannot print the graph (you get only the comet head), and it disappears if you cause a redraw (e.g., by resizing the window).

Examples

Create a simple comet graph:

```
t = 0:.01:2*pi;
x = cos(2*t).*(cos(t).^2);
y = sin(2*t).*(sin(t).^2);
comet(x,y);
```

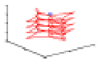
See Also

`comet3`

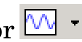
"Direction and Velocity Plots" on page 1-88 for related functions

Purpose

3-D comet 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

```
comet3(z)
comet3(x,y,z)
comet3(x,y,z,p)
comet3(axes_handle,...)
```

Description

A comet plot is an animated graph in which a circle (the comet *head*) traces the data points on the screen. The comet *body* is a trailing segment that follows the head. The *tail* is a solid line that traces the entire function.

`comet3(z)` displays a 3-D comet graph of the vector `z`.

`comet3(x,y,z)` displays a comet graph of the curve through the points `[x(i),y(i),z(i)]`.

`comet3(x,y,z,p)` specifies a comet body of length `p*length(y)`.

`comet3(axes_handle,...)` plots into the axes with the handle `axes_handle` instead of into the current axes (`gca`).

Remarks

The trace left by `comet3` is created by using an `EraseMode` of `none`, which means you cannot print the graph (you get only the comet head), and it disappears if you cause a redraw (e.g., by resizing the window).

Examples

Create a 3-D comet graph.

```
t = -10*pi:pi/250:10*pi;
comet3((cos(2*t).^2).*sin(t),(sin(2*t).^2).*cos(t),t);
```

See Also

`comet`

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

commandhistory

Purpose

Open Command History window, or select it if already open

GUI Alternatives

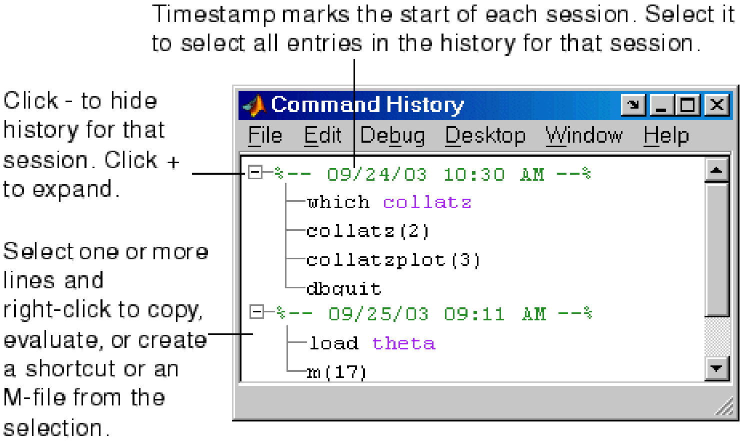
As an alternative to `commandhistory`, select **Desktop > Command History** to open it, or **Window > Command History** to select it.

Syntax

```
commandhistory
```

Description

`commandhistory` opens the MATLAB Command History window when it is closed, and selects the Command History window when it is open. The Command History window presents a log of the statements most recently run in the Command Window.



See Also

`diary`, `prefdir`, `startup`

MATLAB Desktop Tools and Development Environment Documentation

- “Recalling Previous Lines”
- “Command History”

Purpose

Open Command Window, or select it if already open

GUI Alternatives

As an alternative to `commandwindow`, select **Desktop > Command Window** to open it, or **Window > Command Window** to select it.

Syntax

```
commandwindow
```

Description

`commandwindow` opens the MATLAB Command Window when it is closed, and selects the Command Window when it is open.

Remarks

To determine the number of columns and rows that display in the Command Window, given its current size, use

```
get(0,'CommandWindowSize')
```

The number of columns is based on the width of the Command Window. With the matrix display width preference set to 80 columns, the number of columns is always 80.

See Also

`commandhistory`, `input`, `inputdlg`

MATLAB Desktop Tools and Development Environment documentation

- “Opening and Arranging Tools”
- “Running Functions and Programs, and Entering Variables”
- “Preferences for the Command Window”

Purpose

Companion matrix

Syntax

```
A = compan(u)
```

Description

`A = compan(u)` returns the corresponding companion matrix whose first row is `-u(2:n)/u(1)`, where `u` is a vector of polynomial coefficients. The eigenvalues of `compan(u)` are the roots of the polynomial.

Examples

The polynomial $(x-1)(x-2)(x+3) = x^3 - 7x + 6$ has a companion matrix given by

```
u = [1  0  -7  6]
A = compan(u)
A =
     0     7    -6
     1     0     0
     0     1     0
```

The eigenvalues are the polynomial roots:

```
eig(compan(u))

ans =
    -3.0000
     2.0000
     1.0000
```

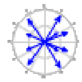
This is also `roots(u)`.

See Also

`eig`, `poly`, `polyval`, `roots`

Purpose

Plot arrows emanating from origin



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

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

Description

A compass graph displays the vectors with components (`U,V`) as arrows emanating from the origin. `U`, `V`, and `Z` are in Cartesian coordinates and plotted on a circular grid.

`compass(U,V)` displays a compass graph having *n* arrows, where *n* is the number of elements in `U` or `V`. The location of the base of each arrow is the origin. The location of the tip of each arrow is a point relative to the base and determined by `[U(i),V(i)]`.

`compass(Z)` displays a compass graph having *n* arrows, where *n* is the number of elements in `Z`. The location of the base of each arrow is the origin. The location of the tip of each arrow is relative to the base as determined by the real and imaginary components of `Z`. This syntax is equivalent to `compass(real(Z),imag(Z))`.

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

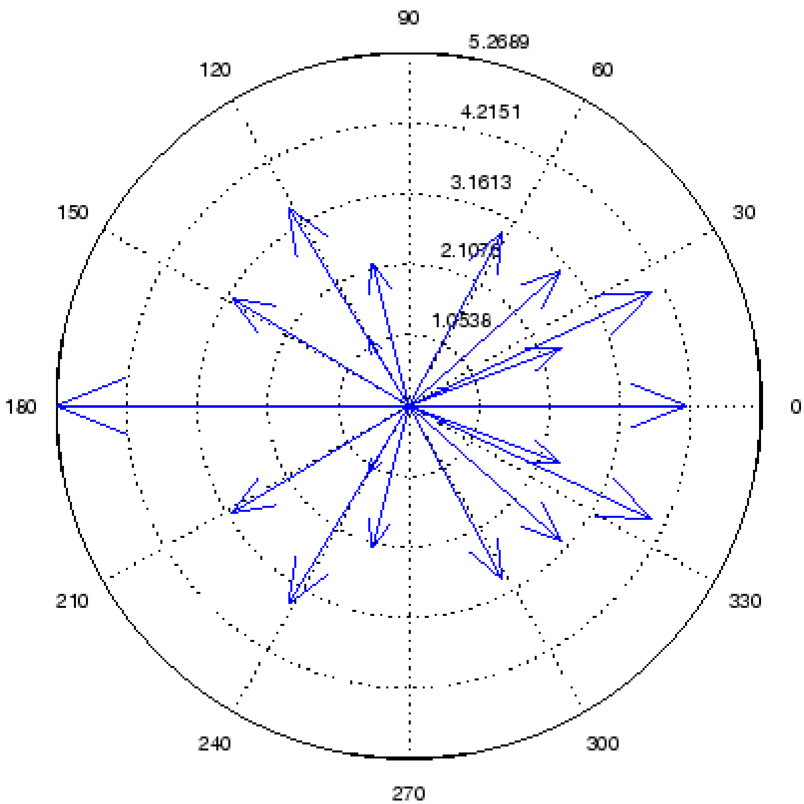
`compass(axes_handle,...)` plots into the axes with the handle `axes_handle` instead of into the current axes (`gca`).

`h = compass(...)` returns handles to line objects.

Examples

Draw a compass graph of the eigenvalues of a matrix.

```
Z = eig(randn(20,20));
compass(Z)
```



See Also

`feather`, `LineSpec`, `quiver`, `rose`

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

"Compass Plots" for another example

Purpose

Construct complex data from real and imaginary components

Syntax

```
c = complex(a,b)
```

Description

`c = complex(a,b)` creates a complex output, `c`, from the two real inputs.

```
c = a + bi
```

The output is the same size as the inputs, which must be scalars or equally sized vectors, matrices, or multi-dimensional arrays.

Note If `b` is all zeros, `c` is complex and the value of all its imaginary components is `0`. In contrast, the result of the addition `a+0i` returns a strictly real result.

The following describes when `a` and `b` can have different data types, and the resulting data type of the output `c`:

- If either of `a` or `b` has type `single`, `c` has type `single`.
- If either of `a` or `b` has an integer data type, the other must have the same integer data type or type scalar `double`, and `c` has the same integer data type.

`c = complex(a)` for real `a` returns the complex result `c` with real part `a` and `0` as the value of all imaginary components. Even though the value of all imaginary components is `0`, `c` is complex and `isreal(c)` returns false.

The `complex` function provides a useful substitute for expressions such as

```
a + i*b   or   a + j*b
```

in cases when the names "i" and "j" may be used for other variables (and do not equal $\sqrt{-1}$), when a and b are not single or double, or when b is all zero.

Example

Create complex uint8 vector from two real uint8 vectors.

```
a = uint8([1;2;3;4])
b = uint8([2;2;7;7])
c = complex(a,b)
c =
   1.0000 + 2.0000i
   2.0000 + 2.0000i
   3.0000 + 7.0000i
   4.0000 + 7.0000i
```

See Also

abs, angle, conj, i, imag, isreal, j, real

Purpose

Information about computer on which MATLAB is running

Syntax

```
str = computer
[str,maxsize] = computer
[str,maxsize,endian] = computer
```

Description

`str = computer` returns the string `str` with the computer type on which MATLAB is running.

`[str,maxsize] = computer` returns the integer `maxsize`, which contains the maximum number of elements allowed in an array with this version of MATLAB.

`[str,maxsize,endian] = computer` also returns either 'L' for little endian byte ordering or 'B' for big endian byte ordering.

The list of supported computers changes as new computers are added and others become obsolete. A typical list follows.

32–bit Platforms

str	Computer	ispc	isunix
GLNX86	GNU Linux on x86	0	1
MAC	Apple Macintosh OS X on PPC	0	1
MACI	Apple Macintosh OS X on x86	0	1
PCWIN	Microsoft Windows on x86	1	0

64–bit Platforms

str	Computer	ispc	isunix
GLNXA64	GNU Linux on x86_64	0	1
PCWIN64	Microsoft Windows on x64	1	0
SOL64	Sun Solaris on SPARC	0	1

See Also `getenv`, `setenv`, `ispc`, `isunix`

Purpose

Condition number with respect to inversion

Syntax

```
c = cond(X)
c = cond(X,p)
```

Description

The *condition number* of a matrix measures the sensitivity of the solution of a system of linear equations to errors in the data. It gives an indication of the accuracy of the results from matrix inversion and the linear equation solution. Values of `cond(X)` and `cond(X,p)` near 1 indicate a well-conditioned matrix.

`c = cond(X)` returns the 2-norm condition number, the ratio of the largest singular value of `X` to the smallest.

`c = cond(X,p)` returns the matrix condition number in `p`-norm:

```
norm(X,p) * norm(inv(X),p
```

If p is...	Then cond(X,p) returns the...
1	1-norm condition number
2	2-norm condition number
'fro'	Frobenius norm condition number
inf	Infinity norm condition number

Algorithm

The algorithm for `cond` (when `p = 2`) uses the singular value decomposition, `svd`.

See Also

`condeig`, `condest`, `norm`, `normest`, `rank`, `rcond`, `svd`

References

[1] Anderson, E., Z. Bai, C. Bischof, S. Blackford, J. Demmel, J. Dongarra, J. Du Croz, A. Greenbaum, S. Hammarling, A. McKenney, and D. Sorensen, *LAPACK User's Guide* (`http://www.netlib.org/lapack/lug/lapack_lug.html`), Third Edition, SIAM, Philadelphia, 1999.

condeig

Purpose

Condition number with respect to eigenvalues

Syntax

```
c = condeig(A)
[V,D,s] = condeig(A)
```

Description

`c = condeig(A)` returns a vector of condition numbers for the eigenvalues of `A`. These condition numbers are the reciprocals of the cosines of the angles between the left and right eigenvectors.

`[V,D,s] = condeig(A)` is equivalent to

```
[V,D] = eig(A);
s = condeig(A);
```

Large condition numbers imply that `A` is near a matrix with multiple eigenvalues.

See Also

`balance`, `cond`, `eig`

Purpose

1-norm condition number estimate

Syntax

```
c = condest(A)
c = condest(A,t)
[c,v] = condest(A)
```

Description

`c = condest(A)` computes a lower bound C for the 1-norm condition number of a square matrix A.

`c = condest(A,t)` changes `t`, a positive integer parameter equal to the number of columns in an underlying iteration matrix. Increasing the number of columns usually gives a better condition estimate but increases the cost. The default is `t = 2`, which almost always gives an estimate correct to within a factor 2.

`[c,v] = condest(A)` also computes a vector `v` which is an approximate null vector if `c` is large. `v` satisfies `norm(A*v,1) = norm(A,1)*norm(v,1)/c`.

Note `condest` invokes `rand`. If repeatable results are required then invoke `rand('state',j)`, for some `j`, before calling this function.

This function is particularly useful for sparse matrices.

Algorithm

`condest` is based on the 1-norm condition estimator of Hager [1] and a block oriented generalization of Hager's estimator given by Higham and Tisseur [2]. The heart of the algorithm involves an iterative search to estimate $\|A^{-1}\|_1$ without computing A^{-1}. This is posed as the convex, but nondifferentiable, optimization problem

$$\max \|A^{-1}x\|_1 \text{ subject to } \|x\|_1 = 1$$

See Also

`cond`, `norm`, `normest`

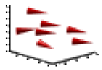
Reference

[1] William W. Hager, "Condition Estimates," *SIAM J. Sci. Stat. Comput. 5*, 1984, 311-316, 1984.

[2] Nicholas J. Higham and Françoise Tisseur, "A Block Algorithm for Matrix 1-Norm Estimation with an Application to 1-Norm Pseudospectra, "*SIAM J. Matrix Anal. Appl.*, Vol. 21, 1185-1201, 2000.

Purpose

Plot velocity vectors as cones in 3-D vector field



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

```
coneplot(X,Y,Z,U,V,W,Cx,Cy,Cz)
coneplot(U,V,W,Cx,Cy,Cz)
coneplot(...,s)
coneplot(...,color)
coneplot(...,'quiver')
coneplot(...,'method')
coneplot(X,Y,Z,U,V,W,'nointerp')
coneplot(axes_handle,...)
h = coneplot(...)
```

Description

`coneplot(X,Y,Z,U,V,W,Cx,Cy,Cz)` plots velocity vectors as cones pointing in the direction of the velocity vector and having a length proportional to the magnitude of the velocity vector.

- `X`, `Y`, `Z` define the coordinates for the vector field.
- `U`, `V`, `W` define the vector field. These arrays must be the same size, monotonic, and 3-D plaid (such as the data produced by `meshgrid`).
- `Cx`, `Cy`, `Cz` define the location of the cones in the vector field. The section "Specifying Starting Points for Stream Plots" in Visualization Techniques provides more information on defining starting points.

`coneplot(U,V,W,Cx,Cy,Cz)` (omitting the `X`, `Y`, and `Z` arguments) assumes `[X,Y,Z] = meshgrid(1:n,1:m,1:p)`, where `[m,n,p]= size(U)`.

`coneplot(...,s)` MATLAB automatically scales the cones to fit the graph and then stretches them by the scale factor `s`. If you do not specify a value for `s`, MATLAB uses a value of 1. Use `s = 0` to plot the cones without automatic scaling.

`coneplot(...,color)` interpolates the array `color` onto the vector field and then colors the cones according to the interpolated values. The size of the `color` array must be the same size as the `U`, `V`, `W` arrays. This option works only with cones (i.e., not with the `quiver` option).

`coneplot(...,'quiver')` draws arrows instead of cones (see `quiver3` for an illustration of a quiver plot).

`coneplot(...,'`*`method`*`')` specifies the interpolation method to use. *`method`* can be `linear`, `cubic`, or `nearest`. `linear` is the default. (See `interp3` for a discussion of these interpolation methods.)

`coneplot(X,Y,Z,U,V,W,'nointerp')` does not interpolate the positions of the cones into the volume. The cones are drawn at positions defined by `X`, `Y`, `Z` and are oriented according to `U`, `V`, `W`. Arrays `X`, `Y`, `Z`, `U`, `V`, `W` must all be the same size.

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

`h = coneplot(...)` returns the handle to the `patch` object used to draw the cones. You can use the `set` command to change the properties of the cones.

Remarks

`coneplot` automatically scales the cones to fit the graph, while keeping them in proportion to the respective velocity vectors.

It is usually best to set the data aspect ratio of the axes before calling `coneplot`. You can set the ratio using the `daspect` command.

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

Examples

This example plots the velocity vector cones for vector volume data representing the motion of air through a rectangular region of space. The final graph employs a number of enhancements to visualize the data more effectively:

- Cone plots indicate the magnitude and direction of the wind velocity.
- Slice planes placed at the limits of the data range provide a visual context for the cone plots within the volume.
- Directional lighting provides visual cues to the orientation of the cones.
- View adjustments compose the scene to best reveal the information content of the data by selecting the view point, projection type, and magnification.

1. Load and Inspect Data

The `winds` data set contains six 3-D arrays: `u`, `v`, and `w` specify the vector components at each of the coordinates specified in `x`, `y`, and `z`. The coordinates define a lattice grid structure where the data is sampled within the volume.

It is useful to establish the range of the data to place the slice planes and to specify where you want the cone plots (`min`, `max`).

```
load wind
xmin = min(x(:));
xmax = max(x(:));
ymin = min(y(:));
ymax = max(y(:));
zmin = min(z(:));
```

2. Create the Cone Plot

- Decide where in data space you want to plot cones. This example selects the full range of `x` and `y` in eight steps and the range 3 to 15 in four steps in `z` (`linspace`, `meshgrid`).

- Use `daspect` to set the data aspect ratio of the axes before calling `coneplot` so MATLAB can determine the proper size of the cones.
- Draw the cones, setting the scale factor to 5 to make the cones larger than the default size.
- Set the coloring of each cone (`FaceColor`, `EdgeColor`).

```
daspect([2,2,1])
xrange = linspace(xmin,xmax,8);
yrange = linspace(ymin,ymax,8);
zrange = 3:4:15;
[cx cy cz] = meshgrid(xrange,yrange,zrange);
hcones = coneplot(x,y,z,u,v,w,cx,cy,cz,5);
set(hcones,'FaceColor','red','EdgeColor','none')
```

3. Add the Slice Planes

- Calculate the magnitude of the vector field (which represents wind speed) to generate scalar data for the `slice` command.
- Create slice planes along the *x*-axis at `xmin` and `xmax`, along the *y*-axis at `ymax`, and along the *z*-axis at `zmin`.
- Specify interpolated face color so the slice coloring indicates wind speed, and do not draw edges (`hold`, `slice`, `FaceColor`, `EdgeColor`).

```
hold on
wind_speed = sqrt(u.^2 + v.^2 + w.^2);
hsurfaces = slice(x,y,z,wind_speed,[xmin,xmax],ymax,zmin);
set(hsurfaces,'FaceColor','interp','EdgeColor','none')
hold off
```

4. Define the View

- Use the `axis` command to set the axis limits equal to the range of the data.
- Orient the `view` to azimuth = 30 and elevation = 40. (`rotate3d` is a useful command for selecting the best view.)

- Select perspective projection to provide a more realistic looking volume (`camproj`).
- Zoom in on the scene a little to make the plot as large as possible (`camzoom`).

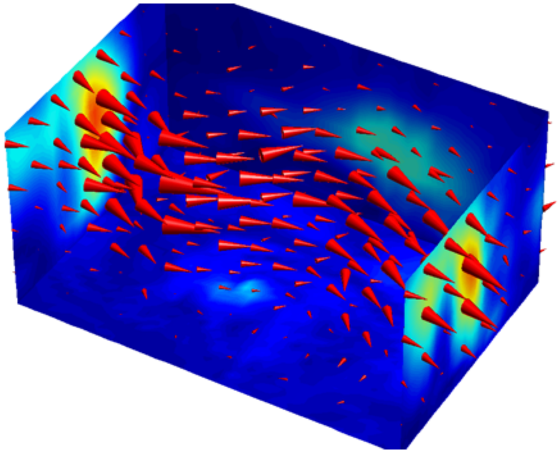
```
axis tight; view(30,40); axis off
camproj perspective; camzoom(1.5)
```

5. Add Lighting to the Scene

The light source affects both the slice planes (surfaces) and the cone plots (patches). However, you can set the lighting characteristics of each independently:

- Add a light source to the right of the camera and use Phong lighting to give the cones and slice planes a smooth, three-dimensional appearance (`camlight`, `lighting`).
- Increase the value of the `AmbientStrength` property for each slice plane to improve the visibility of the dark blue colors. (Note that you can also specify a different `colormap` to change the coloring of the slice planes.)
- Increase the value of the `DiffuseStrength` property of the cones to brighten particularly those cones not showing specular reflections.

```
camlight right; lighting phong
set(hsurfaces,'AmbientStrength',.6)
set(hcones,'DiffuseStrength',.8)
```



See Also

`isosurface`, `patch`, `reducevolume`, `smooth3`, `streamline`, `stream2`, `stream3`, `subvolume`

"Volume Visualization" on page 1-101 for related functions

Purpose Complex conjugate

Syntax

```
ZC = conj(Z)
```

Description `ZC = conj(Z)` returns the complex conjugate of the elements of `Z`.

Algorithm If `Z` is a complex array:

```
conj(Z) = real(Z) - i*imag(Z)
```

See Also `i`, `j`, `imag`, `real`

continue

Purpose Pass control to next iteration of `for` or `while` loop

Syntax `continue`

Description `continue` passes control to the next iteration of the `for` or `while` loop in which it appears, skipping any remaining statements in the body of the loop.

In nested loops, `continue` passes control to the next iteration of the `for` or `while` loop enclosing it.

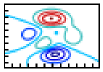
Examples The example below shows a `continue` loop that counts the lines of code in the file `magic.m`, skipping all blank lines and comments. A `continue` statement is used to advance to the next line in `magic.m` without incrementing the count whenever a blank line or comment line is encountered.

```
fid = fopen('magic.m','r');
count = 0;
while ~feof(fid)
    line = fgetl(fid);
    if isempty(line) | strncmp(line,'%',1)
        continue
    end
    count = count + 1;
end
disp(sprintf('%d lines',count));
```

See Also `for`, `while`, `end`, `break`, `return`

Purpose

Contour plot of matrix



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

```
contour(Z)
contour(Z,n)
contour(Z,v)
contour(X,Y,Z)
contour(X,Y,Z,n)
contour(X,Y,Z,v)
contour(...,LineSpec)
contour(ax,...)
[C,h] = contour(...)
[C,h] = contour('v6',...)
```

Description

A contour plot displays isolines of matrix `Z`. Label the contour lines using `clabel`.

`contour(Z)` draws a contour plot of matrix `Z`, where `Z` is interpreted as heights with respect to the *x*-*y* plane. `Z` must be at least a 2-by-2 matrix that contains at least two different values. The number of contour levels and the values of the contour levels are chosen automatically based on the minimum and maximum values of `Z`. The ranges of the *x*- and *y*-axis are `[1:n]` and `[1:m]`, where `[m,n] = size(Z)`.

`contour(Z,n)` draws a contour plot of matrix `Z` with `n` contour levels.

`contour(Z,v)` draws a contour plot of matrix `Z` with contour lines at the data values specified in vector `v`. The number of contour levels is equal to `length(v)`. To draw a single contour of level `i`, use `contour(Z,[i i])`.

`contour(X,Y,Z)`, `contour(X,Y,Z,n)`, and `contour(X,Y,Z,v)` draw contour plots of `Z`. `X` and `Y` specify the *x*- and *y*-axis limits. When `X` and `Y` are matrices, they must be the same size as `Z`, in which case they specify a surface, as defined by the `surf` function. `X` and `Y` must be monotonically increasing.

If `X` or `Y` is irregularly spaced, `contour` calculates contours using a regularly spaced contour grid, and then transforms the data to `X` or `Y`.

`contour(...,LineSpec)` draws the contours using the line type and color specified by `LineSpec`. `contour` ignores marker symbols.

`contour(ax,...)` plots into axes `ax` instead of `gca`.

`[C,h] = contour(...)` returns a contour matrix, `C`, derived from the matrix returned by the low-level `contourc` function, and a handle, `h`, to a contourgroup object. `clabel` uses the contour matrix `C` to create the labels. (See descriptions of `contourgroup properties`.)

Backward Compatible Version

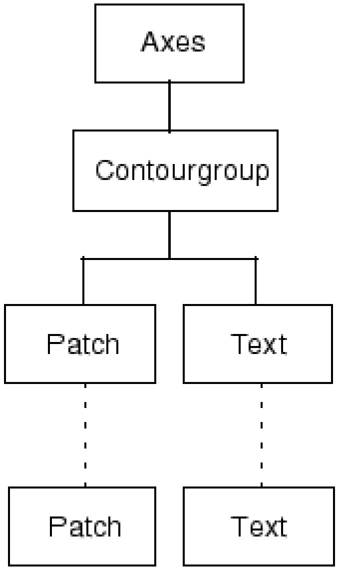
`[C,h] = contour('v6',...)` returns the contour matrix `C` (see `contourc`) and a vector of handles, `h`, to graphics objects. `clabel` uses the contour matrix `C` to create the labels. When called with the `'v6'` flag, `contour` creates patch graphics objects, unless you specify a `LineSpec`, in which case `contour` creates line graphics objects. In this case, contour lines are not mapped to colors in the figure colormap, but are colored using the colors defined in the axes `ColorOrder` property. If you do not specify a `LineSpec` argument, the figure colormap (`colormap`) and the color limits (`caxis`) control the color of the contour lines (patch objects).

See “Plot Objects and Backward Compatibility” for more information.

Remarks

Use contourgroup object properties to control the contour plot appearance.

The following diagram illustrates the parent-child relationship in contour plots.



Examples

Contour Plot of a Function

To view a contour plot of the function

$$z = xe^{(-x^2 - y^2)}$$

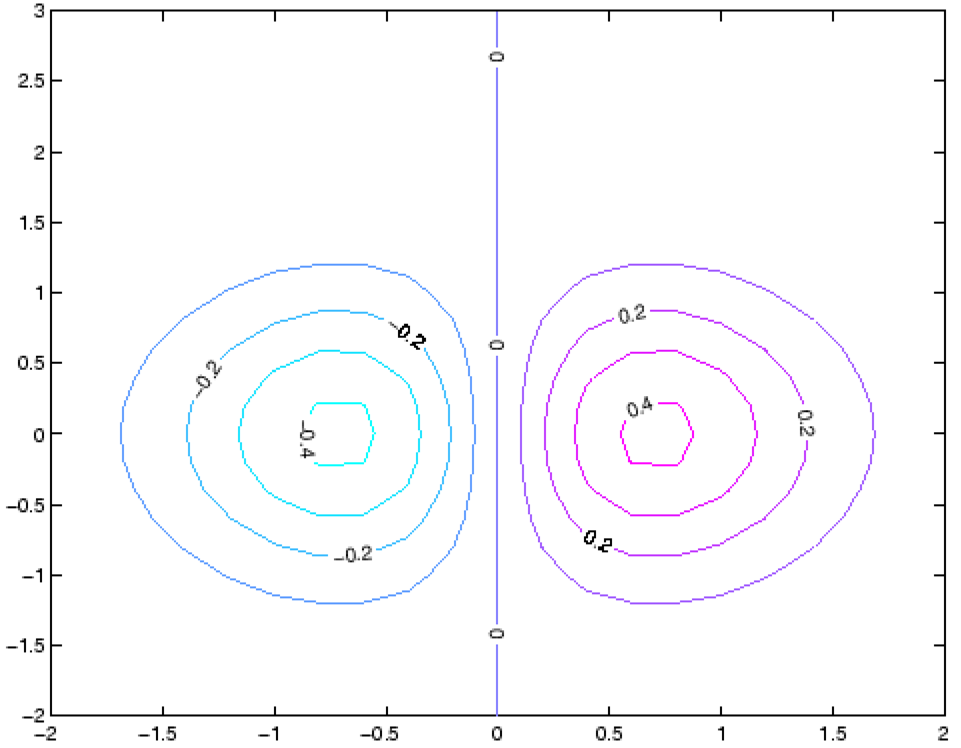
over the range $-2 \le x \le 2$, $-2 \le y \le 3$, create matrix `Z` using the statements

```
[X,Y] = meshgrid(-2:.2:2,-2:.2:3);
Z = X.*exp(-X.^2-Y.^2);
```

Then, generate a contour plot of `Z`.

- Display contour labels by setting the `ShowText` property to `on`.
- Label every other contour line by setting the `TextStep` property to twice the contour interval (i.e., two times the `LevelStep` property).
- Use a smoothly varying colormap.

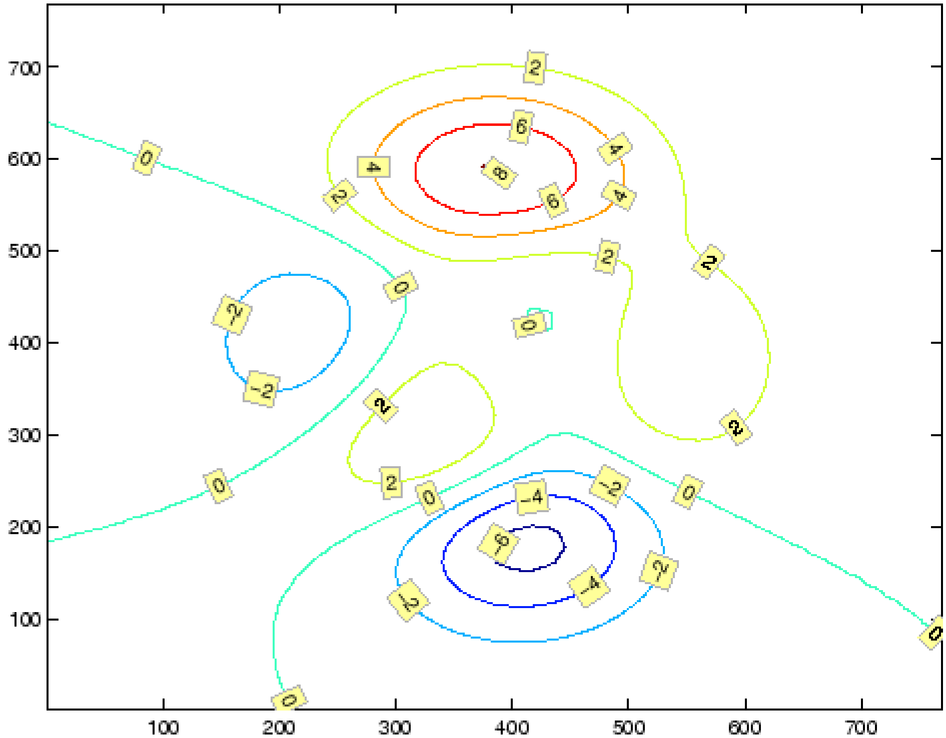
```
[C,h] = contour(X,Y,Z);
set(h,'ShowText','on','TextStep',get(h,'LevelStep')*2)
colormap cool
```



Smoothing Contour Data

Use `interp2` to create smoother contours. Also set the contour label text `BackgroundColor` to a light yellow and the `EdgeColor` to light gray.

```
Z = peaks;
[C,h] = contour(interp2(Z,4));
text_handle = clabel(C,h);
set(text_handle,'BackgroundColor',[1 1 .6],...
    'Edgecolor',[.7 .7 .7])
```



Setting the Axis Limits on Contour Plots

Suppose, for example, your data represents a region that is 1000 meters in the *x* dimension and 3000 meters in the *y* dimension. Use the following statements to set the axis limits correctly:

```
Z = rand(24,36); % assume data is a 24-by-36 matrix
X = linspace(0,1000,size(Z,2));
Y = linspace(0,3000,size(Z,1));
[c,h] = contour(X,Y,Z);
axis equal tight % set the axes aspect ratio
```

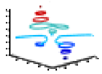
See Also

`contour3`, `contourc`, `contourf`, `contourslice`

See `Contourgroup Properties` for property descriptions.

Purpose

3-D contour 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

```
contour3(Z)
contour3(Z,n)
contour3(Z,v)
contour3(X,Y,Z)
contour3(X,Y,Z,n)
contour3(X,Y,Z,v)
contour3(...,LineSpec)
contour3(axes_handle,...)
[C,h] = contour3(...)
```

Description

`contour3` creates a 3-D contour plot of a surface defined on a rectangular grid.

`contour3(Z)` draws a contour plot of matrix `Z` in a 3-D view. `Z` is interpreted as heights with respect to the *x*-*y* plane. `Z` must be at least a 2-by-2 matrix that contains at least two different values. The number of contour levels and the values of contour levels are chosen automatically. The ranges of the *x*- and *y*-axis are `[1:n]` and `[1:m]`, where `[m,n] = size(Z)`.

`contour3(Z,n)` draws a contour plot of matrix `Z` with `n` contour levels in a 3-D view.

`contour3(Z,v)` draws a contour plot of matrix `Z` with contour lines at the values specified in vector `v`. The number of contour levels is equal to `length(v)`. To draw a single contour of level `i`, use `contour(Z,[i i])`.

contour3(X,Y,Z), contour3(X,Y,Z,n), and contour3(X,Y,Z,v) use X and Y to define the *x*- and *y*-axis limits. If X is a matrix, X(1,:) defines the *x*-axis. If Y is a matrix, Y(:,1) defines the *y*-axis. When X and Y are matrices, they must be the same size as Z, in which case they specify a surface as surf does.

contour3(...,LineSpec) draws the contours using the line type and color specified by LineSpec.

contour3(axes_handle,...) plots into the axes with the handle axes_handle instead of into the current axes (gca).

[C,h] = contour3(...) returns the contour matrix C, as described in the function contourc and a column vector h, containing handles to graphics objects. contour3 creates patch graphics objects unless you specify LineSpec, in which case contour3 creates line graphics objects.

Remarks

If X or Y is irregularly spaced, contour3 calculates contours using a regularly spaced contour grid, and then transforms the data to X or Y.

If you do not specify LineSpec, colormap and caxis control the color.

contour3(...) works the same as contour(...) with these exceptions:

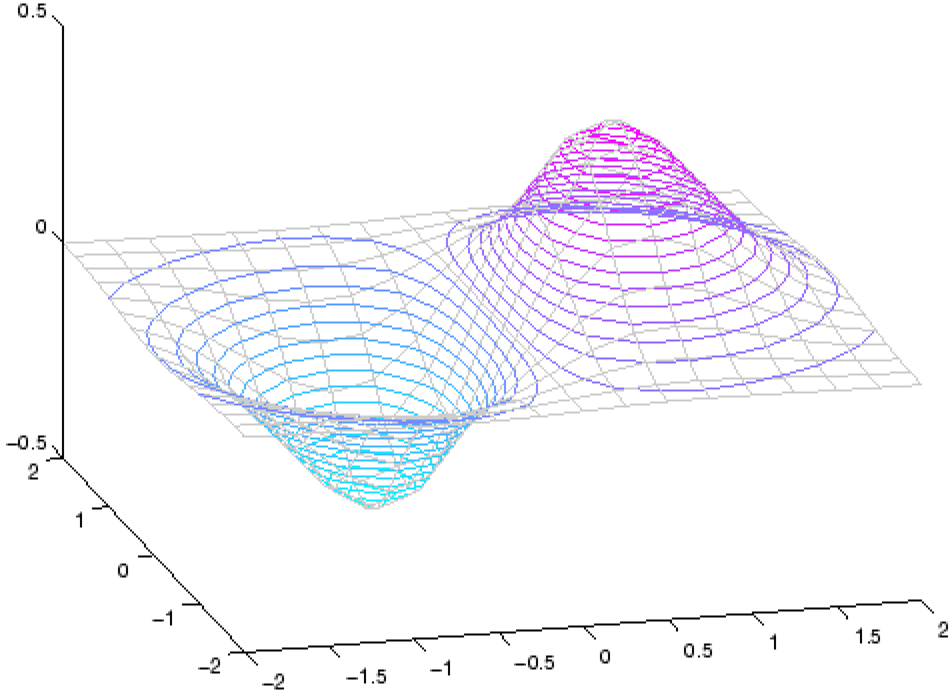
- The contours are drawn at their corresponding Z level.
- Multiple patch objects are created instead of a contourgroup.
- Calling contour3 with trailing property-value pairs is not allowed.

Examples

Plot the three-dimensional contour of a function and superimpose a surface plot to enhance visualization of the function.

```
[X,Y] = meshgrid([-2:.25:2]);
Z = X.*exp(-X.^2-Y.^2);
contour3(X,Y,Z,30)
surface(X,Y,Z,'EdgeColor',[.8 .8 .8],'FaceColor','none')
grid off
view(-15,25)
```

```
colormap cool
```



See Also

`contour`, `contourc`, `meshc`, `meshgrid`, `surfc`

"Contour Plots" on page 1-88 category for related functions

"Contour Plots" section for more examples

Purpose

Low-level contour plot computation

Syntax

```
C = contourc(Z)
C = contourc(Z,n)
C = contourc(Z,v)
C = contourc(x,y,Z)
C = contourc(x,y,Z,n)
C = contourc(x,y,Z,v)
```

Description

`contourc` calculates the contour matrix `C` used by `contour`, `contour3`, and `contourf`. The values in `Z` determine the heights of the contour lines with respect to a plane. The contour calculations use a regularly spaced grid determined by the dimensions of `Z`.

`C = contourc(Z)` computes the contour matrix from data in matrix `Z`, where `Z` must be at least a 2-by-2 matrix. The contours are isolines in the units of `Z`. The number of contour lines and the corresponding values of the contour lines are chosen automatically.

`C = contourc(Z,n)` computes contours of matrix `Z` with `n` contour levels.

`C = contourc(Z,v)` computes contours of matrix `Z` with contour lines at the values specified in vector `v`. The length of `v` determines the number of contour levels. To compute a single contour of level `i`, use `contourc(Z,[i i])`.

`C = contourc(x,y,Z)`, `C = contourc(x,y,Z,n)`, and `C = contourc(x,y,Z,v)` compute contours of `Z` using vectors `x` and `y` to determine the *x*- and *y*-axis limits. `x` and `y` must be monotonically increasing.

Remarks

`C` is a two-row matrix specifying all the contour lines. Each contour line defined in matrix `C` begins with a column that contains the value of the contour (specified by `v` and used by `clabel`), and the number of `(x,y)` vertices in the contour line. The remaining columns contain the data for the `(x,y)` pairs.

```
C = [value1xdata(1)xdata(2)..value2xdata(1)xdata(2)...;
```

```
dim1ydata(1)ydata(2)...dim2 ydata(1)ydata(2)...]
```

Specifying irregularly spaced `x` and `y` vectors is not the same as contouring irregularly spaced data. If `x` or `y` is irregularly spaced, `contourc` calculates contours using a regularly spaced contour grid, then transforms the data to `x` or `y`.

See Also

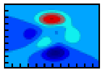
`clabel`, `contour`, `contour3`, `contourf`

"Contour Plots" on page 1-88 for related functions

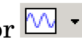
"The Contouring Algorithm" for more information

Purpose

Filled 2-D contour 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

```
contourf(Z)
contourf(Z,n)
contourf(Z,v)
contourf(X,Y,Z)
contourf(X,Y,Z,n)
contourf(X,Y,Z,v)
contourf(axes_handle,...)
C = contourf(...)
[C,h] = contourf(...)
[C,h,CF] = contourf(...)
```

Description

A filled contour plot displays isolines calculated from matrix `Z` and fills the areas between the isolines using constant colors. The color of the filled areas depends on the current figure's colormap. `NaN`s in the Z-data leave white holes with black borders in the contour plot. The function creates and optionally returns a handle to a `Contourgroup Properties` object containing the filled contours.

`contourf(Z)` draws a contour plot of matrix `Z`, where `Z` is interpreted as heights with respect to a plane. `Z` must be at least a 2-by-2 matrix that contains at least two different values. The number of contour lines and the values of the contour lines are chosen automatically.

`contourf(Z,n)` draws a contour plot of matrix `Z` with `n` contour levels.

`contourf(Z,v)` draws a contour plot of matrix `Z` with contour levels at the values specified in vector `v`. When you use the `contourf(Z,v)` syntax to specify a vector of contour levels (`v` must increase monotonically), contour regions with `Z`-values less than `v(1)` are not filled (they are rendered in white). To fill such regions with a color, make `v(1)` less than or equal to the minimum `Z`-data value.

`contourf(X,Y,Z)`, `contourf(X,Y,Z,n)`, and `contourf(X,Y,Z,v)` produce contour plots of `Z` using `X` and `Y` to determine the *x*- and *y*-axis limits. When `X` and `Y` are matrices, they must be the same size as `Z`, in which case they specify a surface as `surf` does. `X` and `Y` must be monotonically increasing.

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

`C = contourf(...)` returns the contour matrix `C` as calculated by the function `contourc` and used by `clabel`.

`[C,h] = contourf(...)` also returns a handle `h` for the contourgroup object.

Backward-Compatible Version

`[C,h,CF] = contourf(...)` returns the contour matrix `C` as calculated by the function `contourc` and used by `clabel`, a vector of handles `h` to patch graphics objects (instead of a contourgroup object, for compatibility with MATLAB 6.5 and earlier) and a contour matrix `CF` for the filled areas.

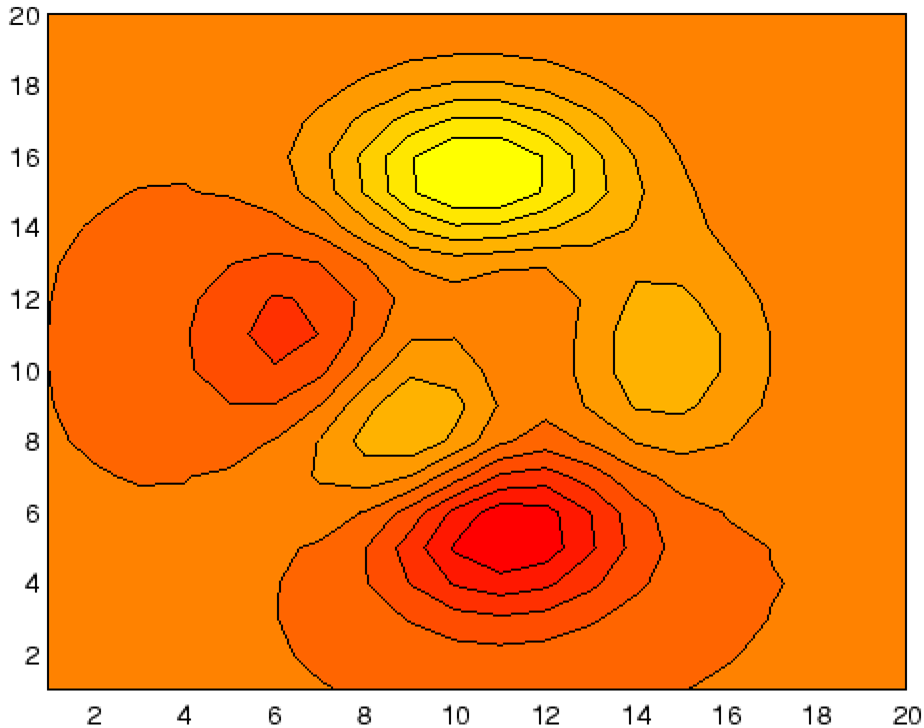
Remarks

If `X` or `Y` is irregularly spaced, `contourf` calculates contours using a regularly spaced contour grid, and then transforms the data to `X` or `Y`.

Examples

Create a filled contour plot of the `peaks` function.

```
[C,h] = contourf(peaks(20),10);
colormap autumn
```



See Also

`clabel`, `contour`, `contour3`, `contourc`, `quiver`

"Contour Plots" on page 1-88 for related functions

Contourgroup Properties

Purpose

Define contourgroup properties

Modifying Properties

You can set and query graphics object properties using the `set` and `get` commands or the Property Editor (`propertyeditor`).

Note that you cannot define default properties for contourgroup objects.

See “Plot Objects” for more information on contourgroup objects.

Contourgroup 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 if objects are in the process of being deleted. MATLAB sets the `BeingDeleted` property to `on` when the object’s delete function callback is called (see the `DeleteFcn` property). It remains set to `on` while the delete function executes, after which the object no longer exists.

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

`BusyAction`

`cancel | {queue}`

Callback routine interruption. The `BusyAction` property enables you to control how MATLAB handles events that potentially interrupt executing callbacks. If there is a callback function executing, callbacks invoked subsequently always attempt to interrupt it.

If the `Interruptible` property of the object whose callback is executing is set to `on` (the default), then interruption occurs at the next point where the event queue is processed. If the `Interruptible` property is `off`, the `BusyAction` property (of the object owning the executing callback) determines how MATLAB handles the event. The choices are

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

`ButtonDownFcn`
string or function handle

Button press callback function. A callback that executes whenever you press a mouse button while the pointer is over this object, but not over another graphics object. See the `HitTestArea` property for information about selecting objects of this type.

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

This property can be

- A string that is a valid MATLAB expression
- The name of an M-file
- A function handle

Set this property to a function handle that references the callback. The expressions execute in the MATLAB workspace.

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

`Children`
array of graphics object handles

Children of this object. The handle of a patch object that is the child of this object (whether visible or not).

Note that if a child object's `HandleVisibility` property is set to `callback` or `off`, its handle does not show up in this object's `Children` property unless you set the root `ShowHiddenHandles` property to `on`:

```
set(0,'ShowHiddenHandles','on')
```

`Clipping`
: `{on} | off`

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.

`ContourMatrix`
: 2-by-n matrix Read Only

A two-row matrix specifying all the contour lines. Each contour line defined in the `ContourMatrix` begins with a column that contains the value of the contour (specified by the `LevelList` property and is used by `clabel`), and the number of `(x,y)` vertices in the contour line. The remaining columns contain the data for the `(x,y)` pairs:

```
C = [value1 xdata(1) xdata(2)...value2 xdata(1) xdata(2)...;
           dim1 ydata(1) ydata(2)...  dim2 ydata(1) ydata(2)...]
```

That is,

```
C = [C(1) C(2)...C(I)...C(N)]
```

where `N` is the number of contour levels, and

```
C(i) = [ level(i) x(1) x(2)...x(  numel(i));
```

```
numel(i) y(1) y(2)...y(  numel(i))];
```

For further information, see The Contouring Algorithm.

`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.

`Fill`

`{off} | on`

Color spaces between contour lines. By default, `contour` draws only the contour lines of the surface. If you set `Fill` to `on`, `contour` colors the regions in between the contour lines according to the Z-value of the region and changes the contour lines to black.

`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).

`HitTestArea`
`on | {off}`

Select the object by clicking lines or area of extent. This property enables you to select plot objects in two ways:

- Select by clicking lines or markers (default).
- Select by clicking anywhere in the extent of the plot.

When `HitTestArea` is `off`, you must click th eobject's lines or markers (excluding the baseline, if any) to select the object. When `HitTestArea` is `on`, you can select this object by clicking anywhere within the extent of the plot (i.e., anywhere within a rectangle that encloses it).

`Interruptible`
`{on} | off`

Callback routine interruption mode. The `Interruptible` property controls whether an object's callback can be interrupted by callbacks invoked subsequently.

Only callbacks defined for the `ButtonDownFcn` property are affected by the `Interruptible` property. MATLAB checks for events that can interrupt a callback only when it encounters a `drawnow`, `figure`, `getframe`, or `pause` command in the routine. See the `BusyAction` property for related information.

Setting `Interruptible` to `on` allows any graphics object's callback to interrupt callback routines originating from a bar property. Note that MATLAB does not save the state of variables or the display (e.g., the handle returned by the `gca` or `gcf` command) when an interruption occurs.

`LabelSpacing`
distance in points (default = 144)

Spacing between labels on each contour line. When you display contour line labels using either the `ShowText` property or the `clabel` command, the labels are spaced 144 points (2 inches) apart on each line. You can specify the spacing by setting the

`LabelSpacing` property to a value in points. If the length of an individual contour line is less than the specified value, MATLAB displays only one contour label on that line.

`LevelList`
vector of `ZData`-values

Values at which contour lines are drawn. When the `LevelListMode` property is `auto`, the `contour` function automatically chooses contour values that span the range of values in `ZData` (the input argument `Z`). You can set this property to the values at which you want contour lines drawn.

To specify the contour interval (space between contour lines) use the `LevelStep` property.

`LevelListMode`
{auto} | manual

User-specified or autogenerated `LevelList` *values*. By default, the `contour` function automatically generates the values at which contours are drawn. If you set this property to `manual`, contour does not change the values in `LevelList` as you change the values of `ZData`.

`LevelStep`
scalar

Spacing of contour lines. The `contour` function draws contour lines at regular intervals determined by the value of `LevelStep`. When the `LevelStepMode` property is set to `auto`, `contour` determines the contour interval automatically based on the `ZData`.

`LevelStepMode`
{auto} | manual

User-specified or autogenerated `LevelStep` *values*. By default, the `contour` function automatically determines a value for the `LevelStep` property. If you set this property to `manual`, contour does not change the value of `LevelStep` as you change the values of `ZData`.

`LineColor`
`{auto} | ColorSpec | none`

Color of the contour lines. This property determines how MATLAB colors the contour lines.

- `auto`— Each contour line is a single color determined by its contour value, the figure colormap, and the color axis (`caxis`).
- `ColorSpec` — A three-element RGB vector or one of the MATLAB predefined names, specifying a single color for edges. The default edge color is black. See `ColorSpec` for more information on specifying color.
- `none` — No contour lines are drawn.

`LineStyle`
`{-} | -- | : | -. | none`

Line style. This property specifies the line style of the object. Available line styles are shown in the following table.

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

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

`LineWidth`
scalar

The width of linear objects and edges of filled areas. Specify this value in points (1 point = $^1/_{72}$ inch). The default `LineWidth` is 0.5 points.

`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.

`ShowText`
`on | {off}`

Display labels on contour lines. When you set this property to on, MATLAB displays text labels on each contour line indicating the contour value. See also `LevelList`, `clabel`, and the example "Contour Plot of a Function" on page 2-621.

`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')
```

`TextList`

vector of contour values

Contour values to label. This property contains the contour values where text labels are placed. By default, these values are the same as those contained in the `LevelList` property, which define where the contour lines are drawn. Note that there must be an equivalent contour line to display a text label.

For example, the following statements create and label a contour plot:

```
[c,h]=contour(peaks);
clabel(c,h)
```

You can get the `LevelList` property to see the contour line values:

```
get(h,'LevelList')
```

Suppose you want to view the contour value `4.375` instead of the value of `4` that the contour function used. To do this, you need to set both the `LevelList` and `TextList` properties:

```
set(h,'LevelList',[-6 -4 -2 0 2 4.375 6 8],...
 'TextList',[-6 -4 -2 0 2 4.375 6 8])
```

See the example "Contour Plot of a Function" on page 2-621 for additional information.

`TextListMode`

`{auto} | manual`

User-specified or auto `TextList` values. When this property is set to `auto`, MATLAB sets the `TextList` property equal to the values of the `LevelList` property (i.e., a text label for each contour line). When this property is set to `manual`, MATLAB does not set the values of the `TextList` property. Note that specifying values for the `TextList` property causes the `TextListMode` property to be set to `manual`.

`TextStep`

scalar

Determines which contour line have numeric labels. The `contour` function labels contour lines at regular intervals which are determined by the value of the `TextStep` property. When the `TextStepMode` property is set to `auto`, `contour` labels every contour line when the `ShowText` property is `on`. See "Contour Plot of a Function" on page 2-621 for an example that uses the `TextStep` property.

`TextStepMode`
{auto} | manual

User-specified or autogenerated `TextStep` values. By default, the `contour` function automatically determines a value for the `TextStep` property. If you set this property to `manual`, `contour` does not change the value of `TextStep` as you change the values of `ZData`.

`Type`
string (read only)

Type of graphics object. This property contains a string that identifies the class of graphics object. For contourgroup objects, `Type` is '`hggroup`'. This statement finds all the hggroup objects in the current axes.

```
t = findobj(gca,'Type','hggroup');
```

`UIContextMenu`
handle of a uicontextmenu object

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

`UserData`
array

User-specified data. This property can be any data you want to associate with this object (including cell arrays and structures). The object does not set values for this property, but you can access it using the `set` and `get` functions.

`Visible`
`{on} | off`

Visibility of this object and its children. By default, a new object's visibility is on. This means all children of the object are visible unless the child object's `Visible` property is set to `off`. Setting an object's `Visible` property to `off` prevents the object from being displayed. However, the object still exists and you can set and query its properties.

`XData`
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`

scalar, vector, or matrix

Y-axis limits. This property determines the *y*-axis limits used in the contour plot. If you do not specify a `Y` argument, the `contour` function calculates *y*-axis limits based on the size of the input argument `Z`.

`YData` can be either a matrix equal in size to `ZData` or a vector equal in length to the number of columns in `ZData`.

Use `YData` to define meaningful coordinates for the underlying surface whose topography is being mapped. See "Setting the Axis Limits on Contour Plots" on page 2-623 for more information.

`YDataMode`
{auto} | manual

Use automatic or user-specified y-axis values. In `auto` mode (the default) the `contour` function automatically determines the *y*-axis limits. If you set this property to `manual`, specify a value for `YData`, or specify a `Y` argument, then `contour` sets this property to `manual` and does not change the axis limits.

`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`
matrix

Contour data. This property contains the data from which the contour lines are generated (specified as the input argument `Z`). `ZData` must be at least a 2-by-2 matrix. The number of contour levels and the values of the contour levels are chosen automatically based on the minimum and maximum values of `ZData`. The limits of the *x*- and *y*-axis are `[1:n]` and `[1:m]`, where `[m,n] = size(ZData)`.

`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`.

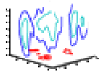
You can use the `refreshdata` function to force an update of the object's data. `refreshdata` also enables you to specify that the data source variable be evaluated in the workspace of a function from which you call `refreshdata`.

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

Draw contours in volume slice planes



GUI Alternatives

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

Syntax

```
contourslice(X,Y,Z,V,Sx,Sy,Sz)
contourslice(X,Y,Z,V,Xi,Yi,Zi)
contourslice(V,Sx,Sy,Sz)
contourslice(V,Xi,Yi,Zi)
contourslice(...,n)
contourslice(...,cvals)
contourslice(...,[cv cv])
contourslice(...,'method')
contourslice(axes_handle,...)
h = contourslice(...)
```

Description

`contourslice(X,Y,Z,V,Sx,Sy,Sz)` draws contours in the *x*-, *y*-, and *z*-axis aligned planes at the points in the vectors `Sx`, `Sy`, `Sz`. The arrays `X`, `Y`, and `Z` define the coordinates for the volume `V` and must be monotonic and 3-D plaid (such as the data produced by `meshgrid`). The color at each contour is determined by the volume `V`, which must be an m-by-n-by-p volume array.

`contourslice(X,Y,Z,V,Xi,Yi,Zi)` draws contours through the volume `V` along the surface defined by the 2-D arrays `Xi,Yi,Zi`. The surface should lie within the bounds of the volume.

`contourslice(V,Sx,Sy,Sz)` and `contourslice(V,Xi,Yi,Zi)` (omitting the `X`, `Y`, and `Z` arguments) assume `[X,Y,Z] = meshgrid(1:n,1:m,1:p)`, where `[m,n,p]= size(v)`.

`contourslice(...,n)` draws `n` contour lines per plane, overriding the automatic value.

`contourslice(...,cvals)` draws `length(cval)` contour lines per plane at the values specified in vector `cvals`.

`contourslice(...,[cv cv])` computes a single contour per plane at the level `cv`.

`contourslice(...,'method')` specifies the interpolation method to use. *`method`* can be `linear`, `cubic`, or `nearest`. `nearest` is the default except when the contours are being drawn along the surface defined by `Xi`, `Yi`, `Zi`, in which case `linear` is the default. (See `interp3` for a discussion of these interpolation methods.)

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

`h = contourslice(...)` returns a vector of handles to `patch` objects that are used to implement the contour lines.

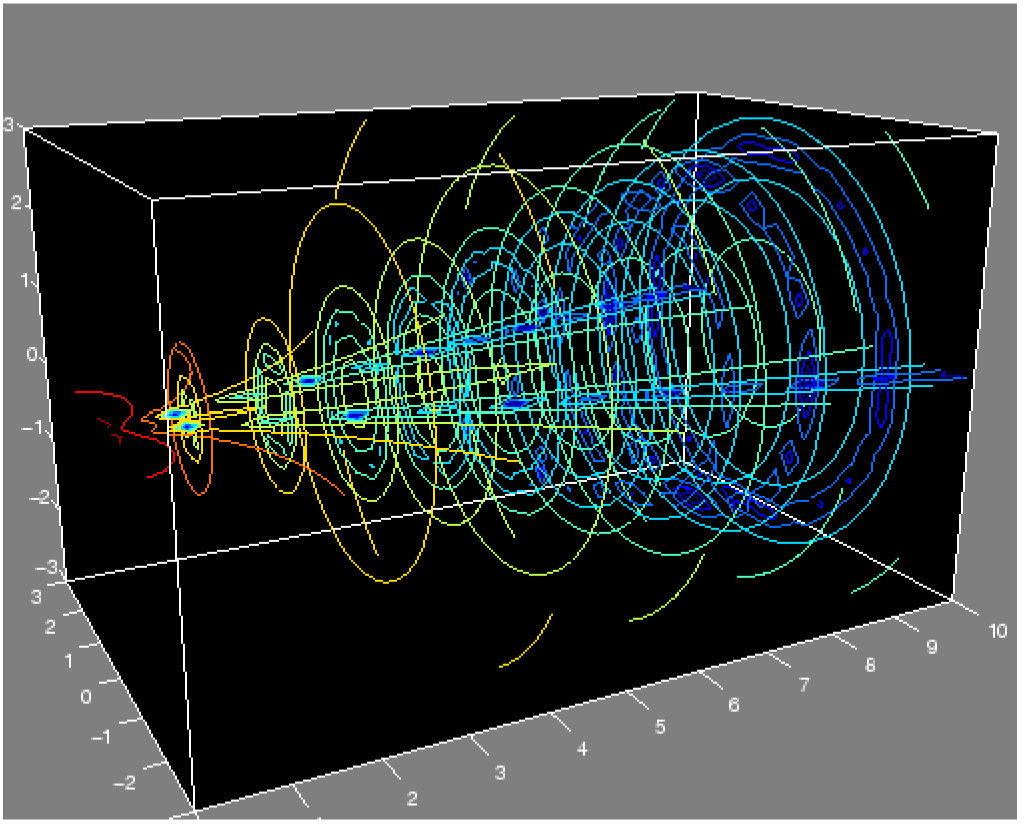
Examples

This example uses the `flow` data set to illustrate the use of contoured slice planes. (Type `doc flow` for more information on this data set.) Notice that this example

- Specifies a vector of `length = 9` for `Sx`, an empty vector for the `Sy`, and a scalar value (0) for `Sz`. This creates nine contour plots along the x direction in the y-z plane, and one in the x-y plane at z = 0.
- Uses `linspace` to define a 10-element vector of linearly spaced values from -8 to 2. This vector specifies that 10 contour lines be drawn, one at each element of the vector.
- Defines the view and projection type (`camva`, `camproj`, `campos`).
- Sets figure (`gcf`) and axes (`gca`) characteristics.

```
[x y z v] = flow;
h = contourslice(x,y,z,v,[1:9],[],[0],linspace(-8,2,10));
axis([0,10,-3,3,-3,3]); daspect([1,1,1])
camva(24); camproj perspective;
```

```
campos([-3,-15,5])
set(gcf,'Color',[.5,.5,.5],'Renderer','zbuffer')
set(gca,'Color','black','XColor','white', ...
 'YColor','white','ZColor','white')
box on
```



This example draws contour slices along a spherical surface within the volume.

```
[x,y,z] = meshgrid(-2:.2:2,-2:.25:2,-2:.16:2);
v = x.*exp(-x.^2-y.^2-z.^2); % Create volume data
```

```
[xi,yi,zi] = sphere; % Plane to contour
contourslice(x,y,z,v,xi,yi,zi)
view(3)
```

See Also

`isosurface`, `slice`, `smooth3`, `subvolume`, `reducevolume`

"Volume Visualization" on page 1-101 for related functions

Purpose

Grayscale colormap for contrast enhancement

Syntax

```
cmap = contrast(X)
cmap = contrast(X,m)
```

Description

The `contrast` function enhances the contrast of an `image`. It creates a new gray colormap, `cmap`, that has an approximately equal intensity distribution. All three elements in each row are identical.

`cmap = contrast(X)` returns a gray colormap that is the same length as the current colormap.

`cmap = contrast(X,m)` returns an `m`-by-3 gray colormap.

Examples

Add contrast to the clown image defined by `X`.

```
load clown;
cmap = contrast(X);
image(X);
colormap(cmap);
```

See Also

`brighten`, `colormap`, `image`

"Colormaps" on page 1-98 for related functions

Purpose Convolution and polynomial multiplication

Syntax

```
w = conv(u,v)
```

Description

`w = conv(u,v)` convolves vectors `u` and `v`. Algebraically, convolution is the same operation as multiplying the polynomials whose coefficients are the elements of `u` and `v`.

Definition

Let `m = length(u)` and `n = length(v)` . Then `w` is the vector of length `m+n-1` whose `k`th element is

$$w(k) = \sum_j u(j)v(k+1-j)$$

The sum is over all the values of `j` which lead to legal subscripts for `u(j)` and `v(k+1-j)`, specifically `j = max(1,k+1-n): min(k,m)`. When `m = n`, this gives

```
w(1) = u(1)*v(1)
w(2) = u(1)*v(2)+u(2)*v(1)
w(3) = u(1)*v(3)+u(2)*v(2)+u(3)*v(1)
...
w(n) = u(1)*v(n)+u(2)*v(n-1)+ ... +u(n)*v(1)
...
w(2*n-1) = u(n)*v(n)
```

Algorithm

The convolution theorem says, roughly, that convolving two sequences is the same as multiplying their Fourier transforms. In order to make this precise, it is necessary to pad the two vectors with zeros and ignore roundoff error. Thus, if

```
X = fft([x zeros(1,length(y)-1)])
```

and

```
Y = fft([y zeros(1,length(x)-1)])
```

then `conv(x,y) = ifft(X.*Y)`

See Also `conv2`, `convn`, `deconv`, `filter`

`convmtx` and `xcorr` in the Signal Processing Toolbox

Purpose

2-D convolution

Syntax

```
C = conv2(A,B)
C = conv2(hcol,hrow,A)
C = conv2(...,'shape')
```

Description

`C = conv2(A,B)` computes the two-dimensional convolution of matrices `A` and `B`. If one of these matrices describes a two-dimensional finite impulse response (FIR) filter, the other matrix is filtered in two dimensions.

The size of `C` in each dimension is equal to the sum of the corresponding dimensions of the input matrices, minus one. That is, if the size of `A` is `[ma,na]` and the size of `B` is `[mb,nb]`, then the size of `C` is `[ma+mb-1,na+nb-1]`.

The value of an element of `C` is the sum of the element-wise product of `B` and the elements in the *neighborhood* of the corresponding element of `A`. For any `A(i,j)`, if you overlay `B` on `A` with the center element of `B` over `A(i,j)`, the neighborhood of `A(i,j)` includes all the elements of A that are under an element of `B`. `A` is padded with zeros if necessary.

The indices of the center element of B are defined as `floor(([mb nb]+1)/2)`.

`C = conv2(hcol,hrow,A)` convolves `A` first with the vector `hcol` along the rows and then with the vector `hrow` along the columns. If `hcol` is a column vector and `hrow` is a row vector, this case is the same as `C = conv2(hcol*hrow,A)`.

`C = conv2(...,'shape')` returns a subsection of the two-dimensional convolution, as specified by the `shape` parameter:

`full`	Returns the full two-dimensional convolution (default).
`same`	Returns the central part of the convolution of the same size as `A`.
`valid`	Returns only those parts of the convolution that are computed without the zero-padded edges. Using this option, `C` has size `[ma-mb+1,na-nb+1]` when `all(size(A) >= size(B))`. Otherwise `conv2` returns `[]`.

Note If any of `A`, `B`, `hcol`, and `hrow` are empty, then `C` is an empty matrix `[]`.

Algorithm

`conv2` uses a straightforward formal implementation of the two-dimensional convolution equation in spatial form. If a and b are functions of two discrete variables, n_1 and n_2, then the formula for the two-dimensional convolution of a and b is

$$c(n_1, n_2) = \sum_{k_1 = -\infty}^{\infty} \sum_{k_2 = -\infty}^{\infty} a(k_1, k_2)\, b(n_1 - k_1, n_2 - k_2)$$

In practice however, `conv2` computes the convolution for finite intervals.

Note that matrix indices in MATLAB always start at 1 rather than 0. Therefore, matrix elements `A(1,1)`, `B(1,1)`, and `C(1,1)` correspond to mathematical quantities a (0,0), b (0,0), and c (0,0).

Examples

Example 1

For the `'same'` case, `conv2` returns the central part of the convolution. If there are an odd number of rows or columns, the “center” leaves one more at the beginning than the end.

This example first computes the convolution of A using the default ('full') shape, then computes the convolution using the 'same' shape. Note that the array returned using 'same' corresponds to the underlined elements of the array returned using the default shape.

```
A = rand(3);
B = rand(4);
C = conv2(A,B)          % C is 6-by-6

C =
   0.1838  0.2374  0.9727  1.2644  0.7890  0.3750
   0.6929  1.2019  1.5499  2.1733  1.3325  0.3096
   0.5627  1.5150  2.3576  3.1553  2.5373  1.0602
   0.9986  2.3811  3.4302  3.5128  2.4489  0.8462
   0.3089  1.1419  1.8229  2.1561  1.6364  0.6841
   0.3287  0.9347  1.6464  1.7928  1.2422  0.5423

Cs = conv2(A,B,'same')   % Cs is the same size as A: 3-by-3
Cs =
   2.3576  3.1553  2.5373
   3.4302  3.5128  2.4489
   1.8229  2.1561  1.6364
```

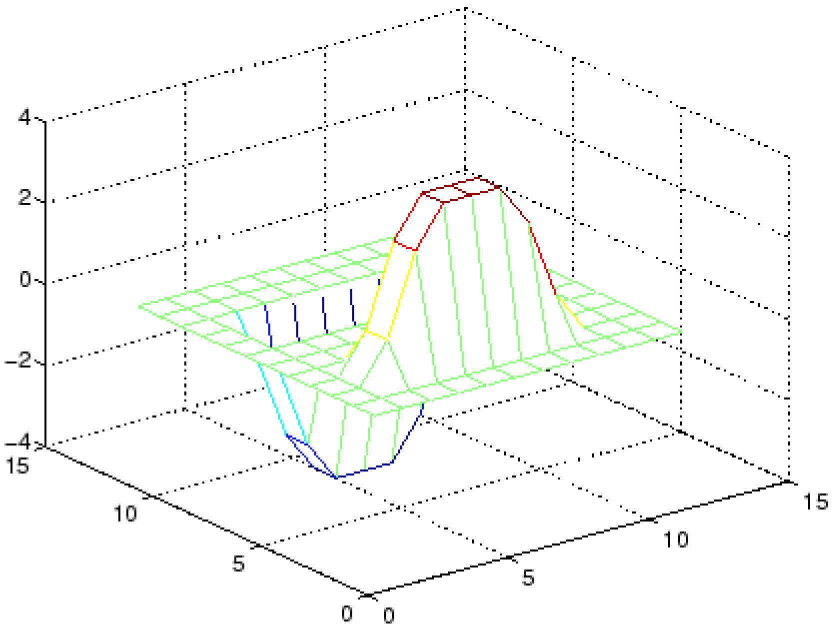
Example 2

In image processing, the Sobel edge finding operation is a two-dimensional convolution of an input array with the special matrix

```
s = [1 2 1; 0 0 0; -1 -2 -1];
```

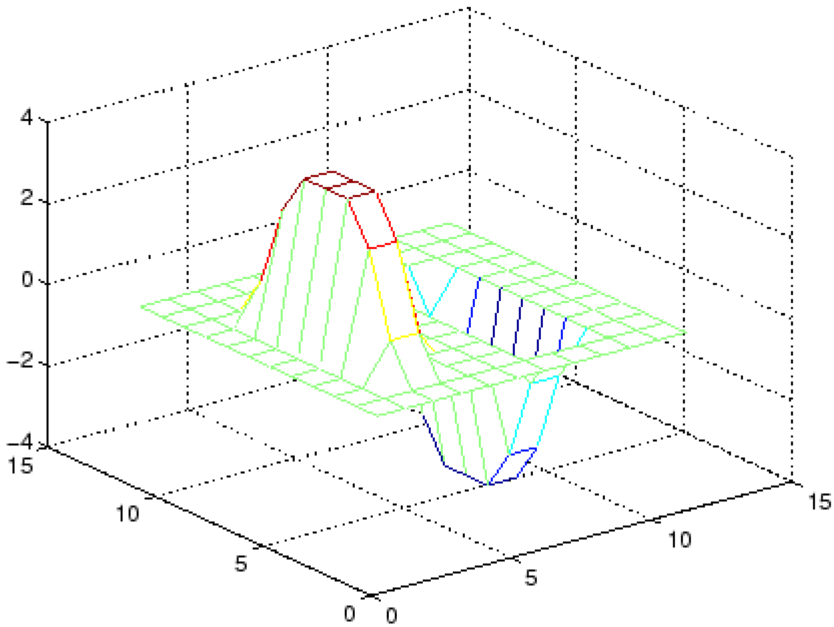
These commands extract the horizontal edges from a raised pedestal.

```
A = zeros(10);
A(3:7,3:7) = ones(5);
H = conv2(A,s);
mesh(H)
```



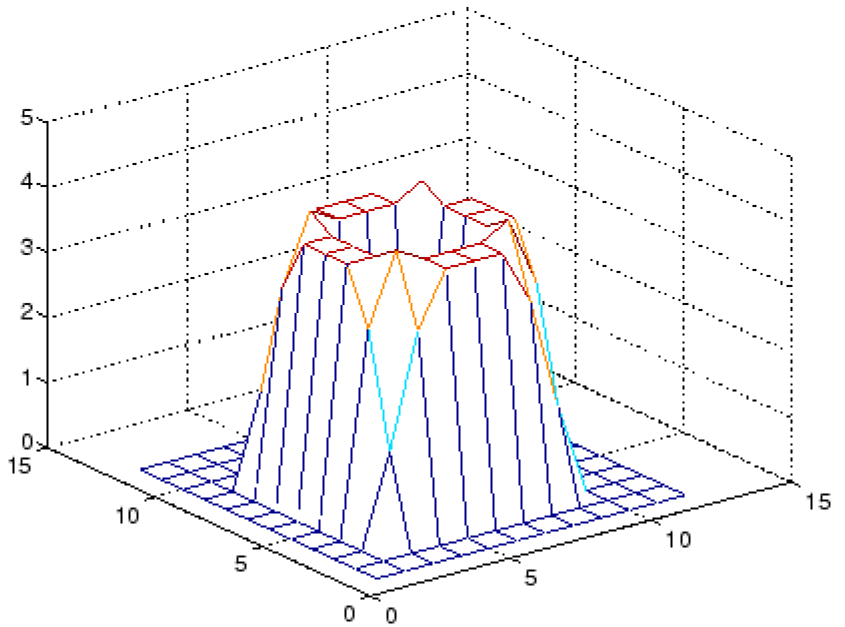
Transposing the filter `s` extracts the vertical edges of `A`.

```
V = conv2(A,s');
figure, mesh(V)
```



This figure combines both horizontal and vertical edges.

```
figure
mesh(sqrt(H.^2 + V.^2))
```



See Also

`conv`, `convn`, `filter2`

`xcorr2` in the Signal Processing Toolbox

Purpose Convex hull

Syntax

```
K = convhull(x,y)
K = convhull(x,y,options)
[K,a] = convhull(...)
```

Description `K = convhull(x,y)` returns indices into the `x` and `y` vectors of the points on the convex hull.

`convhull` uses Qhull.

`K = convhull(x,y,options)` specifies a cell array of strings `options` to be used in Qhull via `convhulln`. The default option is `{'Qt'}`.

If `options` is `[]`, the default options are used. If `options` is `{''}`, no options will be used, not even the default. For more information on Qhull and its options, see `http://www.qhull.org`.

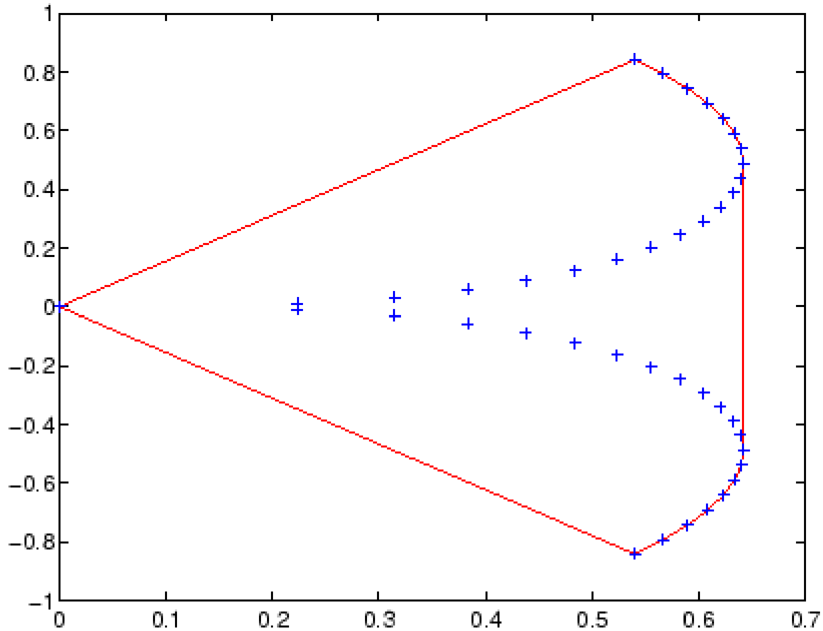
`[K,a] = convhull(...)` also returns the area of the convex hull.

Visualization Use `plot` to plot the output of `convhull`.

Examples

Example 1

```
xx = -1:.05:1; yy = abs(sqrt(xx));
[x,y] = pol2cart(xx,yy);
k = convhull(x,y);
plot(x(k),y(k),'r-',x,y,'b+')
```



Example 2

The following example illustrates the `options` input for `convhull`. The following commands

```
X = [0 0 0 1];
Y = [0 1e-10 0 1];
K = convhull(X,Y)
```

return a warning.

```
Warning: qhull precision warning:
The initial hull is narrow (cosine of min. angle is
0.9999999999999998).
A coplanar point may lead to a wide facet. Options 'QbB' (scale
to unit box)
or 'Qbb' (scale last coordinate) may remove this warning. Use 'Pp'
to skip
```

```
this warning.
```

To suppress this warning, use the option `'Pp'`. The following command passes the option `'Pp'`, along with the default `'Qt'`, to `convhull`.

```
K = convhull(X,Y,{'Qt','Pp'})

K =

     2
     1
     4
     2
```

Algorithm

`convhull` is based on Qhull [1]. For information about Qhull, see `http://www.qhull.org/`. For copyright information, see `http://www.qhull.org/COPYING.txt`.

See Also

`convhulln`, `delaunay`, `plot`, `polyarea`, `voronoi`

Reference

[1] Barber, C. B., D.P. Dobkin, and H.T. Huhdanpaa, "The Quickhull Algorithm for Convex Hulls," *ACM Transactions on Mathematical Software*, Vol. 22, No. 4, Dec. 1996, p. 469-483. Available in PDF format at `http://www.acm.org/pubs/citations/journals/toms/1996-22-4/p469-barber`.

[2] National Science and Technology Research Center for Computation and Visualization of Geometric Structures (The Geometry Center), *University of Minnesota*, 1993.

Purpose

N-D convex hull

Syntax

```
K = convhulln(X)
K = convulln(X, options)
[K, v] = convhulln(...)
```

Description

`K = convhulln(X)` returns the indices `K` of the points in `X` that comprise the facets of the convex hull of `X`. `X` is an `m`-by-`n` array representing `m` points in N-dimensional space. If the convex hull has `p` facets then `K` is `p`-by-`n`.

`convhulln` uses Qhull.

`K = convulln(X, options)` specifies a cell array of strings `options` to be used as options in Qhull. The default options are:

- `{'Qt'}` for 2-, 3-. and 4-dimensional input
- `{'Qt','Qx'}` for 5-dimensional input and higher.

If `options` is `[]`, the default options are used. If `options` is `{''}`, no options are used, not even the default. For more information on Qhull and its options, see `http://www.qhull.org/`.

`[K, v] = convhulln(...)` also returns the volume `v` of the convex hull.

Visualization

Plotting the output of `convhulln` depends on the value of `n`:

- For `n = 2`, use `plot` as you would for `convhull`.
- For `n = 3`, you can use `trisurf` to plot the output. The calling sequence is

  ```
  K = convhulln(X);
  trisurf(K,X(:,1),X(:,2),X(:,3))
  ```

  For more control over the color of the facets, use `patch` to plot the output. For an example, see "Tessellation and Interpolation of Scattered Data in Higher Dimensions" in the MATLAB documentation.

- You cannot plot `convhulln` output for `n > 3`.

Example

The following example illustrates the `options` input for `convhulln`. The following commands

```
X = [0 0; 0 1e-10; 0 0; 1 1];
K = convhulln(X)
```

return a warning.

```
Warning: qhull precision warning:
The initial hull is narrow
(cosine of min. angle is 0.9999999999999998).
A coplanar point may lead to a wide facet.
Options 'QbB' (scale to unit box) or 'Qbb'
(scale last coordinate) may remove this warning.
Use 'Pp' to skip this warning.
```

To suppress the warning, use the option `'Pp'`. The following command passes the option `'Pp'`, along with the default `'Qt'`, to `convhulln`.

```
K = convhulln(X,{'Qt','Pp'})

K =

     1     4
     1     2
     4     2
```

Algorithm

`convhulln` is based on Qhull [1]. For information about Qhull, see `http://www.qhull.org/`. For copyright information, see `http://www.qhull.org/COPYING.txt`.

See Also

`convhull`, `delaunayn`, `dsearchn`, `tsearchn`, `voronoin`

Reference

[1] Barber, C. B., D.P. Dobkin, and H.T. Huhdanpaa, “The Quickhull Algorithm for Convex Hulls,” ACM *Transactions on Mathematical Software*, Vol. 22, No. 4, Dec. 1996, p. 469-483.

Purpose

N-D convolution

Syntax

```
C = convn(A,B)
C = convn(A,B,'shape')
```

Description

`C = convn(A,B)` computes the N-dimensional convolution of the arrays `A` and `B`. The size of the result is `size(A)+size(B)-1`.

`C = convn(A,B,'shape')` returns a subsection of the N-dimensional convolution, as specified by the `shape` parameter:

`'full'`	Returns the full N-dimensional convolution (default).
`'same'`	Returns the central part of the result that is the same size as `A`.
`'valid'`	Returns only those parts of the convolution that can be computed without assuming that the array A is zero-padded. The size of the result is `max(size(A)-size(B) + 1, 0)`

See Also

`conv`, `conv2`

Purpose

Copy file or directory

Graphical Interface

In the Current Directory browser, select **Edit > Copy**, then **Paste**. See details.

Syntax

```
copyfile('source','destination')
copyfile('source','destination','f')
[status,message,messageid] = copyfile('source','destination',
   'f')
```

Description

`copyfile('source','destination')` copies the file or directory, `source` (and all its contents) to the file or directory, `destination`, where `source` and `destination` are the absolute or relative pathnames for the directory or file. If `source` is a directory, `destination` cannot be a file. If `source` is a directory, `copyfile` copies the contents of `source`, not the directory itself. To rename a file or directory when copying it, make `destination` a different name than `source`. If `destination` already exists, `copyfile` replaces it without warning. Use the wildcard `*` at the end of `source` to copy all matching files. Note that the read-only and archive attributes of `source` are not preserved in `destination`.

`copyfile('source','destination','f')` copies `source` to `destination`, regardless of the read-only attribute of `destination`.

`[status,message,messageid] = copyfile('source','destination','f')` copies `source` to `destination`, returning the status, a message, and the MATLAB error message ID (see `error` and `lasterror`). Here, `status` is `1` for success and `0` for error. Only one output argument is required and the `f` input argument is optional.

Remarks

The `*` wildcard in a path string is supported. Current behavior of `copyfile` differs between UNIX and Windows when using the wildcard `*` or copying directories.

The timestamp given to the `destination` file is identical to that taken from the `source` file.

Examples

Copy File in Current Directory, Assigning a New Name to It

To make a copy of a file `myfun.m` in the current directory, assigning it the name `myfun2.m`, type

```
copyfile('myfun.m','myfun2.m')
```

Copy File to Another Directory

To copy `myfun.m` to the directory `d:/work/myfiles`, keeping the same filename, type

```
copyfile('myfun.m','d:/work/myfiles')
```

Copy All Matching Files by Using a Wildcard

To copy all files in the directory `myfiles` whose names begin with my to the directory `newprojects`, where `newprojects` is at the same level as the current directory, type

```
copyfile('myfiles/my*','../newprojects')
```

Copy Directory and Return Status

In this example, all files and subdirectories in the current directory's `myfiles` directory are copied to the `directory d:/work/myfiles`. Note that before running the `copyfile` function, `d:/work` does not contain the directory `myfiles`. It is created because `myfiles` is appended to `destination` in the `copyfile` function:

```
[s,mess,messid]=copyfile('myfiles','d:/work/myfiles')
s =
     1

mess =
     ''

messid =
     ''
```

The message returned indicates that `copyfile` was successful.

Copy File to Read-Only Directory

Copy `myfile.m` from the current directory to `d:/work/restricted`, where `restricted` is a read-only directory:

```
copyfile('myfile.m','d:/work/restricted','f')
```

After the copy, `myfile.m` exists in `d:/work/restricted`.

See Also

`cd`, `delete`, `dir`, `fileattrib`, `filebrowser`, `fileparts`, `mkdir`, `movefile`, `rmdir`

Purpose Copy graphics objects and their descendants

Syntax

```
new_handle = copyobj(h,p)
```

Description

`copyobj` creates copies of graphics objects. The copies are identical to the original objects except the copies have different values for their `Parent` property and a new handle. The new parent must be appropriate for the copied object (e.g., you can copy a line object only to another axes object).

`new_handle = copyobj(h,p)` copies one or more graphics objects identified by `h` and returns the handle of the new object or a vector of handles to new objects. The new graphics objects are children of the graphics objects specified by `p`.

Remarks

`h` and `p` can be scalars or vectors. When both are vectors, they must be the same length, and the output argument, `new_handle`, is a vector of the same length. In this case, `new_handle(i)` is a copy of `h(i)` with its `Parent` property set to `p(i)`.

When `h` is a scalar and `p` is a vector, `h` is copied once to each of the parents in `p`. Each `new_handle(i)` is a copy of `h` with its `Parent` property set to `p(i)`, and `length(new_handle)` equals `length(p)`.

When `h` is a vector and `p` is a scalar, each `new_handle(i)` is a copy of `h(i)` with its `Parent` property set to `p`. The length of `new_handle` equals `length(h)`.

Graphics objects are arranged as a hierarchy. See "Handle Graphics Objects" for more information.

Examples

Copy a surface to a new axes within a different figure.

```
h = surf(peaks);
colormap hot
figure    % Create a new figure
axes    % Create an axes object in the figure
new_handle = copyobj(h,gca);
```

```
colormap hot
view(3)
grid on
```

Note that while the surface is copied, the `colormap` (`figure` property), `view`, and `grid` (`axes` properties) are not copies.

See Also

`findobj`, `gcf`, `gca`, `gco`, `get`, `set`

`Parent` property for all graphics objects

"Finding and Identifying Graphics Objects" on page 1-92 for related functions

corrcoef

Purpose

Correlation coefficients

Syntax

```
R = corrcoef(X)
R = corrcoef(x,y)
[R,P]=corrcoef(...)
[R,P,RLO,RUP]=corrcoef(...)
[...]=corrcoef(...,'param1',val1,'param2',val2,...)
```

Description

`R = corrcoef(X)` returns a matrix `R` of correlation coefficients calculated from an input matrix `X` whose rows are observations and whose columns are variables. The matrix `R = corrcoef(X)` is related to the covariance matrix `C = cov(X)` by

$$R(i, j) = \frac{C(i, j)}{\sqrt{C(i, i)C(j, j)}}$$

`corrcoef(X)` is the zeroth lag of the normalized covariance function, that is, the zeroth lag of `xcov(x,'coeff')` packed into a square array.

`R = corrcoef(x,y)` where `x` and `y` are column vectors is the same as `corrcoef([x y])`.

`[R,P]=corrcoef(...)` also returns `P`, a matrix of p-values for testing the hypothesis of no correlation. Each p-value is the probability of getting a correlation as large as the observed value by random chance, when the true correlation is zero. If `P(i,j)` is small, say less than `0.05`, then the correlation `R(i,j)` is significant.

`[R,P,RLO,RUP]=corrcoef(...)` also returns matrices `RLO` and `RUP`, of the same size as `R`, containing lower and upper bounds for a 95% confidence interval for each coefficient.

`[...]=corrcoef(...,'param1',val1,'param2',val2,...)` specifies additional parameters and their values. Valid parameters are the following.

'alpha'	A number between 0 and 1 to specify a confidence level of 100*(1 - alpha)%. Default is 0.05 for 95% confidence intervals.
'rows'	Either 'all' (default) to use all rows, 'complete' to use rows with no NaN values, or 'pairwise' to compute R(i,j) using rows with no NaN values in either column i or j.

The p-value is computed by transforming the correlation to create a t statistic having n-2 degrees of freedom, where n is the number of rows of X. The confidence bounds are based on an asymptotic normal distribution of 0.5*log((1+R)/(1-R)), with an approximate variance equal to 1/(n-3). These bounds are accurate for large samples when X has a multivariate normal distribution. The 'pairwise' option can produce an R matrix that is not positive definite.

Examples

Generate random data having correlation between column 4 and the other columns.

```
x = randn(30,4);     % Uncorrelated data
x(:,4) = sum(x,2);   % Introduce correlation.
[r,p] = corrcoef(x)  % Compute sample correlation and p-values.
[i,j] = find(p<0.05);  % Find significant correlations.
[i,j]                % Display their (row,col) indices.

r =
    1.0000   -0.3566    0.1929    0.3457
   -0.3566    1.0000   -0.1429    0.4461
    0.1929   -0.1429    1.0000    0.5183
    0.3457    0.4461    0.5183    1.0000

p =
    1.0000    0.0531    0.3072    0.0613
    0.0531    1.0000    0.4511    0.0135
    0.3072    0.4511    1.0000    0.0033
    0.0613    0.0135    0.0033    1.0000
```

```
ans =
     4     2
     4     3
     2     4
     3     4
```

See Also

`cov`, `mean`, `median`, `std`, `var`

`xcorr`, `xcov` in the Signal Processing Toolbox

Purpose

Cosine of argument in radians

Syntax

```
Y = cos(X)
```

Description

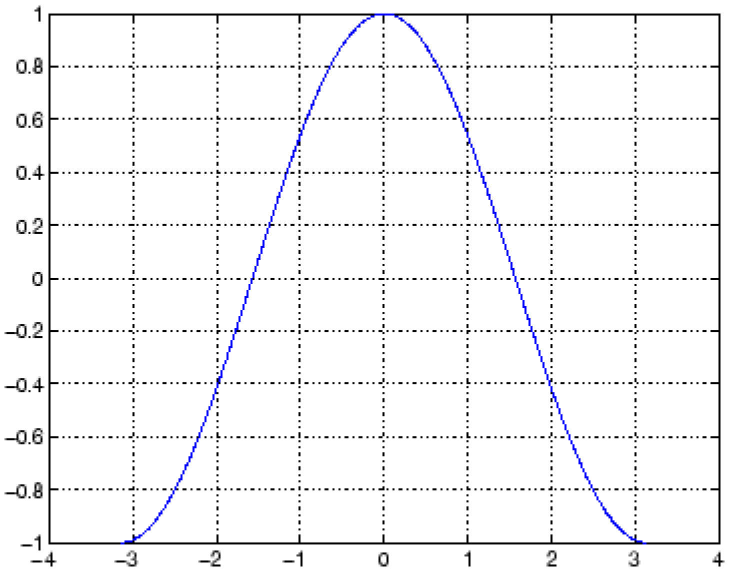
The `cos` function operates element-wise on arrays. The function's domains and ranges include complex values. All angles are in radians.

`Y = cos(X)` returns the circular cosine for each element of `X`.

Examples

Graph the cosine function over the domain $-\pi \leq x \leq \pi$.

```
x = -pi:0.01:pi;
plot(x,cos(x)), grid on
```



The expression `cos(pi/2)` is not exactly zero but a value the size of the floating-point accuracy, `eps`, because `pi` is only a floating-point approximation to the exact value of π.

Definition

The cosine can be defined as

$$\cos(x+iy) = \cos(x)\cosh(y) - i\sin(x)\sinh(y)$$

$$\cos(z) = \frac{e^{iz}+e^{-iz}}{2}$$

Algorithm

`cos` 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

`cosd`, `cosh`, `acos`, `acosd`, `acosh`

Purpose

Cosine ofo argument in degrees

Syntax

```
Y = cosd(X)
```

Description

`Y = cosd(X)` is the cosine of the elements of `X`, expressed in degrees. For odd integers `n`, `cosd(n*90)` is exactly zero, whereas `cos(n*pi/2)` reflects the accuracy of the floating point value of `pi`.

See Also

`cos`, `cosh`, `acos`, `acosd`, `acosh`

Purpose Hyperbolic cosine

Syntax

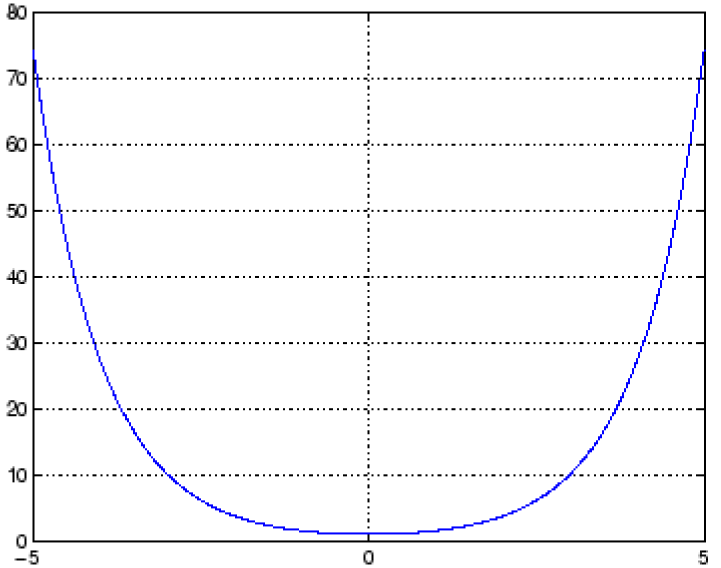
```
Y = cosh(X)
```

Description The `cosh` function operates element-wise on arrays. The function's domains and ranges include complex values. All angles are in radians.

`Y = cosh(X)` returns the hyperbolic cosine for each element of `X`.

Examples Graph the hyperbolic cosine function over the domain $-5 \le x \le 5$.

```
x = -5:0.01:5;
plot(x,cosh(x)), grid on
```



Definition The hyperbolic cosine can be defined as

$$\cosh(z) = \frac{e^{z} + e^{-z}}{2}$$

Algorithm

`cosh` 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

`acos`, `acosh`, `cos`

Purpose Cotangent of argument in radians

Syntax

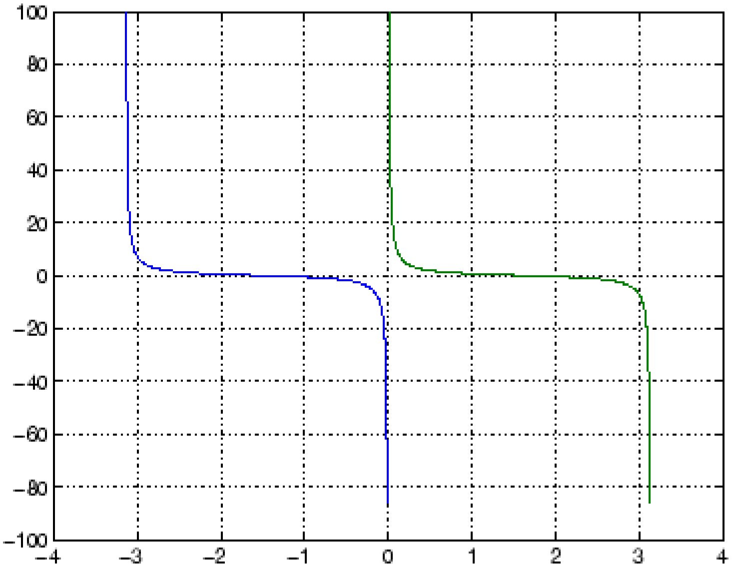
```
Y = cot(X)
```

Description The `cot` function operates element-wise on arrays. The function's domains and ranges include complex values. All angles are in radians.

`Y = cot(X)` returns the cotangent for each element of `X`.

Examples Graph the cotangent the domains $-\pi < x < 0$ and $0 < x < \pi$.

```
x1 = -pi+0.01:0.01:-0.01;
x2 = 0.01:0.01:pi-0.01;
plot(x1,cot(x1),x2,cot(x2)), grid on
```



Definition The cotangent can be defined as

$$\cot(z) = \frac{1}{\tan(z)}$$

Algorithm

`cot` 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

`cotd`, `coth`, `acot`, `acotd`, `acoth`

cotd

Purpose Cotangent of argument in degrees

Syntax

```
Y = cotd(X)
```

Description `Y = cotd(X)` is the cotangent of the elements of `X`, expressed in degrees. For integers `n`, `cotd(n*180)` is infinite, whereas `cot(n*pi)` is large but finite, reflecting the accuracy of the floating point value of `pi`.

See Also `cot`, `coth`, `acot`, `acotd`, `acoth`

Purpose

Hyperbolic cotangent

Syntax

```
Y = coth(X)
```

Description

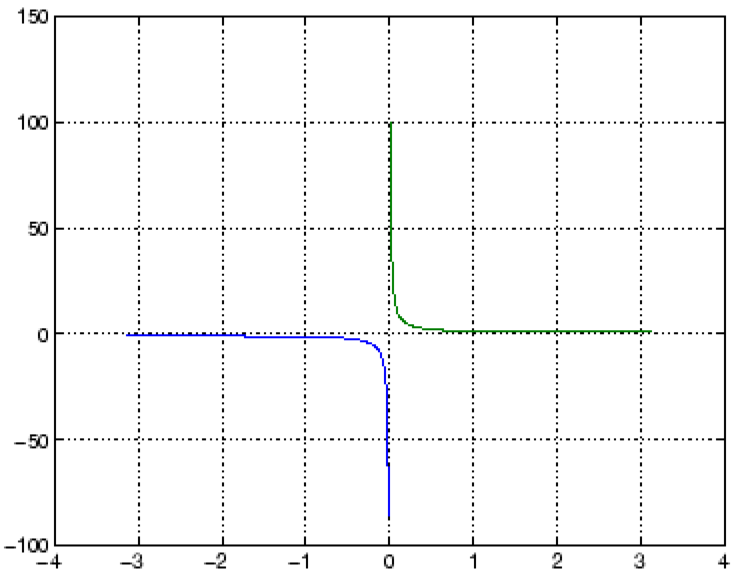
The `coth` function operates element-wise on arrays. The function's domains and ranges include complex values. All angles are in radians.

`Y = coth(X)` returns the hyperbolic cotangent for each element of `X`.

Examples

Graph the hyperbolic cotangent over the domains $-\pi < x < 0$ and $0 < x < \pi$.

```
x1 = -pi+0.01:0.01:-0.01;
x2 = 0.01:0.01:pi-0.01;
plot(x1,coth(x1),x2,coth(x2)), grid on
```



Definition

The hyperbolic cotangent can be defined as

$$\coth(z) = \frac{1}{\tanh(z)}$$

Algorithm

coth 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

acot, acoth, cot

Purpose Covariance matrix

Syntax

```
cov(x)
cov(x) or cov(x,y)
cov(x,1) or cov(x,y,1)
```

Description `cov(x)`, if `X` is a vector, returns the variance. For matrices, where each row is an observation, and each column is a variable, `cov(X)` is the covariance matrix. `diag(cov(X))` is a vector of variances for each column, and `sqrt(diag(cov(X)))` is a vector of standard deviations. `cov(X,Y)`, where `X` and `Y` are matrices with the same number of elements, is equivalent to `cov([X(:)  Y(:)])`.

`cov(x) or cov(x,y)` normalizes by N-1, if N>1, where N is the number of observations. This makes `cov(X)` the best unbiased estimate of the covariance matrix if the observations are from a normal distribution. For N=1, `cov normalizes by N`.

`cov(x,1) or cov(x,y,1)` normalizes by N and produces the second moment matrix of the observations about their mean. `cov(X,Y,0)` is the same as `cov(X,Y)` and `cov(X,0)` is the same as `cov(X)`.

Remarks `cov` removes the mean from each column before calculating the result.

The *covariance* function is defined as

$$\mathrm{cov}(x_1,x_2) = E[(x_1-\mu_1)(x_2-\mu_2)]$$

where E is the mathematical expectation and $\mu_i = Ex_i$.

Examples Consider `A = [-1 1 2 ; -2 3 1 ; 4 0 3]`. To obtain a vector of variances for each column of `A`:

```
v = diag(cov(A))'
v =
   10.3333    2.3333    1.0000
```

Compare vector `v` with covariance matrix `C`:

```
C =
   10.3333   -4.1667    3.0000
   -4.1667    2.3333   -1.5000
    3.0000   -1.5000    1.0000
```

The diagonal elements `C(i,i)` represent the variances for the columns of `A`. The off-diagonal elements `C(i,j)` represent the covariances of columns `i` and `j`.

See Also

`corrcoef`, `mean`, `median`, `std`, `var`

`xcorr`, `xcov` in the Signal Processing Toolbox

Purpose

Sort complex numbers into complex conjugate pairs

Syntax

```
B = cplxpair(A)
B = cplxpair(A,tol)
B = cplxpair(A,[],dim)
B = cplxpair(A,tol,dim)
```

Description

`B = cplxpair(A)` sorts the elements along different dimensions of a complex array, grouping together complex conjugate pairs.

The conjugate pairs are ordered by increasing real part. Within a pair, the element with negative imaginary part comes first. The purely real values are returned following all the complex pairs. The complex conjugate pairs are forced to be exact complex conjugates. A default tolerance of `100*eps` relative to `abs(A(i))` determines which numbers are real and which elements are paired complex conjugates.

If `A` is a vector, `cplxpair(A)` returns `A` with complex conjugate pairs grouped together.

If `A` is a matrix, `cplxpair(A)` returns `A` with its columns sorted and complex conjugates paired.

If `A` is a multidimensional array, `cplxpair(A)` treats the values along the first non-singleton dimension as vectors, returning an array of sorted elements.

`B = cplxpair(A,tol)` overrides the default tolerance.

`B = cplxpair(A,[],dim)` sorts `A` along the dimension specified by scalar dim.

`B = cplxpair(A,tol,dim)` sorts `A` along the specified dimension and overrides the default tolerance.

Diagnostics

If there are an odd number of complex numbers, or if the complex numbers cannot be grouped into complex conjugate pairs within the tolerance, `cplxpair` generates the error message

```
Complex numbers can't be paired.
```

cputime

Purpose

Elapsed CPU time

Syntax

```
cputime
```

Description

`cputime` returns the total CPU time (in seconds) used by MATLAB from the time it was started. This number can overflow the internal representation and wrap around.

Remarks

Although it is possible to measure performance using the `cputime` function, it is recommended that you use the `tic` and `toc` functions for this purpose exclusively. See Using tic and toc Versus the cputime Function in the MATLAB Programming documentation for more information.

Examples

The following code returns the CPU time used to run `surf(peaks(40))`.

```
t = cputime; surf(peaks(40)); e = cputime-t

e =
     0.4667
```

See Also

`clock`, `etime`, `tic`, `toc`

Purpose

Create MATLAB object based on WSDL file

Syntax

```
createClassFromWsdl('source')
```

Description

`createClassFromWsdl('source')` creates a MATLAB object based on a Web Services Description Language (WSDL) application program interface (API). The `source` argument specifies a URL or path to a WSDL API, which defines Web service methods, arguments, and transactions. It returns the name of the new class.

Based on the WSDL API, the `createClassFromWsdl` function creates a new folder in the current directory. The folder contains an M-file for each Web service method. In addition, two default M-files are created: the object's display method (`display.m`) and its constructor (`servicename.m`).

For example, if `myWebService` offers two methods (`method1` and `method2`), the `createClassFromWsdl` function creates

- `@myWebService` folder in the current directory
- `method1.m` — M-file for `method1`
- `method2.m` — M-file for `method2`
- `display.m` — Default M-file for `display` method
- `myWebService.m` — Default M-file for the `myWebService` MATLAB object

Remarks

For more information about WSDL and Web services, see the following resources:

- World Wide Web Consortium (W3C) WSDL specification
- W3C SOAP specification
- XMethods

Example

The following example calls a Web service that returns the stock price for an stock symbol.

```
cd(tempdir)
% Create a class for the Web service
% provided by xmethods.net
url = 'http://services.xmethods.net/soap/
  urn:xmethods-delayed-quotes.wsdl';
createClassFromWsdl(url);
% Instantiate the object
service = StockQuoteService;
% getQuote returns the price of a stock
getQuote(service, 'GOOG');
```

See Also

`callSoapService`, `createSoapMessage`, `parseSoapResponse`

Purpose Create copy of `inputParser` object

Syntax

```
p.createCopy
createCopy(p)
```

Description `p.createCopy` creates a copy of `inputParser` object `p`. Because the `inputParser` class uses handle semantics, a normal assignment statement does not create a copy.

`createCopy(p)` is functionally the same as the syntax above.

Note For more information on the `inputParser` class, see Parsing Inputs with inputParser in the MATLAB Programming documentation.

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

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

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

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

Make a copy of object `p`, assigning it to variable `x`. Use the `Parameters` property of `inputParser` to list the arguments belonging to each object:

```
disp(' ')
```

```
disp 'The input parameters for object p are'
disp(p.Parameters')

x = p.createCopy;

disp(' ')
disp 'The input parameters for the copy of object p are'
disp(x.Parameters')
```

Save the M-file using the **Save** option on the MATLAB **File** menu, and then run it:

```
publish_ip('ipscript.m', 'ppt', 'maxWidth', 500, 'MAXHeight', 300);

The input parameters for object p are
    'format'
    'maxHeight'
    'maxWidth'
    'outputDir'
    'script'

The input parameters for the copy of object p are
    'format'
    'maxHeight'
    'maxWidth'
    'outputDir'
    'script'
```

See Also

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

Purpose Create SOAP message to send to server

Syntax

```
createSoapMessage(namespace, method, values, names, types,
   style)
```

Description `createSoapMessage(namespace, method, values, names, types, style)` creates a SOAP message. `values`, `names`, and `types` are cell arrays. `names` defaults to dummy names and `types` defaults to unspecified. The optional *`style`* argument specifies '**`document`**' or '**`rpc`**' messages; **`rpc`** is the default.

Example

```
message = createSoapMessage(...
 'urn:xmethods-delay-quotes',...
 'getQuote', ...
 {'GOOG'}, ...
 {'symbol'}, ...
 {'http://www.w3.org/2001/XMLSchema}string'}, ...
 'rpc');
response = callSoapService( ...
 'http://64.124.140.30:9090/soap', ...
 'urn:xmethods-delayed-quotes#getQuote' ...
 message);
price = parseSoapResponse(response)
```

See Also `callSoapService`, `createClassFromWsdl`, `parseSoapResponse`

Purpose

Vector cross product

Syntax

```
C = cross(A,B)
C = cross(A,B,dim)
```

Description

`C = cross(A,B)` returns the cross product of the vectors `A` and `B`. That is, `C = A x B`. `A` and `B` must be 3-element vectors. If `A` and `B` are multidimensional arrays, `cross` returns the cross product of `A` and `B` along the first dimension of length 3.

`C = cross(A,B,dim)` where `A` and `B` are multidimensional arrays, returns the cross product of `A` and `B` in dimension `dim`. `A` and `B` must have the same size, and both `size(A,dim)` and `size(B,dim)` must be 3.

Remarks

To perform a dot (scalar) product of two vectors of the same size, use `c = dot(a,b)`.

Examples

The cross and dot products of two vectors are calculated as shown:

```
a = [1 2 3];
b = [4 5 6];
c = cross(a,b)

c =
      -3     6    -3

d = dot(a,b)

d =
      32
```

See Also

`dot`

Purpose

Cosecant of argument in radians

Syntax

```
Y = csc(x)
```

Description

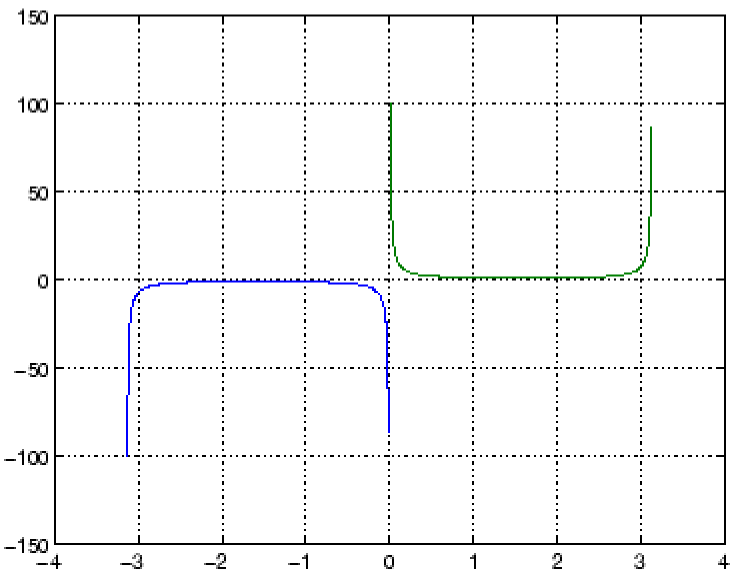
The `csc` function operates element-wise on arrays. The function's domains and ranges include complex values. All angles are in radians.

`Y = csc(x)` returns the cosecant for each element of `x`.

Examples

Graph the cosecant over the domains $-\pi < x < 0$ and $0 < x < \pi$.

```
x1 = -pi+0.01:0.01:-0.01;
x2 = 0.01:0.01:pi-0.01;
plot(x1,csc(x1),x2,csc(x2)), grid on
```



Definition

The cosecant can be defined as

$$\csc(z) = \frac{1}{\sin(z)}$$

Algorithm

`csc` 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

`cscd`, `csch`, `acsc`, `acscd`, `acsch`

Purpose Cosecant of argument in degrees

Syntax

```
Y = cscd(X)
```

Description `Y = cscd(X)` is the cosecant of the elements of `X`, expressed in degrees. For integers `n`, `cscd(n*180)` is infinite, whereas `csc(n*pi)` is large but finite, reflecting the accuracy of the floating point value of `pi`.

See Also `csc`, `csch`, `acsc`, `acscd`, `acsch`

Purpose Hyperbolic cosecant

Syntax

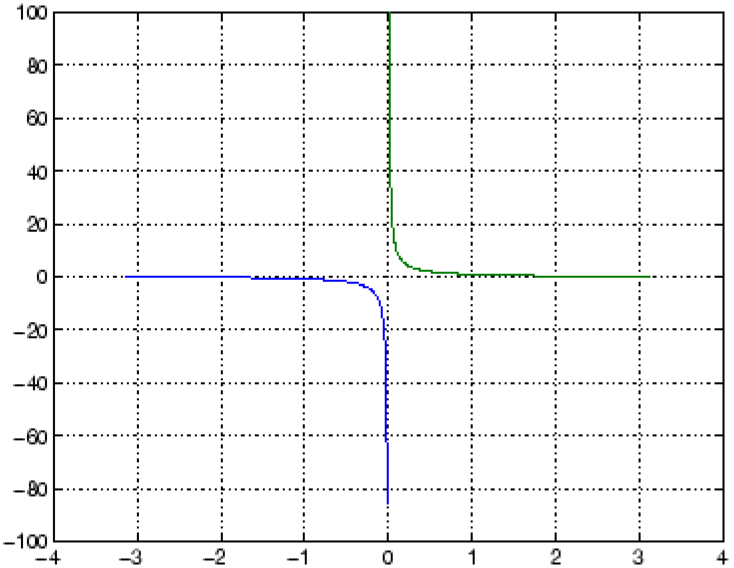
```
Y = csch(x)
```

Description The `csch` function operates element-wise on arrays. The function's domains and ranges include complex values. All angles are in radians.

`Y = csch(x)` returns the hyperbolic cosecant for each element of `x`.

Examples Graph the hyperbolic cosecant over the domains $-\pi < x < 0$ and $0 < x < \pi$.

```
x1 = -pi+0.01:0.01:-0.01;
x2 = 0.01:0.01:pi-0.01;
plot(x1,csch(x1),x2,csch(x2)), grid on
```



Definition The hyperbolic cosecant can be defined as

$$\text{csch}(z) = \frac{1}{\sinh(z)}$$

Algorithm

csch 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

acsc, acsch, csc

csvread

Purpose

Read comma-separated value file

Syntax

```
M = csvread(filename)
M = csvread(filename, row, col)
M = csvread(filename, row, col, range)
```

Description

`M = csvread(filename)` reads a comma-separated value formatted file, `filename`. The `filename` input is a string enclosed in single quotes. The result is returned in `M`. The file can only contain numeric values.

`M = csvread(filename, row, col)` reads data from the comma-separated value formatted file starting at the specified row and column. The row and column arguments are zero based, so that `row=0` and `col=0` specify the first value in the file.

`M = csvread(filename, row, col, range)` reads only the range specified. Specify `range` using the notation `[R1 C1 R2 C2]` where (`R1`,`C1`) is the upper left corner of the data to be read and (`R2`,`C2`) is the lower right corner. You can also specify the range using spreadsheet notation, as in `range = 'A1..B7'`.

Remarks

`csvread` fills empty delimited fields with zero. Data files having lines that end with a nonspace delimiter, such as a semicolon, produce a result that has an additional last column of zeros.

`csvread` imports any complex number as a whole into a complex numeric field, converting the real and imaginary parts to the specified numeric type. Valid forms for a complex number are

Form	Example
—<real>—<imag>i|j	5.7-3.1i
—<imag>i|j	-7j

Embedded white-space in a complex number is invalid and is regarded as a field delimiter.

Examples

Given the file `csvlist.dat` that contains the comma-separated values

```
02, 04, 06, 08, 10, 12
03, 06, 09, 12, 15, 18
05, 10, 15, 20, 25, 30
07, 14, 21, 28, 35, 42
11, 22, 33, 44, 55, 66
```

To read the entire file, use

```
csvread('csvlist.dat')

ans =

     2     4     6     8    10    12
     3     6     9    12    15    18
     5    10    15    20    25    30
     7    14    21    28    35    42
    11    22    33    44    55    66
```

To read the matrix starting with zero-based row 2, column 0, and assign it to the variable `m`,

```
m = csvread('csvlist.dat', 2, 0)

m =

     5    10    15    20    25    30
     7    14    21    28    35    42
    11    22    33    44    55    66
```

To read the matrix bounded by zero-based (2,0) and (3,3) and assign it to `m`,

```
m = csvread('csvlist.dat', 2, 0, [2,0,3,3])

m =
```

```
 5    10    15    20
 7    14    21    28
```

See Also

`csvwrite`, `dlmread`, `textscan`, `wk1read`, `file formats`, `importdata`, `uiimport`

Purpose

Write comma-separated value file

Syntax

```
csvwrite(filename,M)
csvwrite(filename,M,row,col)
```

Description

`csvwrite(filename,M)` writes matrix `M` into `filename` as comma-separated values. The `filename` input is a string enclosed in single quotes.

`csvwrite(filename,M,row,col)` writes matrix `M` into `filename` starting at the specified row and column offset. The row and column arguments are zero based, so that `row=0` and `C=0` specify the first value in the file.

Remarks

`csvwrite` terminates each line with a line feed character and no carriage return.

Examples

The following example creates a comma-separated value file from the matrix `m`.

```
m = [3 6 9 12 15; 5 10 15 20 25; ...
     7 14 21 28 35; 11 22 33 44 55];

csvwrite('csvlist.dat',m)
type csvlist.dat

3,6,9,12,15
5,10,15,20,25
7,14,21,28,35
11,22,33,44,55
```

The next example writes the matrix to the file, starting at a column offset of `2`.

```
csvwrite('csvlist.dat',m,0,2)
type csvlist.dat
```

```
,,3,6,9,12,15
,,5,10,15,20,25
,,7,14,21,28,35
,,11,22,33,44,55
```

See Also `csvread`, `dlmwrite`, `wk1write`,`file formats`, `importdata`, `uiimport`

Purpose Transpose `timeseries` object

Syntax

```
ts1 = ctranspose(ts)
```

Description `ts1 = ctranspose(ts)` returns a new `timeseries` object `ts1` with `IsTimeFirst` value set to the opposite of what it is for `ts`. For example, if `ts` has the first data dimension aligned with the time vector, `ts1` has the last data dimension aligned with the time vector as a result of this operation.

Remarks The `ctranspose` function that is overloaded for `timeseries` objects does not transpose the data. Instead, this function changes whether the first or the last dimension of the data is aligned with the time vector.

Note To transpose the data, you must transpose the `Data` property of the `timeseries` object. For example, you can use the syntax `ctranspose(ts.Data)` or `(ts.Data)'`. `Data` must be a 2-D array.

Consider a `timeseries` object with 10 samples with the property `IsTimeFirst = True`. When you transpose this object, the data size is changed from 10-by-1 to 1-by-1-by-10. Note that the first dimension of the `Data` property is shown explicitly.

The following table summarizes how MATLAB displays the size for Data property of the `timeseries` object (up to three dimensions) before and after transposing.

Data Size Before and After Transposing

Size of Original Data	Size of Transposed Data
N-by-1	1-by-1-by-N
N-by-M	M-by-1-by-N
N-by-M-by-L	M-by-L-by-N

Examples

Suppose that a `timeseries` object `ts` has `ts.data` size 10-by-3-by-2 and its time vector has a length of 10. The `IsTimeFirst` property of `ts` is set to `true`, which means that the first dimension of the data is aligned with the time vector. `ctranspose(ts)` modifies `ts` such that the last dimension of the data is now aligned with the time vector. This permutes the data such that the size of `ts.Data` becomes 3-by-2-by-10.

See Also

`transpose (timeseries)`, `tsprops`

Purpose

Cumulative product

Syntax

```
B = cumprod(A)
B = cumprod(A,dim)
```

Description

`B = cumprod(A)` returns the cumulative product along different dimensions of an array.

If `A` is a vector, `cumprod(A)` returns a vector containing the cumulative product of the elements of `A`.

If `A` is a matrix, `cumprod(A)` returns a matrix the same size as `A` containing the cumulative products for each column of `A`.

If `A` is a multidimensional array, `cumprod(A)` works on the first nonsingleton dimension.

`B = cumprod(A,dim)` returns the cumulative product of the elements along the dimension of `A` specified by scalar `dim`. For example, `cumprod(A,1)` increments the first (row) index, thus working along the rows of `A`.

Examples

```
cumprod(1:5)
ans =
     1   2   6   24   120

A = [1 2 3; 4 5 6];

cumprod(A)
ans =
     1     2     3
     4    10    18

cumprod(A,2)
ans =
     1     2     6
     4    20   120
```

See Also cumsum, prod, sum

Purpose

Cumulative sum

Syntax

```
B = cumsum(A)
B = cumsum(A,dim)
```

Description

`B = cumsum(A)` returns the cumulative sum along different dimensions of an array.

If `A` is a vector, `cumsum(A)` returns a vector containing the cumulative sum of the elements of `A`.

If `A` is a matrix, `cumsum(A)` returns a matrix the same size as `A` containing the cumulative sums for each column of `A`.

If `A` is a multidimensional array, `cumsum(A)` works on the first nonsingleton dimension.

`B = cumsum(A,dim)` returns the cumulative sum of the elements along the dimension of `A` specified by scalar `dim`. For example, `cumsum(A,1)` works across the first dimension (the rows).

Examples

```
cumsum(1:5)
ans =
       [1  3  6  10  15]

A = [1 2 3; 4 5 6];

cumsum(A)
ans =
       1     2     3
       5     7     9

cumsum(A,2)
ans =
       1     3     6
       4     9    15
```

See Also

`cumprod`, `prod`, `sum`

Purpose

Cumulative trapezoidal numerical integration

Syntax

```
Z = cumtrapz(Y)
Z = cumtrapz(X,Y)
Z = cumtrapz(X,Y,dim) or cumtrapz(Y,dim)
```

Description

`Z = cumtrapz(Y)` computes an approximation of the cumulative integral of `Y` via the trapezoidal method with unit spacing. To compute the integral with other than unit spacing, multiply `Z` by the spacing increment. Input `Y` can be complex.

For vectors, `cumtrapz(Y)` is a vector containing the cumulative integral of `Y`.

For matrices, `cumtrapz(Y)` is a matrix the same size as `Y` with the cumulative integral over each column.

For multidimensional arrays, `cumtrapz(Y)` works across the first nonsingleton dimension.

`Z = cumtrapz(X,Y)` computes the cumulative integral of `Y` with respect to `X` using trapezoidal integration. `X` and `Y` must be vectors of the same length, or `X` must be a column vector and `Y` an array whose first nonsingleton dimension is `length(X)`. `cumtrapz` operates across this dimension. Inputs `X` and `Y` can be complex.

If `X` is a column vector and `Y` an array whose first nonsingleton dimension is `length(X)`, `cumtrapz(X,Y)` operates across this dimension.

`Z = cumtrapz(X,Y,dim) or cumtrapz(Y,dim)` integrates across the dimension of `Y` specified by scalar `dim`. The length of `X` must be the same as `size(Y,dim)`.

Example

Example 1

```
Y = [0 1 2; 3 4 5];

cumtrapz(Y,1)
ans =
0          0          0
```

```
    1.5000   2.5000    3.5000

cumtrapz(Y,2)
ans =
0    0.5000    2.0000
        0    3.5000    8.0000
```

Example 2

This example uses two complex inputs:

```
z = exp(1i*pi*(0:100)/100);

ct = cumtrapz(z,1./z);
ct(end)
ans =
   0.0000 + 3.1411i
```

See Also

`cumsum`, `trapz`

Purpose Compute curl and angular velocity of vector field

Syntax

```
[curlx,curly,curlz,cav] = curl(X,Y,Z,U,V,W)
[curlx,curly,curlz,cav] = curl(U,V,W)
[curlz,cav]= curl(X,Y,U,V)
[curlz,cav]= curl(U,V)
[curlx,curly,curlz] = curl(...), curlx,curly] = curl(...)
cav = curl(...)
```

Description

`[curlx,curly,curlz,cav] = curl(X,Y,Z,U,V,W)` computes the curl and angular velocity perpendicular to the flow (in radians per time unit) of a 3-D vector field `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`).

`[curlx,curly,curlz,cav] = curl(U,V,W)` assumes `X`, `Y`, and `Z` are determined by the expression

```
[X Y Z] = meshgrid(1:n,1:m,1:p)
```

where `[m,n,p] = size(U)`.

`[curlz,cav]= curl(X,Y,U,V)` computes the curl `z`-component and the angular velocity perpendicular to `z` (in radians per time unit) of a 2-D vector field `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`).

`[curlz,cav]= curl(U,V)` assumes `X` and `Y` are determined by the expression

```
[X Y] = meshgrid(1:n,1:m)
```

where `[m,n] = size(U)`.

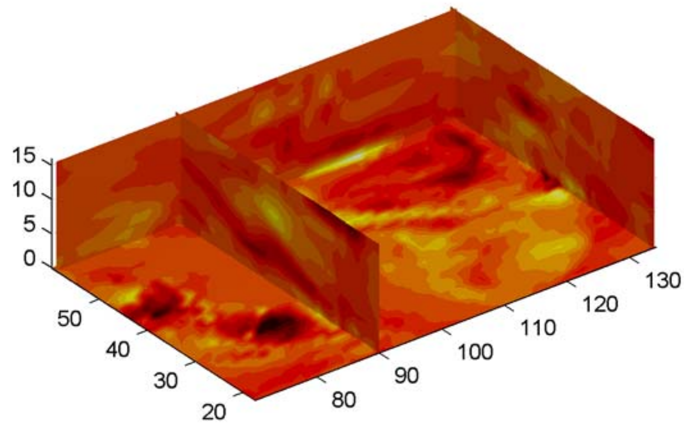
`[curlx,curly,curlz] = curl(...), curlx,curly] = curl(...)` returns only the curl.

`cav = curl(...)` returns only the curl angular velocity.

Examples

This example uses colored slice planes to display the curl angular velocity at specified locations in the vector field.

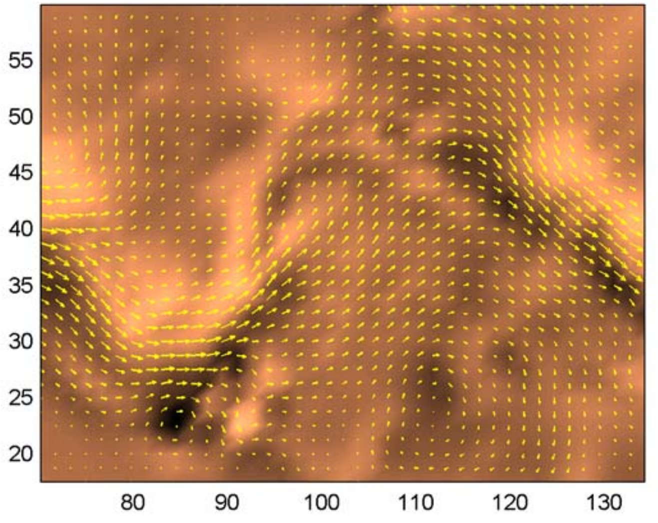
```
load wind
cav = curl(x,y,z,u,v,w);
slice(x,y,z,cav,[90 134],[59],[0]);
shading interp
daspect([1 1 1]); axis tight
colormap hot(16)
camlight
```



This example views the curl angular velocity in one plane of the volume and plots the velocity vectors (`quiver`) in the same plane.

```
load wind
k = 4;
x = x(:,:,k); y = y(:,:,k); u = u(:,:,k); v = v(:,:,k);
cav = curl(x,y,u,v);
pcolor(x,y,cav); shading interp
hold on;
quiver(x,y,u,v,'y')
```

```
hold off
colormap copper
```



See Also

`streamribbon`, `divergence`

"Volume Visualization" on page 1-101 for related functions

"Displaying Curl with Stream Ribbons" for another example

Purpose

Allow custom source control system (UNIX)

Syntax

```
customerverctrl
```

Description

`customerverctrl` function is for customers who want to integrate a source control system that is not supported with MATLAB. When using this function, conform to the structure of one of the supported version control systems, for example, RCS. For examples, see the files `clearcase.m`, `cvs.m`, `pvcs.m`, and `rcs.m` in *`matlabroot`*`\toolbox\matlab\verctrl`.

See Also

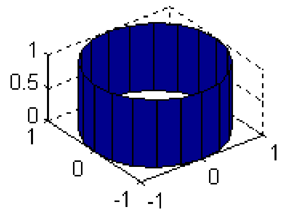
`checkin`, `checkout`, `cmopts`, `undocheckout`

For Windows platforms, use `verctrl`.

cylinder

Purpose

Generate cylinder



Syntax

```
[X,Y,Z] = cylinder
[X,Y,Z] = cylinder(r)
[X,Y,Z] = cylinder(r,n)
cylinder(axes_handle,...)
cylinder(...)
```

Description

`cylinder` generates *x*-, *y*-, and *z*-coordinates of a unit cylinder. You can draw the cylindrical object using `surf` or `mesh`, or draw it immediately by not providing output arguments.

`[X,Y,Z] = cylinder` returns the *x*-, *y*-, and *z*-coordinates of a cylinder with a radius equal to `1`. The cylinder has 20 equally spaced points around its circumference.

`[X,Y,Z] = cylinder(r)` returns the *x*-, *y*-, and *z*-coordinates of a cylinder using `r` to define a profile curve. `cylinder` treats each element in `r` as a radius at equally spaced heights along the unit height of the cylinder. The cylinder has 20 equally spaced points around its circumference.

`[X,Y,Z] = cylinder(r,n)` returns the *x*-, *y*-, and *z*-coordinates of a cylinder based on the profile curve defined by vector `r`. The cylinder has `n` equally spaced points around its circumference.

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

`cylinder(...)`, with no output arguments, plots the cylinder using `surf`.

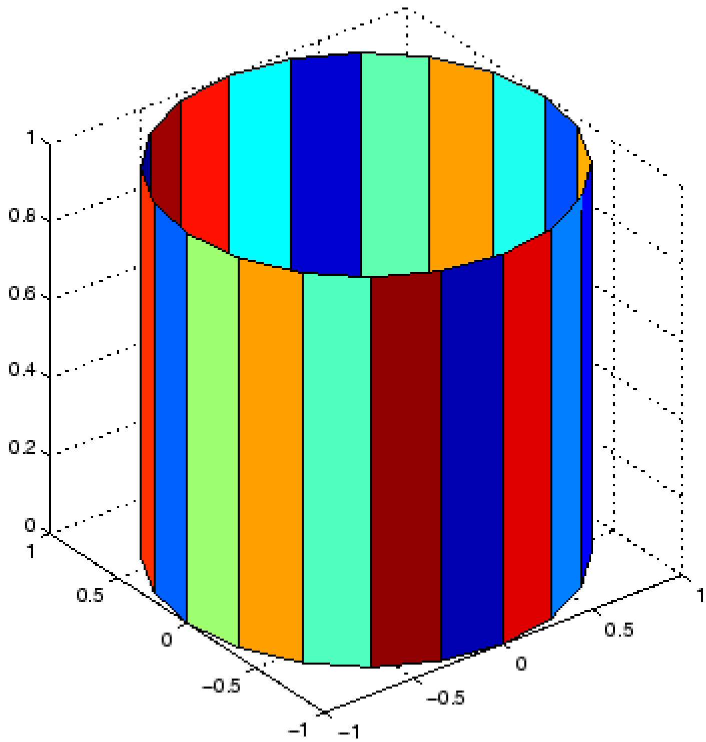
Remarks

`cylinder` treats its first argument as a profile curve. The resulting surface graphics object is generated by rotating the curve about the x-axis, and then aligning it with the z-axis.

Examples

Create a cylinder with randomly colored faces.

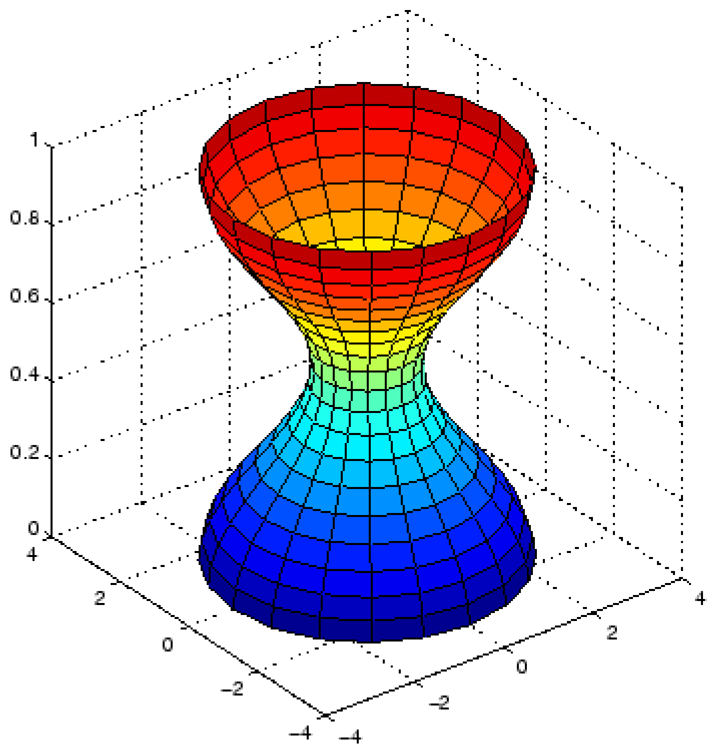
```
cylinder
axis square
h = findobj('Type','surface');
set(h,'CData',rand(size(get(h,'CData'))))
```



Generate a cylinder defined by the profile function `2+sin(t)`.

```
t = 0:pi/10:2*pi;
```

```
[X,Y,Z] = cylinder(2+cos(t));
surf(X,Y,Z)
axis square
```



See Also sphere, surf

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

Purpose Read Data Acquisition Toolbox (`.daq`) file

Syntax

```
data = daqread('filename')
[data, time] = daqread(...)
[data, time, abstime] = daqread(...)
[data, time, abstime, events] = daqread(...)
[data, time, abstime, events, daqinfo] = daqread(...)
data = daqread(...,'Param1', Val1,...)
daqinfo = daqread('filename','info')
```

Description

`data = daqread('filename')` reads all the data from the Data Acquisition Toolbox (`.daq`) file specified by `filename`. `daqread` returns `data`, an *m*-by-*n* data matrix, where *m* is the number of samples and *n* is the number of channels. If `data` includes data from multiple triggers, the data from each trigger is separated by a `NaN`. If you set the `OutputFormat` property to `tscollection`, `daqread` returns a time series collection object. See below for more information.

`[data, time] = daqread(...)` returns time/value pairs. `time` is an *m*-by-1 vector, the same length as `data`, that contains the relative time for each sample. Relative time is measured with respect to the first trigger that occurs.

`[data, time, abstime] = daqread(...)` returns the absolute time of the first trigger. `abstime` is returned as a `clock` vector.

`[data, time, abstime, events] = daqread(...)` returns a log of events. `events` is a structure containing event information. If you specify either the`Samples`, `Time`, or `Triggers` parameters (see below), the events structure contains only the specified events.

`[data, time, abstime, events, daqinfo] = daqread(...)` returns a structure, `daqinfo`, that contains two fields: `ObjInfo` and `HwInfo`. `ObjInfo` is a structure containing property name/property value pairs and `HwInfo` is a structure containing hardware information. The entire event log is returned to `daqinfo.ObjInfo.EventLog`.

`data = daqread(...,'Param1', Val1,...)` specifies the amount of data returned and the format of the data, using the following parameters.

Parameter	Description
Samples	Specify the sample range.
Time	Specify the relative time range.
Triggers	Specify the trigger range.
Channels	Specify the channel range. Channel names can be specified as a cell array.
DataFormat	Specify the data format as doubles (default) or native.
TimeFormat	Specify the time format as vector (default) or matrix.
OutputFormat	Specify the output format as matrix (the default) or tscollection. When you specify tscollection, daqread only returns data.

The Samples, Time, and Triggers properties are mutually exclusive; that is, either Samples, Triggers or Time can be defined at once.

`daqinfo = daqread('filename','info')` returns metadata from the file in the daqinfo structure, without incurring the overhead of reading the data from the file as well. The daqinfo structure contains two fields:

`daqinfo.ObjInfo`
: a structure containing parameter/value pairs for the data acquisition object used to create the file, filename. Note: The UserData property value is not restored.

`daqinfo.HwInfo`
: a structure containing hardware information. The entire event log is returned to daqinfo.ObjInfo.EventLog.

Remarks

More About .daq Files

- The format used by daqread to return data, relative time, absolute time, and event information is identical to the format used by the getdata function that is part of Data Acquisition Toolbox. For more information, see the Data Acquisition Toolbox documentation.
- If data from multiple triggers is read, then the size of the resulting data array is increased by the number of triggers issued because each trigger is separated by a NaN.
- ObjInfo.EventLog always contains the entire event log regardless of the value specified by Samples, Time, or Triggers.
- The UserData property value is not restored when you return device object (ObjInfo) information.
- When reading a .daq file, the daqread function does not return property values that were specified as a cell array.
- Data Acquisition Toolbox (.daq) files are created by specifying a value for the LogFileName property (or accepting the default value), and configuring the LoggingMode property to Disk or Disk&Memory.

More About Time Series Collection Object Returned

When OutputFormat is set to tscollection, daqread returns a time series collection object. This times series collection object contains an absolute time series object for each channel in the file. The following describes how daqread sets some of the properties of the times series collection object and the time series objects.

- The time property of the time series collection object is set to the value of the InitialTriggerTime property specified in the file.
- The name property of each time series object is set to the value of the Name property of a channel in the file. If this name cannot be used as a time series object name, daqread sets the name to 'Channel' with the HwChannel property of the channel appended.

- The value of the Units property of the time series object depends on the value of the DataFormat parameter. If the DataFormat parameter is set to 'double', daqread sets the DataInfo property of each time series object in the collection to the value of the Units property of the corresponding channel in the file. If the DataFormat parameter is set to 'native', daqread sets the Units property to 'native'. See the Data Acquisition Toolbox documentation for more information on these properties.
- Each time series object will have tsdata.event objects attached corresponding to the log of events associated with the channel.

If daqread returns data from multiple triggers, the data from each trigger is separated by a NaN in the time series data. This increases the length of data and time vectors in the time series object by the number of triggers.

Examples

Use Data Acquisition Toolbox to acquire data. The analog input object, ai, acquires one second of data for four channels, and saves the data to the output file data.daq.

```
ai = analoginput('nidaq','Dev1');
chans = addchannel(ai,0:3);
set(ai,'SampleRate',1000)
ActualRate = get(ai,'SampleRate');
set(ai,'SamplesPerTrigger, ActualRate)
set(ai,'LoggingMode','Disk&Memory')
set(ai,'LogFileName','data.daq')
start(ai)
```

After the data has been collected and saved to a disk file, you can retrieve the data and other acquisition-related information using daqread. To read all the sample-time pairs from data.daq:

```
[data,time] = daqread('data.daq');
```

To read samples 500 to 1000 for all channels from data.daq:

```
data = daqread('data.daq','Samples',[500 1000]);
```

To read only samples 1000 to 2000 of channel indices 2, 4 and 7 in native format from the file, `data.daq`:

```
data = daqread('data.daq', 'Samples', [1000 2000],...
               'Channels', [2 4 7], 'DataFormat', 'native');
```

To read only the data which represents the first and second triggers on all channels from the file, `data.daq`:

```
[data, time] = daqread('data.daq', 'Triggers', [1 2]);
```

To obtain the channel property information from `data.daq`:

```
daqinfo = daqread('data.daq','info');
chaninfo = daqinfo.ObjInfo.Channel;
```

To obtain a list of event types and event data contained by `data.daq`:

```
daqinfo = daqread('data.daq','info');
events = daqinfo.ObjInfo.EventLog;
event_type = {events.Type};
event_data = {events.Data};
```

To read all the data from the file `data.daq` and return it as a time series collection object:

```
data = daqread('data.daq','OutputFormat','tscollection');
```

See Also

Functions

`timeseries`, `tscollection`

For more information about using this function, see the Data Acquisition Toolbox documentation.

daspect

Purpose

Set or query axes data aspect ratio

Syntax

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

Description

The data aspect ratio determines the relative scaling of the data units along the *x*-, *y*-, and *z*-axes.

`daspect` with no arguments returns the data aspect ratio of the current axes.

`daspect([aspect_ratio])` sets the data aspect ratio in the current axes to the specified value. Specify the aspect ratio as three relative values representing the ratio of the *x*-, *y*-, and *z*-axis scaling (e.g., `[1 1 3]` means one unit in `x` is equal in length to one unit in `y` and three units in `z`).

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

`daspect('auto')` sets the data aspect ratio mode to `auto`.

`daspect('manual')` sets the data aspect ratio mode to `manual`.

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

Remarks

`daspect` sets or queries values of the axes object `DataAspectRatio` and `DataAspectRatioMode` properties.

When the data aspect ratio mode is `auto`, MATLAB adjusts the data aspect ratio so that each axis spans the space available in the figure window. If you are displaying a representation of a real-life object, you should set the data aspect ratio to `[1 1 1]` to produce the correct proportions.

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

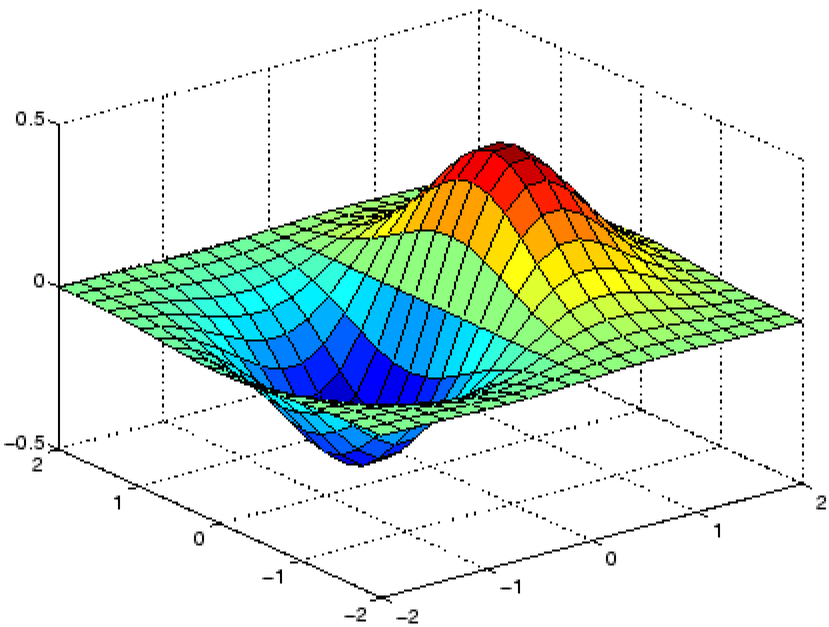
```
daspect(daspect)
```

can cause a change in the way the graphs look. See the Remarks section of the `axes` description for more information.

Examples

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

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

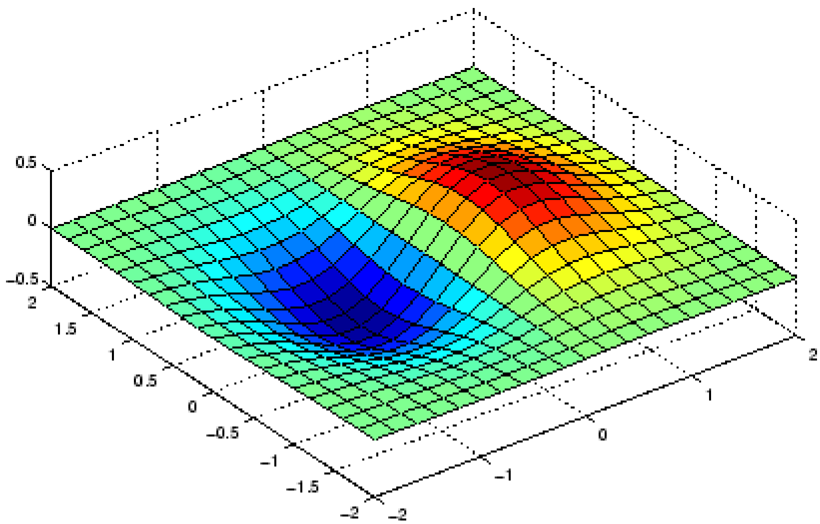


Querying the data aspect ratio shows how MATLAB has drawn the surface.

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

Setting the data aspect ratio to `[1 1 1]` produces a surface plot with equal scaling along each axis.

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



See Also

`axis`, `pbaspect`, `xlim`, `ylim`, `zlim`

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

"Setting the Aspect Ratio and Axis Limits" on page 1-99 for related functions

"Understanding Axes Aspect Ratio" for more information

Purpose

Enable or disable interactive data cursor mode

GUI Alternatives

Use the Data Cursor tool  to label x, y, and z values on graphs and surfaces. For details, see Data Cursor — Displaying Data Values Interactively in the MATLAB Graphics documentation.

Syntax

```
datacursormode on
datacursormode off
datacursormode
datacursormode(figure_handle,...)
dcm_obj = datacursormode(figure_handle)
```

Description

`datacursormode on` enables data cursor mode on the current figure.

`datacursormode off` disables data cursor mode on the current figure.

`datacursormode` toggles data cursor mode on the current figure.

`datacursormode(figure_handle,...)` enables or disables data cursor mode on the specified figure.

`dcm_obj = datacursormode(figure_handle)` returns the figure's data cursor mode object, which enables you to customize the data cursor. See "Data Cursor Mode Object" on page 2-731.

Data Cursor Mode Object

The data cursor mode object has properties that enable you to controls certain aspects of the data cursor. You can use the `set` and `get` commands and the returned object (`dcm_obj` in the above syntax) to set and query property values.

Data Cursor Mode Properties

`Enable`

on | off

Specifies whether this mode is currently enabled on the figure.

`SnapToDataVertex`

on | off

Specifies whether the data cursor snaps to the nearest data value or is located at the actual pointer position.

`DisplayStyle`
datatip | window

Determines how the data is displayed.

- `datatip` displays cursor information in a yellow text box next to a marker indicating the actual data point being displayed.
- `window` displays cursor information in a floating window within the figure.

`Updatefcn`
function handle

This property references a function that customizes the text appearing in the data cursor. The function handle must reference a function that has two implicit arguments (these arguments are automatically passed to the function by MATLAB when the function executes). For example, the following function definition line uses the required arguments:

```
function output_txt = myfunction(obj,event_obj)
% obj    Currently not used (empty)
% event_obj    Handle to event object
% output_txt    Data cursor text string (string or cell array of
%     strings).
```

`event_obj` is an object having the following read-only properties.

- `Target` — Handle of the object the data cursor is referencing (the object on which the user clicked).
- `Position` — An array specifying the x, y, (and z for 3-D graphs) coordinates of the cursor.

You can query these properties within your function. For example,

```
pos = get(event_obj,'Position');
```

returns the coordinates of the cursor.

See `Function Handles` for more information on creating a function handle.

See "Change Data Cursor Text" on page 2-735 for an example.

Data Cursor Method

You can use the `getCursorInfo` function with the data cursor mode object (`dcm_obj` in the above syntax) to obtain information about the data cursor. For example,

```
info_struct = getCursorInfo(dcm_obj);
```

returns a vector of structures, one for each data cursor on the graph. Each structure has the following fields:

- `Target` — The handle of the graphics object containing the data point.
- `Position` — An array specifying the x, y, (and z) coordinates of the cursor.

Line and lineseries objects have an additional field:

- `DataIndex` — A scalar index into the data arrays that correspond to the nearest data point. The value is the same for each array.

Examples

This example creates a plot and enables data cursor mode from the command line.

```
surf(peaks)
datacursormode on
% Click mouse on surface to display data cursor
```

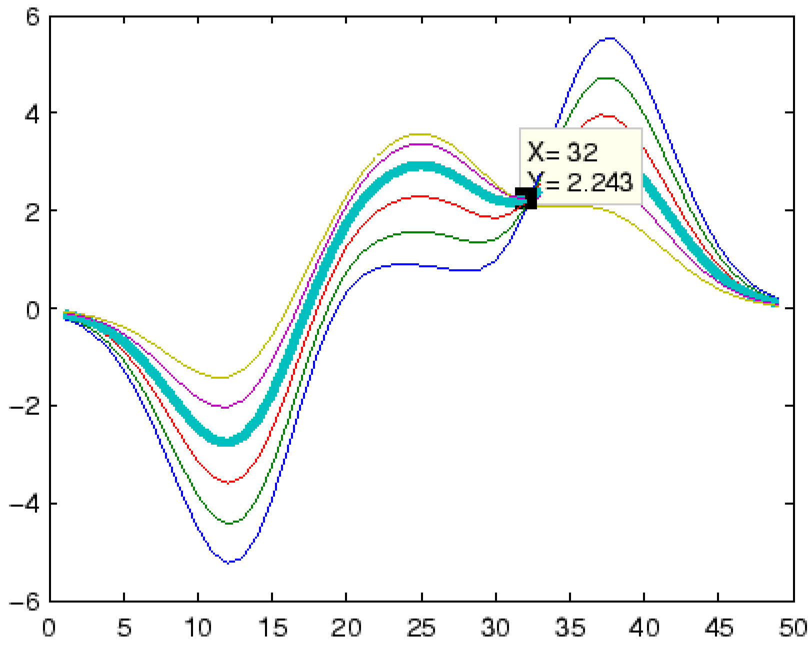
Setting Data Cursor Mode Options

This example enables data cursor mode on the current figure and sets data cursor mode options. The following statements

- Create a graph

- Toggle data cursor mode to on
- Save the data cursor mode object to specify options and get the handle of the line to which the datatip is attached

```
fig = figure;
z = peaks;
plot(z(:,30:35))
dcm_obj = datacursormode(fig);
set(dcm_obj,'DisplayStyle','datatip',...
'SnapToDataVertex','off','Enable','on')

% Click on line to place datatip

c_info = getCursorInfo(dcm_obj);
set(c_info.Target,'LineWidth',2) % Make
selected line wider
```



Change Data Cursor Text

This example shows you how to customize the text that is displayed by the data cursor. Suppose you want to replace the text displayed in the datatip and data window with “Time:” and “Amplitude:”

```
function doc_datacursormode
fig = figure;
a = -16; t = 0:60;
plot(t,sin(a*t))
dcm_obj = datacursormode(fig);
set(dcm_obj,'UpdateFcn',@myupdatefcn)

% Click on line to select data point

function txt = myupdatefcn(empt,event_obj)
pos = get(event_obj,'Position');
txt = {['Time: ',num2str(pos(1))],...
 ['Amplitude: ',num2str(pos(2))]};
```

datatipinfo

Purpose

Produce short description of input variable

Syntax

`datatipinfo(var)`

Description

`datatipinfo(var)` displays a short description of a variable, similar to what is displayed in a datatip in the MATLAB debugger.

Examples

Get datatip information for a 5-by-5 matrix:

```
A = rand(5);

datatipinfo(A)
A: 5x5 double =
    0.4445    0.3567    0.7458    0.0767    0.4400
    0.7962    0.6575    0.3918    0.8289    0.9746
    0.5641    0.9808    0.0265    0.4838    0.6722
    0.9099    0.9653    0.2508    0.4859    0.4054
    0.2857    0.5198    0.7383    0.9301    0.9604
```

Get datatip information for a 50-by-50 matrix. For this larger matrix, `datatipinfo` displays just the size and data type:

```
A = rand(50);

datatipinfo(A)
A: 50x50 double
```

Also for multidimensional matrices, `datatipinfo` displays just the size and data type:

```
A = rand(5);
A(:,:,2) = A(:,:,1);

datatipinfo(A)
A: 5x5x2 double
```

See Also

`debug`

date

Purpose Current date string

Syntax

```
str = date
```

Description `str = date` returns a string containing the date in `dd-mmm-yyyy` format.

See Also `clock`, `datenum`, `now`

datenum

Purpose

Convert date and time to serial date number

Syntax

```
N = datenum(V)
N = datenum(S, F)
N = datenum(S, F, P)
N = datenum([S, P, F])
N = datenum(Y, M, D)
N = datenum(Y, M, D, H, MN, S)
N = datenum(S)
N = datenum(S, P)
```

Description

`datenum` is one of three conversion functions that enable you to express dates and times in any of three formats in MATLAB: a string (or *date string*), a vector of date and time components (or *date vector*), or as a numeric offset from a known date in time (or *serial date number*). Here is an example of a date and time expressed in the three MATLAB formats:

```
Date String:          '24-Oct-2003 12:45:07'
Date Vector:          [2003  10  24  12  45  07]
Serial Date Number:   7.3188e+005
```

A serial date number represents the whole and fractional number of days from a specific date and time, where `datenum('Jan-1-0000 00:00:00')` returns the number 1. (The year 0000 is merely a reference point and is not intended to be interpreted as a real year in time.)

`N = datenum(V)` converts one or more date vectors `V` to serial date numbers `N`. Input `V` can be an `m`-by-6 or `m`-by-3 matrix containing `m` full or partial date vectors respectively. A full date vector has six elements, specifying year, month, day, hour, minute, and second, in that order. A partial date vector has three elements, specifying year, month, and day, in that order. Each element of `V` must be a positive double-precision number. `datenum` returns a column vector of `m` date numbers, where `m` is the total number of date vectors in `V`.

`N = datenum(S, F)` converts one or more date strings `S` to serial date numbers `N` using format string `F` to interpret each date string. Input `S` can be a one-dimensional character array or cell array of date strings. All date strings in S must have the same format, and that format must match one of the date string formats shown in the help for the datestr function. datenum returns a column vector of m date numbers, where m is the total number of date strings in S. MATLAB considers date string years that are specified with only two characters (e.g., '79') to fall within 100 years of the current year.

See the datestr reference page to find valid string values for F. These values are listed in Table 1 in the column labeled "Dateform String." You can use any string from that column except for those that include the letter Q in the string (for example, 'QQ-YYYY'). Certain formats may not contain enough information to compute a date number. In these cases, hours, minutes, seconds, and milliseconds default to 0, the month defaults to January, the day to 1, and the year to the current year.

N = datenum(S, F, P) converts one or more date strings S to date numbers N using format F and pivot year P. The pivot year is used in interpreting date strings that have the year specified as two characters. It is the starting year of the 100-year range in which a two-character date string year resides. The default pivot year is the current year minus 50 years.

N = datenum([S, P, F]) is the same as the syntax shown above, except the order of the last two arguments are switched.

N = datenum(Y, M, D) returns the serial date numbers for corresponding elements of the Y, M, and D (year, month, day) arrays. Y, M, and D must be arrays of the same size (or any can be a scalar) of type double. You can also specify the input arguments as a date vector, [Y M D].

For this and the following syntax, values outside the normal range of each array are automatically carried to the next unit. Values outside the normal range of each array are automatically carried to the next unit. For example, month values greater than 12 are carried to years. Month values less than 1 are set to be 1. All other units can wrap and have valid negative values.

N = datenum(Y, M, D, H, MN, S) returns the serial date numbers for corresponding elements of the Y, M, D, H, MN, and S (year, month, day, hour, minute, and second) array values. datenum does not accept milliseconds in a separate input, but as a fractional part of the seconds (S) input. Inputs Y, M, D, H, MN, and S must be arrays of the same size (or any can be a scalar) of type double. You can also specify the input arguments as a date vector, [Y M D H MN S].

N = datenum(S) converts date string S into a serial date number. String S must be in one of the date formats 0, 1, 2, 6, 13, 14, 15, 16, or 23, as defined in the reference page for the datestr function. MATLAB considers date string years that are specified with only two characters (e.g., '79') to fall within 100 years of the current year. If the format of date string S is known, use the syntax N = datenum(S, F).

N = datenum(S, P) converts date string S, using pivot year P. If the format of date string S is known, use the syntax N = datenum(S, F, P).

Note The last two calling syntaxes are provided for backward compatibility and are significantly slower than the syntaxes that include a format argument F.

Examples

Convert a date string to a serial date number:

```
n = datenum('19-May-2001', 'dd-mmm-yyyy')

n =
      730990
```

Specifying year, month, and day, convert a date to a serial date number:

```
n = datenum(2001, 12, 19)

n =
      731204
```

Convert a date vector to a serial date number:

```
format bank
datenum('March 28, 2005  3:37:07.033 PM')
ans =
     732399.65
```

Convert a date string to a serial date number using the default pivot year:

```
n = datenum('12-jun-17', 'dd-mmm-yy')

n =
      736858
```

Convert the same date string to a serial date number using 1400 as the pivot year:

```
n = datenum('12-jun-17', 'dd-mmm-yy', 1400)

n =
      517712
```

Specify format `'dd.mm.yyyy'` to be used in interpreting a nonstandard date string:

```
n = datenum('19.05.2000', 'dd.mm.yyyy')

n =
      730625
```

See Also

`datestr`, `datevec`, `date`, `clock`, `now`, `datetick`

datestr

Purpose

Convert date and time to string format

Syntax

```
S = datestr(V)
S = datestr(N)
S = datestr(D, F)
S = datestr(S1, F, P)
S = datestr(..., 'local')
```

Description

`datestr` is one of three conversion functions that enable you to express dates and times in any of three formats in MATLAB: a string (or *date string*), a vector of date and time components (or *date vector*), or as a numeric offset from a known date in time (or *serial date number*). Here is an example of a date and time expressed in the three MATLAB formats:

```
Date String:          '24-Oct-2003 12:45:07'
Date Vector:          [2003  10  24  12  45  07]
Serial Date Number:   7.3188e+005
```

A serial date number represents the whole and fractional number of days from 1-Jan-0000 to a specific date. The year 0000 is merely a reference point and is not intended to be interpreted as a real year in time.

`S = datestr(V)` converts one or more date vectors `V` to date strings `S`. Input `V` must be an `m`-by-6 matrix containing `m` full (six-element) date vectors. Each element of `V` must be a positive double-precision number. `datestr` returns a column vector of `m` date strings, where `m` is the total number of date vectors in `V`.

`S = datestr(N)` converts one or more serial date numbers `N` to date strings `S`. Input argument `N` can be a scalar, vector, or multidimensional array of positive double-precision numbers. `datestr` returns a column vector of `m` date strings, where `m` is the total number of date numbers in `N`.

`S = datestr(D, F)` converts one or more date vectors, serial date numbers, or date strings `D` into the same number of date strings `S`.

Input argument `F` is a format number or string that determines the format of the date string output. Valid values for `F` are given in the table Standard MATLAB Date Format Definitions on page 2-743, below. Input `F` may also contain a free-form date format string consisting of format tokens shown in the table Free-Form Date Format Specifiers on page 2-746, below.

Date strings with 2-character years are interpreted to be within the 100 years centered around the current year.

`S = datestr(S1, F, P)` converts date string S1 to date string S, applying format `F` to the output string, and using pivot year `P` as the starting year of the 100-year range in which a two-character year resides. The default pivot year is the current year minus 50 years.

`S = datestr(..., '`**`local`**`')` returns the string in a localized format. The default is US English ('**`en_US`**'). This argument must come last in the argument sequence.

Note The vectorized calling syntax can offer significant performance improvement for large arrays.

Standard MATLAB Date Format Definitions

dateform (number)	dateform (string)	Example
0	'dd-mmm-yyyy HH:MM:SS'	01-Mar-2000 15:45:17
1	'dd-mmm-yyyy'	01-Mar-2000
2	'mm/dd/yy'	03/01/00
3	'mmm'	Mar
4	'm'	M
5	'mm'	03

dateform (number)	dateform (string)	Example
6	'mm/dd'	03/01
7	'dd'	01
8	'ddd'	Wed
9	'd'	W
10	'yyyy'	2000
11	'yy'	00
12	'mmmyy'	Mar00
13	'HH:MM:SS'	15:45:17
14	'HH:MM:SS PM'	3:45:17 PM
15	'HH:MM'	15:45
16	'HH:MM PM'	3:45 PM
17	'QQ-YY'	Q1-01
18	'QQ'	Q1
19	'dd/mm'	01/03
20	'dd/mm/yy'	01/03/00
21	'mmm.dd,yyyy HH:MM:SS'	Mar.01,2000 15:45:17
22	'mmm.dd,yyyy'	Mar.01,2000
23	'mm/dd/yyyy'	03/01/2000
24	'dd/mm/yyyy'	01/03/2000
25	'yy/mm/dd'	00/03/01
26	'yyyy/mm/dd'	2000/03/01
27	'QQ-YYYY'	Q1-2001
28	'mmmyyyy'	Mar2000

dateform (number)	dateform (string)	Example
29 (ISO 8601)	'yyyy-mm-dd'	2000-03-01
30 (ISO 8601)	'yyyymmddTHHMMSS'	20000301T154517
31	'yyyy-mm-dd HH:MM:SS'	2000-03-01 15:45:17

Note `dateform` numbers 0, 1, 2, 6, 13, 14, 15, 16, and 23 produce a string suitable for input to `datenum` or `datevec`. Other date string formats do not work with these functions unless you specify a date form in the function call.

Note For date formats that specify only a time (i.e., `dateform` numbers 13, 14, 15, and 16), MATLAB sets the date to January 1 of the current year.

Time formats like `'h:m:s'`, `'h:m:s.s'`, `'h:m pm'`, ... can also be part of the input array `S`. If you do not specify a format string `F`, or if you specify `F` as `-1`, the date string format defaults to the following:

1	If `S` contains date information only, e.g., 01-Mar-1995
16	If `S` contains time information only, e.g., 03:45 PM
0	If `S` is a date vector, or a string that contains both date and time information, e.g., 01-Mar-1995 03:45

The following table shows the string symbols to use in specifying a free-form format for the output date string. MATLAB interprets these symbols according to your computer's language setting and the current MATLAB language setting.

Note You cannot use more than one format specifier for any date or time field. For example, `datestr(n, 'dddd dd mmmm')` specifies two formats for the day of the week, and thus returns an error.

Free-Form Date Format Specifiers

Symbol	Interpretation	Example
`yyyy`	Show year in full.	`1990, 2002`
`yy`	Show year in two digits.	`90, 02`
`mmmm`	Show month using full name.	`March, December`
`mmm`	Show month using first three letters.	`Mar, Dec`
`mm`	Show month in two digits.	`03, 12`
`m`	Show month using capitalized first letter.	`M, D`
`dddd`	Show day using full name.	`Monday, Tuesday`
`ddd`	Show day using first three letters.	`Mon, Tue`
`dd`	Show day in two digits.	`05, 20`
`d`	Show day using capitalized first letter.	`M, T`
`HH`	Show hour in two digits (no leading zeros when free-form specifier `AM` or `PM` is used (see last entry in this table)).	`05, 5 AM`
`MM`	Show minute in two digits.	`12, 02`

Symbol	Interpretation	Example
`SS`	Show second in two digits.	`07, 59`
`FFF`	Show millisecond in three digits.	`.057`
`AM or PM`	Append `AM` or `PM` to date string (see note below).	`3:45:02 PM`

Note Free-form specifiers `AM` and `PM` from the table above are identical. They do not influence which characters are displayed following the time (`AM` versus `PM`), but only whether or not they are displayed. MATLAB selects `AM` or `PM` based on the time entered.

Remarks

A vector of three or six numbers could represent either a single date vector, or a vector of individual serial date numbers. For example, the vector `[2000 12 15 11 45 03]` could represent either 11:45:03 on December 15, 2000 or a vector of date numbers 2000, 12, 15, etc.. MATLAB uses the following general rule in interpreting vectors associated with dates:

- A 3- or 6-element vector having a first element within an approximate range of 500 greater than or less than the current year is considered by MATLAB to be a date vector. Otherwise, it is considered to be a vector of serial date numbers.

To specify dates outside of this range as a date vector, first convert the vector to a serial date number using the `datenum` function as shown here:

```
datestr(datenum([1400 12 15 11 45 03]), ...
        'mmm.dd,yyyy HH:MM:SS')
ans =
   Dec.15,1400 11:45:03
```

Examples

Return the current date and time in a string using the default format, 0:

```
datestr(now)

ans =
   28-Mar-2005 15:36:23
```

Reformat the date and time, and also show milliseconds:

```
dt = datestr(now, 'mmmm dd, yyyy HH:MM:SS.FFF AM')
dt =
   March 28, 2005  3:37:07.952 PM
```

Format the same showing only the date and in the mm/dd/yy format. Note that you can specify this format either by number or by string.

```
datestr(now, 2)     -or-     datestr(now, 'mm/dd/yy')

ans =
   03/28/05
```

Display the returned date string using your own format made up of symbols shown in the Free-Form Date Format Specifiers on page 2-746 table above.

```
datestr(now, 'dd.mm.yyyy')

ans =
   28.03.2005
```

Convert a nonstandard date form into a standard MATLAB date form by first converting to a date number and then to a string:

```
datestr(datenum('28.03.2005', 'dd.mm.yyyy'), 2)

ans =
   03/28/05
```

See Also

datenum, datevec, date, clock, now, datetick

Purpose Date formatted tick labels

Syntax

```
datetick(tickaxis)
datetick(tickaxis,dateform)
datetick(...,'keeplimits')
datetick(...,'keepticks')
datetick(axes_handle,...)
```

Description

`datetick(tickaxis)` labels the tick lines of an axis using dates, replacing the default numeric labels. `tickaxis` is the string `'x'`, `'y'`, or `'z'`. The default is `'x'`. `datetick` selects a label format based on the minimum and maximum limits of the specified axis.

`datetick(tickaxis,`*`dateform`*`)` formats the labels according to the integer *`dateform`* (see table). To produce correct results, the data for the specified axis must be serial date numbers (as produced by `datenum`).

dateform (number)	*`dateform`* (string)	Example
0	'dd-mmm-yyyy HH:MM:SS'	01-Mar-2000 15:45:17
1	'dd-mmm-yyyy'	01-Mar-2000
2	'mm/dd/yy'	03/01/00
3	'mmm'	Mar
4	'm'	M
5	'mm'	03
6	'mm/dd'	03/01
7	'dd'	01
8	'ddd'	Wed
9	'd'	W
10	'yyyy'	2000
11	'yy'	00

dateform (number)	*dateform* (string)	Example
12	'mmmyy'	Mar00
13	'HH:MM:SS'	15:45:17
14	'HH:MM:SS PM'	3:45:17 PM
15	'HH:MM'	15:45
16	'HH:MM PM'	3:45 PM
17	'QQ-YY'	Q1 01
18	'QQ'	Q1
19	'dd/mm'	01/03
20	'dd/mm/yy'	01/03/00
21	'mmm.dd.yyyy HH:MM:SS'	Mar.01,2000 15:45:17
22	'mmm.dd.yyyy'	Mar.01.2000
23	'mm/dd/yyyy'	03/01/2000
24	'dd/mm/yyyy'	01/03/2000
25	'yy/mm/dd'	00/03/01
26	'yyyy/mm/dd'	2000/03/01
27	'QQ-YYYY'	Q1-2001
28	'mmmyyyy'	Mar2000

`datetick(...,'keeplimits')` changes the tick labels to date-based labels while preserving the axis limits.

`datetick(...,'keepticks')` changes the tick labels to date-based labels without changing their locations.

You can use both `keeplimits` and `keepticks` in the same call to `datetick`.

`datetick(axes_handle,...)` uses the axes specified by the handle `ax` instead of the current axes.

Remarks

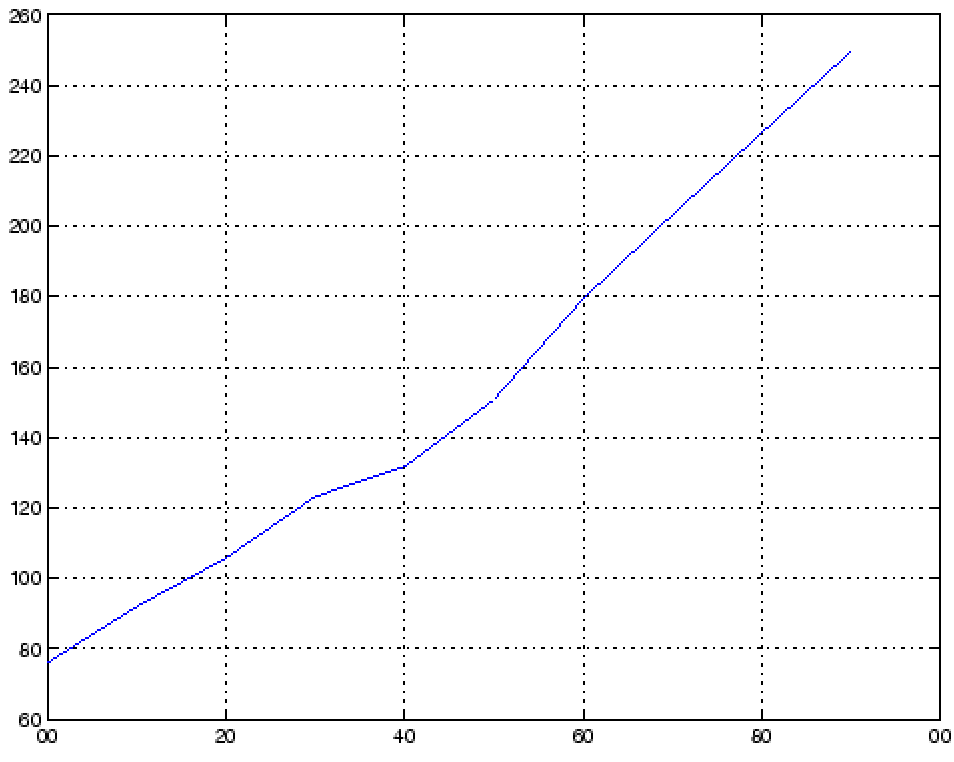
datetick calls datestr to convert date numbers to date strings.

To change the tick spacing and locations, set the appropriate axes property (i.e., XTick, YTick, or ZTick) before calling datetick.

Example

Consider graphing population data based on the 1990 U.S. census:

```
t = (1900:10:1990)';  % Time interval
p = [75.995 91.972 105.711 123.203 131.669 ...
 150.697 179.323 203.212 226.505 249.633]';  % Population
plot(datenum(t,1,1),p) % Convert years to date numbers and plot
grid on
datetick('x',11)   % Replace x-axis ticks with 2-digit year
labels
```



See Also

The axes properties `XTick`, `YTick`, and `ZTick`

`datenum`, `datestr`

"Annotating Plots" on page 1-86 for related functions

Purpose

Convert date and time to vector of components

Syntax

```
V = datevec(N)
V = datevec(S, F)
V = datevec(S, F, P)
V = datevec(S, P, F)
[Y, M, D, H, MN, S] = datevec(...)
V = datevec(S)
V = datevec(S, P)
```

Description

`datevec` is one of three conversion functions that enable you to express dates and times in any of three formats in MATLAB: a string (or *date string*), a vector of date and time components (or *date vector*), or as a numeric offset from a known date in time (or *serial date number*). Here is an example of a date and time expressed in the three MATLAB formats:

```
Date String:          '24-Oct-2003 12:45:07'
Date Vector:          [2003  10  24  12  45  07]
Serial Date Number:   7.3188e+005
```

A serial date number represents the whole and fractional number of days from 1-Jan-0000 to a specific date. The year 0000 is merely a reference point and is not intended to be interpreted as a real year in time.

`V = datevec(N)` converts one or more date numbers `N` to date vectors `V`. Input argument `N` can be a scalar, vector, or multidimensional array of positive date numbers. `datevec` returns an `m`-by-6 matrix containing `m` date vectors, where `m` is the total number of date numbers in `N`.

`V = datevec(S, F)` converts one or more date strings `S` to date vectors `V` using format string `F` to interpret the date strings in `S`. Input argument `S` can be a cell array of strings or a character array where each row corresponds to one date string. All of the date strings in `S` must have the same format which must be composed of date format symbols according to the table “Free-Form Date Format Specifiers” in the `datestr` help.

Formats with 'Q' are not accepted by datevec. datevec returns an m-by-6 matrix of date vectors, where m is the number of date strings in S.

Certain formats may not contain enough information to compute a date vector. In those cases, hours, minutes, and seconds default to 0, days default to 1, months default to January, and years default to the current year. Date strings with two character years are interpreted to be within the 100 years centered around the current year.

V = datevec(S, F, P) converts the date string S to a date vector V using date format F and pivot year P. The pivot year is the starting year of the 100-year range in which a two-character year resides. The default pivot year is the current year minus 50 years.

V = datevec(S, P, F) is the same as the syntax shown above, except the order of the last two arguments are switched.

[Y, M, D, H, MN, S] = datevec(...) takes any of the two syntaxes shown above and returns the components of the date vector as individual variables. datevec does not return milliseconds in a separate output, but as a fractional part of the seconds (S) output.

V = datevec(S) converts date string S to date vector V. Input argument S must be in one of the date formats 0, 1, 2, 6, 13, 14, 15, 16, or 23 as defined in the reference page for the datestr function. This calling syntax is provided for backward compatibility, and is significantly slower than the syntax which specifies the format string. If the format is known, the V = datevec(S, F) syntax is recommended.

V = datevec(S, P) converts the date string S using pivot year P. If the format is known, the V = datevec(S, F, P) or V = datevec(S, P, F) syntax should be used.

Note If more than one input argument is used, the first argument must be a date string or array of date strings.

When creating your own date vector, you need not make the components integers. Any components that lie outside their conventional ranges affect the next higher component (so that, for instance, the anomalous June 31 becomes July 1). A zeroth month, with zero days, is allowed.

Note The vectorized calling syntax can offer significant performance improvement for large arrays.

Examples

Obtain a date vector using a string as input:

```
format short g

datevec('March 28, 2005  3:37:07.952 PM')
ans =
     2005       3       28       15       37       7.952
```

Obtain a date vector using a serial date number as input:

```
t = datenum('March 28, 2005  3:37:07.952 PM')
t =
     7.324e+005

datevec(t)
ans =
     2005       3       28       15       37       7.952
```

Assign elements of the returned date vector:

```
[y, m, d, h, mn, s] = datevec('March 28, 2005  3:37:07.952 PM');
sprintf('Date: %d/%d/%d   Time: %d:%d:%2.3f\n', m, d, y, h, mn, s)

ans =
   Date: 3/28/2005   Time: 15:37:7.952
```

Use free-form date format 'dd.mm.yyyy' to indicate how you want a nonstandard date string interpreted:

```
datevec('28.03.2005', 'dd.mm.yyyy')

ans = 2005   3   28   0  0  0
```

See Also

datenum, datestr, date, clock, now, datetick

Purpose

Clear breakpoints

GUI Alternatives

In the Editor/Debugger, click  to clear a breakpoint, or  to clear all breakpoints. For details, see “Disabling and Clearing Breakpoints”.

Syntax

```
dbclear all
dbclear in mfile ...
dbclear if error ...
dbclear if warning ...
dbclear if naninf
dbclear if infnan
```

Description

`dbclear all` removes all breakpoints in all M-files, as well as breakpoints set for errors, caught errors, caught error identifiers, warnings, warning identifiers, and `naninf/infnan`.

`dbclear in mfile ...` formats are listed here:

Format	Action
`dbclear in mfile`	Removes all breakpoints in `mfile`.
`dbclear in mfile at lineno`	Removes the breakpoint set at line number `lineno` in `mfile`.
`dbclear in mfile at lineno@`	Removes the breakpoint set in the anonymous function at line number `lineno` in `mfile`.
`dbclear in mfile at lineno@n`	Removes the breakpoint set in the `n`the anonymous function at line number `lineno` in `mfile`.
`dbclear in mfile at subfun`	Removes all breakpoints in subfunction `subfun` in `mfile`.

`dbclear if error ...` formats are listed here:

Format	Action
`dbclear if error`	Removes the breakpoints set using the `dbstop if error` and `dbstop if error identifier` statements.
`dbclear if error identifier`	Removes the breakpoint set using `dbstop if error identifier` for the specified `identifier`. Running this produces an error if `dbstop if error` or `dbstop if error all` is set.
`dbclear if caught error`	Removes the breakpoints set using the `dbstop if caught error` and `dbstop if caught error identifier` statements.
`dbclear if caught error identifier`	Removes the breakpoints set using the `dbstop if caught error identifier` statement for the specified identifier. Running this produces an error if `dbstop if caught error` or `dbstop if caught error all` is set.

`dbclear if warning ...` formats are listed here:

`dbclear if warning`	Removes the breakpoints set using the `dbstop if warning` and `dbstop if warning identifier` statements.
`dbclear if warning identifier`	Removes the breakpoint set using `dbstop if warning identifier` for the specified `identifier`. Running this produces an error if `dbstop if warning` or `dbstop if warning all` is set.

`dbclear if naninf` removes the breakpoint set by `dbstop if naninf` or `dbstop if infnan`.

`dbclear if infnan` removes the breakpoint set by `dbstop if infnan` or `dbstop if naninf`.

Remarks

The **at** and **in** keywords are optional.

In the syntax, `mfile` can be an M-file, or the path to a function within a file. For example

```
dbclear in foo>myfun
```

clears the breakpoint at the `myfun` function in the file `foo.m`.

See Also

`dbcont`, `dbdown`, `dbquit`, `dbstack`, `dbstatus`, `dbstep`, `dbstop`, `dbtype`, `dbup`, `partialpath`

dbcont

Purpose

Resume execution

GUI Alternatives

Select **Debug > Continue** from most desktop tools, or in the Editor/Debugger, click .

Syntax

`dbcont`

Description

`dbcont` resumes execution of an M-file from a breakpoint. Execution continues until another breakpoint is encountered, a pause condition is met, an error occurs, or MATLAB returns to the base workspace prompt.

Note If you want to edit an M-file as a result of debugging, it is best to first quit debug mode and then edit and save changes to the M-file. If you edit an M-file while paused in debug mode, you can get unexpected results when you resume execution of the file and the results might not be reliable.

See Also

`dbclear`, `dbdown`, `dbquit`, `dbstack`, `dbstatus`, `dbstep`, `dbstop`, `dbtype`, `dbup`

Purpose

Change local workspace context when in debug mode

GUI Alternatives

Use the **Stack** field 

in the Editor/Debugger or Workspace browser.

Syntax

```
dbdown
```

Description

`dbdown` changes the current workspace context to the workspace of the called M-file when a breakpoint is encountered. You must have issued the `dbup` function at least once before you issue this function. `dbdown` is the opposite of `dbup`.

Multiple `dbdown` functions change the workspace context to each successively executed M-file on the stack until the current workspace context is the current breakpoint. It is not necessary, however, to move back to the current breakpoint to continue execution or to step to the next line.

See Also

`dbclear`, `dbcont`, `dbquit`, `dbstack`, `dbstatus`, `dbstep`, `dbstop`, `dbtype`, `dbup`

dblquad

Purpose Numerically evaluate double integral

Syntax

```
q = dblquad(fun,xmin,xmax,ymin,ymax)
q = dblquad(fun,xmin,xmax,ymin,ymax,tol)
q = dblquad(fun,xmin,xmax,ymin,ymax,tol,method)
```

Description

`q = dblquad(fun,xmin,xmax,ymin,ymax)` calls the `quad` function to evaluate the double integral `fun(x,y)` over the rectangle `xmin <= x <= xmax`, `ymin <= y <= ymax`. `fun` is a function handle. See "Function Handles" in the MATLAB Programming documentation for more information. `fun(x,y)` must accept a vector `x` and a scalar `y` and return a vector of values of the integrand.

"Parameterizing Functions Called by Function Functions" in the MATLAB Mathematics documentation, explains how to provide additional parameters to the function `fun`, if necessary.

`q = dblquad(fun,xmin,xmax,ymin,ymax,tol)` uses a tolerance `tol` instead of the default, which is `1.0e-6`.

`q = dblquad(fun,xmin,xmax,ymin,ymax,tol,method)` uses the quadrature function specified as `method`, instead of the default `quad`. Valid values for `method` are `@quadl` or the function handle of a user-defined quadrature method that has the same calling sequence as `quad` and `quadl`.

Example

Pass M-file function handle `@integrnd` to `dblquad`:

```
Q = dblquad(@integrnd,pi,2*pi,0,pi);
```

where the M-file `integrnd.m` is

```
function z = integrnd(x, y)
z = y*sin(x)+x*cos(y);
```

Pass anonymous function handle `F` to `dblquad`:

```
F = @(x,y)y*sin(x)+x*cos(y);
Q = dblquad(F,pi,2*pi,0,pi);
```

The `integrnd` function integrates `y*sin(x)+x*cos(y)` over the square `pi <= x <= 2*pi`, `0 <= y <= pi`. Note that the integrand can be evaluated with a vector `x` and a scalar `y`.

Nonsquare regions can be handled by setting the integrand to zero outside of the region. For example, the volume of a hemisphere is

```
dblquad(@(x,y)sqrt(max(1-(x.^2+y.^2),0)), -1, 1, -1, 1)
```

or

```
dblquad(@(x,y)sqrt(1-(x.^2+y.^2)).*(x.^2+y.^2<=1), -1, 1, -1, 1)
```

See Also

`quad`, `quadl`, `triplequad`, `function_handle` (`@`), "Anonymous Functions"

dbmex

Purpose

Enable MEX-file debugging

Syntax

```
dbmex on
dbmex off
dbmex stop
```

Description

`dbmex on` enables MEX-file debugging for UNIX platforms. It is not supported on the Sun Solaris platform. To use this option, first start MATLAB from within a debugger by typing `matlab -Ddebugger`, where `debugger` is the name of the debugger.

`dbmex off` disables MEX-file debugging.

`dbmex stop` returns to the debugger prompt.

Remarks

On Sun Solaris platforms, `dbmex` is not supported.
See the Technical Support solution 1-17Z0R at
`http://www.mathworks.com/support/solutions/data/1-17Z0R.html`
for an alternative method of debugging.

See Also

`dbclear`, `dbcont`, `dbdown`, `dbquit`, `dbstack`, `dbstatus`, `dbstep`, `dbstop`, `dbtype`, `dbup`

Purpose

Quit debug mode

GUI Alternative

From most desktop tools, select **Debug > Exit Debug Mode**, or in the Editor/Debugger, click .

Syntax

```
dbquit
dbquit('all')
dbquit all
```

Description

`dbquit` terminates debug mode. The Command Window then displays the standard prompt (>>). The M-file being processed is *not* completed and no results are returned. All breakpoints remain in effect. As an alternative to `dbquit`, press **Shift+F5**.

If you debug `file1` and step into `file2`, running `dbquit` terminates debugging for both files. However, if you debug `file3` and also debug `file4`, running `dbquit` terminates debugging for `file4`, but `file3` remains in debug mode until you run `dbquit` again.

`dbquit('all')` or the command form, `dbquit all`, ends debugging for all files at once.

Examples

This example illustrates the use of `dbquit` relative to `dbquit('all')`. Set breakpoints in and run `file1` and `file2`:

```
>> dbstop in file1
>> dbstop in file2
>> file1
K>> file2
K>> dbstack
```

MATLAB returns

```
K>> dbstack
  In file1 at 11
  In file2 at 22
```

If you use the `dbquit` syntax

```
K>> dbquit
```

MATLAB ends debugging for `file2` but `file1` is still in debug mode as shown here

```
K>> dbstack
    in file1 at 11
```

Run `dbquit` again to exit debug mode for `file1`.

Alternatively, `dbquit('all')` ends debugging for both files at once:

```
K>> dbstack
  In file1 at 11
  In file2 at 22
dbquit('all')
dbstack
```

returns no result.

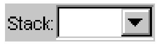
See Also

`dbclear`, `dbcont`, `dbdown`, `dbstack`, `dbstatus`, `dbstep`, `dbstop`, `dbtype`, `dbup`

Purpose

Function call stack

GUI Alternatives

Use the **Stack** field 

in the Editor/Debugger or Workspace browser.

Syntax

```
dbstack
dbstack(n)
dbstack('-completenames')
[ST,I] = dbstack
```

Description

`dbstack` displays the line numbers and M-file names of the function calls that led to the current breakpoint, listed in the order in which they were executed. The line number of the most recently executed function call (at which the current breakpoint occurred) is listed first, followed by its calling function, which is followed by its calling function, and so on, until the topmost M-file function is reached. Each line number is a hyperlink you can click to go directly to that line in the Editor/Debugger. The notation `functionname>subfunctionname` is used to describe the subfunction location.

`dbstack(n)` omits from the display the first `n` frames. This is useful when issuing a `dbstack` from within, say, an error handler.

`dbstack('`**`-completenames`**`')` outputs the “complete name“ (the absolute file name and the entire sequence of functions that nests the function in the stack frame) of each function in the stack.

Either none, one, or both `n` and `'`**`-completenames`**`'` can appear. If both appear, the order is irrelevant.

`[ST,I] = dbstack` returns the stack trace information in an `m`-by-`1` structure `ST` with the fields

`file`	The file in which the function appears. This field will be the empty string if there is no file.
`name`	Function name within the file.
`line`	Function line number.

The current workspace index is returned in `I`.

If you step past the end of an M-file, then `dbstack` returns a negative line number value to identify that special case. For example, if the last line to be executed is line 15, then the `dbstack` line number is 15 before you execute that line and -15 afterwards.

Examples

```
dbstack

In /usr/local/matlab/toolbox/matlab/cond.m at line 13
In test1.m at line 2
In test.m at line 3
```

See Also

`dbclear`, `dbcont`, `dbdown`, `dbquit`, `dbstatus`, `dbstep`, `dbstop`, `dbtype`, `dbup`, `evalin`, `mfilename`, `whos`

"Editing and Debugging M-Files" and "Examining Values"

Purpose

List all breakpoints

GUI Alternative

Breakpoint line numbers are displayed graphically via the breakpoint icons when the file is open in the Editor/Debugger.

Syntax

```
dbstatus
dbstatus mfile
dbstatus('-completenames')
s = dbstatus(...)
```

Description

`dbstatus` lists all the breakpoints in effect including errors, caught errors, warnings, and `naninfs`.

`dbstatus mfile` displays a list of the line numbers for which breakpoints are set in the specified M-file, where `mfile` is an M-file function name or a MATLAB relative partial pathname. Each line number is a hyperlink you can click to go directly to that line in the Editor/Debugger.

`dbstatus('`**`-completenames`**`')` displays, for each breakpoint, the absolute filename and the sequence of functions that nest the function containing the breakpoint.

`s = dbstatus(...)` returns breakpoint information in an `m`-by-`1` structure with the fields listed in the following table. Use this syntax to save breakpoint status and restore it at a later time using `dbstop(s)`—see `dbstop` for an example.

`name`	Function name.
`file`	Full pathname for file containing breakpoints.
`line`	Vector of breakpoint line numbers.
`anonymous`	Vector of integers representing the anonymous functions in the `line` field. For example, 2 means the second anonymous function in that line. A value of `0` means the breakpoint is at the start of the line, not in an anonymous function.

`expression`	Cell vector of breakpoint conditional expression strings corresponding to lines in the `line` field.
`cond`	Condition string (`'error'`, `'caught error'`, `'warning'`, or `'naninf'`).
`identifier`	When `cond` is `'error'`, `'caught error'`, or `'warning'`, a cell vector of MATLAB message identifier strings for which the particular `cond` state is set.

Use `dbstatus class/function`, `dbstatus private/function`, or `dbstatus class/private/function` to determine the status for methods, private functions, or private methods (for a class named `class`).

In all forms you can further qualify the function name with a subfunction name, as in `dbstatus function>subfunction`.

Remarks

In the syntax, `mfile` can be an M-file, or the path to a function within a file. For example

```
Breakpoint for foo>mfun is on line 9
```

means there is a breakpoint at the `myfun` subfunction, which is line 9 in the file `foo.m`.

See Also

`dbclear`, `dbcont`, `dbdown`, `dbquit`, `dbstack`, `dbstep`, `dbstop`, `dbtype`, `dbup`, `error`, `partialpath`, `warning`

Purpose

Execute one or more lines from current breakpoint

GUI Alternatives

As an alternative to `dbstep`, you can select **Debug > Step** or **Step In** in most desktop tools, or click the Step or Step In buttons on the Editor/Debugger toolbar.

Syntax

```
dbstep
dbstep nlines
dbstep in
dbstep out
```

Description

This function allows you to debug an M-file by following its execution from the current breakpoint. At a breakpoint, the `dbstep` function steps through execution of the current M-file one line at a time or at the rate specified by `nlines`.

`dbstep` executes the next executable line of the current M-file. `dbstep` steps over the current line, skipping any breakpoints set in functions called by that line.

`dbstep nlines` executes the specified number of executable lines.

`dbstep` **`in`** steps to the next executable line. If that line contains a call to another M-file function, execution will step to the first executable line of the called M-file function. If there is no call to an M-file on that line, `dbstep in` is the same as `dbstep`.

`dbstep` **`out`** runs the rest of the function and stops just after leaving the function.

For all forms, MATLAB also stops execution at any breakpoint it encounters.

Note If you want to edit an M-file as a result of debugging, it is best to first quit debug mode and then edit and save changes to the M-file. If you edit an M-file while paused in debug mode, you can get unexpected results when you resume execution of the file and the results might not be reliable.

See Also

`dbclear`, `dbcont`, `dbdown`, `dbquit`, `dbstack`, `dbstatus`, `dbstop`, `dbtype`, `dbup`

Purpose Set breakpoints

GUI Alternative Use the **Debug** menu in most desktop tools, or the context menu in Editor/Debugger. See details.

Syntax

```
dbstop in mfile ...
dbstop in nonmfile
dbstop if error ...
dbstop if warning ...
dbstop if naninf
dbstop if infnan
dbstop(s)
```

Description `dbstop in mfile ...` formats are listed here:

Format	Action	Additional Information
`dbstop in mfile`	Temporarily stops execution of running `mfile` at the first executable line, putting MATLAB in debug mode. `mfile` must be in a directory that is on the search path, or in the current directory. `mfile` can be an M-file, or the path to a function (`subfun`) within the file, using the notation `mfile > subfun`. The **in** keyword is optional.	If you have graphical debugging enabled, the MATLAB Debugger opens with a breakpoint at the first executable line of `mfile`. You can then use the debugging utilities, review the workspace, or issue any valid MATLAB function. Use `dbcont` or `dbstep` to resume execution of `mfile`. Use `dbquit` to exit from debug mode.

Format	Action	Additional Information
`dbstop` **`in`** `mfile` **`at`** `lineno`	Temporarily stops execution of running `mfile` just prior to execution of the line whose number is `lineno`, putting MATLAB in debug mode. If that line is not executable, execution stops and the breakpoint is set at the next executable line following `lineno`. `mfile` must be in a directory that is on the search path, or in the current directory. The **`at`** keyword is optional.	If you have graphical debugging enabled, MATLAB opens `mfile` with a breakpoint at line `lineno`. When execution stops, you can use the debugging utilities, review the workspace, or issue any valid MATLAB function. Use `dbcont` or `dbstep` to resume execution of `mfile`. Use `dbquit` to exit from debug mode
`dbstop` **`in`** `mfile` **`at`** `lineno@`	Stops just after any call to the first anonymous function in the specified line number in `mfile`.	
`dbstop` **`in`** `mfile` **`at`** `lineno@n`	Stops just after any call to the `n`the anonymous function in the specified line number in `mfile`.	
`dbstop` **`in`** `mfile` **`at`** `subfun`	Temporarily stops execution of running `mfile` just prior to execution of the subfunction `subfun`, putting MATLAB in debug mode. `mfile` must be in a directory that is on the search path, or in the current directory.	If you have graphical debugging enabled, MATLAB opens `mfile` with a breakpoint at the subfunction `subfun`. You can then use the debugging utilities, review the workspace, or issue any valid MATLAB function. Use `dbcont` or `dbstep` to resume execution of `mfile`. Use `dbquit` to exit from debug mode.

Format	Action	Additional Information
`dbstop in mfile at lineno if expression`	Temporarily stops execution of running `mfile`, just prior to execution of the line whose number is `lineno`, putting MATLAB in debug mode. Execution stops only if expression evaluates to `true`. `expression` is evaluated (as if by `eval`), in `mfile`'s workspace when the breakpoint is encountered, and must evaluate to a scalar logical value (`1` or `0` for true or false). If that line is not executable, execution stops and the breakpoint is set at the next executable line following `lineno`. `mfile` must be in a directory that is on the search path, or in the current directory.	If you have graphical debugging enabled, MATLAB opens `mfile` with a breakpoint at line `lineno`. When execution stops, you can use the debugging utilities, review the workspace, or issue any valid MATLAB function. Use `dbcont` or `dbstep` to resume execution of `mfile`. Use `dbquit` to exit from debug mode.
`dbstop in mfile at lineno@ if expression`	Stops just after any call to the first anonymous function in the specified line number in `mfile` if `expression` evaluates to logical `1` (true).	
`dbstop in mfile at lineno@n if expression`	Stops just after any call to the nthe anonymous function in the specified line number in `mfile` if `expression` evaluates to logical `1` (true).	

Format	Action	Additional Information
`dbstop in mfile if expression`	Temporarily stops execution of running `mfile`, at the first executable line, putting MATLAB in debug mode. Execution stops only if `expression` evaluates to logical `1` (true). `expression` is evaluated (as if by `eval`), in `mfile`'s workspace when the breakpoint is encountered, and must evaluate to a scalar logical value (`0` or `1` for true or false). `mfile` must be in a directory on the search path, or in the current directory	If you have graphical debugging enabled, MATLAB opens `mfile` with a breakpoint at the first executable line of `mfile`. You can then use the debugging utilities, review the workspace, or issue any valid MATLAB function. Use `dbcont` or `dbstep` to resume execution of `mfile`. Use `dbquit` to exit from debug mode.
`dbstop in mfile at subfun if expression`	Temporarily stops execution of running `mfile`, just prior to execution of the subfunction `subfun`, putting MATLAB in debug mode. Execution stops only if `expression` evaluates to logical `1` (true). `expression` is evaluated (as if by `eval`), in `mfile`'s workspace when the breakpoint is encountered, and must evaluate to a scalar logical value (`0` or `1` for true or false). `mfile` must be in a directory on the search path, or in the current directory	If you have graphical debugging enabled, MATLAB opens `mfile` with a breakpoint at the subfunction specified by `subfun`. You can then use the debugging utilities, review the workspace, or issue any valid MATLAB function. Use `dbcont` or `dbstep` to resume execution of `mfile`. Use `dbquit` to exit from debug mode.

`dbstop in nonmfile` temporarily stops execution of the running M-file at the point where `nonmfile` is called. This puts MATLAB in debug mode, where `nonmfile` is, for example, a built-in or MDL-file. MATLAB issues a warning because it cannot actually stop *in* the file;

rather MATLAB stops prior to the file's execution. Once stopped, you can examine values and code around that point in the execution. Use `dbstop in nonmfile` with caution because the debugger stops in M-files it uses for running and debugging if they contain `nonmfile`. As a result, some debugging features do not operate as expected, such as typing `help functionname` at the `K>>` prompt.

`dbstop` **`if error ...`** formats are listed here:

Format	Action
`dbstop` **`if error`**	Stops execution when any M-file you subsequently run produces a run-time error, putting MATLAB in debug mode, paused at the line that generated the error. The errors that stop execution do not include run-time errors that are detected within a `try...catch` block. You cannot resume execution after an uncaught run-time error. Use `dbquit` to exit from debug mode.
`dbstop` **`if error`** `identifier`	Stops execution when any M-file you subsequently run produces a run-time error whose message identifier is `identifier`, putting MATLAB in debug mode, paused at the line that generated the error. The errors that stop execution do not include run-time errors that are detected within a `try...catch` block. You cannot resume execution after an uncaught run-time error. Use `dbquit` to exit from debug mode.
`dbstop` **`if caught error`**	Stops execution when any M-file you subsequently run produces a run-time error, putting MATLAB in debug mode, paused at the line in the `try` portion of the block that generated the error. The errors that stop execution are those detected within a `try...catch` block.
`dbstop` **`if caught error`** `identifier`	Stops execution when any M-file you subsequently run produces a run-time error whose message identifier is `identifier`, putting MATLAB in debug mode, paused at the line in the `try` portion of the block that generated the error. The errors that stop execution are those detected within a `try...catch` block.

`dbstop` **`if warning ...`** formats are listed here:

Format	Action
`dbstop if warning`	Stops execution when any M-file you subsequently run produces a run-time warning, putting MATLAB in debug mode, paused at the line that generated the warning. Use `dbcont` or `dbstep` to resume execution.
`dbstop if warning identifier`	Stops execution when any M-file you subsequently run produces a runtime warning whose message identifier is `identifier`, putting MATLAB in debug mode, paused at the line that generated the warning. Use `dbcont` or `dbstep` to resume execution.

`dbstop` **`if naninf`** or `dbstop` **`if infnan`** stops execution when any M-file you subsequently run produces an infinite value (`Inf`) or a value that is not a number (`NaN`) as a result of an operator, function call, or scalar assignment, putting MATLAB in debug mode, paused immediately after the line where `Inf` or `NaN` was encountered. For convenience, you can use either **`naninf`** or **`infnan`**—they perform in exactly the same manner. Use `dbcont` or `dbstep` to resume execution. Use `dbquit` to exit from debug mode.

`dbstop(s)` restores breakpoints previously saved to the structure `s` using `s=dbstatus`. The files for which the breakpoints have been saved need to be on the search path or in the current directory. In addition, because the breakpoints are assigned by line number, the lines in the file need to be the same as when the breakpoints were saved, or the results are unpredictable. See the example "Restore Saved Breakpoints" on page 2-781 and `dbstatus` for more information.

Remarks

Note that MATLAB could become nonresponsive if it stops at a breakpoint while displaying a modal dialog box or figure that your M-file creates. In that event, use **Ctrl+C** to go the MATLAB prompt.

To open the M-file in the Editor/Debugger when execution reaches a breakpoint, select **Debug > Open M-Files When Debugging**.

To stop at each pass through a for loop, do not set the breakpoint at the for statement. For example, in

```
for n = 1:10
    m = n+1;
end
```

MATLAB executes the `for` statement only once, which is efficient. Therefore, when you set a breakpoint at the `for` statement and step through the file, you only stop at the `for` statement once. Instead place the breakpoint at the next line, `m=n+1` to stop at each pass through the loop.

Examples

The file `buggy`, used in these examples, consists of three lines.

```
function z = buggy(x)
n = length(x);
z = (1:n)./x;
```

Stop at First Executable Line

The statements

```
dbstop in buggy
buggy(2:5)
```

stop execution at the first executable line in `buggy`:

```
n = length(x);
```

The function

```
dbstep
```

advances to the next line, at which point you can examine the value of `n`.

Stop if Error

Because `buggy` only works on vectors, it produces an error if the input `x` is a full matrix. The statements

```
dbstop if error
buggy(magic(3))
```

produce

```
??? Error using ==> ./
Matrix dimensions must agree.
Error in ==> c:\buggy.m
On line 3 ==> z = (1:n)./x;
K>>
```

and put MATLAB in debug mode.

Stop if InfNaN

In `buggy`, if any of the elements of the input `x` is zero, a division by zero occurs. The statements

```
dbstop if naninf
buggy(0:2)
```

produce

```
Warning: Divide by zero.
> In c:\buggy.m at line 3
K>>
```

and put MATLAB in debug mode.

Stop at Function in File

In this example, MATLAB stops at the `newTemp` function in the M-file `yearlyAvgs`:

```
dbstop in yearlyAvgs>newTemp
```

Stop at Non M-File

In this example, MATLAB stops at the built-in function `clear` when you run `myfile.m`.

```
dbstop in clear; myfile
```

MATLAB issues a warning, but permits the stop:

```
Warning: MATLAB debugger can only stop in M-files, and
"m_interpreter>clear" is not an M-file.
Instead, the debugger will stop at the point right before
"m_interpreter>clear" is called.
```

Execution stops in `myfile` at the point where the `clear` function is called.

Restore Saved Breakpoints

1. Set breakpoints in `myfile` as follows:

   ```
   dbstop at 12 in myfile
   dbstop if error
   ```

2. Running `dbstatus` shows

   ```
   Breakpoint for myfile is on line 12.
   Stop if error.
   ```

3. Save the breakpoints to the structure `s`, and then save `s` to the MAT-file `myfilebrkpnts`.

   ```
   s = dbstatus
   save myfilebrkpnts s
   ```

   Use `s=dbstatus('completenames')` to save absolute pathnames and the breakpoint function nesting sequence.

4. At this point, you can end the debugging session and clear all breakpoints, or even end the MATLAB session.

   When you want to restore the breakpoints, be sure all of the files containing the breakpoints are on the search path or in the current directory. Then load the MAT-file, which adds `s` to the workspace, and restore the breakpoints as follows:

   ```
   load myfilebrkpnts
   dbstop(s)
   ```

5 Verify the breakpoints by running `dbstatus`, which shows

```
dbstop at 12 in myfile
dbstop if error
```

If you made changes to `myfile` after saving the breakpoints, the results from restoring the breakpoints are not predictable. For example, if you added a new line prior to line 12 in `myfile`, the breakpoint will now be set at the new line 12.

See Also

`assignin`, `break`, `dbclear`, `dbcont`, `dbdown`, `dbquit`, `dbstack`, `dbstatus`, `dbstep`, `dbtype`, `dbup`, `evalin`, `keyboard`, `partialpath`, `return`, `whos`

Purpose

List M-file with line numbers

GUI Alternatives

As an alternative to the `dbtype` function, you can see an M-file with line numbers by opening it in the Editor/Debugger.

Syntax

```
dbtype mfilename
dbtype mfilename start:end
```

Description

The `dbtype` command is used to list an M-file with line numbers, which is helpful when setting breakpoints with `dbstop`.

`dbtype mfilename` displays the contents of the specified M-file, with the line number preceding each line. mfilename must be the full pathname of an M-file, or a MATLAB relative `partial pathname`.

`dbtype mfilename start:end` displays the portion of the M-file specified by a range of line numbers from `start` to `end`.

You cannot use `dbtype` for built-in functions.

Examples

To see only the input and output arguments for a function, that is, the first line of the M-file, use the syntax

```
dbtype mfilename 1
```

For example,

```
dbtype fileparts 1
```

returns

```
1     function [path, fname, extension,version] = fileparts(name)
```

See Also

`dbclear`, `dbcont`, `dbdown`, `dbquit`, `dbstack`, `dbstatus`, `dbstep`, `dbstop`, `dbup`, `partialpath`

dbup

Purpose

Change local workspace context

GUI Alternatives

As an alternative to the `dbup` function, you can select a different workspace from the **Stack** field in the Editor/Debugger toolbar.

Syntax

```
dbup
```

Description

This function allows you to examine the calling M-file to determine what led to the arguments' being passed to the called function.

`dbup` changes the current workspace context, while the user is in the debug mode, to the workspace of the calling M-file.

Multiple `dbup` functions change the workspace context to each previous calling M-file on the stack until the base workspace context is reached. (It is not necessary, however, to move back to the current breakpoint to continue execution or to step to the next line.)

See Also

`dbclear`, `dbcont`, `dbdown`, `dbquit`, `dbstack`, `dbstatus`, `dbstep`, `dbstop`, `dbtype`

Purpose

Solve delay differential equations (DDEs) with constant delays

Syntax

```
sol = dde23(ddefun,lags,history,tspan)
sol = dde23(ddefun,lags,history,tspan,options)
```

Arguments

`ddefun`

Function handle that evaluates the right side of the differential equations $y'(t) = f(t, y(t), y(t-\tau_1), \ldots, y(t-\tau_k))$. The function must have the form

```
dydt = ddefun(t,y,Z)
```

where `t` corresponds to the current t, `y` is a column vector that approximates $y(t)$, and `Z(:,j)` approximates $y(t-\tau_j)$ for delay τ_j = `lags(j)`. The output is a column vector corresponding to $f(t, y(t), y(t-\tau_1), \ldots, y(t-\tau_k))$.

`lags`

Vector of constant, positive delays $\tau_1, \ldots, \tau_k$.

`history`

Specify `history` in one of three ways:

- A function of t such that `y = history(t)` returns the solution $y(t)$ for $t \le t_0$ as a column vector
- A constant column vector, if $y(t)$ is constant
- The solution `sol` from a previous integration, if this call continues that integration

`tspan`	Interval of integration as a vector `[t0,tf]` with `t0 < tf`.
`options`	Optional integration argument. A structure you create using the `ddeset` function. See `ddeset` for details.

Description

`sol = dde23(ddefun,lags,history,tspan)` integrates the system of DDEs

$$y'(t) = f(t, y(t), y(t-\tau_1), \ldots, y(t-\tau_k))$$

on the interval $[t_0, t_f]$, where $\tau_1, \ldots, \tau_k$ are constant, positive delays and $t_0 < t_f$. `ddefun` 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 provide additional parameters to the function `ddefun`, if necessary.

`dde23` returns the solution as a structure `sol`. Use the auxiliary function `deval` and the output `sol` to evaluate the solution at specific points `tint` in the interval `tspan = [t0,tf]`.

```
yint = deval(sol,tint)
```

The structure `sol` returned by `dde23` has the following fields.

`sol.x`	Mesh selected by `dde23`
`sol.y`	Approximation to $y(x)$ at the mesh points in `sol.x`.
`sol.yp`	Approximation to $y'(x)$ at the mesh points in `sol.x`
`sol.solver`	Solver name, `'dde23'`

`sol = dde23(ddefun,lags,history,tspan,options)` solves as above with default integration properties replaced by values in `options`, an argument created with `ddeset`. See `ddeset` and "Initial Value Problems for DDEs" in the MATLAB documentation for details.

Commonly used options are scalar relative error tolerance `'RelTol'` (`1e-3` by default) and vector of absolute error tolerances `'AbsTol'` (all components are `1e-6` by default).

Use the `'Jumps'` option to solve problems with discontinuities in the history or solution. Set this option to a vector that contains the locations of discontinuities in the solution prior to `t0` (the history) or in coefficients of the equations at known values of t after `t0`.

Use the `'Events'` option to specify a function that `dde23` calls to find where functions $g(t, y(t), y(t-\tau_1), \ldots, y(t-\tau_k))$ vanish. This function must be of the form

```
[value,isterminal,direction] = events(t,y,Z)
```

and contain an event function for each event to be tested. For the `k`th event function in `events`:

- `value(k)` is the value of the `k`th event function.
- `isterminal(k) = 1` if you want the integration to terminate at a zero of this event function and `0` otherwise.
- `direction(k) = 0` if you want `dde23` to compute all zeros of this event function, `+1` if only zeros where the event function increases, and `-1` if only zeros where the event function decreases.

If you specify the `'Events'` option and events are detected, the output structure `sol` also includes fields:

sol.xe	Row vector of locations of all events, i.e., times when an event function vanished
sol.ye	Matrix whose columns are the solution values corresponding to times in sol.xe
sol.ie	Vector containing indices that specify which event occurred at the corresponding time in sol.xe

Examples

This example solves a DDE on the interval [0, 5] with lags 1 and 0.2. The function `ddex1de` computes the delay differential equations, and `ddex1hist` computes the history for `t <= 0`.

Note The demo `ddex1` contains the complete code for this example. To see the code in an editor, click the example name, or type `edit ddex1` at the command line. To run the example type `ddex1` at the command line.

```
sol = dde23(@ddex1de,[1, 0.2],@ddex1hist,[0, 5]);
```

This code evaluates the solution at 100 equally spaced points in the interval `[0,5]`, then plots the result.

```
tint = linspace(0,5);
yint = deval(sol,tint);
plot(tint,yint);
```

`ddex1` shows how you can code this problem using subfunctions. For more examples see `ddex2`.

Algorithm

`dde23` tracks discontinuities and integrates with the explicit Runge-Kutta (2,3) pair and interpolant of `ode23`. It uses iteration to take steps longer than the lags.

See Also

`ddesd`, `ddeget`, `ddeset`, `deval`, `function_handle` (`@`)

References

[1] Shampine, L.F. and S. Thompson, "Solving DDEs in MATLAB, "*Applied Numerical Mathematics*, Vol. 37, 2001, pp. 441-458.

[2] Kierzenka, J., L.F. Shampine, and S. Thompson, "Solving Delay Differential Equations with DDE23," available at `www.mathworks.com/dde_tutorial`.

ddeadv

Purpose

Set up advisory link

Syntax

Description

`ddeadv` sets up an advisory link between MATLAB and a server application. When the data identified by the `item` argument changes, the string specified by the `callback` argument is passed to the `eval` function and evaluated. If the advisory link is a hot link, DDE modifies `upmtx`, the update matrix, to reflect the data in `item`.

If you omit optional arguments that are not at the end of the argument list, you must substitute the empty matrix for the missing argument(s).

If successful, `ddeadv` returns 1 in variable, `rc`. Otherwise it returns 0.

Arguments

`channel`	Conversation channel from `ddeinit`.
`item`	String specifying the DDE item name for the advisory link. Changing the data identified by `item` at the server triggers the advisory link.
`callback`	String specifying the callback that is evaluated on update notification. Changing the data identified by `item` at the server causes `callback` to get passed to the `eval` function to be evaluated.
`upmtx` (*optional*)	String specifying the name of a matrix that holds data sent with an update notification. If `upmtx` is included, changing `item` at the server causes `upmtx` to be updated with the revised data. Specifying `upmtx` creates a hot link. Omitting `upmtx` or specifying it as an empty string creates a warm link. If `upmtx` exists in the workspace, its contents are overwritten. If `upmtx` does not exist, it is created.

format (*optional*)	Two-element array specifying the format of the data to be sent on update. The first element specifies the Windows clipboard format to use for the data. The only currently supported format is `cf_text`, which corresponds to a value of 1. The second element specifies the type of the resultant matrix. Valid types are `numeric` (the default, which corresponds to a value of `0`) and `string` (which corresponds to a value of `1`). The default format array is `[1 0]`.
timeout (*optional*)	Scalar specifying the time-out limit for this operation. `timeout` is specified in milliseconds. (1000 milliseconds = 1 second). If advisory link is not established within `timeout` milliseconds, the function fails. The default value of `timeout` is three seconds.

Examples

Set up a hot link between a range of cells in Excel (Row 1, Column 1 through Row 5, Column 5) and the matrix `x`. If successful, display the matrix:

```
rc = ddeadv(channel, 'r1c1:r5c5', 'disp(x)', 'x');
```

Communication with Excel must have been established previously with a `ddeinit` command.

See Also

`ddeexec`, `ddeinit`, `ddepoke`, `ddereq`, `ddeterm`, `ddeunadv`

ddeexec

Purpose

Send string for execution

Syntax

Description

ddeexec sends a string for execution to another application via an established DDE conversation. Specify the string as the command argument.

If you omit optional arguments that are not at the end of the argument list, you must substitute the empty matrix for the missing argument(s).

If successful, ddeexec returns 1 in variable, rc. Otherwise it returns 0.

Arguments

channel	Conversation channel from ddeinit.
command	String specifying the command to be executed.
item (*optional*)	String specifying the DDE item name for execution. This argument is not used for many applications. If your application requires this argument, it provides additional information for command. Consult your server documentation for more information.
timeout (*optional*)	Scalar specifying the time-out limit for this operation. timeout is specified in milliseconds. (1000 milliseconds = 1 second). The default value of timeout is three seconds.

Examples

Given the channel assigned to a conversation, send a command to Excel:

```
rc = ddeexec(channel,'[formula.goto("r1c1")]')
```

Communication with Excel must have been established previously with a ddeinit command.

See Also

ddeadv, ddeinit, ddepoke, ddereq, ddeterm, ddeunadv

Purpose

Extract properties from delay differential equations options structure

Syntax

```
val = ddeget(options,'name')
val = ddeget(options,'name',default)
```

Description

`val = ddeget(options,'name')` extracts the value of the named property from the structure `options`, returning an empty matrix if the property value is not specified in `options`. It is sufficient to type only the leading characters that uniquely identify the property. Case is ignored for property names. `[]` is a valid `options` argument.

`val = ddeget(options,'name',default)` extracts the named property as above, but returns `val = default` if the named property is not specified in `options`. For example,

```
val = ddeget(opts,'RelTol',1e-4);
```

returns `val = 1e-4` if the `RelTol` is not specified in `opts`.

See Also

`dde23`, `ddesd`, `ddeset`

ddeinit

Purpose Initiate Dynamic Data Exchange (DDE) conversation

Syntax

```
channel = ddeinit('service','topic')
```

Description `channel = ddeinit('service','topic')` returns a channel handle assigned to the conversation, which is used with other MATLAB DDE functions. `'service'` is a string specifying the service or application name for the conversation. `'topic'` is a string specifying the topic for the conversation.

Examples To initiate a conversation with Excel for the spreadsheet `'stocks.xls'`:

```
channel = ddeinit('excel','stocks.xls')

channel =
0.00
```

See Also `ddeadv`, `ddeexec`, `ddepoke`, `ddereq`, `ddeterm`, `ddeunadv`

Purpose

Send data to application

Syntax

Description

ddepoke sends data to an application via an established DDE conversation. ddepoke formats the data matrix as follows before sending it to the server application:

- String matrices are converted, element by element, to characters and the resulting character buffer is sent.
- Numeric matrices are sent as tab-delimited columns and carriage-return, line-feed delimited rows of numbers. Only the real part of nonsparse matrices are sent.

If you omit optional arguments that are not at the end of the argument list, you must substitute the empty matrix for the missing argument(s).

If successful, ddepoke returns 1 in variable, rc. Otherwise it returns 0.

Arguments

channel	Conversation channel from ddeinit.
item	String specifying the DDE item for the data sent. Item is the server data entity that is to contain the data sent in the data argument.
data	Matrix containing the data to send.
format (*optional*)	Scalar specifying the format of the data requested. The value indicates the Windows clipboard format to use for the data transfer. The only format currently supported is cf_text, which corresponds to a value of 1.
timeout (*optional*)	Scalar specifying the time-out limit for this operation. timeout is specified in milliseconds. (1000 milliseconds = 1 second). The default value of timeout is three seconds.

Examples

Assume that a conversation channel with Excel has previously been established with `ddeinit`. To send a 5-by-5 identity matrix to Excel, placing the data in Row 1, Column 1 through Row 5, Column 5:

```
rc = ddepoke(channel, 'r1c1:r5c5', eye(5));
```

See Also

`ddeadv`, `ddeexec`, `ddeinit`, `ddereq`, `ddeterm`, `ddeunadv`

Purpose

Request data from application

Syntax

Description

ddereq requests data from a server application via an established DDE conversation. ddereq returns a matrix containing the requested data or an empty matrix if the function is unsuccessful.

If you omit optional arguments that are not at the end of the argument list, you must substitute the empty matrix for the missing argument(s).

If successful, ddereq returns a matrix containing the requested data in variable, data. Otherwise, it returns an empty matrix.

Arguments

channel	Conversation channel from ddeinit.
item	String specifying the server application's DDE item name for the data requested.
format (*optional*)	Two-element array specifying the format of the data requested. The first element specifies the Windows clipboard format to use. The only currently supported format is cf_text, which corresponds to a value of 1. The second element specifies the type of the resultant matrix. Valid types are numeric (the default, which corresponds to 0) and string (which corresponds to a value of 1). The default format array is [1 0].
timeout (*optional*)	Scalar specifying the time-out limit for this operation. timeout is specified in milliseconds. (1000 milliseconds = 1 second). The default value of timeout is three seconds.

Examples

Assume that you have an Excel spreadsheet stocks.xls. This spreadsheet contains the prices of three stocks in row 3 (columns 1 through 3) and the number of shares of these stocks in rows 6 through 8 (column 2). Initiate conversation with Excel with the command

```
channel = ddeinit('excel','stocks.xls')
```

DDE functions require the *rxcy* reference style for Excel worksheets. In Excel terminology the prices are in r3c1:r3c3 and the shares in r6c2:r8c2.

Request the prices from Excel:

```
prices = ddereq(channel,'r3c1:r3c3')

prices =
42.50
15.00
78.88
```

Next, request the number of shares of each stock:

```
shares = ddereq(channel, 'r6c2:r8c2')

shares =
100.00
500.00
300.00
```

See Also

ddeadv, ddeexec, ddeinit, ddepoke, ddeterm, ddeunadv

Purpose

Solve delay differential equations (DDEs) with general delays

Syntax

```
sol = ddesd(ddefun,delays,history,tspan)
sol = ddesd(ddefun,delays,history,tspan,options)
```

Arguments

`ddefun` — Function handle that evaluates the right side of the differential equations $y'(t) = f(t, y(t), y(d(1)), \ldots, y(d(k)))$. The function must have the form

```
dydt = ddefun(t,y,Z)
```

where `t` corresponds to the current t, `y` is a column vector that approximates $y(t)$, and `Z(:,j)` approximates $y(d(j))$ for delay $d(j)$ given as component j of `delays(t,y)`. The output is a column vector corresponding to $f(t, y(t), y(d(1)), \ldots, y(d(k)))$.

`delays` — Function handle that returns a column vector of delays $d(j)$. The delays can depend on both t and $y(t)$. `ddesd` imposes the requirement that $d(j) \le t$ by using `min(`$d(j)$, t`)`.

If all the delay functions have the form $d(j) = t - \tau_j$, you can set the argument `delays` to a constant vector `delays`$(j) = \tau_j$. With delay functions of this form, `ddesd` is used exactly like `dde23`.

`history`	Specify `history` in one of three ways: • A function of t such that `y = history(t)` returns the solution $y(t)$ for $t \le t_0$ as a column vector • A constant column vector, if $y(t)$ is constant • The solution `sol` from a previous integration, if this call continues that integration
`tspan`	Interval of integration as a vector `[t0,tf]` with `t0 < tf`.
`options`	Optional integration argument. A structure you create using the `ddeset` function. See `ddeset` for details.

Description

`sol = ddesd(ddefun,delays,history,tspan)` integrates the system of DDEs

$$y'(t) = f(t, y(t), y(d(1)), \ldots, y(d(k)))$$

on the interval $[t_0, t_f]$, where delays $d(j)$ can depend on both t and $y(t)$, and $t_0 < t_f$. Inputs `ddefun` and `delays` are function handles. 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 functions `ddefun`, `delays`, and `history`, if necessary.

`ddesd` returns the solution as a structure `sol`. Use the auxiliary function `deval` and the output `sol` to evaluate the solution at specific points `tint` in the interval `tspan = [t0,tf]`.

```
yint = deval(sol,tint)
```

The structure `sol` returned by `ddesd` has the following fields.

`sol.x`	Mesh selected by `ddesd`
`sol.y`	Approximation to $y(x)$ at the mesh points in `sol.x`.
`sol.yp`	Approximation to $y'(x)$ at the mesh points in `sol.x`
`sol.solver`	Solver name, `'ddesd'`

`sol = ddesd(ddefun,delays,history,tspan,options)` solves as above with default integration properties replaced by values in `options`, an argument created with `ddeset`. See `ddeset` and "Initial Value Problems for DDEs" in the MATLAB documentation for details.

Commonly used options are scalar relative error tolerance `'RelTol'` (`1e-3` by default) and vector of absolute error tolerances `'AbsTol'` (all components are `1e-6` by default).

Use the `'Events'` option to specify a function that `ddesd` calls to find where functions $g(t, y(t), y(d(1)), \ldots, y(d(k)))$ vanish. This function must be of the form

```
[value,isterminal,direction] = events(t,y,Z)
```

and contain an event function for each event to be tested. For the `k`th event function in `events`:

- `value(k)` is the value of the `k`th event function.
- `isterminal(k) = 1` if you want the integration to terminate at a zero of this event function and `0` otherwise.
- `direction(k) = 0` if you want `ddesd` to compute all zeros of this event function, `+1` if only zeros where the event function increases, and `-1` if only zeros where the event function decreases.

If you specify the 'Events' option and events are detected, the output structure sol also includes fields:

sol.xe	Row vector of locations of all events, i.e., times when an event function vanished
sol.ye	Matrix whose columns are the solution values corresponding to times in sol.xe
sol.ie	Vector containing indices that specify which event occurred at the corresponding time in sol.xe

Examples

The equation

```
sol = ddesd(@ddex1de,@ddex1delays,@ddex1hist,[0,5]);
```

solves a DDE on the interval [0,5] with delays specified by the function ddex1delays and differential equations computed by ddex1de. The history is evaluated for $t \le 0$ by the function ddex1hist. The solution is evaluated at 100 equally spaced points in [0,5]:

```
tint = linspace(0,5);
yint = deval(sol,tint);
```

and plotted with

```
plot(tint,yint);
```

This problem involves constant delays. The delay function has the form

```
function d = ddex1delays(t,y)
%DDEX1DELAYS  Delays for using with DDEX1DE.
d = [ t - 1
      t - 0.2];
```

The problem can also be solved with the syntax corresponding to constant delays

```
delays = [1, 0.2];
```

```
sol = ddesd(@ddex1de,delays,@ddex1hist,[0, 5]);
```

or using `dde23`:

```
sol = dde23(@ddex1de,delays,@ddex1hist,[0, 5]);
```

For more examples of solving delay differential equations see `ddex2` and `ddex3`.

See Also

`dde23`, `ddeget`, `ddeset`, `deval`, `function_handle` (`@`)

References

[1] Shampine, L.F., "Solving ODEs and DDEs with Residual Control," *Applied Numerical Mathematics*, Vol. 52, 2005, pp. 113-127.

Purpose

Create or alter delay differential equations options structure

Syntax

```
options = ddeset('name1',value1,'name2',value2,...)
options = ddeset(oldopts,'name1',value1,...)
options = ddeset(oldopts,newopts)
ddeset
```

Description

`options = ddeset('name1',value1,'name2',value2,...)` creates an integrator options structure `options` in which the named properties have the specified values. Any unspecified properties have default values. It is sufficient to type only the leading characters that uniquely identify the property. `ddeset` ignores case for property names.

`options = ddeset(oldopts,'name1',value1,...)` alters an existing options structure `oldopts`. This overwrites any values in `oldopts` that are specified using name/value pairs and returns the modified structure as the output argument.

`options = ddeset(oldopts,newopts)` combines an existing options structure `oldopts` with a new options structure `newopts`. Any values set in `newopts` overwrite the corresponding values in `oldopts`.

`ddeset` with no input arguments displays all property names and their possible values, indicating defaults with braces `{}`.

You can use the function `ddeget` to query the `options` structure for the value of a specific property.

DDE Properties

The following sections describe the properties that you can set using `ddeset`. There are several categories of properties:

- Error control
- Solver output
- Step size
- Event location
- Discontinuities

Error Control Properties

At each step, solvers dde23 and ddesd estimate an error e. dde23 estimates the local truncation error, and ddesd estimates the residual. In either case, 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, dde23 and ddesd 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.

DDE Error Control Properties

<table>
<tr><th>Property</th><th>Value</th><th>Description</th></tr>
<tr><td><code>RelTol</code></td><td>Positive scalar {<code>1e-3</code>}</td><td>A relative error tolerance that applies to all components of the solution vector <code>y</code>. It 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 <code>AbsTol(i)</code>. The default, <code>1e-3</code>, corresponds to 0.1% accuracy.

The estimated error in each integration step satisfies <code>|e(i)|max(RelTol*abs(y(i)), AbsTol(i))</code>.</td></tr>
<tr><td><code>AbsTol</code></td><td>Positive scalar or vector {<code>1e-6</code>}</td><td>Absolute error tolerances that apply to the individual components of the solution vector. <code>AbsTol(i)</code> is a threshold below which the value of the <code>i</code>th solution component is unimportant. The absolute error tolerances determine the accuracy when the solution approaches zero. Even if you are not interested in a component <code>y(i)</code> when it is small, you may have to specify <code>AbsTol(i)</code> small enough to get some correct digits in <code>y(i)</code> so that you can accurately compute more interesting components.

If <code>AbsTol</code> is a vector, the length of <code>AbsTol</code> must be the same as the length of the solution vector <code>y</code>. If <code>AbsTol</code> is a scalar, the value applies to all components of <code>y</code>.</td></tr>
<tr><td><code>NormControl</code></td><td><code>on | {off}</code></td><td>Control error relative to norm of solution. Set this property <code>on</code> to request that the solvers control the error in each integration step with <code>norm(e)<= max(RelTol*norm(y),AbsTol)</code>. By default, solvers <code>dde23</code> and <code>ddesd</code> use a more stringent component-wise error control.</td></tr>
</table>

Solver Output Properties

You can use the solver output properties to control the output that the solvers generate.

DDE Solver Output Properties

Property	Value	Description

`OutputFcn`	Function handle `{@odeplot}`	The output function is a function that the solver calls after every successful integration step. To specify an output function, set `'OutputFcn'` to a function handle. For example,
		`options = ddeset('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:

Property	Value	Description
		• `init` — The solver calls `myfun(tspan,y0,'init')` before beginning the integration to allow the output function to initialize. `tspan` is the input argument to solvers `dde23` and `ddesd`. `y0` is the initial value of the solution, either from `history(t0)` or specified in the `initialY` option. • {none} — 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 `i`th column of `y` corresponds to the `i`th element of `t`. `myfun` must return a `status` output value of `0` or `1`. If literal > `status`, 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 functionname` at the command line for more information. • `odeplot` – time series plotting (default when you call the solver with no output argument and you have not specified an output function) • `odephas2` – two-dimensional phase plane plotting • `odephas3` – three-dimensional phase plane plotting • `odeprint` – print solution as the solver computes it

Property	Value	Description

`OutputSel`	Vector of indices	Vector of indices specifying which components of the solution vector the `dde23` or `ddesd` solver passes 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 = ddeset...`
		`('OutputFcn',@odeplot,...`
		`'OutputSel',[1 3]);`
		By default, the solver passes all components of the solution to the output function.

`Stats`	`on` | `{off}`	Specifies whether the solver should display statistics about its computations. By default, `Stats` is `off`. If it is `on`, after solving the problem the solver displays: • The number of successful steps • The number of failed attempts • The number of times the DDE function was called

Step Size Properties

The step size properties let you 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.

DDE Step Size Properties

Property	Value	Description
`InitialStep`	Positive scalar	Suggested initial step size. `InitialStep` sets an upper bound on the magnitude of the first step size the solver tries. If you do not set `InitialStep`, the solver bases the initial step size on the slope of the solution at the initial time `tspan(1)`. The initial step size is limited by the shortest delay. 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`.

Property	Value	Description
MaxStep	Positive scalar {0.1* abs(t0-tf)}	Upper bound on solver step size. If the differential equation has periodic coefficients or solutions, it may 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: • 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 2-805 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 (dde23 or ddesd) 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 DDE problems, the times of specific events are important. While solving a problem, the dde23 and ddesd solvers can detect such events by locating transitions to, from, or through zeros of user-defined functions.

The following table describes the Events property.

DDE Events Property

String	Value	Description

`Events`	Function handle	Handle to a function that includes one or more event functions. See "Function Handles" in the MATLAB Programming documentation for more information. The function is of the form
		
		`[value,isterminal,direction] =`
		`events(t,y,Z)`
		
		`value`, `isterminal`, and `direction` are vectors for which the `i`th element corresponds to the `i`th event function:

String	Value	Description
		• `value(i)` is the value of the `i`th event function. • `isterminal(i) = 1` if you want the integration to terminate at a zero of this event function, and `0` otherwise. • `direction(i) = 0` if you want the solver (`dde23` or `ddesd`) to locate all zeros (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 fields in the solution structure `sol`: • `sol.xe` is a row vector of times at which events occur. • `sol.ye` is a matrix whose columns are the solution values corresponding to times in `sol.xe`. • `sol.ie` is a vector containing indices that specify which event occurred at the corresponding time in `sol.xe`.
		For examples that use an event function while solving ordinary differential equation problems, see "Example: Simple Event Location" (`ballode`) and "Example: Advanced Event Location" (`orbitode`), in the MATLAB Mathematics documentation.

Discontinuity Properties

Solvers `dde23` and `ddesd` can solve problems with discontinuities in the history or in the coefficients of the equations. The following properties enable you to provide these solvers with a different initial value, and, for `dde23`, locations of known discontinuities. See "Discontinuities" in the MATLAB Mathematics documentation for more information.

The following table describes the discontinuity properties.

DDE Discontinuity Properties

String	Value	Description
`Jumps`	Vector	Location of discontinuities. Points t where the history or solution may have a jump discontinuity in a low-order derivative. This applies only to the `dde23` solver.
`InitialY`	Vector	Initial value of solution. By default the initial value of the solution is the value returned by `history` at the initial point. Supply a different initial value as the value of the `InitialY` property.

Example

To create an options structure that changes the relative error tolerance of the solver from the default value of `1e-3` to `1e-4`, enter

```
options = ddeset('RelTol', 1e-4);
```

To recover the value of `'RelTol'` from `options`, enter

```
ddeget(options, 'RelTol')

ans =

  1.0000e-004
```

See Also

`dde23`, `ddesd`, `ddeget`, `function_handle` (@)

Purpose

Terminate Dynamic Data Exchange (DDE) conversation

Syntax

```
rc = ddeterm(channel)
```

Description

`rc = ddeterm(channel)` accepts a channel handle returned by a previous call to `ddeinit` that established the DDE conversation. `ddeterm` terminates this conversation. `rc` is a return code where `0` indicates failure and `1` indicates success.

Examples

To close a conversation channel previously opened with `ddeinit`:

```
rc = ddeterm(channel)

rc =
1.00
```

See Also

`ddeadv`, `ddeexec`, `ddeinit`, `ddepoke`, `ddereq`, `ddeunadv`

ddeunadv

Purpose

Release advisory link

Syntax

Description

`ddeunadv` releases the advisory link between MATLAB and the server application established by an earlier `ddeadv` call. The `channel`, *`item`*, and `format` must be the same as those specified in the call to `ddeadv` that initiated the link. If you include the `timeout` argument but accept the default `format`, you must specify `format` as an empty matrix.

If successful, `ddeunadv` returns 1 in variable, `rc`. Otherwise it returns 0.

Arguments

`channel`	Conversation channel from `ddeinit`.
`item`	String specifying the DDE item name for the advisory link. Changing the data identified by `item` at the server triggers the advisory link.
format (*optional*)	Two-element array. This must be the same as the `format` argument for the corresponding `ddeadv` call.
timeout (*optional*)	Scalar specifying the time-out limit for this operation. `timeout` is specified in milliseconds. (1000 milliseconds = 1 second). The default value of `timeout` is three seconds.

Example

To release an advisory link established previously with `ddeadv`:

```
rc = ddeunadv(channel, 'r1c1:r5c5')
rc =

     1.00
```

See Also

`ddeadv`, `ddeexec`, `ddeinit`, `ddepoke`, `ddereq`, `ddeterm`

Purpose

Distribute inputs to outputs

Note As of MATLAB Version 7.0, you can access the contents of cell arrays and structure fields without using the `deal` function. See Example 3, below.

Syntax

```
[Y1, Y2, Y3, ...] = deal(X)
[Y1, Y2, Y3, ...] = deal(X1, X2, X3, ...)
[S.field] = deal(X)
[X{:}] = deal(A.field)
[Y1, Y2, Y3, ...] = deal(X{:})
[Y1, Y2, Y3, ...] = deal(S.field)
```

Description

`[Y1, Y2, Y3, ...]  = deal(X)` copies the single input to all the requested outputs. It is the same as `Y1 = X`, `Y2 = X`, `Y3 = X`, `...`

`[Y1, Y2, Y3, ...]  = deal(X1, X2, X3, ...)` is the same as `Y1 = X1`; `Y2 = X2`; `Y3 = X3`; `...`

Remarks

`deal` is most useful when used with cell arrays and structures via comma-separated list expansion. Here are some useful constructions:

`[S.field] = deal(X)` sets all the fields with the name `field` in the structure array `S` to the value `X`. If `S` doesn't exist, use `[S(1:m).field] = deal(X)`.

`[X{:}] = deal(A.field)` copies the values of the field with name `field` to the cell array `X`. If `X` doesn't exist, use `[X{1:m}] = deal(A.field)`.

`[Y1, Y2, Y3, ...]  = deal(X{:})` copies the contents of the cell array `X` to the separate variables `Y1, Y2, Y3, ...`

`[Y1, Y2, Y3, ...]  = deal(S.field)` copies the contents of the fields with the name `field` to separate variables `Y1, Y2, Y3, ...`

Examples

Example 1 — Assign Data From a Cell Array

Use `deal` to copy the contents of a 4-element cell array into four separate output variables.

```
C = {rand(3) ones(3,1) eye(3) zeros(3,1)};
[a,b,c,d] = deal(C{:})

a =
    0.9501    0.4860    0.4565
    0.2311    0.8913    0.0185
    0.6068    0.7621    0.8214

b =
    1
    1
    1

c =
    1    0    0
    0    1    0
    0    0    1

d =
    0
    0
    0
```

Example 2 — Assign Data From Structure Fields

Use `deal` to obtain the contents of all the name fields in a structure array:

```
A.name = 'Pat'; A.number = 176554;
A(2).name = 'Tony'; A(2).number = 901325;
[name1,name2] = deal(A(:).name)

name1 =
   Pat
```

```
name2 =
   Tony
```

Example 3 — Doing the Same Without deal

As of MATLAB Version 7.0, you can, in most cases, access the contents of cell arrays and structure fields without using the `deal` function. The two commands shown below perform the same operation as those used in the previous two examples, except that these commands do not require `deal`.

```
[a,b,c,d] = C{:}
[name1,name2] = A(:).name
```

See Also

`cell`, `iscell`, `celldisp`, `struct`, `isstruct`, `fieldnames`, `isfield`, `orderfields`, `rmfield`, `cell2struct`, `struct2cell`

deblank

Purpose

Strip trailing blanks from end of string

Syntax

```
str = deblank(str)
c = deblank(c)
```

Description

`str = deblank(str)` removes all trailing whitespace and null characters from the end of character string `str`. A whitespace is any character for which the `isspace` function returns logical 1 (`true`).

`c = deblank(c)` when `c` is a cell array of strings, applies `deblank` to each element of `c`.

The `deblank` function is useful for cleaning up the rows of a character array.

Examples

Example 1 – Removing Trailing Blanks From a String

Compose a string `str` that contains space, tab, and null characters:

```
NL = char(0);    TAB = char(9);
str = [NL 32 TAB NL 'AB' 32 NL 'CD' NL 32 TAB NL 32];
```

Display all characters of the string between | symbols:

```
['|' str '|']
ans =
      |    AB  CD        |
```

Remove trailing whitespace and null characters, and redisplay the string:

```
newstr = deblank(str);

['|' newstr '|']
ans =
      |    AB  CD|
```

Example 2– Removing Trailing Blanks From a Cell Array of Strings

```
A{1,1} = 'MATLAB    ';
A{1,2} = 'SIMULINK    ';
A{2,1} = 'Toolboxes    ';
A{2,2} = 'The MathWorks    ';
A =

    'MATLAB    '        'SIMULINK    '
    'Toolboxes    '     'The MathWorks    '


deblank(A)
ans =

    'MATLAB'            'SIMULINK'
    'Toolboxes'         'The MathWorks'
```

See Also

strjust, strtrim

debug

Purpose List M-file debugging functions

GUI Alternatives Use the **Debug** menu in most desktop tools, or use the Editor/Debugger.

Syntax

```
debug
```

Description `debug` lists M-file debugging functions.

Use debugging functions (listed in the See Also section) to help you identify problems in your M-files. Set breakpoints using `dbstop`. When MATLAB encounters a breakpoint during execution, it enters debug mode, the Editor/Debugger becomes active, and the prompt in the Command Window changes to a `K>>`. Any MATLAB command is allowed at the prompt. To resume execution, use `dbcont` or `dbstep`. To exit from debug mode, use `dbquit`.

To open the M-File in the Editor/Debugger when execution reaches a breakpoint, select **Debug > Open M-Files When Debugging**.

See Also `dbclear`, `dbcont`, `dbdown`, `dbquit`, `dbstack`, `dbstatus`, `dbstep`, `dbstop`, `dbtype`, `dbup`, `evalin`, `whos`

"Finding Errors, Debugging, and Correcting M-Files" in the MATLAB Desktop Tools and Development Environment documentation

Purpose

Convert decimal to base N number in string

Syntax

```
str = dec2base(d, base)
str = dec2base(d, base, n)
```

Description

`str = dec2base(d, base)` converts the nonnegative integer `d` to the specified `base`. `d` must be a nonnegative integer smaller than 2^52, and `base` must be an integer between 2 and 36. The returned argument `str` is a string.

`str = dec2base(d, base, n)` produces a representation with at least `n` digits.

Examples

The expression `dec2base(23, 2)` converts 23_{10} to base 2, returning the string `'10111'`.

See Also

`base2dec`

dec2bin

Purpose

Convert decimal to binary number in string

Syntax

```
str = dec2bin(d)
str = dec2bin(d,n)
```

Description

returns the

`str = dec2bin(d)` binary representation of `d` as a string. `d` must be a nonnegative integer smaller than 2^52.

`str = dec2bin(d,n)` produces a binary representation with at least `n` bits.

Examples

Decimal 23 converts to binary 010111:

```
dec2bin(23)
ans =
    10111
```

See Also

`bin2dec`, `dec2hex`

Purpose

Convert decimal to hexadecimal number in string

Syntax

```
str = dec2hex(d)
str = dec2hex(d, n)
```

Description

`str = dec2hex(d)` converts the decimal integer `d` to its hexadecimal representation stored in a MATLAB string. `d` must be a nonnegative integer smaller than 2^52.

`str = dec2hex(d, n)` produces a hexadecimal representation with at least `n` digits.

Examples

To convert decimal 1023 to hexadecimal,

```
dec2hex(1023)

ans =
    3FF
```

See Also

`dec2bin`, `format`, `hex2dec`, `hex2num`

Purpose

Compute consistent initial conditions for `ode15i`

Syntax

```
[y0mod,yp0mod] = decic(odefun,t0,y0,fixed_y0,yp0,fixed_yp0)
[y0mod,yp0mod] = decic(odefun,t0,y0,fixed_y0,yp0,fixed_yp0,
   options)
[y0mod,yp0mod,resnrm] = decic(odefun,t0,y0,fixed_y0,yp0,
   fixed_yp0...)
```

Description

`[y0mod,yp0mod] = decic(odefun,t0,y0,fixed_y0,yp0,fixed_yp0)` uses the inputs `y0` and `yp0` as initial guesses for an iteration to find output values that satisfy the requirement $f(\mathrm{t0}, \mathrm{y0mod}, \mathrm{yp0mod}) = 0$, i.e., `y0mod` and `yp0mod` are consistent initial conditions. `odefun` is a function handle. See "Function Handles" in the MATLAB Programming documentation for more information. The function `decic` changes as few components of the guesses as possible. You can specify that `decic` holds certain components fixed by setting `fixed_y0(i) = 1` if no change is permitted in the guess for `y0(i)` and 0 otherwise. `decic` interprets `fixed_y0 = []` as allowing changes in all entries. `fixed_yp0` is handled similarly.

"Parameterizing Functions Called by Function Functions" in the MATLAB Mathematics documentation, explains how to provide additional parameters to the function `odefun`, if necessary.

You cannot fix more than `length(y0)` components. Depending on the problem, it may not be possible to fix this many. It also may not be possible to fix certain components of `y0` or `yp0`. It is recommended that you fix no more components than necessary.

`[y0mod,yp0mod] = decic(odefun,t0,y0,fixed_y0,yp0,fixed_yp0,options)` computes as above with default tolerances for consistent initial conditions, `AbsTol` and `RelTol`, replaced by the values in options, a structure you create with the `odeset` function.

`[y0mod,yp0mod,resnrm] = decic(odefun,t0,y0,fixed_y0,yp0,fixed_yp0...)` returns the norm of odefun(t0,y0mod,yp0mod) as resnrm. If the norm seems unduly large, use options to decrease RelTol (1e-3 by default).

Examples

These demos provide examples of the use of decic in solving implicit ODEs: ihb1dae, iburgersode.

See Also

ode15i, odeget, odeset, function_handle (@)

Purpose

Deconvolution and polynomial division

Syntax

```
[q,r] = deconv(v,u)
```

Description

`[q,r] = deconv(v,u)` deconvolves vector `u` out of vector `v`, using long division. The quotient is returned in vector `q` and the remainder in vector `r` such that `v = conv(u,q)+r` .

If `u` and `v` are vectors of polynomial coefficients, convolving them is equivalent to multiplying the two polynomials, and deconvolution is polynomial division. The result of dividing `v` by `u` is quotient `q` and remainder `r`.

Examples

If

```
u = [1    2    3    4]
v = [10   20   30]
```

the convolution is

```
c = conv(u,v)
c =
    10      40      100      160      170      120
```

Use deconvolution to recover `u`:

```
[q,r] = deconv(c,u)
q =
    10     20     30
r =
    0       0       0       0       0       0
```

This gives a quotient equal to `v` and a zero remainder.

Algorithm

`deconv` uses the `filter` primitive.

See Also

`conv`, `residue`

Purpose Discrete Laplacian

Syntax

```
L = del2(U)
-L = del2(U)
L = del2(U,h)
L = del2(U,hx,hy)
L = del2(U,hx,hy,hz,...)
```

Definition If the matrix `U` is regarded as a function $u(x, y)$ evaluated at the point on a square grid, then `4*del2(U)` is a finite difference approximation of Laplace's differential operator applied to u, that is:

$$l = \frac{\nabla^2 u}{4} = \frac{1}{4}\left(\frac{d^2 u}{dx^2} + \frac{d^2 u}{dy^2}\right)$$

where:

$$l_{ij} = \frac{1}{4}(u_{i+1,\,j} + u_{i-1,\,j} + u_{i,\,j+1} + u_{i,\,j-1}) - u_{i,}$$

in the interior. On the edges, the same formula is applied to a cubic extrapolation.

For functions of more variables $u(x, y, z, \ldots)$, `del2(U)` is an approximation,

$$l = \frac{\nabla^2 u}{2N} = \frac{1}{2N}\left(\frac{d^2 u}{dx^2} + \frac{d^2 u}{dy^2} + \frac{d^2 u}{dz^2} + \ldots\right)$$

where N is the number of variables in u.

Description `L = del2(U)` where `U` is a rectangular array is a discrete approximation of

$$l = \frac{\nabla^2 u}{4} = \frac{1}{4}\left(\frac{d^2 u}{dx^2} + \frac{d^2 u}{dy^2}\right)$$

The matrix L is the same size as U with each element equal to the difference between an element of U and the average of its four neighbors.

-L = del2(U) when U is an multidimensional array, returns an approximation of

$$\frac{\nabla^2 u}{2N}$$

where N is ndims(u).

L = del2(U,h) where H is a scalar uses H as the spacing between points in each direction (h=1 by default).

L = del2(U,hx,hy) when U is a rectangular array, uses the spacing specified by hx and hy. If hx is a scalar, it gives the spacing between points in the x-direction. If hx is a vector, it must be of length size(u,2) and specifies the x-coordinates of the points. Similarly, if hy is a scalar, it gives the spacing between points in the y-direction. If hy is a vector, it must be of length size(u,1) and specifies the y-coordinates of the points.

L = del2(U,hx,hy,hz,...) where U is multidimensional uses the spacing given by hx, hy, hz, ...

Remarks

MATLAB computes the boundaries of the grid by extrapolating the second differences from the interior. The algorithm used for this computation can be seen in the del2 M-file code. To view this code, type

```
type del2
```

Examples

The function

$$u(x, y) = x^2 + y^2$$

has

$$\nabla^2 u = 4$$

For this function, `4*del2(U)` is also `4`.

```
[x,y] = meshgrid(-4:4,-3:3);
U = x.*x+y.*y
U =
    25    18    13    10     9    10    13    18    25
    20    13     8     5     4     5     8    13    20
    17    10     5     2     1     2     5    10    17
    16     9     4     1     0     1     4     9    16
    17    10     5     2     1     2     5    10    17
    20    13     8     5     4     5     8    13    20
    25    18    13    10     9    10    13    18    25

V = 4*del2(U)
V =
     4     4     4     4     4     4     4     4     4
     4     4     4     4     4     4     4     4     4
     4     4     4     4     4     4     4     4     4
     4     4     4     4     4     4     4     4     4
     4     4     4     4     4     4     4     4     4
     4     4     4     4     4     4     4     4     4
     4     4     4     4     4     4     4     4     4
```

See Also

`diff`, `gradient`

delaunay

Purpose

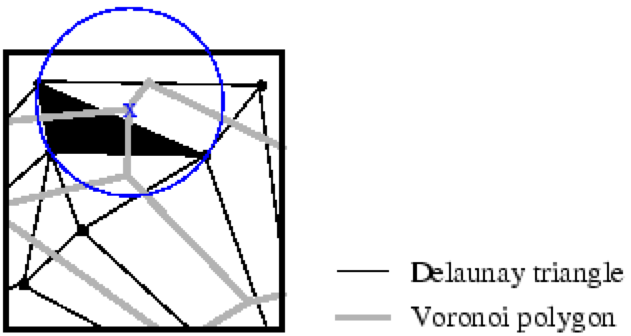
Delaunay triangulation

Syntax

```
TRI = delaunay(x,y)
TRI = delaunay(x,y,options)
```

Definition

Given a set of data points, the *Delaunay triangulation* is a set of lines connecting each point to its natural neighbors. The Delaunay triangulation is related to the Voronoi diagram — the circle circumscribed about a Delaunay triangle has its center at the vertex of a Voronoi polygon.



Description

`TRI = delaunay(x,y)` for the data points defined by vectors `x` and `y`, returns a set of triangles such that no data points are contained in any triangle's circumscribed circle. Each row of the `m`-by-3 matrix `TRI` defines one such triangle and contains indices into `x` and `y`. If the original data points are collinear or `x` is empty, the triangles cannot be computed and `delaunay` returns an empty matrix.

`delaunay` uses Qhull.

`TRI = delaunay(x,y,options)` specifies a cell array of strings `options` to be used in Qhull via `delaunayn`. The default options are `{'Qt','Qbb','Qc'}`.

If `options` is `[]`, the default options are used. If `options` is `{''}`, no options are used, not even the default. For more information on Qhull and its options, see `http://www.qhull.org`.

Remarks

The Delaunay triangulation is used by: `griddata` (to interpolate scattered data), `voronoi` (to compute the `voronoi` diagram), and is useful by itself to create a triangular grid for scattered data points.

The functions `dsearch` and `tsearch` search the triangulation to find nearest neighbor points or enclosing triangles, respectively.

Visualization

Use one of these functions to plot the output of `delaunay`:

`triplot` — Displays the triangles defined in the `m`-by-3 matrix `TRI`. See Example 1.

`trisurf` — Displays each triangle defined in the m-by-3 matrix TRI as a surface in 3-D space. To see a 2-D surface, you can supply a vector of some constant value for the third dimension. For example

```
trisurf(TRI,x,y,zeros(size(x)))
```

See Example 2.

`trimesh` — Displays each triangle defined in the m-by-3 matrix TRI as a mesh in 3-D space. To see a 2-D surface, you can supply a vector of some constant value for the third dimension. For example,

```
trimesh(TRI,x,y,zeros(size(x)))
```

produces almost the same result as `triplot`, except in 3-D space. See Example 2.

Examples

Example 1

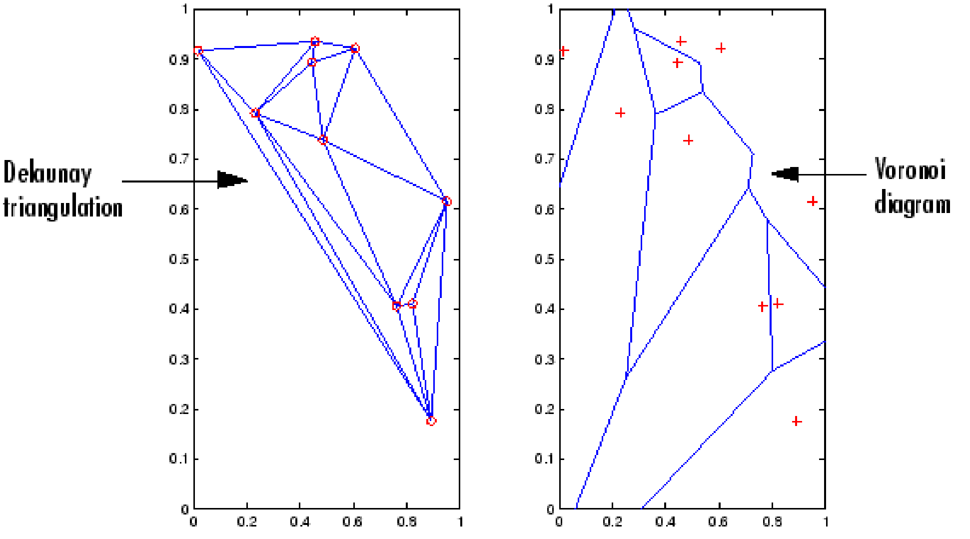
Plot the Delaunay triangulation for 10 randomly generated points.

```
rand('state',0);
x = rand(1,10);
y = rand(1,10);
```

```
TRI = delaunay(x,y);
subplot(1,2,1),...
triplot(TRI,x,y)
axis([0 1 0 1]);
hold on;
plot(x,y,'or');
hold off
```

Compare the Voronoi diagram of the same points:

```
[vx, vy] = voronoi(x,y,TRI);
subplot(1,2,2),...
plot(x,y,'r+',vx,vy,'b-'),...
axis([0 1 0 1])
```

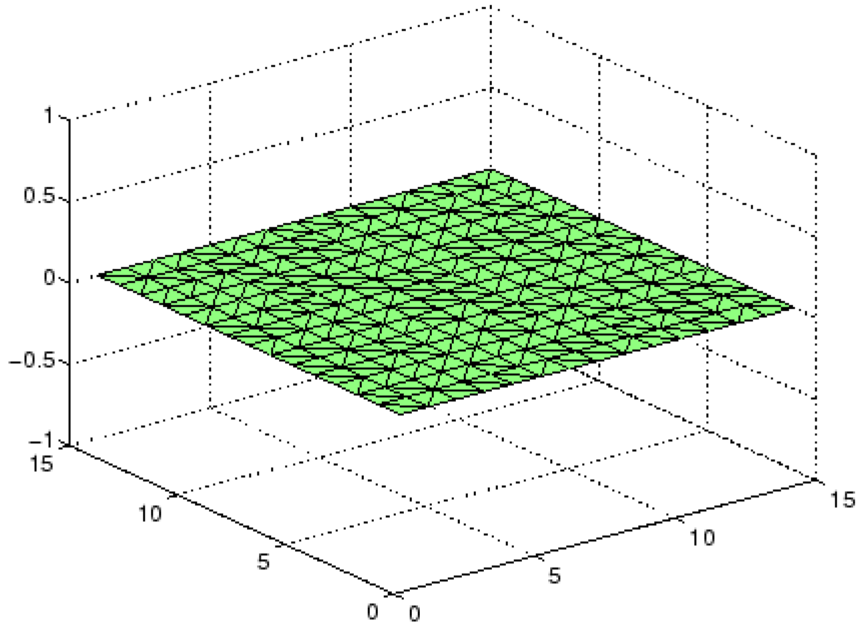


Example 2

Create a 2-D grid then use `trisurf` to plot its Delaunay triangulation in 3-D space by using `0`s for the third dimension.

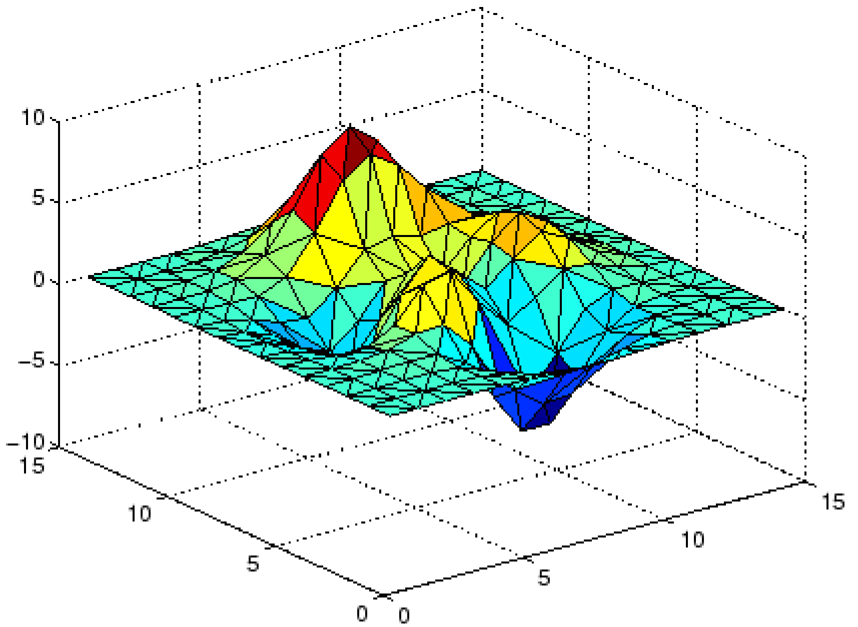
```
[x,y] = meshgrid(1:15,1:15);
```

```
tri = delaunay(x,y);
trisurf(tri,x,y,zeros(size(x)))
```



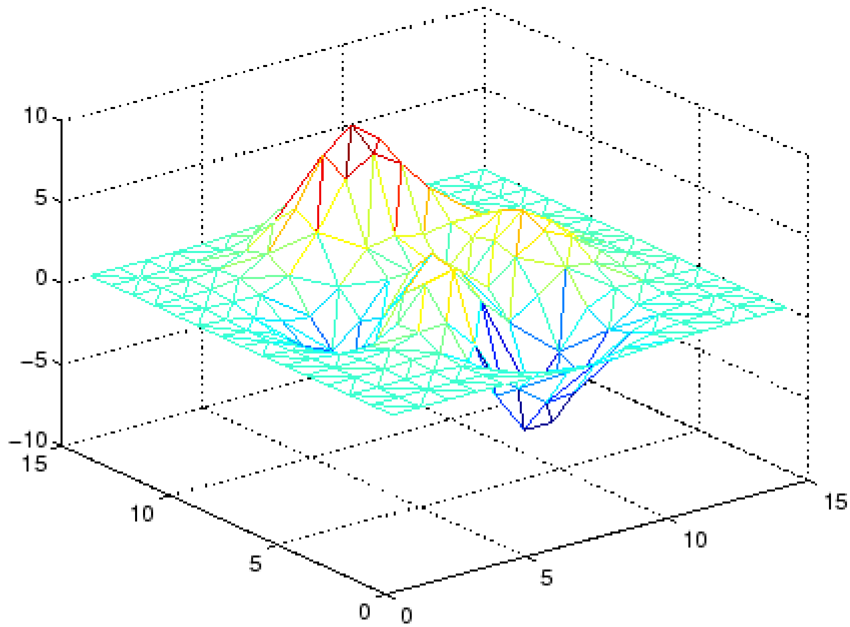
Next, generate peaks data as a 15-by-15 matrix, and use that data with the Delaunay triangulation to produce a surface in 3-D space.

```
z = peaks(15);
trisurf(tri,x,y,z)
```



You can use the same data with `trimesh` to produce a mesh in 3-D space.

```
trimesh(tri,x,y,z)
```



Example 3

The following example illustrates the `options` input for `delaunay`.

```
x = [-0.5 -0.5 0.5 0.5];
       y = [-0.5 0.5 0.5 -0.5];
```

The command

```
T = delaunay(X);
```

returns the following error message.

```
??? qhull input error: can not scale last coordinate. Input is
cocircular
   or cospherical. Use option 'Qz' to add a point at infinity.
```

The error message indicates that you should add `'Qz'` to the default Qhull options.

```
tri = delaunay(x,y,{'Qt','Qbb','Qc','Qz'})

tri =

     3     2     1
     3     4     1
```

Algorithm

`delaunay` is based on Qhull [1]. For information about Qhull, see `http://www.qhull.org/`. For copyright information, see `http://www.qhull.org/COPYING.txt`.

See Also

`delaunay3`, `delaunay`, `dsearch`, `griddata`, `plot`, `triplot`, `trimesh`, `trisurf`, `tsearch`, `voronoi`

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.

Purpose

3-D Delaunay tessellation

Syntax

```
T = delaunay3(x,y,z)
T = delaunay3(x,y,z,options)
```

Description

`T = delaunay3(x,y,z)` returns an array `T`, each row of which contains the indices of the points in `(x,y,z)` that make up a tetrahedron in the tessellation of `(x,y,z)`. `T` is a `numtes`-by-4 array where `numtes` is the number of facets in the tessellation. `x`, `y`, and `z` are vectors of equal length. If the original data points are collinear or `x`, `y`, and `z` define an insufficient number of points, the triangles cannot be computed and `delaunay3` returns an empty matrix.

`delaunay3` uses Qhull.

`T = delaunay3(x,y,z,options)` specifies a cell array of strings `options` to be used in Qhull via `delaunay3`. The default options are `{'Qt','Qbb','Qc'}`.

If `options` is `[]`, the default options are used. If `options` is `{''}`, no options are used, not even the default. For more information on Qhull and its options, see `http://www.qhull.org`.

Visualization

Use `tetramesh` to plot `delaunay3` output. `tetramesh` displays the tetrahedrons defined in `T` as mesh. `tetramesh` uses the default transparency parameter value `'FaceAlpha' = 0.9`.

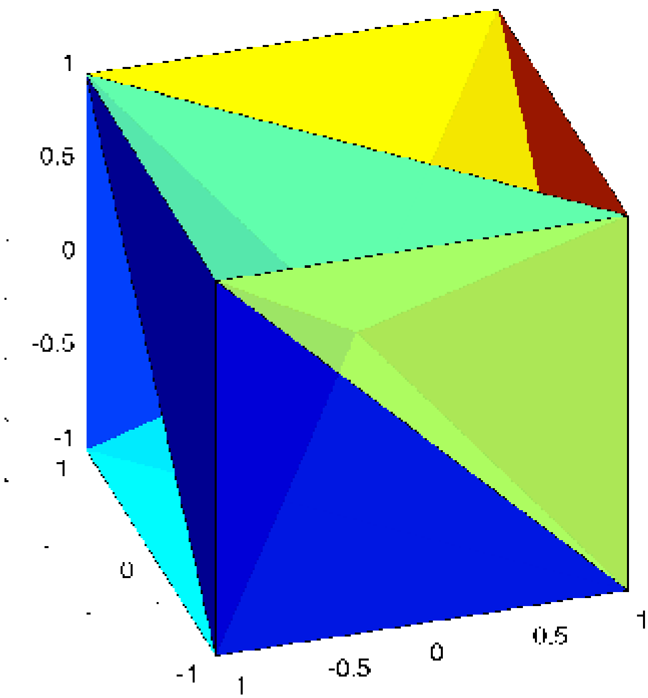
Examples

Example 1

This example generates a 3-dimensional Delaunay tessellation, then uses `tetramesh` to plot the tetrahedrons that form the corresponding simplex. `camorbit` rotates the camera position to provide a meaningful view of the figure.

```
d = [-1 1];
[x,y,z] = meshgrid(d,d,d);  % A cube
x = [x(:);0];
y = [y(:);0];
z = [z(:);0];
```

```
% [x,y,z] are corners of a cube plus the center.
Tes = delaunay3(x,y,z)

Tes =

     9     1     5     6
     3     9     1     5
     2     9     1     6
     2     3     9     4
     2     3     9     1
     7     9     5     6
     7     3     9     5
     8     7     9     6
     8     2     9     6
     8     2     9     4
     8     3     9     4
     8     7     3     9

X = [x(:) y(:) z(:)];
tetramesh(Tes,X);camorbit(20,0)
```



Example 2

The following example illustrates the `options` input for `delaunay3`.

```
X = [-0.5 -0.5 -0.5 -0.5 0.5 0.5 0.5 0.5];
Y = [-0.5 -0.5 0.5 0.5 -0.5 -0.5 0.5 0.5];
Z = [-0.5 0.5 -0.5 0.5 -0.5 0.5 -0.5 0.5];
```

The command

```
T = delaunay3(X);
```

returns the following error message.

```
??? qhull input error: can not scale last coordinate. Input is
cocircular
```

```
    or cospherical. Use option 'Qz' to add a point at infinity.
```

The error message indicates that you should add `'Qz'` to the default Qhull options.

```
T = delaunay3( X, Y, Z, {'Qt', 'Qbb', 'Qc', 'Qz'} )

T =

     4     3     5     1
     4     2     5     1
     4     7     3     5
     4     7     8     5
     4     6     2     5
     4     6     8     5
```

Algorithm

`delaunay3` is based on Qhull [1]. For information about Qhull, see `http://www.qhull.org/`. For copyright information, see `http://www.qhull.org/COPYING.txt`.

See Also

`delaunay`, `delaunayn`

Reference

[1] Barber, C. B., D.P. Dobkin, and H.T. Huhdanpaa, "The Quickhull Algorithm for Convex Hulls," ACM Transactions on Mathematical Software, Vol. 22, No. 4, Dec. 1996, p. 469-483.

Purpose

N-D Delaunay tessellation

Syntax

```
T = delaunayn(X)
T = delaunayn(X, options)
```

Description

`T = delaunayn(X)` computes a set of simplices such that no data points of `X` are contained in any circumspheres of the simplices. The set of simplices forms the Delaunay tessellation. `X` is an `m`-by-`n` array representing m points in n-dimensional space. `T` is a `numt`-by-(`n+1`) array where each row contains the indices into `X` of the vertices of the corresponding simplex.

`delaunayn` uses Qhull.

`T = delaunayn(X, options)` specifies a cell array of strings `options` to be used as options in Qhull. The default options are:

- `{'Qt','Qbb','Qc'}` for 2- and 3-dimensional input
- `{'Qt','Qbb','Qc','Qx'}` for 4 and higher-dimensional input

If `options` is `[]`, the default options used. If `options` is `{''}`, no options are used, not even the default. For more information on Qhull and its options, see `http://www.qhull.org`.

Visualization

Plotting the output of `delaunayn` depends of the value of `n`:

- For `n = 2`, use `triplot`, `trisurf`, or `trimesh` as you would for `delaunay`.
- For `n = 3`, use `tetramesh` as you would for `delaunay3`.

  For more control over the color of the facets, use `patch` to plot the output. For an example, see “Tessellation and Interpolation of Scattered Data in Higher Dimensions” in the MATLAB documentation.
- You cannot plot `delaunayn` output for `n > 3`.

Examples

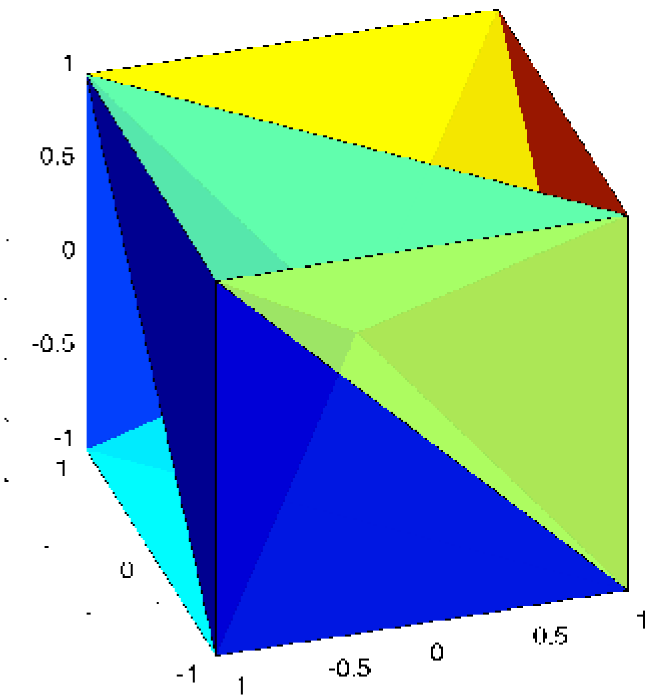
Example 1

This example generates an n-dimensional Delaunay tessellation, where `n = 3`.

```
d = [-1 1];
[x,y,z] = meshgrid(d,d,d);  % A cube
x = [x(:);0];
y = [y(:);0];
z = [z(:);0];
% [x,y,z] are corners of a cube plus the center.
X = [x(:) y(:) z(:)];
Tes = delaunayn(X)

Tes =
     9     1     5     6
     3     9     1     5
     2     9     1     6
     2     3     9     4
     2     3     9     1
     7     9     5     6
     7     3     9     5
     8     7     9     6
     8     2     9     6
     8     2     9     4
     8     3     9     4
     8     7     3     9
```

You can use `tetramesh` to visualize the tetrahedrons that form the corresponding simplex. `camorbit` rotates the camera position to provide a meaningful view of the figure.

```
tetramesh(Tes,X);camorbit(20,0)
```



Example 2

The following example illustrates the `options` input for `delaunayn`.

```
X = [-0.5 -0.5  -0.5;...
            -0.5 -0.5   0.5;...
            -0.5  0.5  -0.5;...
            -0.5  0.5   0.5;...
             0.5 -0.5  -0.5;...
             0.5 -0.5   0.5;...
             0.5  0.5  -0.5;...
             0.5  0.5   0.5];
```

The command

```
T = delaunayn(X);
```

returns the following error message.

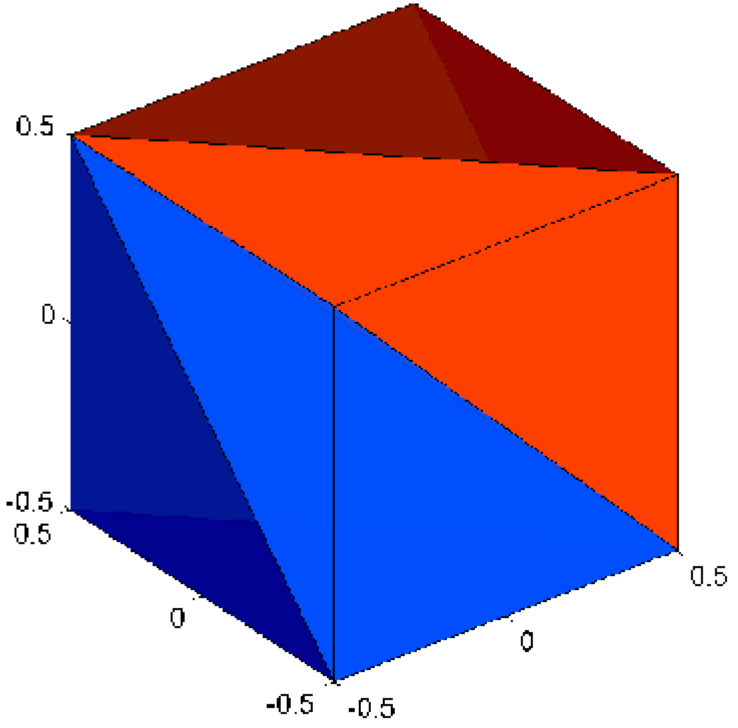
??? qhull input error: can not scale last coordinate. Input is cocircular or cospherical. Use option 'Qz' to add a point at infinity.

This suggests that you add `'Qz'` to the default options.

```
T = delaunayn(X,{'Qt','Qbb','Qc','Qz'});
```

To visualize this answer you can use the `tetramesh` function:

```
tetramesh(T,X)
```



Algorithm

delaunayn is based on Qhull [1]. For information about Qhull, see http://www.qhull.org/. For copyright information, see http://www.qhull.org/COPYING.txt.

See Also

convhulln, delaunayn, delaunay3, tetramesh, voronoin

Reference

[1] Barber, C. B., D.P. Dobkin, and H.T. Huhdanpaa, "The Quickhull Algorithm for Convex Hulls," ACM Transactions on Mathematical Software, Vol. 22, No. 4, Dec. 1996, p. 469-483.

Purpose

Remove files or graphics objects

Graphical Interface

As an alternative to the `delete` function, you can delete files using the "Current Directory Browser", as described in the Desktop Tools and Development Environment documentation.

Syntax

```
delete filename
delete(h)
delete('filename')
```

Description

`delete filename` deletes the named file from the disk. The `filename` may include an absolute pathname or a pathname relative to the current directory. The `filename` may also include wildcards, (`*`).

`delete(h)` deletes the graphics object with handle `h`. The function deletes the object without requesting verification even if the object is a window.

`delete('filename')` is the function form of `delete`. Use this form when the filename is stored in a string.

Note MATLAB does not ask for confirmation when you enter the `delete` command. To avoid accidentally losing files or graphics objects that you need, make sure that you have accurately specified the items you want deleted.

Remarks

The action that the delete function takes on deleted files depends upon the setting of the MATLAB recycle state. If you set the recycle state to `on`, MATLAB moves deleted files to your recycle bin or temporary directory. With the recycle state set to `off` (the default), deleted files are permanently removed from the system.

To set the recycle state for all MATLAB sessions, use the **Preferences** dialog box. Open the **Preferences** dialog and select **General**. To enable or disable recycling, click **Move files to the recycle bin** or **Delete files permanently**. See "General Preferences for MATLAB" in the Desktop Tools and Development Environment documentation for more information.

The `delete` function deletes files and handles to graphics objects only. Use the `rmdir` function to delete directories.

Examples

To delete all files with a `.mat` extension in the `../mytests/` directory, type

```
delete('../mytests/*.mat')
```

To delete a directory, use `rmdir` rather than `delete`:

```
rmdir mydirectory
```

See Also

`recycle`, `dir`, `edit`, `fileparts`, `mkdir`, `rmdir`, `type`

delete (COM)

Purpose

Remove COM control or server

Syntax

```
h.delete
delete(h)
```

Description

`h.delete` releases all interfaces derived from the specified COM server or control, and then deletes the server or control itself. This is different from releasing an interface, which releases and invalidates only that interface.

`delete(h)` is an alternate syntax for the same operation.

Examples

Create a Microsoft Calender application. Then create a `TitleFont` interface and use it to change the appearance of the font of the calendar's title:

```
f = figure('position',[300 300 500 500]);
cal = actxcontrol('mscal.calendar', [0 0 500 500], f);

TFont = cal.TitleFont
TFont =
   Interface.Standard_OLE_Types.Font

TFont.Name = 'Viva BoldExtraExtended';
TFont.Bold = 0;
```

When you're finished working with the title font, release the `TitleFont` interface:

```
TFont.release;
```

Now create a `GridFont` interface and use it to modify the size of the calendar's date numerals:

```
GFont = cal.GridFont
GFont =
   Interface.Standard_OLE_Types.Font
```

```
GFont.Size = 16;
```

When you're done, delete the `cal` object and the figure window. Deleting the `cal` object also releases all interfaces to the object (e.g., `GFont`):

```
cal.delete;
delete(f);
clear f;
```

Note that, although the object and interfaces themselves have been destroyed, the variables assigned to them still reside in the MATLAB workspace until you remove them with `clear`:

```
whos
  Name        Size                    Bytes  Class

  GFont       1x1                         0  handle
  TFone       1x1                         0  handle
  cal         1x1                         0  handle

Grand total is 3 elements using 0 bytes
```

See Also

`release`, `save`, `load`, `actxcontrol`, `actxserver`

delete (ftp)

Purpose Remove file on FTP server

Syntax

```
delete(f,'filename')
```

Description `delete(f,'filename')` removes the file `filename` from the current directory of the FTP server `f`, where `f` was created using `ftp`.

Examples Connect to server `testsite`.

```
test=ftp('ftp.testsite.com')
```

Change the current directory to `testdir` and view the contents.

```
cd(test,'testdir');
dir(test)
```

See Also `ftp`

Purpose

Remove serial port object from memory

Syntax

```
delete(obj)
```

Arguments

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

Description

`delete(obj)` removes `obj` from memory.

Remarks

When you delete `obj`, it becomes an *invalid* object. Because you cannot connect an invalid serial port object to the device, you should remove it from the workspace with the `clear` command. If multiple references to `obj` exist in the workspace, then deleting one reference invalidates the remaining references.

If `obj` is connected to the device, it has a `Status` property value of `open`. If you issue `delete` while `obj` is connected, then the connection is automatically broken. You can also disconnect `obj` from the device with the `fclose` function.

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

```
help serial/delete
```

Example

This example creates the serial port object `s`, connects `s` to the device, writes and reads text data, disconnects `s` from the device, removes `s` from memory using `delete`, and then removes `s` from the workspace using `clear`.

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

See Also

Functions

`clear`, `fclose`, `isvalid`

Properties

`Status`

Purpose Remove timer object from memory

Syntax

```
delete(obj)
```

Description

`delete(obj)` removes the timer object, `obj`, from memory. If `obj` is an array of timer objects, `delete` removes all the objects from memory.

When you delete a timer object, it becomes invalid and cannot be reused. Use the `clear` command to remove invalid timer objects from the workspace.

If multiple references to a timer object exist in the workspace, deleting the timer object invalidates the remaining references. Use the `clear` command to remove the remaining references to the object from the workspace.

See Also `clear`, `isvalid(timer)`, `timer`

deleteproperty

Purpose

Remove custom property from object

Syntax

```
h.deleteproperty('propertyname')
deleteproperty(h, 'propertyname')
```

Description

`h.deleteproperty('propertyname')` deletes the property specified in the string `propertyname` from the custom properties belonging to object or interface, `h`.

`deleteproperty(h, 'propertyname')` is an alternate syntax for the same operation.

Note You can only delete properties that have been created with `addproperty`.

Examples

Create an `mwsamp` control and add a new property named `Position` to it. Assign an array value to the property:

```
f = figure('position', [100 200 200 200]);
h = actxcontrol('mwsamp.mwsampctrl.2', [0 0 200 200], f);
h.get
     Label: 'Label'
    Radius: 20

h.addproperty('Position');
h.Position = [200 120];
h.get
       Label: 'Label'
      Radius: 20
    Position: [200 120]
```

Delete the custom `Position` property:

```
h.deleteproperty('Position');
h.get
     Label: 'Label'
```

```
Radius: 20
```

See Also

addproperty, get, set, inspect

delevent

Purpose

Remove `tsdata.event` objects from `timeseries` object

Syntax

```
ts = delevent(ts,event)
ts = delevent(ts,events)
ts = delevent(ts,event,n)
```

Description

`ts = delevent(ts,event)` removes the `tsdata.event` object from the `ts.events` property, where `event` is an event name string.

`ts = delevent(ts,events)` removes the `tsdata.event` object from the `ts.events` property, where `events` is a cell array of event name strings.

`ts = delevent(ts,event,n)` removes the `nth` `tsdata.event` object from the `ts.events` property. `event` is the name of the `tsdata.event` object.

Examples

The following example shows how to remove an event from a `timeseries` object:

1. Create a time series.

   ```
   ts = timeseries(rand(5,4))
   ```

2. Create an event object called `'test'` such that the event occurs at time `3`.

   ```
   e = tsdata.event('test',3)
   ```

3. Add the event object to the time series `ts`.

   ```
   ts = addevent(ts,e)
   ```

4. Remove the event object from the time series `ts`.

   ```
   ts = delevent(ts,'test')
   ```

See Also

`addevent`, `timeseries`, `tsdata.event`, `tsprops`

delsample

Purpose

Remove sample from `timeseries` object

Syntax

```
ts = delsample(ts,'Index',N)
ts = delsample(ts,'Value',Time)
```

Description

`ts = delsample(ts,'Index',N)` deletes samples from the `timeseries` object `ts`. `N` specifies the indices of the `ts` time vector that correspond to the samples you want to delete.

`ts = delsample(ts,'Value',Time)` deletes samples from the `timeseries` object `ts`. `Time` specifies the time values that correspond to the samples you want to delete.

See Also

`addsample`

delsamplefromcollection

Purpose

Remove sample from `tscollection` object

Syntax

```
tsc = delsamplefromcollection(tsc,'Index',N)
tsc = delsamplefromcollection(tsc,'Value',Time)
```

Description

`tsc = delsamplefromcollection(tsc,'Index',N)` deletes samples from the `tscollection` object tsc. N specifies the indices of the tsc time vector that correspond to the samples you want to delete.

`tsc = delsamplefromcollection(tsc,'Value',Time)` deletes samples from the `tscollection` object tsc. Time specifies the time values that correspond to the samples you want to delete.

See Also

`addsampletocollection`, `tscollection`

Purpose

Access product demos via Help browser

GUI Alternatives

As an alternative to the `demo` function, you can select **Help > Demos** from any desktop tool, or click the **Demos** tab when the Help browser is open.

Syntax

```
demo
demo subtopic
demo subtopic category
demo('subtopic', 'category')
```

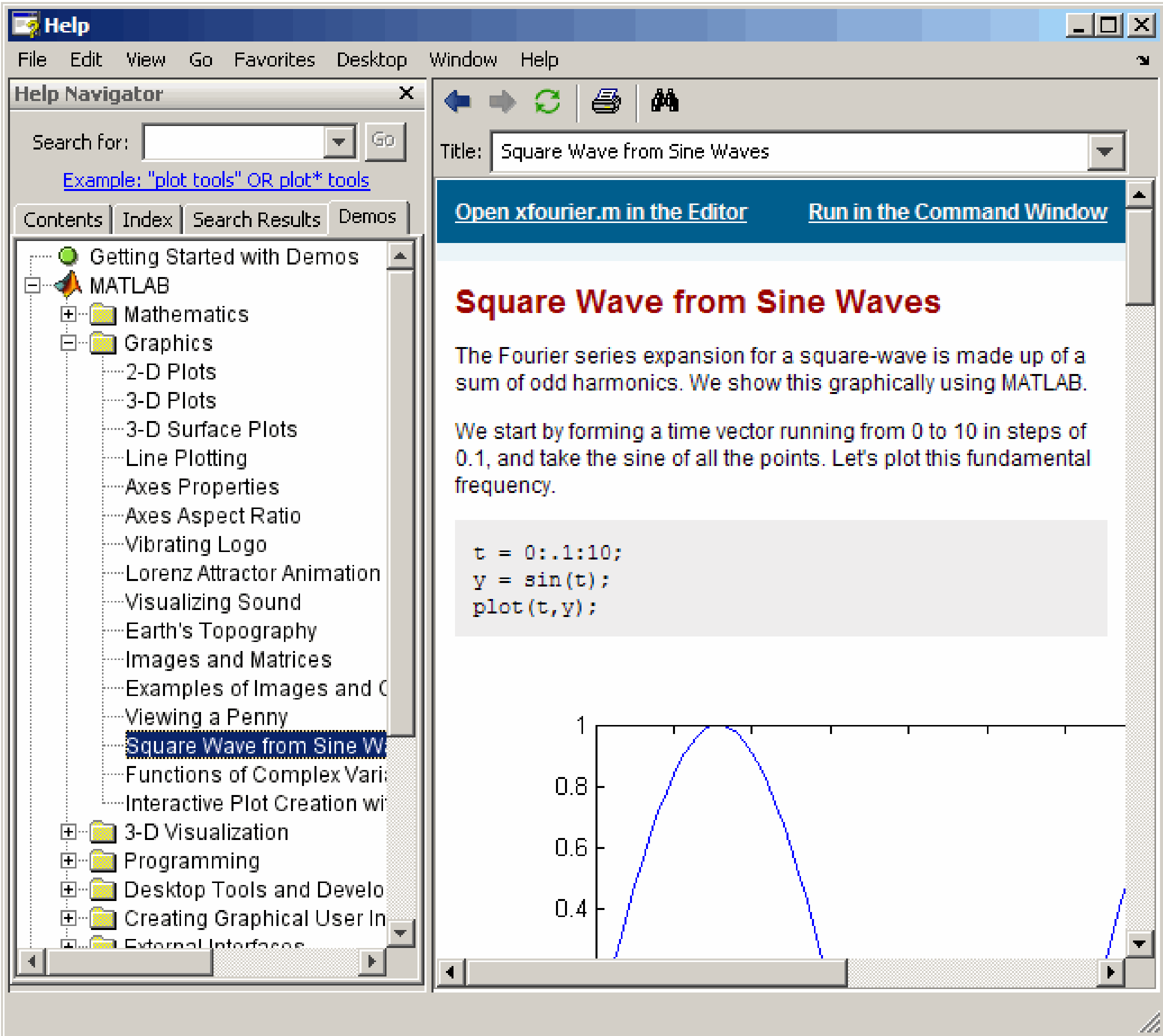
Description

`demo` opens the **Demos** pane in the Help browser. In the left pane, expand the listing for a product area (for example, MATLAB). Within that product area, expand the listing for a product or product category (for example, MATLAB Graphics). Select a specific demo from the list (for example, Square Wave from Sine Waves). In the right pane, view instructions for using the demo. For more information, see the topic "Demos in the Help Browser" in the MATLAB Desktop Tools and Development Environment documentation. To run a demo from the command line, type the demo name. To run an M-file demo, open it in the Editor/Debugger and run it using **Cell > Evaluate Current Cell and Advance**, or run `echodemo` followed by the demo name.

`demo` *`subtopic`* opens the **Demos** pane in the Help browser with the specified subtopic expanded. Subtopics are `matlab`, `toolbox`, `simulink`, and `blockset`.

`demo` *`subtopic category`* opens the **Demos** pane in the Help browser to the specified product or category within the subtopic. The `demo` function uses the full name displayed in the **Demo** pane for `category`.

`demo('`*`subtopic`*`', '`*`category`*`')` is the function form of the syntax. Use this form when `category` is more than one word.



Examples

Accessing Toolbox Demos

To find the demos relating to Communications Toolbox, type

```
demo toolbox communications
```

The Help browser opens to the **Demos** pane with the Toolbox subtopic expanded and with the Communications product highlighted and expanded to show the available demos.

Accessing Simulink Demos

To access the demos within Simulink, type

```
demo simulink automotive
```

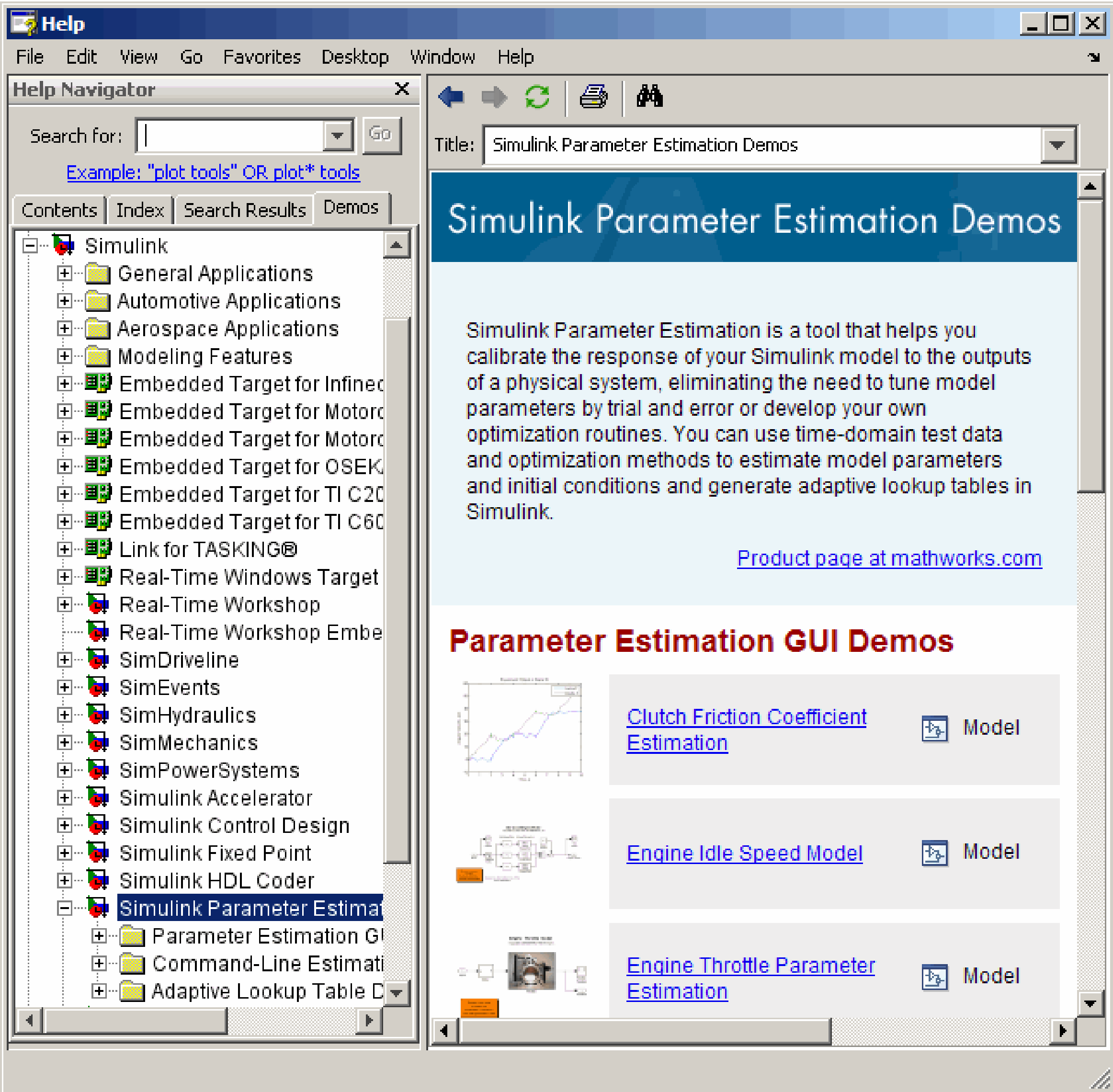
The **Demos** pane opens with the Simulink subtopic and Automotive category expanded.

Function Form of demo

To access the Simulink Parameter Estimation demos, run

```
demo('simulink', 'simulink parameter estimation')
```

which displays



Help
File Edit View Go Favorites Desktop Window Help
Help Navigator
Search for:
Go
Example: "plot tools" OR plot* tools
Contents Index Search Results Demos
Simulink
General Applications
Automotive Applications
Aerospace Applications
Modeling Features
Embedded Target for Infined
Embedded Target for Motoro
Embedded Target for Motoro
Embedded Target for OSEK
Embedded Target for TI C20
Embedded Target for TI C60
Link for TASKING®
Real-Time Windows Target
Real-Time Workshop
Real-Time Workshop Embe
SimDriveline
SimEvents
SimHydraulics
SimMechanics
SimPowerSystems
Simulink Accelerator
Simulink Control Design
Simulink Fixed Point
Simulink HDL Coder
Simulink Parameter Estima
Parameter Estimation G
Command-Line Estimati
Adaptive Lookup Table D
Title: Simulink Parameter Estimation Demos
Simulink Parameter Estimation Demos
Simulink Parameter Estimation is a tool that helps you calibrate the response of your Simulink model to the outputs of a physical system, eliminating the need to tune model parameters by trial and error or develop your own optimization routines. You can use time-domain test data and optimization methods to estimate model parameters and initial conditions and generate adaptive lookup tables in Simulink.
Product page at mathworks.com
Parameter Estimation GUI Demos
Clutch Friction Coefficient Estimation
Model
Engine Idle Speed Model
Model
Engine Throttle Parameter Estimation
Model

Running a Demo from the Command Line

Type

```
vibes
```

to run a visualization demonstration showing an animated L-shaped membrane.

Running an M-File Demo from the Command Line

Type

```
quake
```

to run an earthquake data demo. Not much appears to happen because `quake` is an M-file demo and executes from start to end without stopping. Verify this by viewing the M-file, `quake.m`, for example, by typing

```
edit quake
```

The first line, that is, the H1 line for `quake`, is

```
%% Loma Prieta Earthquake
```

The `%%` indicates that `quake` is an M-file demo. To step through the demo cell-by-cell, from the Editor/Debugger select **Cell > Evaluate Current Cell and Advance**.

Alternatively, run

```
echodemo quake
```

and the earthquake demo runs step-by-step in the Command Window.

See Also

`echodemo`, `grabcode`, `help`, `helpbrowser`, `helpwin`, `lookfor`

depdir

Purpose List dependent directories of M-file or P-file

Syntax

```
list = depdir('file_name')
[list, prob_files, prob_sym,
   prob_strings] = depdir('file_name')
[...] = depdir('file_name1', 'file_name2',...)
```

Description The `depdir` function lists the directories of all the functions that a specified M-file or P-file needs to operate. This function is useful for finding all the directories that need to be included with a run-time application and for determining the run-time path.

`list = depdir('file_name')` creates a cell array of strings containing the directories of all the M-files and P-files that `file_name.m` or `file_name.p` uses. This includes the second-level files that are called directly by `file_name`, as well as the third-level files that are called by the second-level files, and so on.

`[list, prob_files, prob_sym, prob_strings] = depdir('file_name')` creates three additional cell arrays containing information about any problems with the `depdir` search. `prob_files` contains filenames that `depdir` was unable to parse. `prob_sym` contains symbols that `depdir` was unable to find. `prob_strings` contains callback strings that `depdir` was unable to parse.

`[...]  = depdir('file_name1', 'file_name2',...)` performs the same operation for multiple files. The dependent directories of all files are listed together in the output cell arrays.

Example

```
list = depdir('mesh')
```

See Also `depfun`

Purpose

List dependencies of M-file or P-file

Syntax

```
list = depfun('fun')
[list, builtins, classes] = depfun('fun')
[list, builtins, classes, prob_files, prob_sym, eval_strings,
   ... called_from, java_classes] = depfun('fun')
[...] = depfun('fun1', 'fun2',...)
[...] = depfun({'fun1', 'fun2', ...})
[...] = depfun('fig_file')
[...] = depfun(..., options)
```

Description

The `depfun` function lists the paths of all files a specified M-file or P-file needs to operate.

Note It cannot be guaranteed that `depfun` will find every dependent file. Some dependent files can be hidden in callbacks, or can be constructed dynamically for evaluation, for example. Also note that the list of functions returned by `depfun` often includes extra files that would never be called if the specified function were actually evaluated.

`list = depfun('fun')` creates a cell array of strings containing the paths of all the files that function `fun` uses. This includes the second-level files that are called directly by `fun`, and the third-level files that are called by the second-level files, and so on.

Function `fun` must be on the MATLAB path, as determined by the `which` function. If the MATLAB path contains any relative directories, then files in those directories will also have a relative path.

Note If MATLAB returns a parse error for any of the input functions, or if the `prob_files` output below is nonempty, then the rest of the output of `depfun` might be incomplete. You should correct the problematic files and invoke `depfun` again.

`[list, builtins, classes] = depfun('fun')` creates three cell arrays containing information about dependent functions. `list` contains the paths of all the files that function `fun` and its subordinates use. `builtins` contains the built-in functions that `fun` and its subordinates use. `classes` contains the MATLAB classes that `fun` and its subordinates use.

`[list, builtins, classes, prob_files, prob_sym, eval_strings,... called_from, java_classes] = depfun('fun')` creates additional cell arrays or structure arrays containing information about any problems with the `depfun` search and about where the functions in `list` are invoked. The additional outputs are

- `prob_files` — Indicates which files `depfun` was unable to parse, find, or access. Parsing problems can arise from MATLAB syntax errors. `prob_files` is a structure array having these fields:
  - `name` (path to the file)
  - `listindex` (index of the file in `list`)
  - `errmsg` (problems encountered)
- *`unused`* — This is a placeholder for an output argument that is not fully implemented at this time. MATLAB returns an empty structure array for this output.
- `called_from` — Cell array of the same length as `list` that indicates which functions call other functions. This cell array is arranged so that the following statement returns all functions in function `fun` that invoke the function `list{i}`:

  ```
  list(called_from{i})
  ```

- `java_classes` — Cell array of Java class names used by `fun` and its subordinate functions.

`[...] = depfun('fun1', 'fun2',...)` performs the same operation for multiple functions. The dependent functions of all files are listed together in the output arrays.

`[...] = depfun({'fun1', 'fun2', ...})` performs the same operation, but on a cell array of functions. The dependent functions of all files are listed together in the output array.

`[...] = depfun('fig_file')` looks for dependent functions among the callback strings of the GUI elements that are defined in the figure file named `fig_file`.

`[...] = depfun(..., options)` modifies the `depfun` operation according to the *`options`* specified (see table below).

Option	Description
`'-all'`	Computes all possible left-side arguments and displays the results in the report(s). Only the specified arguments are returned.
`'-calltree'`	Returns a `call` list in place of a `called_from` list. This is derived from the `called_from` list as an extra step.
`'-expand'`	Includes both indices and full paths in the `call` or `called_from` list.
`'-print', 'file'`	Prints a full report to `file`.
`'-quiet'`	Displays only error and warning messages, and not a summary report.
`'-toponly'`	Examines *only* the files listed explicitly as input arguments. It does not examine the files on which they depend.
`'-verbose'`	Outputs additional internal messages.

Examples

```
list = depfun('mesh'); % Files mesh.m depends on
list = depfun('mesh','-toponly') % Files mesh.m depends on
directly
```

```
[list,builtins,classes] = depfun('gca');
```

See Also

depdir

Purpose Matrix determinant

Syntax `d = det(X)`

Description `d = det(X)` returns the determinant of the square matrix `X`. If `X` contains only integer entries, the result `d` is also an integer.

Remarks Using `det(X) == 0` as a test for matrix singularity is appropriate only for matrices of modest order with small integer entries. Testing singularity using `abs(det(X)) <= tolerance` is not recommended as it is difficult to choose the correct tolerance. The function `cond(X)` can check for singular and nearly singular matrices.

Algorithm The determinant is computed from the triangular factors obtained by Gaussian elimination

```
[L,U] = lu(A)
s =  det(L)        % This is always +1 or -1
det(A) = s*prod(diag(U))
```

Examples The statement `A = [1 2 3; 4 5 6; 7 8 9]`

produces

```
A =
     1     2     3
     4     5     6
     7     8     9
```

This happens to be a singular matrix, so `d = det(A)` produces `d = 0`. Changing `A(3,3)` with `A(3,3) = 0` turns `A` into a nonsingular matrix. Now `d = det(A)` produces `d = 27`.

See Also `cond`, `condest`, `inv`, `lu`, `rref`

The arithmetic operators `\`, `/`

detrend

Purpose

Remove linear trends

Syntax

```
y = detrend(x)
y = detrend(x,'constant')
y = detrend(x,'linear',bp)
```

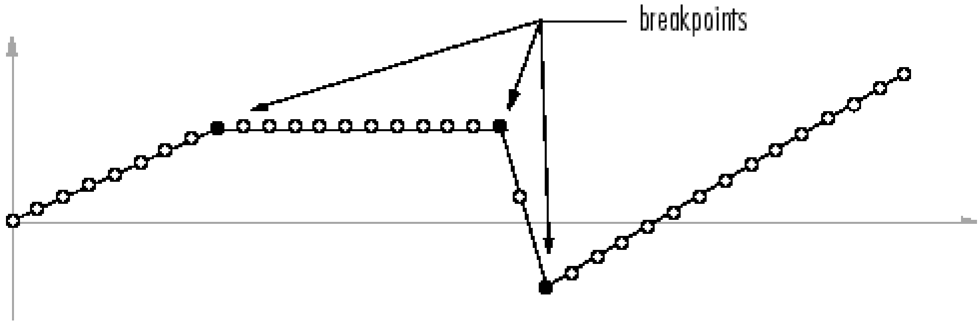
Description

`detrend` removes the mean value or linear trend from a vector or matrix, usually for FFT processing.

`y = detrend(x)` removes the best straight-line fit from vector `x` and returns it in `y`. If `x` is a matrix, `detrend` removes the trend from each column.

`y = detrend(x,'constant')` removes the mean value from vector `x` or, if `x` is a matrix, from each column of the matrix.

`y = detrend(x,'linear',bp)` removes a continuous, piecewise linear trend from vector `x` or, if `x` is a matrix, from each column of the matrix. Vector `bp` contains the indices of the breakpoints between adjacent linear segments. The breakpoint between two segments is defined as the data point that the two segments share.



`detrend(x,'linear')`, with no breakpoint vector specified, is the same as `detrend(x)`.

Example

```
sig = [0 1 -2 1 0 1 -2 1 0];      % signal with no linear trend
trend = [0 1 2 3 4 3 2 1 0];      % two-segment linear trend
```

```
x = sig+trend;                  % signal with added trend
y = detrend(x,'linear',5)       % breakpoint at 5th element

y =

   -0.0000
    1.0000
   -2.0000
    1.0000
    0.0000
    1.0000
   -2.0000
    1.0000
   -0.0000
```

Note that the breakpoint is specified to be the fifth element, which is the data point shared by the two segments.

Algorithm

`detrend` computes the least-squares fit of a straight line (or composite line for piecewise linear trends) to the data and subtracts the resulting function from the data. To obtain the equation of the straight-line fit, use `polyfit`.

See Also

`polyfit`

detrend (timeseries)

Purpose

Subtract mean or best-fit line and all `NaN`s from time series

Syntax

```
ts = detrend(ts1,method)
ts = detrend(ts1,Method,Index)
```

Description

`ts = detrend(ts1,method)` subtracts either a mean or a best-fit line from time-series data, usually for FFT processing. Method is a string that specifies the detrend method and has two possible values:

- `'constant'` — Subtracts the mean
- `'linear'` — Subtracts the best-fit line

`ts = detrend(ts1,Method,Index)` uses the optional `Index` integer array to specify the columns or rows to detrend. 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

You cannot apply `detrend` to time-series data with more than two dimensions.

Purpose

Evaluate solution of differential equation problem

Syntax

```
sxint = deval(sol,xint)
sxint = deval(xint,sol)
sxint = deval(sol,xint,idx)
sxint = deval(xint,sol,idx)
[sxint, spxint] = deval(...)
```

Description

`sxint = deval(sol,xint)` and `sxint = deval(xint,sol)` evaluate the solution of a differential equation problem. `sol` is a structure returned by one of these solvers:

- An initial value problem solver (`ode45`, `ode23`, `ode113`, `ode15s`, `ode23s`, `ode23t`, `ode23tb`, `ode15i`)
- A delay differential equations solver (`dde23` or `ddesd`),
- The boundary value problem solver (`bvp4c`).

`xint` is a point or a vector of points at which you want the solution. The elements of `xint` must be in the interval `[sol.x(1),sol.x(end)]`. For each `i`, `sxint(:,i)` is the solution at `xint(i)`.

`sxint = deval(sol,xint,idx)` and `sxint = deval(xint,sol,idx)` evaluate as above but return only the solution components with indices listed in the vector `idx`.

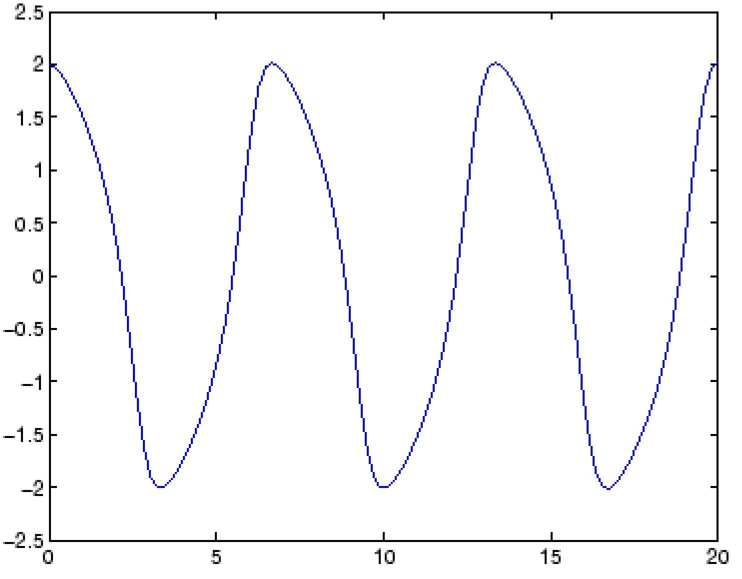
`[sxint, spxint] = deval(...)` also returns `spxint`, the value of the first derivative of the polynomial interpolating the solution.

Note For multipoint boundary value problems, the solution obtained by `bvp4c` might be discontinuous at the interfaces. For an interface point `xc`, `deval` returns the average of the limits from the left and right of `xc`. To get the limit values, set the `xint` argument of `deval` to be slightly smaller or slightly larger than `xc`.

Example

This example solves the system $y' = \mathbf{vdp1}(t, y)$ using ode45, and evaluates and plots the first component of the solution at 100 points in the interval [0,20].

```
sol = ode45(@vdp1,[0 20],[2 0]);
x = linspace(0,20,100);
y = deval(sol,x,1);
plot(x,y);
```



See Also

ODE solvers: ode45, ode23, ode113, ode15s, ode23s, ode23t, ode23tb, ode15i

DDE solvers: dde23, ddesd

BVP solver: bvp4c

Purpose

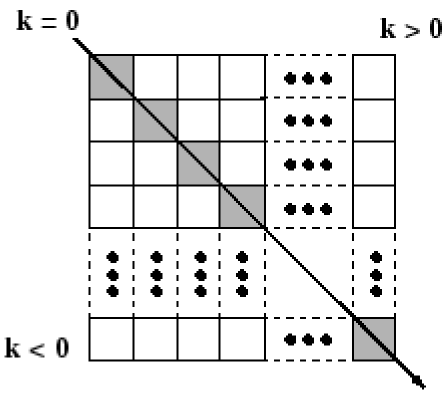
Diagonal matrices and diagonals of matrix

Syntax

```
X = diag(v,k)
X = diag(v)
v = diag(X,k)
v = diag(X)
```

Description

`X = diag(v,k)` when `v` is a vector of `n` components, returns a square matrix `X` of order `n+abs(k)`, with the elements of `v` on the `k`th diagonal. `k = 0` represents the main diagonal, `k > 0` above the main diagonal, and `k < 0` below the main diagonal.



`X = diag(v)` puts `v` on the main diagonal, same as above with `k = 0`.

`v = diag(X,k)` for matrix `X`, returns a column vector `v` formed from the elements of the `k`th diagonal of `X`.

`v = diag(X)` returns the main diagonal of `X`, same as above with `k = 0` .

Remarks

`(diag(X))` is a diagonal matrix.

`sum(diag(X))` is the trace of `X`.

`diag([])` generates an empty matrix, (`[]`).

`diag(m-by-1,k)` generates a matrix of size `m+abs(k)`-by-`m+abs(k)`.

diag(1-by-n,k) generates a matrix of size n+abs(k)-by-n+abs(k).

Examples

The statement

```
diag(-m:m)+diag(ones(2*m,1),1)+diag(ones(2*m,1),-1)
```

produces a tridiagonal matrix of order 2*m+1.

See Also

spdiags, tril, triu, blkdiag

Purpose

Create and display dialog box

Syntax

```
h = dialog('PropertyName',PropertyValue,...)
```

Description

`h = dialog('PropertyName',PropertyValue,...)` returns a handle to a dialog box. This function creates a figure graphics object and sets the figure properties recommended for dialog boxes. You can specify any valid figure property value except `DockControls`, which is always `off`.

Note By default, the dialog box is modal. A modal dialog box prevents the user from interacting with other windows before responding. For more information, see `WindowStyle` in the MATLAB Figure Properties.

By default, the message dialog box is modal. A modal dialog box prevents the user from interacting with other windows before responding. For more information, see `WindowStyle` in the MATLABFigure Properties.

See Also

`errordlg`, `helpdlg`, `inputdlg`, `listdlg`, `msgbox`, `questdlg`, `warndlg`

`figure`, `uiwait`, `uiresume`

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

diary

Purpose

Save session to file

Syntax

```
diary
diary('filename')
diary off
diary on
diary filename
```

Description

The `diary` function creates a log of keyboard input and the resulting text output, with some exceptions (see "Remarks" on page 2-880 for details). The output of `diary` is an ASCII file, suitable for searching in, printing, inclusion in most reports and other documents. If you do not specify `filename`, MATLAB creates a file named `diary` in the current directory.

`diary` toggles `diary` mode on and off. To see the status of `diary`, type `get(0,'Diary')`. MATLAB returns either `on` or `off` indicating the `diary` status.

`diary('filename')` writes a copy of all subsequent keyboard input and the resulting output (except it does not include graphics) to the named file, where `filename` is the full pathname or `filename` is in the current MATLAB directory. If the file already exists, output is appended to the end of the file. You cannot use a `filename` called `off` or `on`. To see the name of the `diary` file, use `get(0,'DiaryFile')`.

`diary off` suspends the diary.

`diary on` resumes diary mode using the current filename, or the default filename `diary` if none has yet been specified.

`diary filename` is the unquoted form of the syntax.

Remarks

Because the output of `diary` is plain text, the file does not exactly mirror input and output from the Command Window:

- Output does not include graphics (figure windows).
- Syntax highlighting and font preferences are not preserved.

- Hidden components of Command Window output such as hyperlink information generated with `matlab:` are shown in plain text. For example, if you enter the following statement

  ```
  str = sprintf('%s%s', ...
     '<a href="matlab:magic(4)">', ...
     'Generate magic square</a>');
  disp(str)
  ```

  MATLAB displays

  Generate magic square

  However, the diary file, when viewed in a text editor, shows

  ```
  str = sprintf('%s%s', ...
     '<a href="matlab:magic(4)">', ...
     'Generate magic square</a>');
  disp(str)
  <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 displays it as a hyperlink.

- Viewing the output of `diary` in a console window might produce different results compared to viewing `diary` output in the desktop Command Window. One example is using the `\r` option for the `fprintf` function; using the `\n` option might alleviate that problem.

See Also

`evalc`

"Command History" in the MATLAB Desktop Tools and Development Environment documentation

Purpose

Differences and approximate derivatives

Syntax

```
Y = diff(X)
Y = diff(X,n)
Y = diff(X,n,dim)
```

Description

`Y = diff(X)` calculates differences between adjacent elements of `X`.

If `X` is a vector, then `diff(X)` returns a vector, one element shorter than `X`, of differences between adjacent elements:

```
[X(2)-X(1) X(3)-X(2) ... X(n)-X(n-1)]
```

If `X` is a matrix, then `diff(X)` returns a matrix of row differences:

```
[X(2:m,:)-X(1:m-1,:)]
```

In general, `diff(X)` returns the differences calculated along the first non-singleton (`size(X,dim) > 1`) dimension of `X`.

`Y = diff(X,n)` applies `diff` recursively `n` times, resulting in the nth difference. Thus, `diff(X,2)` is the same as `diff(diff(X))`.

`Y = diff(X,n,dim)` is the nth difference function calculated along the dimension specified by scalar `dim`. If order `n` equals or exceeds the length of dimension `dim`, `diff` returns an empty array.

Remarks

Since each iteration of `diff` reduces the length of `X` along dimension `dim`, it is possible to specify an order `n` sufficiently high to reduce `dim` to a singleton (`size(X,dim) = 1`) dimension. When this happens, `diff` continues calculating along the next nonsingleton dimension.

Examples

The quantity `diff(y)./diff(x)` is an approximate derivative.

```
x = [1 2 3 4 5];
y = diff(x)
y =
     1     1     1     1
```

```
z = diff(x,2)
z =
     0     0     0
```

Given,

```
A = rand(1,3,2,4);
```

`diff(A)` is the first-order difference along dimension 2.

`diff(A,3,4)` is the third-order difference along dimension 4.

See Also

`gradient`, `prod`, `sum`

Purpose

Calculate diffuse reflectance

Syntax

```
R = diffuse(Nx,Ny,Nz,S)
```

Description

`R = diffuse(Nx,Ny,Nz,S)` returns the reflectance of a surface with normal vector components `[Nx,Ny,Nz]`. `S` specifies the direction to the light source. You can specify these directions as three vectors`[x,y,z]` or two vectors `[Theta Phi` (in spherical coordinates).

Lambert's Law: `R = cos(PSI)` where `PSI` is the angle between the surface normal and light source.

See Also

`specular`, `surfnorm`, `surfl`

"Lighting as a Visualization Tool"

Purpose Directory listing

Graphical Interface As an alternative to the dir function, use the "Current Directory Browser".

Syntax

```
dir
dir name
files = dir('dirname')
```

Description

dir lists the files in the current working directory. Results are not sorted, but presented in the order returned by the operating system.

dir name lists the specified files. The name argument can be a pathname, filename, or can include both. You can use absolute and relative pathnames and wildcards (*).

files = dir('dirname') returns the list of files in the specified directory (or the current directory, if dirname is not specified) to an m-by-1 structure with the fields.

Fieldname	Description	Data Type
name	Filename	char array
date	Modification date timestamp	char array
bytes	Number of bytes allocated to the file	double
isdir	1 if name is a directory; 0 if not	logical
datenum	Modification date as serial date number	char array

Remarks

Listing Drives

On Windows, obtain a list of drives available using the DOS net use command. In the Command Window, run

```
dos('net use')
```

Or run

```
[s,r] = dos('net use')
```

to return the results to the character array r.

DOS Filenames

The MATLAB dir function is consistent with the Microsoft Windows OS dir command in that both support short filenames generated by DOS. For example, both of the following commands are equivalent in both Windows and MATLAB:

```
dir long_matlab_mfile_name.m
   long_matlab_mfile_name.m

dir long_m~1.m
   long_matlab_m-file_name.m
```

Examples

List Directory Contents

To view the contents of the matlab/audiovideo directory, type

```
dir(fullfile(matlabroot, 'toolbox/matlab/audiovideo'))
```

Using Wildcard and File Extension

To view the MAT files in your current working directory that include the term java, type

```
dir *java*.mat
```

MATLAB returns all filenames that match this specification:

```
java_array.mat  javafrmobj.mat  testjava.mat
```

Using Relative Pathname

To view the M-files in the MATLAB audiovideo directory, type

```
dir(fullfile(matlabroot,'toolbox/matlab/audiovideo/*.m'))
```

MATLAB returns

```
Contents.m           aviinfo.m                   render_uimgraudiotoolbar.m
audiodevinfo.m       aviread.m                   sound.m
audioplayerreg.m     lin2mu.m                    soundsc.m
audiorecorderreg.m   mmcompinfo.m                wavfinfo.m
audiouniquename.m    mmfileinfo.m                wavplay.m
aufinfo.m            movie2avi.m                 wavread.m
auread.m             mu2lin.m                    wavrecord.m
auwrite.m            prefspanel.m                wavwrite.m
avifinfo.m           render_fullaudiotoolbar.m
```

Returning File List to Structure

To return the list of files to the variable `av_files`, type

```
av_files = dir(fullfile(matlabroot, ...
                  'toolbox/matlab/audiovideo/*.m'))
```

MATLAB returns the information in a structure array.

```
av_files =
26x1 struct array with fields:
    name
    date
    bytes
    isdir
    datenum
```

Index into the structure to access a particular item. For example,

```
av_files(3).name
ans =
   audioplayerreg.m
```

See Also

`cd`, `copyfile`, `delete`, `fileattrib`, `filebrowser`, `fileparts`, `genpath`, `isdir`, `ls`, `matlabroot`, `mkdir`, `mfilename`, `movefile`, `rmdir`, `type`, `what`

dir (ftp)

Purpose Directory contents on FTP server

Syntax

```
dir(f,'dirname')
d=dir(...)
```

Description

`dir(f,'dirname')` lists the files in the specified directory, `dirname`, on the FTP server `f`, where `f` was created using `ftp`. If `dirname` is unspecified, `dir` lists the files in the current directory of `f`.

`d=dir(...)` returns the results in an m-by-1 structure with the following fields for each file:

Fieldname	Description	Data Type
`name`	Filename	char array
`date`	Modification date timestamp	char array
`bytes`	Number of bytes allocated to the file	double
`isdir`	`1` if name is a directory; `0` if not	logical
`datenum`	Modification date as serial date number	char array

Examples

Connect to the MathWorks FTP server and view the contents.

```
tmw=ftp('ftp.mathworks.com');
dir(tmw)

README    incoming  matlab    outgoing  pub       pubs
```

Change to the directory `pub/pentium`.

```
cd(tmw,'pub/pentium')
```

View the contents of that directory.

```
dir(tmw)

.                      Intel_resp.txt       NYT_2.txt
..                     Intel_support.txt    NYT_Dec14.uu
Andy_Grove.txt         Intel_white.ps       New_York_Times.txt
Associated_Press.txt   MathWorks_press.txt  Nicely_1.txt
CNN.html               Mathisen.txt         Nicely_2.txt
Coe.txt                Moler_1.txt          Nicely_3.txt
Cygnus.txt             Moler_2.txt          Pratt.txt
EE_Times.txt           Moler_3.txt          README.txt
FAQ.txt                Moler_4.txt          SPSS.txt
IBM_study.txt          Moler_5.txt          Smith.txt
Intel_FAX.txt          Moler_6.ps           p87test.txt
Intel_fix.txt          Moler_7.txt          p87test.zip
Intel_replace.txt      Myths.txt            test
```

Or return the results to the structure m.

```
m=dir(tmw)

m =

37x1 struct array with fields:
    name
    date
    bytes
    isdir
    datanum
```

View element 17.

```
m(17)

ans =

     name: 'Moler_1.txt'
```

```
     date: '1995 Mar  27'
    bytes: 3427
    isdir: 0
  datenum: 728745
```

See Also

ftp, mkdir (ftp), rmdir (ftp)

Purpose Display text or array

Syntax

```
disp(X)
```

Description

`disp(X)` displays an array, without printing the array name. If `X` contains a text string, the string is displayed.

Another way to display an array on the screen is to type its name, but this prints a leading "`X=,`" which is not always desirable.

Note that `disp` does not display empty arrays.

Examples

One use of `disp` in an M-file is to display a matrix with column labels:

```
disp('          Corn          Oats          Hay')
disp(rand(5,3))
```

which results in

```
  Corn          Oats          Hay
0.2113        0.8474        0.2749
0.0820        0.4524        0.8807
0.7599        0.8075        0.6538
0.0087        0.4832        0.4899
0.8096        0.6135        0.7741
```

You can also use the `disp` command to display a hyperlink in the Command Window. Include the full hypertext string on a single line as input to `disp`.

```
disp('<a href = "http://www.mathworks.com">The MathWorks Web Site</a>')
```

generates this hyperlink in the Command Window:

```
The MathWorks Web Site
```

Click on this link to display The MathWorks home page in a MATLAB Web browser.

See Also `format`, `int2str`, `matlabcolon`, `num2str`, `rats`, `sprintf`

Purpose

Serial port object summary information

Syntax

```
obj
disp(obj)
```

Arguments

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

Description

`obj` or `disp(obj)` displays summary information for `obj`.

Remarks

In addition to the syntax shown above, you can display summary information for `obj` by excluding the semicolon when:

- Creating a serial port object
- Configuring property values using the dot notation

Use the display summary to quickly view the communication settings, communication state information, and information associated with read and write operations.

Example

The following commands display summary information for the serial port object `s`.

```
s = serial('COM1')
s.BaudRate = 300
s
```

disp (timer)

Purpose Information about timer object

Syntax

```
disp(obj)
obj
```

Description `disp(obj)` displays summary information for the timer object, `obj`.

If `obj` is an array of timer objects, `disp` outputs a table of summary information about the timer objects in the array.

`obj`, that is, typing the object name alone, does the same as `disp(obj)`

In addition to the syntax shown above, you can display summary information for `obj` by excluding the semicolon when

- Creating a timer object, using the `timer` function
- Configuring property values using the dot notation

Examples The following commands display summary information for timer object `t`.

```
t = timer

Timer Object: timer-1

   Timer Settings
      ExecutionMode: singleShot
             Period: 1
           BusyMode: drop
            Running: off

   Callbacks
           TimerFcn: []
           ErrorFcn: []
           StartFcn: []
            StopFcn: []
```

This example shows the format of summary information displayed for an array of timer objects.

```
t2 = timer;
disp(timerfind)

Timer Object Array
Timer Object Array

   Index:  ExecutionMode:  Period:  TimerFcn:     Name:
   1       singleShot      1        ''            timer-1
   2       singleShot      1        ''            timer-2
```

See Also

`timer`, `get(timer)`

display

Purpose

Display text or array (overloaded method)

Syntax

```
display(X)
```

Description

`display(X)` prints the value of a variable or expression, `X`. MATLAB calls `display(X)` when it interprets a variable or expression, `X`, that is not terminated by a semicolon. For example, `sin(A)` calls `display`, while `sin(A);` does not.

If `X` is an instance of a MATLAB class, then MATLAB calls the `display` method of that class, if such a method exists. If the class has no `display` method or if `X` is not an instance of a MATLAB class, then the MATLAB built-in `display` function is called.

Examples

A typical implementation of `display` calls `disp` to do most of the work and looks like this.

```
function display(X)
if isequal(get(0,'FormatSpacing'),'compact')
   disp([inputname(1) ' =']);
   disp(X)
else
   disp(' ')
   disp([inputname(1) ' =']);
   disp(' ');
   disp(X)
end
```

The expression `magic(3)`, with no terminating semicolon, calls this function as `display(magic(3))`.

```
magic(3)

ans =

     8     1     6
     3     5     7
     4     9     2
```

As an example of a class `display` method, the function below implements the `display` method for objects of the MATLAB class `polynom`.

```
function display(p)
% POLYNOM/DISPLAY Command window display of a polynom
disp(' ');
disp([inputname(1),' = '])
disp(' ');
disp(['   ' char(p)])
disp(' ');
```

The statement

```
p = polynom([1 0 -2 -5])
```

creates a `polynom` object. Since the statement is not terminated with a semicolon, the MATLAB interpreter calls `display(p)`, resulting in the output

```
p =

    x^3 - 2*x - 5
```

See Also

`disp`, `ans`, `sprintf`, special characters

divergence

Purpose

Compute divergence of vector field

Syntax

```
div = divergence(X,Y,Z,U,V,W)
div = divergence(U,V,W)
div = divergence(X,Y,U,V)
div = divergence(U,V)
```

Description

`div = divergence(X,Y,Z,U,V,W)` computes the divergence of a 3-D vector field `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`).

`div = divergence(U,V,W)` assumes `X`, `Y`, and `Z` are determined by the expression

```
[X Y Z] = meshgrid(1:n,1:m,1:p)
```

where `[m,n,p] = size(U)`.

`div = divergence(X,Y,U,V)` computes the divergence of a 2-D vector field `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`).

`div = divergence(U,V)` assumes `X` and `Y` are determined by the expression

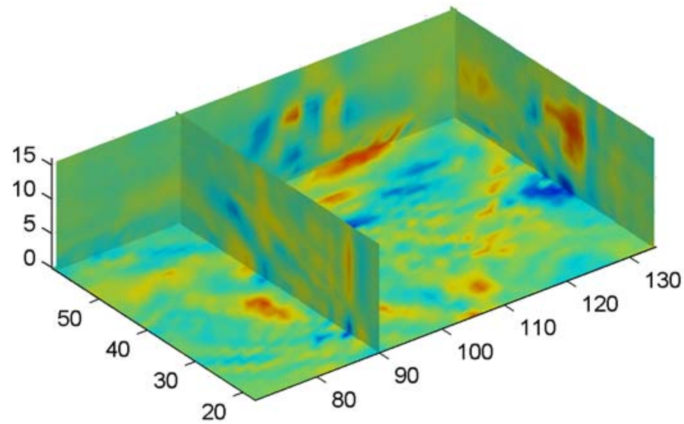
```
[X Y] = meshgrid(1:n,1:m)
```

where `[m,n] = size(U)`.

Examples

This example displays the divergence of vector volume data as slice planes, using color to indicate divergence.

```
load wind
div = divergence(x,y,z,u,v,w);
slice(x,y,z,div,[90 134],[59],[0]);
shading interp
daspect([1 1 1])
camlight
```



See Also `streamtube`, `curl`, `isosurface`

"Volume Visualization" on page 1-101 for related functions

"Displaying Divergence with Stream Tubes" for another example

Purpose

Read ASCII-delimited file of numeric data into matrix

Graphical Interface

As an alternative to `dlmread`, use the Import Wizard. To activate the Import Wizard, select **Import data** from the **File** menu.

Syntax

```
M = dlmread(filename)
M = dlmread(filename, delimiter)
M = dlmread(filename, delimiter, R, C)
M = dlmread(filename, delimiter, range)
```

Description

`M = dlmread(filename)` reads from the ASCII-delimited numeric data file `filename` to output matrix `M`. The `filename` input is a string enclosed in single quotes. The delimiter separating data elements is inferred from the formatting of the file. Comma (`,`) is the default delimiter.

`M = dlmread(filename, delimiter)` reads numeric data from the ASCII-delimited file `filename`, using the specified `delimiter`. Use `\t` to specify a tab delimiter.

Note When a delimiter is inferred from the formatting of the file, consecutive whitespaces are treated as a single delimiter. By contrast, if a delimiter is specified by the `delimiter` input, any repeated delimiter character is treated as a separate delimiter.

`M = dlmread(filename, delimiter, R, C)` reads numeric data from the ASCII-delimited file `filename`, using the specified `delimiter`. The values `R` and `C` specify the row and column where the upper left corner of the data lies in the file. `R` and `C` are zero based, so that `R=0`, `C=0` specifies the first value in the file, which is the upper left corner.

Note dlmread reads numeric data only. The file being read may contain nonnumeric data, but this nonnumeric data cannot be within the range being imported.

M = dlmread(filename, delimiter, range) reads the range specified by range = [R1 C1 R2 C2] where (R1,C1) is the upper left corner of the data to be read and (R2,C2) is the lower right corner. You can also specify the range using spreadsheet notation, as in range = 'A1..B7'.

Remarks

If you want to specify an R, C, or range input, but not a delimiter, set the delimiter argument to the empty string, (two consecutive single quotes with no spaces in between, ''). For example,

```
M = dlmread('myfile.dat', '', 5, 2)
```

Using this syntax enables you to specify the starting row and column or range to read while having dlmread treat repeated whitespaces as a single delimiter.

dlmread fills empty delimited fields with zero. Data files having lines that end with a nonspace delimiter, such as a semicolon, produce a result that has an additional last column of zeros.

dlmread imports any complex number as a whole into a complex numeric field, converting the real and imaginary parts to the specified numeric type. Valid forms for a complex number are

<table>
<tr><th>Form</th><th>Example</th></tr>
<tr><td>–<real>–<imag>i|j</td><td>5.7-3.1i</td></tr>
<tr><td>–<imag>i|j</td><td>-7j</td></tr>
</table>

Embedded white-space in a complex number is invalid and is regarded as a field delimiter.

Examples

Example 1

Export the 5-by-8 matrix M to a file, and read it with dlmread, first with no arguments other than the filename:

```
rand('state', 0);   M = rand(5,8);   M = floor(M * 100);
dlmwrite('myfile.txt', M, 'delimiter', '\t')

dlmread('myfile.txt')
ans =
    95    76    61    40     5    20     1    41
    23    45    79    93    35    19    74    84
    60     1    92    91    81    60    44    52
    48    82    73    41     0    27    93    20
    89    44    17    89    13    19    46    67
```

Now read a portion of the matrix by specifying the row and column of the upper left corner:

```
dlmread('myfile.txt', '\t', 2, 3)
ans =
    91    81    60    44    52
    41     0    27    93    20
    89    13    19    46    67
```

This time, read a different part of the matrix using a range specifier:

```
dlmread('myfile.txt', '\t', 'C1..G4')
ans =
    61    40     5    20     1
    79    93    35    19    74
    92    91    81    60    44
    73    41     0    27    93
```

Example 2

Export matrix M to a file, and then append an additional matrix to the file that is offset one row below the first:

```
M = magic(3);
```

```
dlmwrite('myfile.txt', [M*5 M/5], ' ')

dlmwrite('myfile.txt', rand(3), '-append', ...
   'roffset', 1, 'delimiter', ' ')

type myfile.txt

80 10 15 65 3.2 0.4 0.6 2.6
25 55 50 40 1 2.2 2 1.6
45 35 30 60 1.8 1.4 1.2 2.4
20 70 75 5 0.8 2.8 3 0.2

0.99008 0.49831 0.32004
0.78886 0.21396 0.9601
0.43866 0.64349 0.72663
```

When `dlmread` imports these two matrices from the file, it pads the smaller matrix with zeros:

```
dlmread('myfile.txt')
   40.0000    5.0000   30.0000    1.6000    0.2000    1.2000
   15.0000   25.0000   35.0000    0.6000    1.0000    1.4000
   20.0000   45.0000   10.0000    0.8000    1.8000    0.4000
    0.6038    0.0153    0.9318         0         0         0
    0.2722    0.7468    0.4660         0         0         0
    0.1988    0.4451    0.4187         0         0         0
```

See Also

`dlmwrite`, `textscan`, `csvread`, `csvwrite`, `wk1read`, `wk1write`

Purpose

Write matrix to ASCII-delimited file

Syntax

```
dlmwrite(filename, M)
dlmwrite(filename, M, 'D')
dlmwrite(filename, M, 'D', R, C)
dlmwrite(filename, M, 'attrib1', value1, 'attrib2', value2,
   ...)
dlmwrite(filename, M, '-append')
dlmwrite(filename, M, '-append', attribute-value list)
```

Description

`dlmwrite(filename, M)` writes matrix `M` into an ASCII format file using the default delimiter (`,`) to separate matrix elements. The data is written starting at the first column of the first row in the destination file, `filename`. The `filename` input is a string enclosed in single quotes.

`dlmwrite(filename, M, 'D')` writes matrix `M` into an ASCII format file, using delimiter `D` to separate matrix elements. The data is written starting at the first column of the first row in the destination file, `filename`. A comma (`,`) is the default delimiter. Use `\t` to produce tab-delimited files.

`dlmwrite(filename, M, 'D', R, C)` writes matrix `M` into an ASCII format file, using delimiter `D` to separate matrix elements. The data is written starting at row `R` and column `C` in the destination file, `filename`. `R` and `C` are zero based, so that `R=0`, `C=0` specifies the first value in the file, which is the upper left corner.

`dlmwrite(filename, M, 'attrib1', value1, 'attrib2', value2, ...)` is an alternate syntax to those shown above, in which you specify any number of attribute-value pairs in any order in the argument list. Each attribute must be immediately followed by a corresponding value (see the table below).

Attribute	Value
`delimiter`	Delimiter string to be used in separating matrix elements

Attribute	Value
newline	Character(s) to use in terminating each line (see table below)
roffset	Offset, in rows, from the top of the destination file to where matrix data is to be written. Offset is zero based.
coffset	Offset, in columns, from the left side of the destination file to where matrix data is to be written. Offset is zero based.
precision	Numeric precision to use in writing data to the file. Specify the number of significant digits or a C-style format string starting in `%`, such as `'%10.5f'`.

This table shows which values you can use when setting the **newline** attribute.

Line Terminator	Description
`'pc'`	PC terminator (implies carriage return/line feed (`CR/LF`))
`'unix'`	UNIX terminator (implies line feed (`LF`))

`dlmwrite(filename, M, '-append')` appends the matrix to the file. If you do not specify `'-append'`, `dlmwrite` overwrites any existing data in the file.

`dlmwrite(filename, M, '-append', attribute-value list)` is the same as the syntax shown above, but accepts a list of `attribute-value` pairs. You can place the `'-append'` flag in the argument list anywhere between `attribute-value` pairs, but not in between an `attribute` and its `value`.

Remarks

The resulting file is readable by spreadsheet programs.

Examples

Example 1

Export matrix M to a file delimited by the tab character and using a precision of six significant digits:

```
dlmwrite('myfile.txt', M, 'delimiter', '\t', ...
         'precision', 6)
type myfile.txt

0.893898      0.284409      0.582792      0.432907
0.199138      0.469224      0.423496      0.22595
0.298723      0.0647811     0.515512      0.579807
0.661443      0.988335      0.333951      0.760365
```

Example 2

Export matrix M to a file using a precision of six decimal places and the conventional line terminator for the PC platform:

```
dlmwrite('myfile.txt', m, 'precision', '%.6f', ...
         'newline', 'pc')
type myfile.txt

16.000000,2.000000,3.000000,13.000000
5.000000,11.000000,10.000000,8.000000
9.000000,7.000000,6.000000,12.000000
4.000000,14.000000,15.000000,1.000000
```

Example 3

Export matrix M to a file, and then append an additional matrix to the file that is offset one row below the first:

```
M = magic(3);
dlmwrite('myfile.txt', [M*5 M/5], ' ')

dlmwrite('myfile.txt', rand(3), '-append', ...
   'roffset', 1, 'delimiter', ' ')

type myfile.txt
```

```
80 10 15 65 3.2 0.4 0.6 2.6
25 55 50 40 1 2.2 2 1.6
45 35 30 60 1.8 1.4 1.2 2.4
20 70 75 5 0.8 2.8 3 0.2

0.99008 0.49831 0.32004
0.78886 0.21396 0.9601
0.43866 0.64349 0.72663
```

When `dlmread` imports these two matrices from the file, it pads the smaller matrix with zeros:

```
dlmread('myfile.txt')
   40.0000    5.0000   30.0000    1.6000    0.2000    1.2000
   15.0000   25.0000   35.0000    0.6000    1.0000    1.4000
   20.0000   45.0000   10.0000    0.8000    1.8000    0.4000
    0.6038    0.0153    0.9318         0         0         0
    0.2722    0.7468    0.4660         0         0         0
    0.1988    0.4451    0.4187         0         0         0
```

See Also

`dlmread`, `csvwrite`, `csvread`, `wk1write`, `wk1read`

dmperm

Purpose

Dulmage-Mendelsohn decomposition

Syntax

```
p = dmperm(A)
[p,q,r,s] = dmperm(A)
```

Description

`p = dmperm(A)` if `A` is square and has full rank, returns a row permutation `p` so that `A(p,:)` has nonzero diagonal elements. This permutation is also called a *perfect matching*. If `A` is not square or not full rank, `p` is a vector that identifies a matching of maximum size: for each column `j` of `A`, either `p(j)=0` or `A(p(j),j)` is nonzero.

`[p,q,r,s] = dmperm(A)`, where `A` need not be square or full rank, finds permutations `p` and `q` and index vectors `r` and `s` so that `A(p,q)` is block upper triangular. The `k`th block has indices `(r(k):r(k+1)-1, s(k):s(k+1)-1)`. When `A` is square and has full rank, `r = s`.

If `A` is not square or not full rank, the first block may have more columns and the last block may have more rows. All other blocks are square and irreducible. `dmperm` permutes nonzeros to the diagonals of square blocks, but does not do this for non-square blocks.

Remarks

If `A` is a reducible matrix, the linear system $Ax = b$ can be solved by permuting `A` to a block upper triangular form, with irreducible diagonal blocks, and then performing block backsubstitution. Only the diagonal blocks of the permuted matrix need to be factored, saving fill and arithmetic in the blocks above the diagonal.

In graph theoretic terms, `dmperm` finds a maximum-size matching in the bipartite graph of `A`, and the diagonal blocks of `A(p,q)` correspond to the strong Hall components of that graph. The output of `dmperm` can also be used to find the connected or strongly connected components of an undirected or directed graph. For more information see Pothen and Fan [1].

See Also

`sprank`

References

[1] Pothen, Alex and Chin-Ju Fan, “Computing the Block Triangular Form of a Sparse Matrix,” *ACM Transactions on Mathematical Software*, Vol. 16, No. 4, Dec. 1990, pp. 303-324.

Purpose

Reference page in Help browser

GUI Alternatives

As an alternative to the `doc` function, use the Help browser **Search for** field. Type the function name and click **Go**.

Syntax

```
doc
doc functionname
doc toolboxname
doc toolboxname/functionname
doc classname.methodname
```

Description

`doc` opens the Help browser, if it is not already running, or brings the window to the top, displaying the **Contents** pane when the Help browser is already open.

`doc functionname` displays the reference page for the MATLAB function `functionname` in the Help browser. For example, you are looking at the reference page for the `doc` function. Here `functionname` can be a function, block, property, method, or object. If `functionname` is overloaded, that is, if `functionname` appears in multiple directories on the MATLAB search path, `doc` displays the reference page for the first `functionname` on the search path and displays a hyperlinked list of the other functions and their directories in the MATLAB Command Window. Overloaded functions within the same product are not listed — use the `overloaddirectory` form of the syntax. If a reference page for `functionname` does not exist, `doc` displays its M-file help in the Help browser. The `doc` function is intended only for help files supplied by The MathWorks, and is not supported for use with HTML files you create yourself.

`doc toolboxname` displays the roadmap page for `toolboxname` in the Help browser, which provides a summary of the most pertinent documentation for that product.

`doc toolboxname/functionname` displays the reference page for the `functionname` that belongs to the specified `toolboxname`, in the Help browser. This is useful for overloaded functions.

`doc classname.methodname` displays the reference page for the `methodname` that is a member of `classname`.

Note If there is a function called `name` as well as a toolbox called `name`, the roadmap page for the toolbox called `name` displays. To see the reference page for the function called `name`, use `doc toolboxname/name`, where `toolboxname` is the name of the toolbox in which the function `name` resides. For example, `doc matlab` displays the roadmap page for MATLAB (that is, the `matlab` toolbox), while `doc matlab/matlab` displays the reference page for the `matlab` startup function for UNIX, which is in MATLAB.

Examples

Type `doc abs` to display the reference page for the `abs` function. If Simulink and Signal Processing Toolbox are installed and on the search path, the Command Window lists hyperlinks for the `abs` function in those products:

```
doc signal/abs
doc simulink/abs
```

Type `doc signal/abs` to display the reference page for the `abs` function in Signal Processing Toolbox.

Type `doc signal` to display the roadmap page for Signal Processing Toolbox.

Type `doc serial.get` to display the reference page for the `get` method located in the `serial` directory of MATLAB. This syntax is required because there is at least one other `get` function in MATLAB.

See Also

`docopt`, `docsearch`, `help`, `helpbrowser`, `lookfor`, `type`, `web`

For additional information see also "Help for Using MATLAB" in the MATLAB Desktop Tools and Development Environment documentation.

docopt

Purpose

Web browser for UNIX platforms

Syntax

```
docopt
doccmd = docopt
```

Description

`docopt` displays the Web browser used with MATLAB on non-Macintosh UNIX platforms, with the default being `netscape` (for Netscape). For non-Macintosh UNIX platforms, you can modify the `docopt.m` file to specify the Web browser MATLAB uses. The Web browser is used with the `web` function and its `-browser` option. It is also used for links to external Web sites from the Help.

`doccmd = docopt` returns a string containing the command that `web -browser` uses to invoke a Web browser.

To change the browser, edit the `docopt.m` file and change line 51. For example,

```
50 elseif isunix                      % UNIX
51 %   doccmd = '';
```

Remove the comment symbol. In the quote, enter the command that starts your Web browser, and save the file. For example,

```
51     doccmd = 'mozilla';
```

specifies Mozilla as the Web browser MATLAB uses.

See Also

`doc`, `edit`, `helpbrowser`, `web`

Purpose

Open Help browser **Search** pane and search for specified term

GUI Alternatives

As an alternative to the `docsearch` function, select **Desktop > Help**, type in the **Search for** field, and click **Go**.

Syntax

```
docsearch
docsearch word
docsearch('word1 word2 ...')
docsearch('"word1 word2" ...')
docsearch('wo*rd ...')
docsearch('word1 word2 BOOLEANOP word3')
```

Description

`docsearch` opens the Help browser to the **Search Results** pane, or if the Help browser is already open to that pane, brings it to the top.

`docsearch word` executes a Help browser full-text search for `word`, displaying results in the Help browser **Search Results** pane. If `word` is a `functionname` or `blockname`, the first entry in **Search Results** is the reference page, or reference pages for overloaded functions.

`docsearch('word1 word2 ...')` executes a Help browser full-text search for pages containing `word1` and `word2` and any other specified words, displaying results in the Help browser **Search Results** pane.

`docsearch('"word1 word2" ...')` executes a Help browser full-text search for pages containing the exact phrase `word1 word2` and any other specified words, displaying results in the Help browser **Search Results** pane.

`docsearch('wo*rd ...')` executes a Help browser full-text search for pages containing words that begin with `wo` and end with `rd`, and any other specified words, displaying results in the Help browser **Search Results** pane. This is also called a wildcard or partial word search. You can use a wildcard symbol (`*`) multiple times within a word. You cannot use the wildcard symbol within an exact phrase. You must use at least two letters or digits with a wildcard symbol.

`docsearch('word1 word2 BOOLEANOP word3')` executes a Help browser full-text search for the term `word1 word2 BOOLEANOP word3`, where `BOOLEANOP` is a Boolean operator (`AND`, `NOT`, `OR`) used to refine the search. docsearch evaluates `NOT`s first, then `OR`s, and finally `AND`s. Results display in the Help browser **Search Results** pane.

Examples

`docsearch plot` finds all pages that contain the word `plot`.

`docsearch('plot tools')` finds all pages that contain the words `plot` and `tools` anywhere in the page.

`docsearch('"plot tools"')` finds all pages that contain the exact phrase `plot tools`.

`docsearch('plot* tools')` finds all pages that contain the word `tools` and the word `plot` or variations of `plot`, such as `plotting`, and `plots`.

`docsearch('"plot tools" NOT "time series"')` finds all pages that contain the exact phrase `plot tools`, but only if the pages do not contain the exact phrase `time series`.

See Also

`builddocsearchdb`, `doc`, `helpbrowser`

"Search Documentation and Demos with the Help Browser" in the MATLAB Desktop Tools and Development Environment documentation

Purpose

Execute DOS command and return result

Syntax

```
dos command
status = dos('command')
[status,result] = dos('command')
[status,result] = dos('command','-echo')
```

Description

`dos command` calls upon the shell to execute the given command for Windows systems.

`status = dos('command')` returns completion status to the `status` variable.

`[status,result] = dos('command')` in addition to completion status, returns the result of the command to the `result` variable.

`[status,result] = dos('command','-echo')` forces the output to the Command Window, even though it is also being assigned into a variable.

Both console (DOS) programs and Windows programs may be executed, but the syntax causes different results based on the type of programs. Console programs have `stdout` and their output is returned to the result variable. They are always run in an iconified DOS or Command Prompt Window except as noted below. Console programs never execute in the background. Also, MATLAB will always wait for the `stdout` pipe to close before continuing execution. Windows programs may be executed in the background as they have no `stdout`.

The ampersand, `&`, character has special meaning. For console programs this causes the console to open. Omitting this character will cause console programs to run iconically. For Windows programs, appending this character will cause the application to run in the background. MATLAB will continue processing.

Note Running `dos` with a `command` that relies upon the current directory will fail when the current directory is specified using a UNC pathname. This is because DOS does not support UNC pathnames. In that event, MATLAB returns this error: `???  Error using ==> dos DOS commands may not be executed when the current directory is a UNC pathname`. To work around this limitation, change the directory to a mapped drive prior to running `dos` or a function that calls `dos`.

Examples

The following example performs a directory listing, returning a zero (success) in `s` and the string containing the listing in `w`.

```
[s, w] = dos('dir');
```

To open the DOS 5.0 editor in a DOS window

```
dos('edit &')
```

To open the notepad editor and return control immediately to MATLAB

```
dos('notepad file.m &')
```

The next example returns a one in `s` and an error message in `w` because `foo` is not a valid shell command.

```
[s, w] = dos('foo')
```

This example echoes the results of the `dir` command to the Command Window as it executes as well as assigning the results to `w`.

```
[s, w] = dos('dir', '-echo');
```

See Also

`!` (exclamation point), `perl`, `system`, `unix`, `winopen`

"Running External Programs" in the MATLAB Desktop Tools and Development Environment documentation

Purpose

Vector dot product

Syntax

```
C = dot(A,B)
C = dot(A,B,dim)
```

Description

`C = dot(A,B)` returns the scalar product of the vectors `A` and `B`. `A` and `B` must be vectors of the same length. When `A` and `B` are both column vectors, `dot(A,B)` is the same as `A'*B`.

For multidimensional arrays `A` and `B`, `dot` returns the scalar product along the first non-singleton dimension of `A` and `B`. `A` and `B` must have the same size.

`C = dot(A,B,dim)` returns the scalar product of `A` and `B` in the dimension `dim`.

Examples

The dot product of two vectors is calculated as shown:

```
a = [1 2 3]; b = [4 5 6];
c = dot(a,b)

c =
     32
```

See Also

`cross`

double

Purpose Convert to double precision

Syntax

```
double(x)
```

Description `double(x)` returns the double-precision value for `X`. If `X` is already a double-precision array, `double` has no effect.

Remarks `double` is called for the expressions in `for`, `if`, and `while` loops if the expression isn't already double-precision. `double` should be overloaded for any object when it makes sense to convert it to a double-precision value.

Purpose

Drag rectangles with mouse

Syntax

```
[finalrect] = dragrect(initialrect)
[finalrect] = dragrect(initialrect,stepsize)
```

Description

`[finalrect] = dragrect(initialrect)` tracks one or more rectangles anywhere on the screen. The n-by-4 matrix `initialrect` defines the rectangles. Each row of `initialrect` must contain the initial rectangle position as `[left bottom width height]` values. `dragrect` returns the final position of the rectangles in `finalrect`.

`[finalrect] = dragrect(initialrect,stepsize)` moves the rectangles in increments of `stepsize`. The lower left corner of the first rectangle is constrained to a grid of size equal to `stepsize` starting at the lower left corner of the figure, and all other rectangles maintain their original offset from the first rectangle.

`[finalrect] = dragrect(...)` returns the final positions of the rectangles when the mouse button is released. The default step size is `1`.

Remarks

`dragrect` returns immediately if a mouse button is not currently pressed. Use `dragrect` in a `ButtonDownFcn`, or from the command line in conjunction with `waitforbuttonpress`, to ensure that the mouse button is down when `dragrect` is called. `dragrect` returns when you release the mouse button.

If the drag ends over a figure window, the positions of the rectangles are returned in that figure's coordinate system. If the drag ends over a part of the screen not contained within a figure window, the rectangles are returned in the coordinate system of the figure over which the drag began.

Note You cannot use normalized figure units with `dragrect`.

Example

Drag a rectangle that is 50 pixels wide and 100 pixels in height.

```
waitforbuttonpress
point1 = get(gcf,'CurrentPoint') % button down detected
rect = [point1(1,1) point1(1,2) 50 100]
[r2] = dragrect(rect)
```

See Also

`rbbox`, `waitforbuttonpress`

"Selecting Region of Interest" on page 1-100 for related functions

Purpose Complete pending drawing events

Syntax

```
drawnow
drawnow expose
```

Description `drawnow` flushes the event queue and updates the figure window.

`drawnow expose` causes only graphics objects to refresh, if needed. It does not allow callbacks to execute and does not process other events in the queue.

Other Events That Cause Event Queue Processing

Other events that cause MATLAB to flush the event queue and draw the figure includes:

- Returning to the MATLAB prompt
- Executing the following functions
  - pause
  - `getframe`
  - `figure`
- Functions that wait for user input (e.g., `waitforbuttonpress`, `waitfor`, `ginput`)

Examples Executing the statements

```
x = -pi:pi/20:pi;
plot(x,cos(x))
drawnow
title('A Short Title')
grid on
```

as an M-file updates the current figure after executing the `drawnow` function and after executing the final statement.

See Also `waitfor`, `waitforbuttonpress`

"Figure Windows" on page 1-94 for related functions

Purpose

Search Delaunay triangulation for nearest point

Syntax

```
K = dsearch(x,y,TRI,xi,yi)
K = dsearch(x,y,TRI,xi,yi,S)
```

Description

`K = dsearch(x,y,TRI,xi,yi)` returns the index into `x` and `y` of the nearest point to the point (`xi`,`yi`). `dsearch` requires a triangulation `TRI` of the points `x`,`y` obtained using `delaunay`. If `xi` and `yi` are vectors, `K` is a vector of the same size.

`K = dsearch(x,y,TRI,xi,yi,S)` uses the sparse matrix `S` instead of computing it each time:

```
S = sparse(TRI(:,[1 1 2 2 3 3]),TRI(:,[2 3 1 3 1 2]),1,nxy,nxy)
```

where `nxy = prod(size(x))`.

See Also

`delaunay`, `tsearch`, `voronoi`

Purpose

N-D nearest point search

Syntax

```
k = dsearchn(X,T,XI)
k = dsearchn(X,T,XI,outval)
k = dsearchn(X,XI)
[k,d] = dsearchn(X,...)
```

Description

`k = dsearchn(X,T,XI)` returns the indices `k` of the closest points in `X` for each point in `XI`. `X` is an `m`-by-`n` matrix representing `m` points in n-dimensional space. `XI` is a `p`-by-`n` matrix, representing `p` points in n-dimensional space. `T` is a `numt`-by-`n+1` matrix, a tessellation of the data `X` generated by `delaunayn`. The output `k` is a column vector of length `p`.

`k = dsearchn(X,T,XI,outval)` returns the indices `k` of the closest points in `X` for each point in `XI`, unless a point is outside the convex hull. If `XI(J,:)` is outside the convex hull, then `K(J)` is assigned `outval`, a scalar double. `Inf` is often used for `outval`. If `outval` is `[]`, then `k` is the same as in the case `k = dsearchn(X,T,XI)`.

`k = dsearchn(X,XI)` performs the search without using a tessellation. With large `X` and small `XI`, this approach is faster and uses much less memory.

`[k,d] = dsearchn(X,...)` also returns the distances `d` to the closest points. `d` is a column vector of length `p`.

Algorithm

`dsearchn` is based on Qhull [1]. For information about Qhull, see `http://www.qhull.org/`. For copyright information, see `http://www.qhull.org/COPYING.txt`.

See Also

`tsearch`, `dsearch`, `tsearchn`, `griddatan`, `delaunayn`

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

Echo M-files during execution

Syntax

```
echo on
echo off
echo
echo fcnname on
echo fcnname off
echo fcnname
echo on all
echo off all
```

Description

The `echo` command controls the echoing of M-files during execution. Normally, the commands in M-files are not displayed on the screen during execution. Command echoing is useful for debugging or for demonstrations, allowing the commands to be viewed as they execute.

The `echo` command behaves in a slightly different manner for script files and function files. For script files, the use of `echo` is simple; echoing can be either `on` or `off`, in which case any script used is affected.

`echo on`	Turns on the echoing of commands in all script files
`echo off`	Turns off the echoing of commands in all script files
`echo`	Toggles the echo state

With function files, the use of `echo` is more complicated. If `echo` is enabled on a function file, the file is interpreted, rather than compiled. Each input line is then displayed as it is executed. Since this results in inefficient execution, use `echo` only for debugging.

`echo` *`fcnname`* `on`	Turns on echoing of the named function file
`echo` *`fcnname`* `off`	Turns off echoing of the named function file
`echo` *`fcnname`*	Toggles the echo state of the named function file

`echo on all`	Sets echoing on for all function files
`echo off all`	Sets echoing off for all function files

See Also

`function`

Purpose

Run M-file demo step-by-step in Command Window

GUI Alternatives

As an alternative to the `echodemo` function, select the demo in the Help browser **Demos** tab and click the **Run in the Command Window** link.

Syntax

```
echodemo filename
echodeemo('filename', cellindex)
```

Description

`echodemo filename` runs the M-file demo `filename` step-by-step in the Command Window. At each step, follow links in the Command Window to proceed. Depending on the size of the Command Window, you might have to scroll up to see the links. The script `filename` was created in the Editor/Debugger using cells. (The associated HTML demo file for `filename` that appears in the Help browser **Demos** pane was created using the MATLAB cell publishing feature.) The link to `filename` also shows the current cell number, `n`, and the total number of cells, `m`, as `n/m`, and when clicked, opens `filename` in the Editor/Debugger. To end the demo, click the **Stop** link.

`echodeemo('filename', cellindex)` runs the M-file type demo `filename`, starting with the cell number specified by `cellindex`. Because steps prior to `cellindex` are not run, this statement might produce an error or unexpected result, depending on the demo.

Note M-file demos run as scripts. Therefore, the variables are part of the base workspace, which could result in problems if you have any variables of the same name. For more information, see "Running Demos and Base Workspace Variables" in the Desktop Tools and Development Environment documentation.

Examples

`echodemo quake` runs the MATLAB Loma Prieta Earthquake demo.

`echodemo ('quake', 6)` runs the MATLAB Loma Prieta Earthquake demo, starting at cell 6.

`echodemo ('intro', 3)` produces an error because cell 3 of the MATLAB demo `intro` requires data created when cells 1 and 2 run.

See Also

`demo`, `helpbrowser`

Purpose

Edit or create M-file

GUI Alternatives

As an alternative to the `edit` function, select **File > New** or **Open** in the MATLAB desktop or any desktop tool.

Syntax

```
edit
edit fun.m
edit file.ext
edit fun1 fun2 fun3 ...
edit class/fun
edit private/fun
edit class/private/fun
```

Description

`edit` opens a new editor window.

`edit fun.m` opens the M-file `fun.m` in the default editor. Note that `fun.m` can be a MATLAB `partialpath` or a complete path. If `fun.m` does not exist, a prompt appears asking if you want to create a new file titled `fun.m`. After you click **Yes**, the Editor/Debugger creates a blank file titled `fun.m`. If you do not want the prompt to appear in this situation, select that check box in the prompt. Then when you type `edit fun.m`, where `fun.m` did not previously exist, a new file called `fun.m` is automatically opened in the Editor/Debugger. To make the prompt appear, specify it in preferences for Prompt.

`edit file.ext` opens the specified file.

`edit fun1 fun2 fun3 ...` opens `fun1.m`, `fun2.m`, `fun3.m`, and so on, in the default editor.

`edit class/fun`, or `edit private/fun`, or `edit class/private/fun` edit a method, private function, or private method for the class named `class`.

Remarks

To specify the default editor for MATLAB, select **Preferences** from the **File** menu. On the **Editor/Debugger** pane, select **MATLAB editor** or specify another.

UNIX Users

If you run MATLAB with the `-nodisplay` startup option, or run without the `DISPLAY` environment variable set, `edit` uses the `External Editor` command. It does not use the MATLAB Editor/Debugger, but instead uses the default editor defined for your system in *`matlabroot`*`/X11/app-defaults/Matlab`.

You can specify the editor that the `edit` function uses or specify editor options by adding the following line to your own `.Xdefaults` file, located in `~home`:

```
matlab*externalEditorCommand: $EDITOR -option $FILE
```

where

- `$EDITOR` is the name of your default editor, for example, `emacs`; leaving it as `$EDITOR` means your default system editor will be used.
- `-option` is a valid option flag you can include for the specified editor.
- **`$FILE`** means the filename you type with the `edit` command will open in the specified editor.

For example,

```
emacs $FILE
```

means that when you type `edit foo`, the file `foo` will open in the `emacs` editor.

After adding the line to your `.Xdefaults` file, you must run the following before starting MATLAB:

```
xrdb -merge ~home/.Xdefaults
```

See Also

`open`, `type`

Purpose

Find eigenvalues and eigenvectors

Syntax

```
d = eig(A)
d = eig(A,B)
[V,D] = eig(A)
[V,D] = eig(A,'nobalance')
[V,D] = eig(A,B)
[V,D] = eig(A,B,flag)
```

Description

`d = eig(A)` returns a vector of the eigenvalues of matrix `A`.

`d = eig(A,B)` returns a vector containing the generalized eigenvalues, if `A` and `B` are square matrices.

Note If `S` is sparse and symmetric, you can use `d = eig(S)` to returns the eigenvalues of `S`. If `S` is sparse but not symmetric, or if you want to return the eigenvectors of `S`, use the function `eigs` instead of `eig`.

`[V,D] = eig(A)` produces matrices of eigenvalues (`D`) and eigenvectors (`V`) of matrix `A`, so that `A*V = V*D`. Matrix `D` is the *canonical form* of `A` — a diagonal matrix with `A`'s eigenvalues on the main diagonal. Matrix `V` is the *modal matrix* — its columns are the eigenvectors of `A`.

If `W` is a matrix such that `W'*A = D*W'`, the columns of `W` are the *left eigenvectors* of `A`. Use `[W,D] = eig(A.'); W = conj(W)` to compute the left eigenvectors.

`[V,D] = eig(A,'nobalance')` finds eigenvalues and eigenvectors without a preliminary balancing step. Ordinarily, balancing improves the conditioning of the input matrix, enabling more accurate computation of the eigenvectors and eigenvalues. However, if a matrix contains small elements that are really due to roundoff error, balancing may scale them up to make them as significant as the other elements of the original matrix, leading to incorrect eigenvectors. Use the `nobalance` option in this event. See the `balance` function for more details.

`[V,D] = eig(A,B)` produces a diagonal matrix `D` of generalized eigenvalues and a full matrix `V` whose columns are the corresponding eigenvectors so that `A*V = B*V*D` .

`[V,D] = eig(A,B,`*`flag`*`)` specifies the algorithm used to compute eigenvalues and eigenvectors. *`flag`* can be:

`'chol'`	Computes the generalized eigenvalues of `A` and `B` using the Cholesky factorization of `B`. This is the default for symmetric (Hermitian) `A` and symmetric (Hermitian) positive definite `B`.
`'qz'`	Ignores the symmetry, if any, and uses the QZ algorithm as it would for nonsymmetric (non-Hermitian) `A` and `B`.

Note For `eig(A)`, the eigenvectors are scaled so that the norm of each is 1.0. For `eig(A,B)`, `eig(A,'nobalance')`, and `eig(A,B,flag)`, the eigenvectors are not normalized.

Remarks

The eigenvalue problem is to determine the nontrivial solutions of the equation

$$Ax = \lambda x$$

where A is an `n`-by-`n` matrix, x is a length `n` column vector, and λ is a scalar. The `n` values of λ that satisfy the equation are the *eigenvalues*, and the corresponding values of x are the *right eigenvectors*. In MATLAB, the function `eig` solves for the eigenvalues λ, and optionally the eigenvectors x.

The *generalized* eigenvalue problem is to determine the nontrivial solutions of the equation

$$Ax = \lambda Bx$$

where both A and B are n-by-n matrices and λ is a scalar. The values of λ that satisfy the equation are the *generalized eigenvalues* and the corresponding values of x are the *generalized right eigenvectors*.

If B is nonsingular, the problem could be solved by reducing it to a standard eigenvalue problem

$$B^{-1}Ax = \lambda x$$

Because B can be singular, an alternative algorithm, called the QZ method, is necessary.

When a matrix has no repeated eigenvalues, the eigenvectors are always independent and the eigenvector matrix V *diagonalizes* the original matrix A if applied as a similarity transformation. However, if a matrix has repeated eigenvalues, it is not similar to a diagonal matrix unless it has a full (independent) set of eigenvectors. If the eigenvectors are not independent then the original matrix is said to be *defective*. Even if a matrix is defective, the solution from eig satisfies A*X = X*D.

Examples

The matrix

```
B = [ 3      -2       -.9    2*eps
     -2       4        1    -eps
     -eps/4  eps/2   -1      0
     -.5     -.5       .1     1    ];
```

has elements on the order of roundoff error. It is an example for which the nobalance option is necessary to compute the eigenvectors correctly. Try the statements

```
[VB,DB] = eig(B)
B*VB - VB*DB
[VN,DN] = eig(B,'nobalance')
B*VN - VN*DN
```

Algorithm

Inputs of Type Double

For inputs of type `double`, MATLAB uses the following LAPACK routines to compute eigenvalues and eigenvectors.

Case	Routine
Real symmetric `A`	`DSYEV`
Real nonsymmetric `A`:	
• With preliminary balance step	`DGEEV` (with the scaling factor `SCLFAC` = 2 in `DGEBAL`, instead of the LAPACK default value of 8)
• `d = eig(A,'nobalance')`	`DGEHRD`, `DHSEQR`
• `[V,D] = eig(A,'nobalance')`	`DGEHRD`, `DORGHR`, `DHSEQR`, `DTREVC`
Hermitian `A`	`ZHEEV`
Non-Hermitian `A`:	
• With preliminary balance step	`ZGEEV` (with `SCLFAC = 2` instead of 8 in `ZGEBAL`)
• `d = eig(A,'nobalance')`	`ZGEHRD`, `ZHSEQR`
• `[V,D] = eig(A,'nobalance')`	`ZGEHRD`, `ZUNGHR`, `ZHSEQR`, `ZTREVC`
Real symmetric `A`, symmetric positive definite `B`.	`DSYGV`
Special case: `eig(A,B,'qz')` for real `A`, `B` (same as real nonsymmetric `A`, real general `B`)	`DGGEV`
Real nonsymmetric `A`, real general `B`	`DGGEV`
Complex Hermitian `A`, Hermitian positive definite `B`.	`ZHEGV`

Case	Routine
Special case: `eig(A,B,'qz')` for complex `A` or `B` (same as complex non-Hermitian `A`, complex `B`)	`ZGGEV`
Complex non-Hermitian `A`, complex `B`	`ZGGEV`

Inputs of Type Single

For inputs of type `single`, MATLAB uses the following LAPACK routines to compute eigenvalues and eigenvectors.

Case	Routine
Real symmetric `A`	`SSYEV`
Real nonsymmetric `A`:	
• With preliminary balance step	`SGEEV` (with the scaling factor `SCLFAC` = 2 in `SGEBAL`, instead of the LAPACK default value of `8`)
• `d = eig(A,'nobalance')`	`SGEHRD`, `SHSEQR`
• `[V,D] = eig(A,'nobalance')`	`SGEHRD`, `SORGHR`, `SHSEQR`, `STREVC`
Hermitian `A`	`CHEEV`
Non-Hermitian `A`:	
• With preliminary balance step	`CGEEV`
• `d = eig(A,'nobalance')`	`CGEHRD`, `CHSEQR`
• `[V,D] = eig(A,'nobalance')`	`CGEHRD`, `CUNGHR`, `CHSEQR`, `CTREVC`
Real symmetric `A`, symmetric positive definite `B`.	`CSYGV`
Special case: `eig(A,B,'qz')` for real `A`, `B` (same as real nonsymmetric `A`, real general `B`)	`SGGEV`

Case	Routine
Real nonsymmetric A, real general B	SGGEV
Complex Hermitian A, Hermitian positive definite B.	CHEGV
Special case: eig(A,B,'qz') for complex A or B (same as complex non-Hermitian A, complex B)	CGGEV
Complex non-Hermitian A, complex B	CGGEV

See Also

balance, condeig, eigs, hess, qz, schur

References

[1] Anderson, E., Z. Bai, C. Bischof, S. Blackford, J. Demmel, J. Dongarra, J. Du Croz, A. Greenbaum, S. Hammarling, A. McKenney, and D. Sorensen, *LAPACK User's Guide* (http://www.netlib.org/lapack/lug/lapack_lug.html), Third Edition, SIAM, Philadelphia, 1999.

Purpose

Find largest eigenvalues and eigenvectors of sparse matrix

Syntax

```
d = eigs(A)
[V,D] = eigs(A)
[V,D,flag] = eigs(A)
eigs(A,B)
eigs(A,k)
eigs(A,B,k)
eigs(A,k,sigma)
eigs(A,B,k,sigma
eigs(A,K,sigma,opts)
eigs(A,B,k,sigma,opts)
eigs(Afun,n,...)
```

Description

`d = eigs(A)` returns a vector of `A`'s six largest magnitude eigenvalues. `A` must be a square matrix, and should be large and sparse.

`[V,D] = eigs(A)` returns a diagonal matrix `D` of `A`'s six largest magnitude eigenvalues and a matrix `V` whose columns are the corresponding eigenvectors.

`[V,D,flag] = eigs(A)` also returns a convergence flag. If `flag` is `0` then all the eigenvalues converged; otherwise not all converged.

`eigs(A,B)` solves the generalized eigenvalue problem `A*V == B*V*D`. `B` must be symmetric (or Hermitian) positive definite and the same size as `A`. `eigs(A,[],...)` indicates the standard eigenvalue problem `A*V == V*D`.

`eigs(A,k)` and `eigs(A,B,k)` return the `k` largest magnitude eigenvalues.

`eigs(A,k,`*`sigma`*`)` and `eigs(A,B,k,`*`sigma`*`)` return `k` eigenvalues based on *`sigma`*, which can take any of the following values:

scalar (real or complex, including 0)	The eigenvalues closest to `sigma`. If `A` is a function, `Afun` must return `Y = (A-sigma*B)\x` (i.e., `Y = A\x` when `sigma = 0`). Note, `B` need only be symmetric (Hermitian) positive semi-definite.
`'lm'`	Largest magnitude (default).
`'sm'`	Smallest magnitude. Same as `sigma = 0`. If `A` is a function, `Afun` must return `Y = A\x`. Note, `B` need only be symmetric (Hermitian) positive semi-definite.

For real symmetric problems, the following are also options:

`'la'`	Largest algebraic (`'lr'` in MATLAB 5)
`'sa'`	Smallest algebraic (`'sr'` in MATLAB 5)
`'be'`	Both ends (one more from high end if `k` is odd)

For nonsymmetric and complex problems, the following are also options:

`'lr'`	Largest real part
`'sr'`	Smallest real part
`'li'`	Largest imaginary part
`'si'`	Smallest imaginary part

Note The syntax `eigs(A,k,...)` is not valid when `A` is scalar. To pass a value for `k`, you must specify `B` as the second argument and `k` as the third (`eigs(A,B,k,...)`). If necessary, you can set `B` equal to `[]`, the default.

`eigs(A,K,sigma,opts)` and `eigs(A,B,k,sigma,opts)` specify an options structure. Default values are shown in brackets (`{}`).

Parameter	Description	Values
options.issym	1 if A or A-*sigma**B represented by Afun is symmetric, 0 otherwise.	[{0} | 1]
options.isreal	1 if A or A-*sigma**B represented by Afun is real, 0 otherwise.	[0 | {1}]
options.tol	Convergence: Ritz estimate residual <= tol*norm(A).	[scalar | {eps}]
options.maxit	Maximum number of iterations.	[integer | {300}]
options.p	Number of Lanczos basis vectors. p >= 2k (p >= 2k+1 real nonsymmetric) advised. p must satisfy k < p <= n for real symmetric, k+1 < p <= n otherwise. Note: If you do not specify a p value, the default algorithm uses at least 20 Lanczos vectors.	[integer | {2*k}]
options.v0	Starting vector.	Randomly generated by ARPACK
options.disp	Diagnostic information display level.	[0 | {1} | 2]
options.cholB	1 if B is really its Cholesky factor chol(B), 0 otherwise.	[{0} | 1]
options.permB	Permutation vector permB if sparse B is really chol(B(permB,permB)).	[permB | {1:n}]

`eigs(Afun,n,...)` accepts the function handle `Afun` instead of the matrix `A`. See "Function Handles" in the MATLAB Programming documentation for more information. `Afun` must accept an input vector of size `n`.

`y = Afun(x)` should return:

`A*x`	if *`sigma`* is not specified, or is a string other than `'sm'`
`A\x`	if *`sigma`* is `0` or `'sm'`
`(A-`*`sigma`*`*I)\x`	if *`sigma`* is a nonzero scalar (standard eigenvalue problem). `I` is an identity matrix of the same size as `A`.
`(A-`*`sigma`*`*B)\x`	if *`sigma`* is a nonzero scalar (generalized eigenvalue problem)

"Parameterizing Functions Called by Function Functions" in the MATLAB Mathematics documentation, explains how to provide additional parameters to the function `Afun`, if necessary.

The matrix `A`, `A-`*`sigma`*`*I` or `A-`*`sigma`*`*B` represented by `Afun` is assumed to be real and nonsymmetric unless specified otherwise by `opts.isreal` and `opts.issym`. In all the `eigs` syntaxes, `eigs(A,...)` can be replaced by `eigs(Afun,n,...)`.

Remarks

`d = eigs(A,k)` is not a substitute for

```
d = eig(full(A))
d = sort(d)
d = d(end-k+1:end)
```

but is most appropriate for large sparse matrices. If the problem fits into memory, it may be quicker to use `eig(full(A))`.

Algorithm

`eigs` provides the reverse communication required by the Fortran library ARPACK, namely the routines `DSAUPD`, `DSEUPD`, `DNAUPD`, `DNEUPD`, `ZNAUPD`, and `ZNEUPD`.

Examples

Example 1

```
A = delsq(numgrid('C',15));
d1 = eigs(A,5,'sm')
```

returns

```
Iteration 1: a few Ritz values of the 20-by-20 matrix:
     0
     0
     0
     0
     0

Iteration 2: a few Ritz values of the 20-by-20 matrix:
    1.8117
    2.0889
    2.8827
    3.7374
    7.4954

Iteration 3: a few Ritz values of the 20-by-20 matrix:
    1.8117
    2.0889
    2.8827
    3.7374
    7.4954



d1 =

    0.5520
    0.4787
    0.3469
    0.2676
    0.1334
```

Example 2

This example replaces the matrix A in example 1 with a handle to a function dnRk. The example is contained in an M-file run_eigs that

- Calls eigs with the function handle @dnRk as its first argument.
- Contains dnRk as a nested function, so that all variables in run_eigs are available to dnRk.

The following shows the code for run_eigs:

```
function d2 = run_eigs
n = 139;
opts.issym = 1;
R = 'C';
k = 15;
d2 = eigs(@dnRk,n,5,'sm',opts);

    function y = dnRk(x)
        y = (delsq(numgrid(R,k))) \ x;
    end
end
```

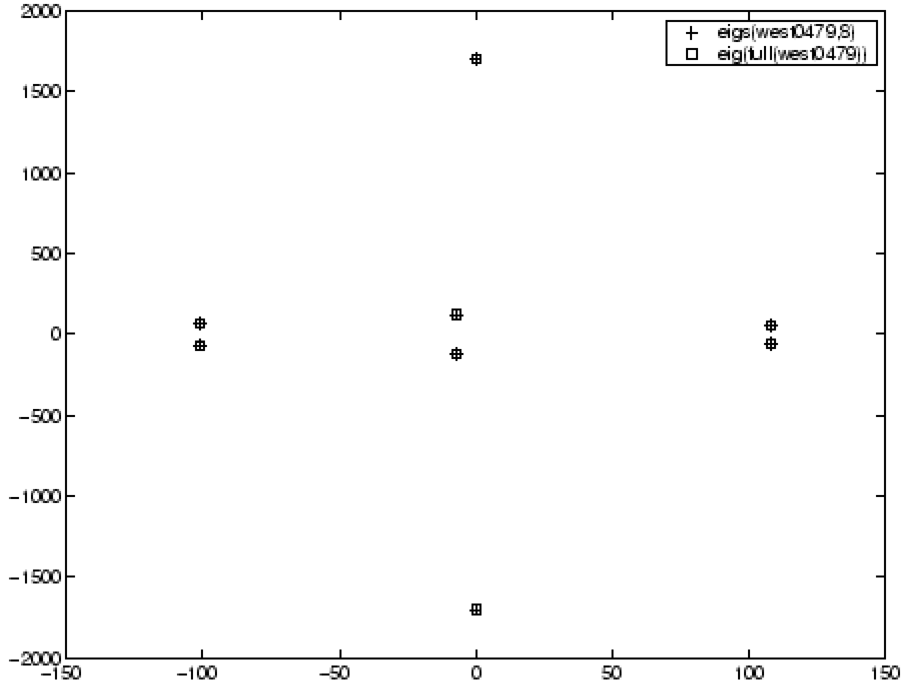
Example 3

west0479 is a real 479-by-479 sparse matrix with both real and pairs of complex conjugate eigenvalues. eig computes all 479 eigenvalues. eigs easily picks out the largest magnitude eigenvalues.

This plot shows the 8 largest magnitude eigenvalues of west0479 as computed by eig and eigs.

```
load west0479
d = eig(full(west0479))
dlm = eigs(west0479,8)
[dum,ind] = sort(abs(d));
plot(dlm,'k+')
hold on
plot(d(ind(end-7:end)),'ks')
```

```
hold off
legend('eigs(west0479,8)','eig(full(west0479))')
```

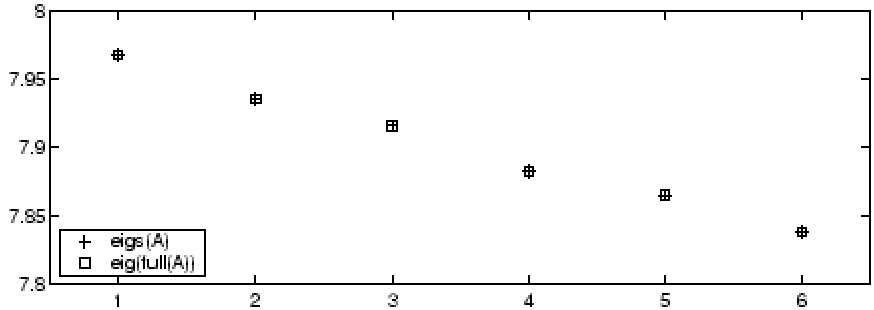


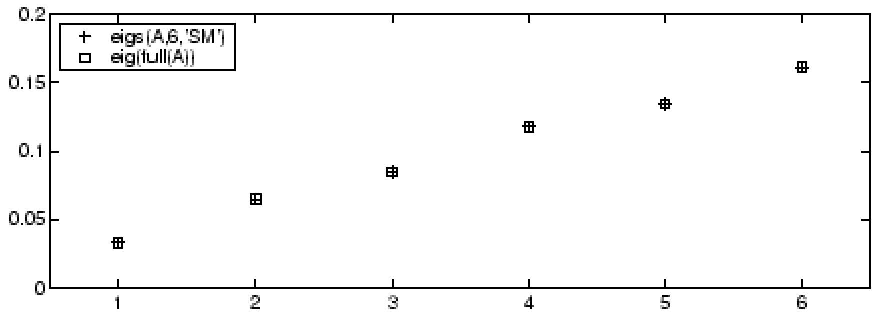
Example 4

`A = delsq(numgrid('C',30))` is a symmetric positive definite matrix of size 632 with eigenvalues reasonably well-distributed in the interval (0 8), but with 18 eigenvalues repeated at 4. The `eig` function computes all 632 eigenvalues. It computes and plots the six largest and smallest magnitude eigenvalues of `A` successfully with:

```
A = delsq(numgrid('C',30));
d = eig(full(A));
[dum,ind] = sort(abs(d));
dlm = eigs(A);
dsm = eigs(A,6,'sm');
```

```
subplot(2,1,1)
plot(dlm,'k+')
hold on
plot(d(ind(end:-1:end-5)),'ks')
hold off
legend('eigs(A)','eig(full(A))',3)
set(gca,'XLim',[0.5 6.5])

subplot(2,1,2)
plot(dsm,'k+')
hold on
plot(d(ind(1:6)),'ks')
hold off
legend('eigs(A,6,''sm'')','eig(full(A))',2)
set(gca,'XLim',[0.5 6.5])
```

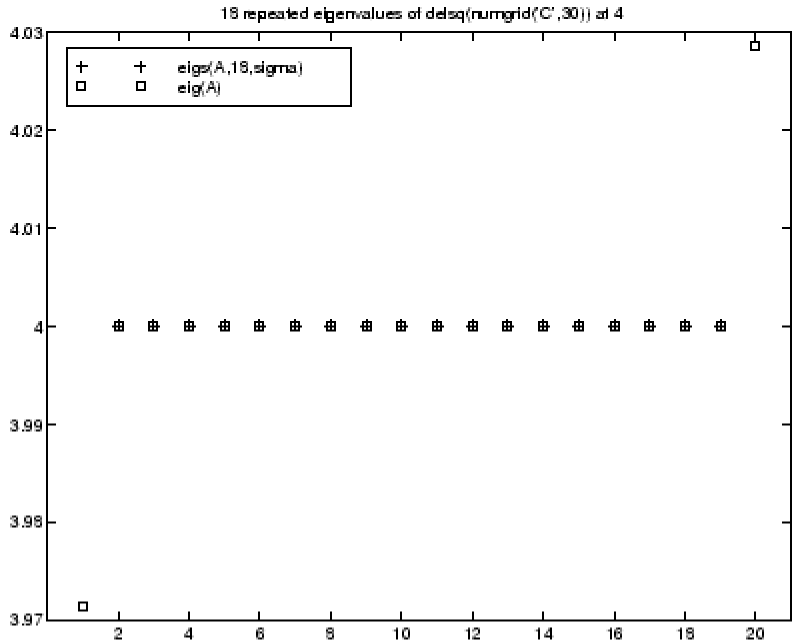




However, the repeated eigenvalue at 4 must be handled more carefully. The call `eigs(A,18,4.0)` to compute 18 eigenvalues near 4.0 tries to find eigenvalues of `A - 4.0*I`. This involves divisions of the form `1/(lambda - 4.0)`, where `lambda` is an estimate of an eigenvalue of `A`. As `lambda` gets closer to 4.0, `eigs` fails. We must use `sigma` near but not equal to 4 to find those 18 eigenvalues.

```
sigma = 4 - 1e-6
[V,D] = eigs(A,18,sigma)
```

The plot shows the 20 eigenvalues closest to 4 that were computed by `eig`, along with the 18 eigenvalues closest to `4 - 1e-6` that were computed by `eigs`.



See Also

`eig`, `svds`, `function_handle` (`@`)

References

[1] Lehoucq, R.B. and D.C. Sorensen, "Deflation Techniques for an Implicitly Re-Started Arnoldi Iteration," *SIAM J. Matrix Analysis and Applications*, Vol. 17, 1996, pp. 789-821.

[2] Lehoucq, R.B., D.C. Sorensen, and C. Yang, *ARPACK Users' Guide: Solution of Large-Scale Eigenvalue Problems with Implicitly Restarted Arnoldi Methods*, SIAM Publications, Philadelphia, 1998.

[3] Sorensen, D.C., "Implicit Application of Polynomial Filters in a k-Step Arnoldi Method," *SIAM J. Matrix Analysis and Applications*, Vol. 13, 1992, pp. 357-385.

Purpose

Jacobi elliptic functions

Syntax

```
[SN,CN,DN] = ellipj(U,M)
[SN,CN,DN] = ellipj(U,M,tol)
```

Definition

The Jacobi elliptic functions are defined in terms of the integral:

$$u = \int_0^{\phi} \frac{d\theta}{(1 - m\sin^2\theta)^{\frac{1}{2}}}$$

Then

$$sn(u) = \sin\phi,\ cn(u) = \cos\phi,\ dn(u) = (1 - m\sin^2\phi)^{\frac{1}{2}},\ am(u) = \phi$$

Some definitions of the elliptic functions use the modulus k instead of the parameter m. They are related by

$$k^2 = m = \sin^2\alpha$$

The Jacobi elliptic functions obey many mathematical identities; for a good sample, see [1].

Description

`[SN,CN,DN] = ellipj(U,M)` returns the Jacobi elliptic functions `SN`, `CN`, and `DN`, evaluated for corresponding elements of argument `U` and parameter `M`. Inputs `U` and `M` must be the same size (or either can be scalar).

`[SN,CN,DN] = ellipj(U,M,tol)` computes the Jacobi elliptic functions to accuracy `tol`. The default is `eps`; increase this for a less accurate but more quickly computed answer.

Algorithm

`ellipj` computes the Jacobi elliptic functions using the method of the arithmetic-geometric mean [1]. It starts with the triplet of numbers:

$$a_0 = 1,\ b_0 = (1 - m)^{\frac{1}{2}},\ c_0 = (m)^{\frac{1}{2}}$$

`ellipj` computes successive iterates with

$$a_i = \frac{1}{2}(a_{i-1} + b_{i-1})$$
$$b_i = (a_{i-1}b_{i-1})^{\frac{1}{2}}$$
$$c_i = \frac{1}{2}(a_{i-1} - b_{i-1})$$

Next, it calculates the amplitudes in radians using:

$$\sin(2\phi_{n-1} - \phi_n) = \frac{c_n}{a_n}\sin(\phi_n)$$

being careful to unwrap the phases correctly. The Jacobian elliptic functions are then simply:

$$sn(u) = \sin\phi_0$$
$$cn(u) = \cos\phi_0$$
$$dn(u) = (1 - m \cdot sn(u)^2)^{\frac{1}{2}}$$

Limitations

The `ellipj` function is limited to the input domain $0 \le m \le 1$. Map other values of `M` into this range using the transformations described in [1], equations 16.10 and 16.11. `U` is limited to real values.

See Also

`ellipke`

References

[1] Abramowitz, M. and I.A. Stegun, *Handbook of Mathematical Functions*, Dover Publications, 1965, 17.6.

Purpose

Complete elliptic integrals of first and second kind

Syntax

```
K = ellipke(M)
[K,E] = ellipke(M)
[K,E] = ellipke(M,tol)
```

Definition

The *complete* elliptic integral of the first kind [1] is

$$K(m) = F(\pi/2|m)$$

where F, the elliptic integral of the first kind, is

$$K(m) = \int_0^1 [(1-t^2)(1-mt^2)]^{\frac{-1}{2}}\,dt = \int_0^{\frac{\pi}{2}} (1-m\sin^2\theta)^{\frac{-1}{2}}\,d\theta$$

The complete elliptic integral of the second kind

$$E(m) = E(K(m)) = E\langle\pi/2|m\rangle$$

is

$$E(m) = \int_0^1 (1-t^2)^{\frac{-1}{2}}(1-mt^2)^{\frac{1}{2}}\,dt = \int_0^{\frac{\pi}{2}} (1-m\sin^2\theta)^{\frac{1}{2}}\,d\theta$$

Some definitions of `K` and `E` use the modulus k instead of the parameter m. They are related by

$$k^2 = m = \sin^2\alpha$$

Description

`K = ellipke(M)` returns the complete elliptic integral of the first kind for the elements of `M`.

`[K,E] = ellipke(M)` returns the complete elliptic integral of the first and second kinds.

`[K,E] = ellipke(M,tol)` computes the complete elliptic integral to accuracy `tol`. The default is `eps`; increase this for a less accurate but more quickly computed answer.

Algorithm

`ellipke` computes the complete elliptic integral using the method of the arithmetic-geometric mean described in [1], section 17.6. It starts with the triplet of numbers

$$a_0 = 1,\ b_0 = (1-m)^{\frac{1}{2}},\ c_0 = (m)^{\frac{1}{2}}$$

`ellipke` computes successive iterations of a_i, b_i, and c_i with

$$\begin{aligned} a_i &= \frac{1}{2}(a_{i-1}+b_{i-1}) \\ b_i &= (a_{i-1}b_{i-1})^{\frac{1}{2}} \\ c_i &= \frac{1}{2}(a_{i-1}-b_{i-1}) \end{aligned}$$

stopping at iteration n when $cn \approx 0$, within the tolerance specified by `eps`. The complete elliptic integral of the first kind is then

$$K(m) = \frac{\pi}{2a_n}$$

Limitations

`ellipke` is limited to the input domain $0 \le m \le 1$.

See Also

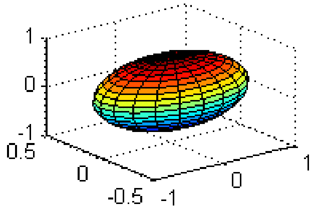
`ellipj`

References

[1] Abramowitz, M. and I.A. Stegun, *Handbook of Mathematical Functions*, Dover Publications, 1965, 17.6.

Purpose

Generate ellipsoid



Syntax

```
[x,y,z] = ellipsoid(xc,yc,zc,xr,yr,zr,n)
[x,y,z] = ellipsoid(xc,yc,zc,xr,yr,zr)
ellipsoid(axes_handle,...)
ellipsoid(...)
```

Description

`[x,y,z] = ellipsoid(xc,yc,zc,xr,yr,zr,n)` generates a surface mesh described by three `n+1`-by-`n+1` matrices, enabling `surf(x,y,z)` to plot an ellipsoid with center `(xc,yc,zc)` and semi-axis lengths `(xr,yr,zr)`.

`[x,y,z] = ellipsoid(xc,yc,zc,xr,yr,zr)` uses `n = 20`.

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

`ellipsoid(...)` with no output arguments plots the ellipsoid as a surface.

Algorithm

`ellipsoid` generates the data using the following equation:

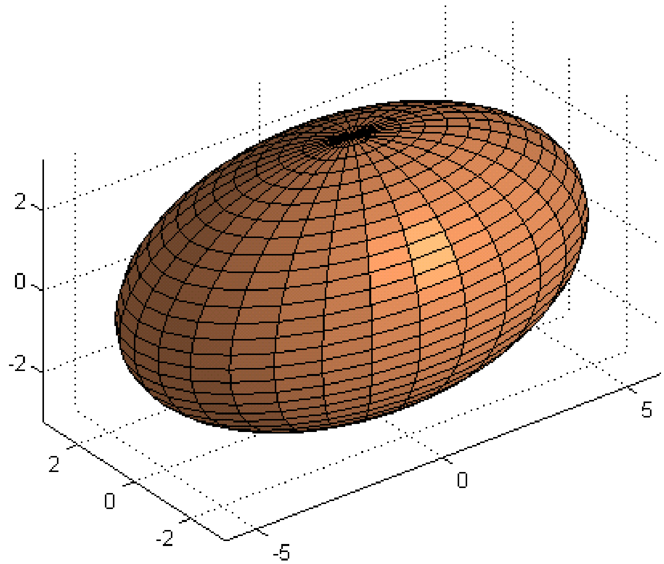
$$\frac{(x-xc)^2}{xr^2} + \frac{(y-yc)^2}{yr^2} + \frac{(z-zc)^2}{zr^2}$$

Note that `ellipsoid(0,0,0, .5,.5,.5)` is equivalent to a unit sphere.

Example

Generate ellipsoid with size and proportions of a standard U.S. football:

```
[x, y, z] = ellipsoid(0,0,0,5.9,3.25,3.25,30);
surfl(x, y, z)
colormap copper
axis equal
```



See Also

`cylinder`, `sphere`, `surf`

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

Purpose

Execute statements if condition is false

Syntax

`if expression, statements1, else statements2, end`

Description

`if expression, statements1, else statements2, end` evaluates *`expression`* and, if the evaluation yields logical `1` (`true`) or a nonzero result, executes one or more MATLAB commands denoted here as *`statements1`* or, if the evaluation yields logical `0` (`false`), executes the commands in *`statements2`*. `else` is used to delineate the alternate block of statements..

A `true` expression has either a logical 1 (`true`) or nonzero value. For nonscalar expressions, (for example, "if (matrix A is less than matrix B)"), `true` means that every element of the resulting matrix has a `true` or nonzero value.

Expressions usually involve relational operations such as `(count < limit)` or `isreal(A)`. Simple expressions can be combined by logical operators (&,|,~) into compound expressions such as `(count < limit) & ((height - offset) >= 0)`.

See "Program Control Statements" in the MATLAB Programming documentation for more information on controlling the flow of your program code.

Examples

In this example, if both of the conditions are not satisfied, then the student fails the course.

```
if ((attendance >= 0.90) & (grade_average >= 60))
   pass = 1;
else
   fail = 1;
end;
```

See Also

`if`, `elseif`, `end`, `for`, `while`, `switch`, `break`, `return`, relational operators, logical operators (elementwise and short-circuit)

elseif

Purpose

Execute statements if additional condition is true

Syntax

```
if expression1, statements1, elseif expression2,
statements2,
   end
```

Description

`if` *`expression1`*, *`statements1`*, `elseif` *`expression2`*, *`statements2`*, `end` evaluates *`expression1`* and, if the evaluation yields logical `1` (`true`) or a nonzero result, executes one or more MATLAB commands denoted here as *`statements1`*. If *`expression1`* is `false`, MATLAB evaluates the `elseif` expression, *`expression2`*. If *`expression2`* evaluates to `true` or a nonzero result, executes the commands in *`statements2`*.

A `true` expression has either a logical 1 (`true`) or nonzero value. For nonscalar expressions, (for example, is matrix A less then matrix B), `true` means that every element of the resulting matrix has a `true` or nonzero value.

Expressions usually involve relational operations such as `(count < limit)` or `isreal(A)`. Simple expressions can be combined by logical operators (&,|,~) into compound expressions such as `(count < limit) & ((height - offset) >= 0)`.

See "Program Control Statements" in the MATLAB Programming documentation for more information on controlling the flow of your program code.

Remarks

`else if` , with a space between the `else` and the `if`, differs from `elseif`, with no space. The former introduces a new, nested `if`, which must have a matching `end`. The latter is used in a linear sequence of conditional statements with only one terminating `end`.

The two segments shown below produce identical results. Exactly one of the four assignments to `x` is executed, depending upon the values of the three logical expressions, `A`, `B`, and `C`.

`if A` `   x = a`	`if A` `    x = a`

```
else                              elseif B
   if B                               x = b
      x = b                       elseif C
   else                               x = c
       if C                       else
          x = c                       x = d
       else                       end
           x = d
       end
   end
end
```

Examples

Here is an example showing `if`, `else`, and `elseif`.

```
for m = 1:k
    for n = 1:k
        if m == n
            a(m,n) = 2;
        elseif abs(m-n) == 2
            a(m,n) = 1;
        else
            a(m,n) = 0;
        end
    end
end
```

For `k=5` you get the matrix

```
a =

     2     0     1     0     0
     0     2     0     1     0
     1     0     2     0     1
     0     1     0     2     0
     0     0     1     0     2
```

See Also

`if`, `else`, `end`, `for`, `while`, `switch`, `break`, `return`, relational operators, logical operators (elementwise and short-circuit)

enableservice

Purpose

Enable, disable, or report status of Automation server; enable DDE server

Syntax

```
state = enableservice('AutomationServer',enable)
state = enableservice('AutomationServer')
enableservice('DDEServer',enable)
```

Description

`state = enableservice('AutomationServer',enable)` enables or disables the MATLAB Automation server.

If `enable` is logical `1` (`true`), `enableservice` converts an existing MATLAB session into an Automation server. If `enable` is logical `0` (`false`), `enableservice` disables the MATLAB Automation server.

`state` indicates the previous state of the Automation server. If `state = 1`, MATLAB was an Automation server. If `state` is logical `0` (`false`), MATLAB was not an Automation server.

`state = enableservice('AutomationServer')` returns the current state of the Automation server. If `state` is logical `1` (`true`), MATLAB is an Automation server.

`enableservice('DDEServer',enable)` enables the MATLAB DDE server. You cannot disable a DDE server once it has been enabled. Therefore, the only allowed value for `enable` is logical `1` (`true`).

Remarks

You can use the outgoing MATLAB DDE commands (`ddeinit`, `ddeterm`, `ddeexec`, `ddereq`, `ddeadv`, `ddeunadv`, `ddepoke`) without starting the DDE server.

Examples

Enable an Automation Server Example

Enable the Automation server in the current MATLAB session:

```
state = enableservice('AutomationServer',true);
```

Next, show the current state of the MATLAB session:

```
state = enableservice('AutomationServer')
```

MATLAB displays `state = 1` (`true`), showing that MATLAB is an Automation server.

Finally, enable the Automation server and show the previous state by typing

```
state = enableservice('AutomationServer',true)
```

MATLAB displays `state = 1` (`true`), showing that MATLAB previously was an Automation server.

Note the previous state may be the same as the current state. As seen in this case, `state = 1` shows MATLAB was, and still is, an Automation server.

Enable a DDE Server Example

Enable the DDE server in the current MATLAB session:

```
enableservice('DDEServer',true)
```

Purpose Terminate block of code, or indicate last array index

Syntax `end`

Description

`end` is used to terminate `for`, `while`, `switch`, `try`, and `if` statements. Without an `end` statement, `for`, `while`, `switch`, `try`, and `if` wait for further input. Each `end` is paired with the closest previous unpaired `for`, `while`, `switch`, `try`, or `if` and serves to delimit its scope.

`end` also marks the termination of an M-file function, although in most cases, it 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.

The `end` function also serves as the last index in an indexing expression. In that context, `end = (size(x,k))` when used as part of the `k`th index. Examples of this use are `X(3:end)` and `X(1,1:2:end-1)`. When using `end` to grow an array, as in `X(end+1)=5`, make sure `X` exists first.

You can overload the `end` statement for a user object by defining an `end` method for the object. The `end` method should have the calling sequence `end(obj,k,n)`, where `obj` is the user object, `k` is the index in the expression where the `end` syntax is used, and `n` is the total number of indices in the expression. For example, consider the expression

```
A(end-1,:)
```

MATLAB will call the `end` method defined for `A` using the syntax

```
end(A,1,2)
```

Examples

This example shows `end` used with the `for` and `if` statements.

```
for k = 1:n
 if a(k) == 0
  a(k) = a(k) + 2;
```

```
    end
end
```

In this example, `end` is used in an indexing expression.

```
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

B = A(end,2:end)

B =

    18    25     2     9
```

See Also

`break`, `for`, `if`, `return`, `switch`, `try`, `while`

Purpose Last day of month

Syntax

```
E = eomday(Y, M)
```

Description `E = eomday(Y, M)` returns the last day of the year and month given by corresponding elements of arrays `Y` and `M`.

Examples Because 1996 is a leap year, the statement `eomday(1996,2)` returns `29`.

To show all the leap years in this century, try:

```
y = 1900:1999;
E = eomday(y, 2);
y(find(E == 29))

ans =
  Columns 1 through 6
     1904     1908     1912     1916     1920     1924

  Columns 7 through 12
     1928     1932     1936     1940     1944     1948

  Columns 13 through 18
     1952     1956     1960     1964     1968     1972

  Columns 19 through 24
     1976     1980     1984     1988     1992     1996
```

See Also `datenum`, `datevec`, `weekday`

Purpose

Floating-point relative accuracy

Syntax

```
eps
d = eps(X)
eps('double')
eps('single')
```

Description

`eps` returns the distance from 1.0 to the next largest double-precision number, that is `eps = 2^(-52)`.

`d = eps(X)` is the positive distance from `abs(X)` to the next larger in magnitude floating point number of the same precision as `X`. `X` may be either double precision or single precision. For all `X`,

```
eps(X) = eps(-X) = eps(abs(X))
```

`eps('double')` is the same as `eps` or `eps(1.0)`.

`eps('single')` is the same as `eps(single(1.0))` or `single(2^-23)`.

Except for numbers whose absolute value is smaller than `realmin` , if `2^E <= abs(X) < 2^(E+1)`, then

```
eps(X) = 2^(E-23) if isa(X,'single')
eps(X) = 2^(E-52) if isa(X,'double')
```

For all `X` of class `double` such that `abs(X) <= realmin`, `eps(X) = 2^(-1074)`. Similarly, for all `X` of class `single` such that `abs(X) <= realmin('single')`, `eps(X) = 2^(-149)`.

Replace expressions of the form

```
if Y < eps * ABS(X)
```

with

```
if Y < eps(X)
```

Examples

```
double precision
eps(1/2) = 2^(-53)
```

```
eps(1) = 2^(-52)
eps(2) = 2^(-51)
eps(realmax) = 2^971
eps(0) = 2^(-1074)

if(abs(x)) <= realmin, eps(x) = 2^(-1074)
eps(realmin/2) = 2^(-1074)
eps(realmin/16) = 2^(-1074)
eps(Inf) = NaN
eps(NaN) = NaN

single precision
eps(single(1/2)) = 2^(-24)
eps(single(1)) = 2^(-23)
eps(single(2)) = 2^(-22)
eps(realmax('single')) = 2^104
eps(single(0)) = 2^(-149)
eps(realmin('single')/2) = 2^(-149)
eps(realmin('single')/16) = 2^(-149)
if(abs(x)) <= realmin('single'), eps(x) = 2^(-149)
eps(single(Inf)) = single(NaN)
eps(single(NaN)) = single(NaN)
```

See Also

realmax, realmin

Purpose

Test for equality

Syntax

```
A == B
eq(A, B)
```

Description

`A == B` compares each element of array `A` for equality with the corresponding element of array `B`, and returns an array with elements set to logical 1 (`true`) where `A` and `B` are equal, or logical 0 (`false`) where they are not 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.

`eq(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 equal to the corresponding elements of `B`:

```
A = magic(6);
B = repmat(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     0     0     0
```

```
     0     1     0     0     0     0
     1     0     0     0     0     0
```

See Also `ne`, `le`, `ge`, `lt`, `gt`, relational operators

Purpose

Error functions

Syntax

```
Y = erf(X)
Y = erfc(X)
Y = erfcx(X)
X = erfinv(Y)
X = erfcinv(Y)
```

Definition

The error function `erf(X)` is twice the integral of the Gaussian distribution with 0 mean and variance of $1/2$.

$$\operatorname{erf}(x) = \frac{2}{\sqrt{\pi}} \int_0^x e^{-t^2} dt$$

The complementary error function `erfc(X)` is defined as

$$\operatorname{erfc}(x) = \frac{2}{\sqrt{\pi}} \int_x^\infty e^{-t^2} dt = 1 - \operatorname{erf}(x)$$

The scaled complementary error function `erfcx(X)` is defined as

$$\operatorname{erfcx}(x) = e^{x^2} \operatorname{erfc}(x)$$

For large `X`, `erfcx(X)` is approximately $\left(\frac{1}{\sqrt{\pi}}\right)\frac{1}{x}$

Description

`Y = erf(X)` returns the value of the error function for each element of real array `X`.

`Y = erfc(X)` computes the value of the complementary error function.

`Y = erfcx(X)` computes the value of the scaled complementary error function.

`X = erfinv(Y)` returns the value of the inverse error function for each element of `Y`. Elements of `Y` must be in the interval `[-1 1]`. The function `erfinv` satisfies $y = \operatorname{erf}(x)$ for $-1 \le y \le 1$ and $-\infty \le x \le \infty$.

`X = erfcinv(Y)` returns the value of the inverse of the complementary error function for each element of `Y`. Elements of `Y` must be in the interval `[0 2]`. The function `erfcinv` satisfies $y = \mathrm{erfc}(x)$ for $2 \geq y \geq 0$ and $-\infty \leq x \leq \infty$.

Remarks

The relationship between the complementary error function `erfc` and the standard normal probability distribution returned by the Statistics Toolbox function `normcdf` is

$$\mathrm{normcdf}(x) = 0.5 * \mathrm{erfc}(-x/\sqrt{2})$$

The relationship between the inverse complementary error function `erfcinv` and the inverse standard normal probability distribution returned by the Statistics Toolbox function `norminv` is

$$\mathrm{norminv}(p) = -\sqrt{2} * \mathrm{erfcinv}(2p)$$

Examples

`erfinv(1)` is `Inf`

`erfinv(-1)` is `-Inf`.

For `abs(Y) > 1`, `erfinv(Y)` is `NaN`.

Algorithms

For the error functions, the MATLAB code is a translation of a Fortran program by W. J. Cody, Argonne National Laboratory, NETLIB/SPECFUN, March 19, 1990. The main computation evaluates near-minimax rational approximations from [1].

For the inverse of the error function, rational approximations accurate to approximately six significant digits are used to generate an initial approximation, which is then improved to full accuracy by one step of Halley's method.

References

[1] Cody, W. J., "Rational Chebyshev Approximations for the Error Function," *Math. Comp.*, pgs. 631-638, 1969

Purpose

Display message and abort function

Syntax

```
error('message')
error('message', a1, a2, ...)
error('message_id', 'message')
error('message_id', 'message', a1, a2, ...)
error(message_struct)
```

Description

`error('message')` displays an error message and returns control to the keyboard. The error message contains the input string `message`.

The `error` command has no effect if `message` is an empty string.

`error('message', a1, a2, ...)` displays a message string that contains formatting conversion characters, such as those used with the MATLAB `sprintf` function. Each conversion character in `message` is converted to one of the values `a1, a2, ...` in the argument list.

Note MATLAB converts special characters (like `\n` and `%d`) in the error message string only when you specify more than one input argument with `error`. See Example 3 below.

`error('message_id', 'message')` attaches a unique message identifier, or `message_id`, to the error message. The identifier enables you to better identify the source of an error. See "Message Identifiers" and "Using Message Identifiers with lasterror" in the MATLAB documentation for more information on the `message_id` argument and how to use it.

`error('message_id', 'message', a1, a2, ...)` includes formatting conversion characters in `message`, and the character translations `a1, a2, ...`.

`error(message_struct)` accepts a scalar error structure input `message_struct` with at least one of the fields `message`, `identifier`, and `stack`. (See the help for `lasterror` for more information on these fields.)

```
error(msgstruct.identifier, msgstruct.message);
```

If the msgstruct input includes a stack field, then the stack field of the error will be set according to the contents of the stack input. As a special case, if msgstruct is an empty structure, no action is taken and error returns without exiting from the M-file.

Remarks

In addition to the message_id and message, the error function also determines where the error occurred, and provides this information using the stack field of the structure returned by lasterror. The stack field contains a structure array in the same format as the output of dbstack. This stack points to the line, function, and M-file in which the error occurred.

Examples

Example 1

The error function provides an error return from M-files:

```
function foo(x,y)
if nargin ~= 2
     error('Wrong number of input arguments')
end
```

The returned error message looks like this:

```
foo(pi)

??? Error using ==> foo
Wrong number of input arguments
```

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 lasterror to determine the message identifier and error message string for the failing operation:

```
err = lasterror;

err.message
ans =
   The angle specified must be less than 90 degrees.

err.identifier
ans =
   MyToolbox:angleTooLarge
```

If this error is thrown from code in an M-file, you can find the M-file name, function, and line number using the `stack` field of the structure returned by `lasterror`:

```
err.stack
ans =
    file: 'd:\mytools\plotshape.m'
    name: 'check_angles'
    line: 26
```

Example 3

MATLAB converts special characters (like `\n` and `%d`) in the error message string only when you specify more than one input argument with `error`. In the single-argument case shown below, `\n` is taken to mean `backslash-n`. It is not converted to a newline character:

```
error('In this case, the newline \n is not converted.')
??? In this case, the newline \n is not converted.
```

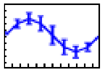
But, when more than one argument is specified, MATLAB does convert special characters. This holds true regardless of whether the additional argument supplies conversion values or is a message identifier:

```
error('ErrorTests:convertTest', ...
      'In this case, the newline \n is converted.')
??? In this case, the newline
 is converted.
```

See Also `lasterror`, `rethrow`, `errordlg`, `warning`, `lastwarn`, `warndlg`, `dbstop`, `disp`, `sprintf`

Purpose

Plot error bars along curve



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

```
errorbar(Y,E)
errorbar(X,Y,E)
errorbar(X,Y,L,U)
errorbar(...,LineSpec)
h = errorbar(...)
hlines = errorbar('v6',...)
```

Description

Error bars show the confidence level of data or the deviation along a curve.

`errorbar(Y,E)` plots `Y` and draws an error bar at each element of `Y`. The error bar is a distance of `E(i)` above and below the curve so that each bar is symmetric and `2*E(i)` long.

`errorbar(X,Y,E)` plots `Y` versus `X` with symmetric error bars `2*E(i)` long. `X`, `Y`, `E` must be the same size. When they are vectors, each error bar is a distance of `E(i)` above and below the point defined by `(X(i),Y(i))`. When they are matrices, each error bar is a distance of `E(i,j)` above and below the point defined by `(X(i,j),Y(i,j))`.

`errorbar(X,Y,L,U)` plots `X` versus `Y` with error bars `L(i)+U(i)` long specifying the lower and upper error bars. `X`, `Y`, `L`, and `U` must be the same size. When they are vectors, each error bar is a distance of `L(i)` below and `U(i)` above the point defined by `(X(i),Y(i))`. When they are matrices, each error bar is a distance of `L(i,j)` below and `U(i,j)` above the point defined by `(X(i,j),Y(i,j))`.

errorbar(...,LineSpec) uses the color and linestyle specified by the string 'LineSpec'. The color is applied to the data line and error bars. The linestyle and marker are applied to the data line only. See plot for examples of styles.

h = errorbar(...) returns handles to the errorbarseries objects created. errorbar creates one object for vector input arguments and one object per column for matrix input arguments. See errorbarseries properties for more information.

Backward-Compatible Version

hlines = errorbar('v6',...) returns the handles of line objects instead of errorbarseries objects for compatibility with MATLAB 6.5 and earlier.

See "Plot Objects and Backward Compatibility" for more information.

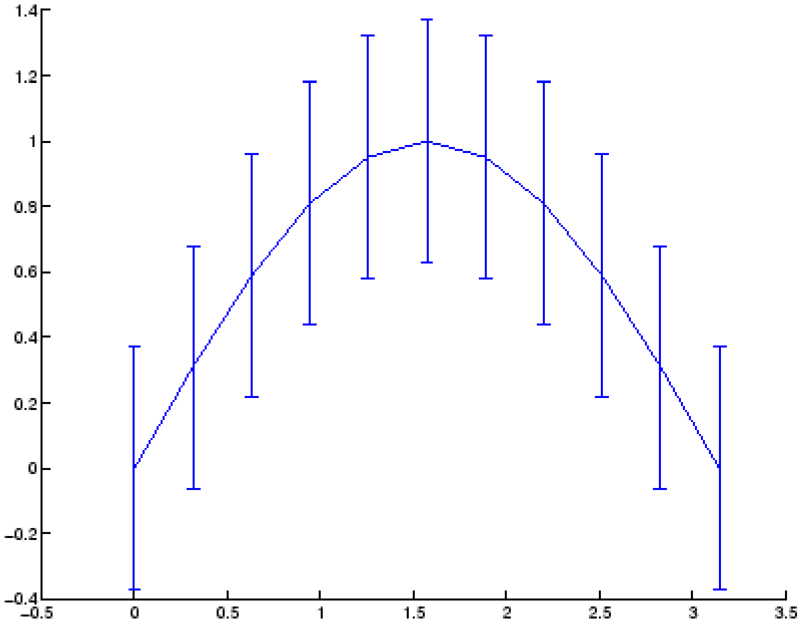
Remarks

When the arguments are all matrices, errorbar draws one line per matrix column. If X and Y are vectors, they specify one curve.

Examples

Draw symmetric error bars that are two standard deviation units in length.

```
X = 0:pi/10:pi;
Y = sin(X);
E = std(Y)*ones(size(X));
errorbar(X,Y,E)
```



See Also

`LineSpec`, `plot`, `std`, `corrcoef`

"Basic Plots and Graphs" on page 1-85 and ConfidenceBounds for related functions

See `Errorbarseries Properties` for property descriptions

Errorbarseries Properties

Purpose

Define errorbarseries properties

Modifying Properties

You can set and query graphics object properties using the `set` and `get` commands or the Property editor (`propertyeditor`).

Note that you cannot define default property values for errorbarseries objects. See “Plot Objects” for more information on errorbarseries objects.

Errorbarseries 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 if objects are in the process of being deleted. MATLAB sets the `BeingDeleted` property to `on` when the object’s delete function callback is called (see the `DeleteFcn` property). It remains set to `on` while the delete function executes, after which the object no longer exists.

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

`BusyAction`

`cancel | {queue}`

Callback routine interruption. The `BusyAction` property enables you to control how MATLAB handles events that potentially interrupt executing callbacks. If there is a callback function executing, callbacks invoked subsequently always attempt to interrupt it.

If the `Interruptible` property of the object whose callback is executing is set to `on` (the default), then interruption occurs at the next point where the event queue is processed. If the `Interruptible` property is `off`, the `BusyAction` property (of the object owning the executing callback) determines how MATLAB handles the event. The choices are

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

`ButtonDownFcn`
string or function handle

Button press callback function. A callback that executes whenever you press a mouse button while the pointer is over this object, but not over another graphics object. See the `HitTestArea` property for information about selecting objects of this type.

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

This property can be

- A string that is a valid MATLAB expression
- The name of an M-file
- A function handle

Set this property to a function handle that references the callback. The expressions execute in the MATLAB workspace.

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

`Children`
array of graphics object handles

Children of this object. The handle of a patch object that is the child of this object (whether visible or not).

Note that if a child object's `HandleVisibility` property is set to `callback` or `off`, its handle does not show up in this object's `Children` property unless you set the root `ShowHiddenHandles` property to `on`:

```
set(0,'ShowHiddenHandles','on')
```

`Clipping`
`{on} | off`

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

Not available on errorbarseries objects.

`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).

`HitTestArea`

`on | {off}`

Select the object by clicking lines or area of extent. This property enables you to select plot objects in two ways:

- Select by clicking lines or markers (default).
- Select by clicking anywhere in the extent of the plot.

When `HitTestArea` is `off`, you must click th eobject's lines or markers (excluding the baseline, if any) to select the object. When `HitTestArea` is `on`, you can select this object by clicking anywhere within the extent of the plot (i.e., anywhere within a rectangle that encloses it).

`Interruptible`
`{on} | off`

Callback routine interruption mode. The `Interruptible` property controls whether an object's callback can be interrupted by callbacks invoked subsequently.

Only callbacks defined for the `ButtonDownFcn` property are affected by the `Interruptible` property. MATLAB checks for events that can interrupt a callback only when it encounters a `drawnow`, `figure`, `getframe`, or `pause` command in the routine. See the `BusyAction` property for related information.

Setting `Interruptible` to `on` allows any graphics object's callback to interrupt callback routines originating from a bar property. Note that MATLAB does not save the state of variables or the display (e.g., the handle returned by the `gca` or `gcf` command) when an interruption occurs.

`LData`
array equal in size to `XData` and `YData`

Errorbar length below data point. The `errorbar` function uses this data to determine the length of the errorbar below each data point. Specify these values in data units. See also `UData`.

`LDataSource`
string (MATLAB variable)

Link `LData` to MATLAB variable. Set this property to a MATLAB variable that is evaluated in the base workspace to generate the `LData`.

MATLAB reevaluates this property only when you set it. Therefore, a change to workspace variables appearing in an expression does not change `LData`.

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.

`LineStyle`

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

Line style. This property specifies the line style of the object. Available line styles are shown in the following table.

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

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

`LineWidth`

scalar

The width of linear objects and edges of filled areas. Specify this value in points (1 point = $^1/_{72}$ inch). The default `LineWidth` is 0.5 points.

`Marker`

character (see table)

Marker symbol. The `Marker` property specifies the type of markers that are displayed at plot vertices. You can set values for the `Marker` property independently from the `LineStyle` property. Supported markers include those shown in the following table.

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

`MarkerEdgeColor`

`ColorSpec | none | {auto}`

Marker edge color. The color of the marker or the edge color for filled markers (circle, square, diamond, pentagram, hexagram, and the four triangles). `ColorSpec` defines the color to use. `none` specifies no color, which makes nonfilled markers invisible. `auto` sets `MarkerEdgeColor` to the same color as the `Color` property.

`MarkerFaceColor`
`ColorSpec | {none} | auto`

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 selection handles on the curve and error bars. 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 errorbarseries object and set the `Tag` property:

```
t = errorbar(Y,E,'Tag','errorbar1')
```

When you want to access the errorbarseries object, you can use `findobj` to find the errorbarseries object's handle.

The following statement changes the `MarkerFaceColor` property of the object whose `Tag` is `errorbar1`.

```
set(findobj('Tag','errorbar1'),'MarkerFaceColor','red')
```

`Type`

string (read only)

Type of graphics object. This property contains a string that identifies the class of the graphics object. For errorbarseries objects, `Type` is 'hggroup'. The following statement finds all the hggroup objects in the current axes.

```
t = findobj(gca,'Type','hggroup');
```

`UData`

array equal in size to `XData` and `YData`

Errorbar length above data point. The `errorbar` function uses this data to determine the length of the errorbar above each data point. Specify these values in data units.

`UDataSource`

string (MATLAB variable)

Link `UData` to MATLAB variable. Set this property to a MATLAB variable that is evaluated in the base workspace to generate the `UData`.

MATLAB reevaluates this property only when you set it. Therefore, a change to workspace variables appearing in an expression does not change `UData`.

You can use the `refreshdata` function to force an update of the object's data. `refreshdata` also enables you to specify that the data source variable be evaluated in the workspace of a function from which you call `refreshdata`.

See the `refreshdata` reference page for more information.

`UIContextMenu`

handle of a uicontextmenu object

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

`UserData`
array

User-specified data. This property can be any data you want to associate with the errorbarseries object (including cell arrays and structures). The errorbarseries object does not set values for this property, but you can access it using the `set` and `get` functions.

`Visible`
`{on} | off`

Visibility of errorbarseries object and its children. By default, errorbarseries object visibility is `on`. This means all children of the errorbarseries object are visible unless the child object's `Visible` property is set to `off`. Setting an errorbarseries object's `Visible` property to `off` also makes its children invisible.

`XData`
array

X-coordinates of the curve. The `errorbar` function plots a curve using the *x*-axis coordinates in the `XData` array. `XData` must be the same size as `YData`.

If you do not specify `XData` (i.e., the input argument `x`), the `errorbar` function uses the indices of `YData` to create the curve. See the `XDataMode` property for related information.

`XDataMode`
{auto} | manual

Use automatic or user-specified x-axis values. If you specify `XData` (by setting the `XData` property or specifying the input argument `x`), the `errorbar` function sets this property to `manual`.

If you set XDataMode to auto after having specified XData, the errorbar function resets the *x* tick-mark labels to the indices of the YData.

XDataSource
string (MATLAB variable)

Link XData to MATLAB variable. Set this property to a MATLAB variable that is evaluated in the base workspace to generate the XData.

MATLAB reevaluates this property only when you set it. Therefore, a change to workspace variables appearing in an expression does not change XData.

You can use the refreshdata function to force an update of the object's data. refreshdata also enables you to specify that the data source variable be evaluated in the workspace of a function from which you call refreshdata.

See the refreshdata reference page for more information.

Note If you change one data source property to a variable that contains data of a different dimension, you might cause the function to generate a warning and not render the graph until you have changed all data source properties to appropriate values.

YData
scalar, vector, or matrix

Data defining curve. YData contains the data defining the curve. If YData is a matrix, the errorbar function displays a curve with error bars for each column in the matrix.

The input argument `Y` in the `errorbar` function calling syntax assigns values to `YData`.

`YDataSource`
string (MATLAB variable)

Link `YData` to MATLAB variable. Set this property to a MATLAB variable that is evaluated in the base workspace to generate the `YData`.

MATLAB reevaluates this property only when you set it. Therefore, a change to workspace variables appearing in an expression does not change `YData`.

You can use the `refreshdata` function to force an update of the object's data. `refreshdata` also enables you to specify that the data source variable be evaluated in the workspace of a function from which you call `refreshdata`.

See the `refreshdata` reference page for more information.

Purpose

Create and open error dialog box

Syntax

```
h = errordlg
h = errordlg(errorstring)
h = errordlg(errorstring,dlgname)
h = errordlg(errorstring,dlgname,createmode)
```

Description

`h = errordlg` creates and displays a dialog box with title `Error Dialog` that contains the string `This is the default error string.` The `errordlg` function returns the handle of the dialog box in `h`.

`h = errordlg(errorstring)` displays a dialog box with title `Error Dialog` that contains the string `errorstring`.

`h = errordlg(errorstring,dlgname)` displays a dialog box with title`dlgname` that contains the string `errorstring`.

`h = errordlg(errorstring,dlgname,`*`createmode`*`)` specifies whether the error dialog box is modal or nonmodal. Optionally, it can also specify an interpreter for `errorstring` and `dlgname`. The *`createmode`* argument can be a string or a structure.

If *`createmode`* is a string, it must be one of the values shown in the following table.

createmode Value	Description
`modal`	Replaces the error dialog box having the specified `Title`, that was last created or clicked on, with a modal error dialog box as specified. All other error dialog boxes with the same title are deleted. The dialog box which is replaced can be either modal or nonmodal.

createmode Value	Description
`non-modal` (default)	Creates a new nonmodal error dialog box with the specified parameters. Existing error dialog boxes with the same title are not deleted.
`replace`	Replaces the error dialog box having the specified `Title`, that was last created or clicked on, with a nonmodal error dialog boxbox as specified. All other error dialog boxes with the same title are deleted. The dialog box which is replaced can be either modal or nonmodal.

Note A modal dialog box prevents the user from interacting with other windows before responding. To block MATLAB program execution as well, use the`uiwait` function. For more information about modal dialog boxes, see `WindowStyle` in theFigure Properties.

If `CreateMode` is a structure, it can have fields `WindowStyle` and `Interpreter`. `WindowStyle` must be one of the options shown in the table above. `Interpreter` is one of the strings `'tex'` or `'none'`. The default value for `Interpreter` is `'none'`.

Remarks

MATLAB sizes the dialog box to fit the string `'errorstring'`. The error dialog box has an **OK** push button and remains on the screen until you press the **OK** button or the **Return** key. After pressing the button, the error dialog box disappears.

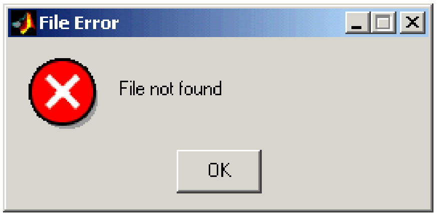
The appearance of the dialog box depends on the platform you use.

Examples

The function

```
errordlg('File not found','File Error');
```

displays this dialog box:



See Also

`dialog`, `helpdlg`, `inputdlg`, `listdlg`, `msgbox`, `questdlg`, `warndlg`

`figure`, `uiwait`, `uiresume`

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

Purpose

Time elapsed between date vectors

Syntax

```
e = etime(t2, t1)
```

Description

`e = etime(t2, t1)` returns the time in seconds between vectors `t1` and `t2`. The two vectors must be six elements long, in the format returned by `clock`:

```
T = [Year Month Day Hour Minute Second]
```

Remarks

When timing the duration of an event, use the `tic` and `toc` functions instead of `clock` or `etime`. These latter two functions are based on the system time which can be adjusted periodically by the operating system and thus might not be reliable in time comparison operations.

The `etime` function measures time elapsed between two points in time, and does not take into account differences in those points brought about by daylight savings time or changes in time zone.

Examples

Calculate how long a 2048-point real FFT takes.

```
x = rand(2048, 1);
t = clock;  fft(x);  etime(clock, t)
ans =
      0.4167
```

Limitations

As currently implemented, the `etime` function fails across month and year boundaries. Since `etime` is an M-file, you can modify the code to work across these boundaries if needed.

See Also

`clock`, `cputime`, `tic`, `toc`

Purpose Elimination tree

Syntax

```
p = etree(A)
p = etree(A,'col')
p = etree(A,'sym')
[p,q] = etree(...)
```

Description

`p = etree(A)` returns an elimination tree for the square symmetric matrix whose upper triangle is that of `A`. `p(j)` is the parent of column `j` in the tree, or `0` if `j` is a root.

`p = etree(A,'col')` returns the elimination tree of `A'*A`.

`p = etree(A,'sym')` is the same as `p = etree(A)`.

`[p,q] = etree(...)` also returns a postorder permutation `q` of the tree.

See Also

`treelayout`, `treeplot`, `etreeplot`

Purpose

Plot elimination tree

Syntax

```
etreeplot(A)
etreeplot(A,nodeSpec,edgeSpec)
```

Description

`etreeplot(A)` plots the elimination tree of `A` (or `A+A'`, if non-symmetric).

`etreeplot(A,nodeSpec,edgeSpec)` allows optional parameters `nodeSpec` and `edgeSpec` to set the node or edge color, marker, and linestyle. Use `''` to omit one or both.

See Also

`etree`, `treeplot`, `treelayout`

Purpose Execute string containing MATLAB expression

Syntax

```
eval(expression)
[a1, a2, a3, ...] = eval(function(b1, b2, b3, ...))
```

Description `eval(expression)` executes `expression`, a string containing any valid MATLAB expression. You can construct `expression` by concatenating substrings and variables inside square brackets:

```
expression = [string1, int2str(var), string2, ...]
```

`[a1, a2, a3, ...]  = eval(function(b1, b2, b3, ...))` executes `function` with arguments `b1, b2, b3, ...`, and returns the results in the specified output variables.

Remarks Using the `eval` output argument list is recommended over including the output arguments in the expression string. The first syntax below avoids strict checking by the MATLAB parser and can produce untrapped errors and other unexpected behavior.

```
% Recommended syntax
  [a1, a2, a3, ...] = eval('function(var)')

% Not recommended
  eval('[a1, a2, a3, ...] = function(var)')
```

Examples

Example 1 – Working with a Series of Files

Load MAT-files `August1.mat` to `August10.mat` into the MATLAB workspace:

```
for d=1:10
   s = ['load August' int2str(d) '.mat']
   eval(s)
end
```

These are the strings being evaluated:

```
s =
   load August1.mat
s =
   load August2.mat
s =
   load August3.mat
      - etc. -
```

Example 2 – Assigning to Variables with Generated Names

Generate variable names that are unique in the MATLAB workspace and assign a value to each using `eval`:

```
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, `eval` creates a unique statement for each assignment:

```
time_elapsed =
    5.0070
time_elapsed1 =
    2.0030
time_elapsed2 =
    7.0010
time_elapsed3 =
    8.0010
time_elapsed4 =
    3.0040
```

Example 3 – Evaluating a Returned Function Name

The following command removes a figure by evaluating its `CloseRequestFcn` property as returned by `get`.

```
eval(get(h,'CloseRequestFcn'))
```

See Also `evalc`, `evalin`, `assignin`, `feval`, `catch`, `lasterror`, `try`

Purpose

Evaluate MATLAB expression with capture

Syntax

```
T = evalc(S)
[T, X, Y, Z, ...] = evalc(S)
```

Description

`T = evalc(S)` is the same as `eval(S)` except that anything that would normally be written to the command window is captured and returned in the character array `T` (lines in `T` are separated by `\n` characters).

`[T, X, Y, Z, ...]  = evalc(S)` is the same as `[X, Y, Z, ...]  = eval(S)` except that any output is captured into `T`.

Remark

When you are using `evalc`, `diary`, `more`, and `input` are disabled.

See Also

`eval`, `evalin`, `assignin`, `feval`, `diary`, `input`, `more`

evalin

Purpose

Execute MATLAB expression in specified workspace

Syntax

```
evalin(ws, expression)
[a1, a2, a3, ...] = evalin(ws, expression)
```

Description

`evalin(ws, expression)` executes *expression*, a string containing any valid MATLAB expression, in the context of the workspace `ws`. `ws` can have a value of `'base'` or `'caller'` to denote the MATLAB base workspace or the workspace of the caller function. You can construct *expression* by concatenating substrings and variables inside square brackets:

```
expression = [string1, int2str(var), string2,...]
```

`[a1, a2, a3, ...]  = evalin(ws, expression)` executes *expression* and returns the results in the specified output variables. Using the `evalin` output argument list is recommended over including the output arguments in the expression string:

```
evalin(ws,'[a1, a2, a3, ...] = function(var)')
```

The above syntax avoids strict checking by the MATLAB parser and can produce untrapped errors and other unexpected behavior.

Remarks

The MATLAB base workspace is the workspace that is seen from the MATLAB command line (when not in the debugger). The caller workspace is the workspace of the function that called the M-file. Note, the base and caller workspaces are equivalent in the context of an M-file that is invoked from the MATLAB command line.

If you use `evalin('caller', ws)` in the MATLAB debugger after having changed your local workspace context with `dbup` or `dbdown`, MATLAB evaluates the expression in the context of the function that is one level up in the stack from your current workspace context.

Examples

This example extracts the value of the variable `var` in the MATLAB base workspace and captures the value in the local variable `v`:

```
v = evalin('base', 'var');
```

Limitation

`evalin` cannot be used recursively to evaluate an expression. For example, a sequence of the form `evalin('caller', 'evalin(''caller'', ''x'')')` doesn't work.

See Also

`assignin`, `eval`, `evalc`, `feval`, `catch`, `lasterror`, `try`

eventlisteners

Purpose

List of events attached to listeners

Syntax

```
C = h.eventlisteners
C = eventlisteners(h)
```

Description

`C = h.eventlisteners` lists any events, along with their event handler routines, that have been registered with control, `h`. The function returns cell array of strings `C`, with each row containing the name of a registered event and the handler routine for that event. If the control has no registered events, then `eventlisteners` returns an empty cell array.

Events and their event handler routines must be registered in order for the control to respond to them. You can register events either when you create the control, using `actxcontrol`, or at any time afterwards, using `registerevent`.

`C = eventlisteners(h)` is an alternate syntax for the same operation.

Examples

mwsamp Control Example

Create an `mwsamp` control, registering only the `Click` event. `eventlisteners` returns the name of the event and its event handler routine, `myclick`:

```
f = figure('position', [100 200 200 200]);
h = actxcontrol('mwsamp.mwsampctrl.2', ...
    [0 0 200 200], f, ...
    {'Click' 'myclick'});

h.eventlisteners
ans =
    'click'    'myclick'
```

Register two more events: `DblClick` and `MouseDown`. `eventlisteners` returns the names of the three registered events along with their respective handler routines:

```
h.registerevent({'DblClick', 'my2click'; ...
    'MouseDown' 'mymoused'});
```

```
h.eventlisteners
ans =
    'click'        'myclick'
    'dblclick'     'my2click'
    'mousedown'    'mymoused'
```

Now unregister all events for the control. `eventlisteners` returns an empty cell array, indicating that no events have been registered for the control:

```
h.unregisterallevents

h.eventlisteners
ans =
     {}
```

Excel Workbook Example

```
excel = actxserver('Excel.Application');
wbs = excel.Workbooks;
wb = wbs.Add;
wb.registerevent({'Activate' 'EvtActivateHandler'})
wb.eventlisteners

ans =

    'Activate'    'EvtActivateHandler'
```

See Also

`events`, `registerevent`, `unregisterevent`, `unregisterallevents`, `isevent`

Purpose List of events control can trigger

Syntax

```
S = h.events
S = events(h)
```

Description `S = h.events` returns structure array `S` containing all events, both registered and unregistered, known to the control, and the function prototype used when calling the event handler routine. For each array element, the structure field is the event name and the contents of that field is the function prototype for that event's handler.

`S = events(h)` is an alternate syntax for the same operation.

Note The `send` function is identical to `events`, but support for `send` will be removed in a future release of MATLAB.

Examples

List Control Events Example

Create an `mwsamp` control and list all events:

```
f = figure ('position', [100 200 200 200]);
h = actxcontrol ('mwsamp.mwsampctrl.2', [0 0 200 200], f);

h.events
   Click = void Click()
   DblClick = void DblClick()
   MouseDown = void MouseDown(int16 Button, int16 Shift,
      Variant x, Variant y)
```

Assign the output to a variable and get one field of the returned structure:

```
ev = h.events;

ev.MouseDown
ans =
```

```
void MouseDown(int16 Button, int16 Shift, Variant x, Variant y)
```

List Excel Workbook Events Example

Open Excel and list all events for a Workbook object:

```
excel = actxserver('Excel.Application');
wbs = excel.Workbooks;
wb = wbs.Add;
wb.events
```

MATLAB displays all events supported by the Workbook object.

```
Open = void Open()
Activate = void Activate()
Deactivate = void Deactivate()
BeforeClose = void BeforeClose(bool Cancel)
                .
                .
```

See Also

`isevent`, `eventlisteners`, `registerevent`, `unregisterevent`, `unregisterallevents`

Purpose

Execute MATLAB command in server

Syntax

MATLAB Client

```
result = h.Execute('command')
result = Execute(h, 'command')
result = invoke(h, 'Execute', 'command')
```

Method Signature

```
BSTR Execute([in] BSTR command)
```

Visual Basic Client

```
Execute(command As String) As String
```

Description

The `Execute` function executes the MATLAB statement specified by the string `command` in the MATLAB Automation server attached to handle `h`.

The server returns output from the command in the string, `result`. The `result` string also contains any warning or error messages that might have been issued by MATLAB as a result of the command.

Note that if you terminate the MATLAB command string with a semicolon and there are no warnings or error messages, `result` might be returned empty.

Remarks

If you want to be able to display output from `Execute` in the client window, you must specify an output variable (i.e., `result` in the above syntax statements).

Server function names, like `Execute`, are case sensitive when used with dot notation (the first syntax shown).

All three versions of the MATLAB client syntax perform the same operation.

Examples

Execute the MATLAB `version` function in the server and return the output to the MATLAB client.

MATLAB Client

```
h = actxserver('matlab.application');
server_version = h.Execute('version')
server_version =
ans =
   6.5.0.180913a (R13)
```

Visual Basic.net Client

```
Dim Matlab As Object
Dim server_version As String
Matlab = CreateObject("matlab.application")
server_version = Matlab.Execute("version")
```

See Also

`Feval`, `PutFullMatrix`, `GetFullMatrix`, `PutCharArray`, `GetCharArray`

exifread

Purpose

Read EXIF information from JPEG and TIFF image files

Syntax

```
output = exifread(filename)
```

Description

`output = exifread(filename)` reads the Exchangeable Image File Format (EXIF) data from the file specified by the string `filename`. `filename` must specify a JPEG or TIFF image file. `output` is a structure containing metadata values about the image or images in `imagefile`.

Note `exifread` returns all EXIF tags and does not process them in any way.

EXIF is a standard used by digital camera manufacturers to store information in the image file, such as, the make and model of a camera, the time the picture was taken and digitized, the resolution of the image, exposure time, and focal length. For more information about EXIF and the meaning of metadata attributes, see `http://www.exif.org/`.

See Also

`imfinfo`, `imread`

Purpose

Check existence of variable, function, directory, or Java class

Graphical Interface

As an alternative to the `exist` function, use the Workspace Browser or the Current Directory Browser.

Syntax

```
exist name
exist name kind
A = exist('name','kind')
```

Description

`exist name` returns the status of `name`:

0	If `name` does not exist.
1	If `name` is a variable in the workspace.
2	If `name` is an M-file on your MATLAB search path. It also returns 2 when `name` is the full pathname to a file or the name of an ordinary file on your MATLAB search path.
3	If `name` is a MEX- or DLL-file on your MATLAB search path.
4	If `name` is an MDL-file on your MATLAB search path.
5	If `name` is a built-in MATLAB function.
6	If `name` is a P-file on your MATLAB search path.
7	If `name` is a directory.
8	If `name` is a Java class. (`exist` returns 0 if you start MATLAB with the `-nojvm` option.)

`exist name` *`kind`* returns the status of `name` for the specified *`kind`*. If `name` of type *`kind`* does not exist, it returns `0`. The *`kind`* argument may be one of the following:

`builtin`	Checks only for built-in functions.
`class`	Checks only for Java classes.
`dir`	Checks only for directories.

`file`	Checks only for files or directories.
`var`	Checks only for variables.

If `name` belongs to more than one category (e.g., if there are both an M-file and variable of the given name) and you do not specify a *`kind`* argument, `exist` returns one value according to the order of evaluation shown in the table below. For example, if `name` matches both a directory and M-file name, `exist` returns `7`, identifying it as a directory.

Order of Evaluation	Return Value	Type of Entity
1	1	Variable
2	5	Built-in
3	7	Directory
4	3	MEX or DLL-file
5	4	MDL-file
6	6	P-file
7	2	M-file
8	8	Java class

`A = exist('name','`*`kind`*`')` is the function form of the syntax.

Remarks

If `name` specifies a filename, that filename may include an extension to preclude conflicting with other similar filenames. For example, `exist('file.ext')`.

If `name` specifies a filename, MATLAB attempts to locate the file, examines the filename extension, and determines the value to return based on the extension alone. MATLAB does not examine the contents or internal structure of the file.

You can specify a partial path to a directory or file. A partial pathname is a pathname relative to the MATLAB path that contains only the trailing one or more components of the full pathname. For example, both of the following commands return 2, identifying mkdir.m as an M-file. The first uses a partial pathname:

```
exist('matlab/general/mkdir.m')
exist([matlabroot '/toolbox/matlab/general/mkdir.m'])
```

If a file or directory is not on the search path, then name must specify either a full pathname, a partial pathname relative to MATLABPATH, a partial pathname relative to your current directory, or the file or directory must reside in your current working directory.

If name is a Java class, then exist('name') returns an 8. However, if name is a Java class file, then exist('name') returns a 2.

Remarks

To check for the existence of more than one variable, use the ismember function. For example,

```
a = 5.83;
c = 'teststring';
ismember({'a','b','c'},who)

ans =

     1     0     1
```

Examples

This example uses exist to check whether a MATLAB function is a built-in function or a file:

```
type = exist('plot')
type =
5
```

This indicates that plot is a built-in function.

In the next example, exist returns 8 on the Java class, Welcome, and returns 2 on the Java class file, Welcome.class:

```
exist Welcome
ans =
```

```
     8

exist javaclasses/Welcome.class
ans =
     2
```

indicates there is a Java class Welcome and a Java class file Welcome.class.

The following example indicates that `testresults` is both a variable in the workspace and a directory on the search path:

```
exist('testresults','var')
ans =
     1
exist('testresults','dir')
ans =
     7
```

See Also

`assignin`, `computer`, `dir`, `evalin`, `help`, `inmem`, `isfield`, `isempty`, `lookfor`, `mfilename`, `partialpath`, `what`, `which`, `who`

Purpose

Terminate MATLAB (same as `quit`)

GUI Alternatives

As an alternative to the `exit` function, select **File > Exit MATLAB** or click the Close box in the MATLAB desktop.

Syntax

```
exit
```

Description

`exit` terminates the current MATLAB session after running `finish.m`, if the file `finish.m` exists. It performs the same as `quit` and takes the same termination options, such as **`force`**. For more information, see `quit`.

See Also

`quit`, `finish`

Purpose Exponential

Syntax

```
Y = exp(X)
```

Description The `exp` function is an elementary function that operates element-wise on arrays. Its domain includes complex numbers.

`Y = exp(X)` returns the exponential for each element of `X`. For complex $z = x + i * y$, it returns the complex exponential $e^z = e^x(\cos(y) + i\sin(y))$.

Remark Use `expm` for matrix exponentials.

See Also `expm`, `log`, `log10`, `expint`

Purpose Exponential integral

Syntax

```
Y = expint(X)
```

Definitions The exponential integral computed by this function is defined as

$$E_1(x) = \int_x^{\infty} \frac{e^{-t}}{t} dt$$

Another common definition of the exponential integral function is the Cauchy principal value integral

$$Ei(x) = \int_{-\infty}^{x} \frac{e^t}{t} dt$$

which, for real positive `x`, is related to `expint` as

$$E_1(-x) = -Ei(x) - i\pi$$

Description `Y = expint(X)` evaluates the exponential integral for each element of `X`.

References

[1] Abramowitz, M. and I. A. Stegun. *Handbook of Mathematical Functions*. Chapter 5, New York: Dover Publications, 1965.

Purpose

Matrix exponential

Syntax

```
Y = expm(X)
```

Description

`Y = expm(X)` raises the constant e to the matrix power `X`.

Although it is not computed this way, if `X` has a full set of eigenvectors `V` with corresponding eigenvalues `D`, then

```
[V,D] = EIG(X) and EXPM(X) = V*diag(exp(diag(D)))/V
```

Use `exp` for the element-by-element exponential.

Algorithm

`expm` uses the Padé approximation with scaling and squaring. See reference [3], below.

Note The `expmdemo1`, `expmdemo2`, and `expmdemo3` demos illustrate the use of Padé approximation, Taylor series approximation, and eigenvalues and eigenvectors, respectively, to compute the matrix exponential. References [1] and [2] describe and compare many algorithms for computing a matrix exponential.

Examples

This example computes and compares the matrix exponential of `A` and the exponential of `A`.

```
A = [1        1        0
      0        0        2
      0        0       -1 ];

expm(A)
ans =
    2.7183   1.7183        1.0862
    0        1.0000        1.2642
    0             0        0.3679
```

```
exp(A)
ans =
    2.7183    2.7183    1.0000
    1.0000    1.0000    7.3891
    1.0000    1.0000    0.3679
```

Notice that the diagonal elements of the two results are equal. This would be true for any triangular matrix. But the off-diagonal elements, including those below the diagonal, are different.

See Also

`exp`, `expm1`, `funm`, `logm`, `eig`, `sqrtm`

References

[1] Golub, G. H. and C. F. Van Loan, *Matrix Computation*, p. 384, Johns Hopkins University Press, 1983.

[2] 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.

[3] Higham, N. J., “The Scaling and Squaring Method for the Matrix Exponential Revisited,” *SIAM J. Matrix Anal. Appl.*, 26(4) (2005), pp. 1179-1193.

expm1

Purpose

Compute `exp(x)-1` accurately for small values of `x`

Syntax

```
y = expm1(x)
```

Description

`y = expm1(x)` computes `exp(x)-1`, compensating for the roundoff in `exp(x)`.

For small `x`, `expm1(x)` is approximately `x`, whereas `exp(x)-1` can be zero.

See Also

`exp`, `expm`, `log1p`

Purpose

Export variables to workspace

Syntax

```
export2wsdlg(checkboxlabels,defaultvariablenames,
itemstoexport)
export2wsdlg(checkboxlabels,defaultvariablenames,
itemstoexport,title)
export2wsdlg(checkboxlabels,defaultvariablenames,
itemstoexport,title,selected)
export2wsdlg(checkboxlabels,defaultvariablenames,
itemstoexport,title,selected,helpfunction)
export2wsdlg(checkboxlabels,defaultvariablenames,
itemstoexport,title,selected,helpfunction,functionlist)
hdialog = export2wsdlg(...)
[hdialog,ok_pressed] = export2wsdlg(...)
```

Description

`export2wsdlg(checkboxlabels,defaultvariablenames, itemstoexport)` creates a dialog with a series of check boxes and edit fields. `checkboxlabels` is a cell array of labels for the check boxes. `defaultvariablenames` is a cell array of strings that serve as a basis for variable names that appear in the edit fields. `itemstoexport` is a cell array of the values to be stored in the variables. If there is only one item to export, `export2wsdlg` creates a text control instead of a check box.

Note By default, the dialog box is modal. A modal dialog box prevents the user from interacting with other windows before responding.

`export2wsdlg(checkboxlabels,defaultvariablenames, itemstoexport,title)` creates the dialog with `title` as its title.

`export2wsdlg(checkboxlabels,defaultvariablenames, itemstoexport,title,selected)` creates the dialog allowing the user to control which check boxes are checked. `selected` is a logical array whose length is the same as `checkboxlabels`. True indicates that the check box should initially be checked, false unchecked.

`export2wsdlg(checkboxlabels,defaultvariablenames, itemstoexport,title,selected,helpfunction)` creates the dialog with a help button. `helpfunction` is a callback that displays help.

`export2wsdlg(checkboxlabels,defaultvariablenames, itemstoexport,title,selected,helpfunction,functionlist)` creates a dialog that enables the user to pass in `functionlist`, a cell array of functions and optional arguments that calculate, then return the value to export. `functionlist` should be the same length as `checkboxlabels`.

`hdialog = export2wsdlg(...)` returns the handle of the dialog.

`[hdialog,ok_pressed] = export2wsdlg(...)` sets `ok_pressed` to true if the OK button is pressed, or false otherwise. If two return arguments are requested, `hdialog` is `[]` and the function does not return until the dialog is closed.

The user can edit the text fields to modify the default variable names. If the same name appears in multiple edit fields, `export2wsdlg` creates a structure using that name. It then uses the `defaultvariablenames` as fieldnames for that structure.

The lengths of `checkboxlabels`, `defaultvariablenames`, `itemstoexport` and `selected` must all be equal.

The strings in `defaultvariablenames` must be unique.

Examples

This example creates a dialog box that enables the user to save the variables `sumA` and/or `meanA` to the workspace. The dialog box title is Save Sums to Workspace.

```
A = randn(10,1);
checkLabels = {'Save sum of A to variable named:' ...
               'Save mean of A to variable named:'};
varNames = {'sumA','meanA'};
items = {sum(A),mean(A)};
export2wsdlg(checkLabels,varNames,items,...
             'Save Sums to Workspace');
```

Purpose

Identity matrix

Syntax

```
Y = eye(n)
Y = eye(m,n)
eye([m n])
Y = eye(size(A))
eye(m, n, classname)
eye([m,n],classname)
```

Description

`Y = eye(n)` returns the `n`-by-`n` identity matrix.

`Y = eye(m,n)` or `eye([m n])` returns an `m`-by-`n` matrix with `1`'s on the diagonal and `0`'s elsewhere.

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

`Y = eye(size(A))` returns an identity matrix the same size as `A`.

`eye(m, n, classname)` or `eye([m,n],classname)` is an m-by-n matrix with 1's of class `classname` on the diagonal and zeros of class `classname` elsewhere. `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 = eye(2,3,'int8');
```

Limitations

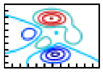
The identity matrix is not defined for higher-dimensional arrays. The assignment `y = eye([2,3,4])` results in an error.

See Also

`ones`, `rand`, `randn`, `zeros`

Purpose

Easy-to-use contour plotter



Syntax

```
ezcontour(fun)
ezcontour(fun,domain)
ezcontour(...,n)
ezcontour(axes_handle,...)
h = ezcontour(...)
```

Description

`ezcontour(fun)` plots the contour lines of `fun(x,y)` using the `contour` function. `fun` is plotted over the default domain: $-2\pi < x < 2\pi$, $-2\pi < y < 2\pi$.

`fun` can be a function handle for an M-file function or an anonymous function (see "Function Handles" and "Anonymous Functions") or a string (see Remarks).

`ezcontour(fun,domain)` plots `fun(x,y)` over the specified `domain`. `domain` can be either a 4-by-1 vector `[xmin, xmax, ymin, ymax]` or a 2-by-1 vector `[min, max]` (where `min` < x < `max`, `min` < y < `max`).

`ezcontour(...,n)` plots `fun` over the default domain using an `n`-by-`n` grid. The default value for `n` is 60.

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

`h = ezcontour(...)` returns the handles to contour objects in `h`.

`ezcontour` automatically adds a title and axis labels.

Remarks

Passing the Function as a String

Array multiplication, division, and exponentiation are always implied in the string expression you pass to `ezcontour`. For example, the MATLAB syntax for a contour plot of the expression

```
sqrt(x.^2 + y.^2)
```

is written as

```
ezcontour('sqrt(x^2 + y^2)')
```

That is, `x^2` is interpreted as `x.^2` in the string you pass to `ezcontour`.

If the function to be plotted is a function of the variables u and v (rather than x and y), the domain endpoints `umin`, `umax`, `vmin`, and `vmax` are sorted alphabetically. Thus, `ezcontour('u^2 - v^3',[0,1],[3,6])` plots the contour lines for $u^2 - v^3$ over $0 < u < 1$, $3 < v < 6$.

Passing a Function Handle

Function handle arguments must point to functions that use MATLAB syntax. For example, the following statements define an anonymous function and pass the function handle `fh` to `ezcontour`.

```
fh = @(x,y) sqrt(x.^2 + y.^2);
ezcontour(fh)
```

When using function handles, you must use the array power, array multiplication, and array division operators (`.^, .*, ./`) since `ezcontour` does not alter the syntax, as in the case with string inputs.

Passing Additional Arguments

If your function has additional parameters, for example, `k` in `myfun`:

```
function z = myfun(x,y,k)
z = x.^k - y.^k - 1;
```

then use an anonymous function to specify that parameter:

```
ezcontour(@(x,y)myfun(x,y,2))
```

Examples

The following mathematical expression defines a function of two variables, x and y.

$$f(x, y) = 3(1-x)^2 e^{-x^2-(y+1)^2} - 10\left(\frac{x}{5} - x^3 - y^5\right)e^{-x^2-y^2} - \frac{1}{3}e^{-(x+1)^2-y^2}$$

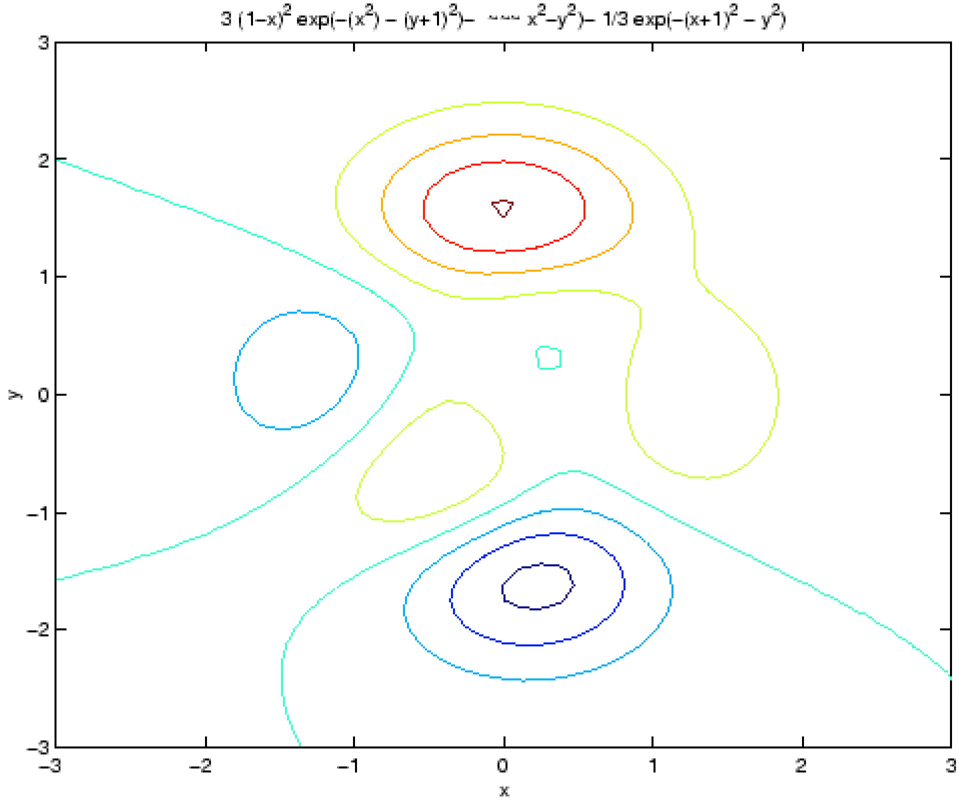
`ezcontour` requires a function handle argument that expresses this function using MATLAB syntax. This example uses an anonymous function, which you can define in the command window without creating an M-file.

```
f=@(x,y) 3*(1-x).^2.*exp(-(x.^2) - (y+1).^2) ...
   - 10*(x/5 - x.^3 - y.^5).*exp(-x.^2-y.^2) ...
   - 1/3*exp(-(x+1).^2 - y.^2);
```

For convenience, this function is written on three lines. The MATLAB `peaks` function evaluates this expression for different sizes of grids.

Pass the function handle `f` to `ezcontour` along with a domain ranging from -3 to 3 in both *x* and *y* and specify a computational grid of 49-by-49:

```
ezcontour(f,[-3,3],49)
```



In this particular case, the title is too long to fit at the top of the graph, so MATLAB abbreviates the string.

See Also

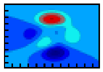
`contour`, `ezcontourf`, `ezmesh`, `ezmeshc`, `ezplot`, `ezplot3`, `ezpolar`, `ezsurf`, `ezsurfc`, `function_handle`

"Contour Plots" on page 1-88 for related functions

ezcontourf

Purpose

Easy-to-use filled contour plotter



Syntax

```
ezcontourf(fun)
ezcontourf(fun,domain)
ezcontourf(...,n)
ezcontourf(axes_handle,...)
h = ezcontourf(...)
```

Description

`ezcontourf(fun)` plots the contour lines of `fun(x,y)`using the `contourf` function. `fun` is plotted over the default domain: -2π < `x` < 2π, -2π < `y` < 2π.

`fun` can be a function handle for an M-file function or an anonymous function (see "Function Handles" and Anonymous Functions) or a string (see Remarks).

`ezcontourf(fun,domain)` plots `fun(x,y)` over the specified `domain`. `domain` can be either a 4-by-1 vector `[xmin, xmax, ymin, ymax]` or a 2-by-1 vector `[min, max]`, where `min` < *x* < `max`, `min` < *y* < `max`).

`ezcontourf(...,n)` plots `fun` over the default domain using an `n`-by-`n` grid. The default value for `n` is 60.

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

`h = ezcontourf(...)` returns the handles to contour objects in `h`.

`ezcontourf` automatically adds a title and axis labels.

Remarks

Passing the Function as a String

Array multiplication, division, and exponentiation are always implied in the string expression you pass to `ezcontourf`. For example, the MATLAB syntax for a filled contour plot of the expression

```
sqrt(x.^2 + y.^2);
```

is written as

```
ezcontourf('sqrt(x^2 + y^2)')
```

That is, `x^2` is interpreted as `x.^2` in the string you pass to `ezcontourf`.

If the function to be plotted is a function of the variables u and v (rather than x and y), then the domain endpoints `umin`, `umax`, `vmin`, and `vmax` are sorted alphabetically. Thus, `ezcontourf('u^2 - v^3',[0,1],[3,6])` plots the contour lines for u^2 - v^3 over 0 < u < 1, 3 < v < 6.

Passing a Function Handle

Function handle arguments must point to functions that use MATLAB syntax. For example, the following statements define an anonymous function and pass the function handle `fh` to `ezcontourf`.

```
fh = @(x,y) sqrt(x.^2 + y.^2);
ezcontourf(fh)
```

When using function handles, you must use the array power, array multiplication, and array division operators (`.^, .*, ./`) since `ezcontourf` does not alter the syntax, as in the case with string inputs.

Passing Additional Arguments

If your function has additional parameters, for example, `k` in `myfun`:

```
function z = myfun(x,y,k)
z = x.^k - y.^k - 1;
```

then you can use an anonymous function to specify that parameter:

```
ezcontourf(@(x,y)myfun(x,y,2))
```

Examples

The following mathematical expression defines a function of two variables, x and y.

$$f(x, y) = 3(1-x)^2 e^{-x^2-(y+1)^2} - 10\left(\frac{x}{5} - x^3 - y^5\right)e^{-x^2-y^2} - \frac{1}{3}e^{-(x+1)^2-y^2}$$

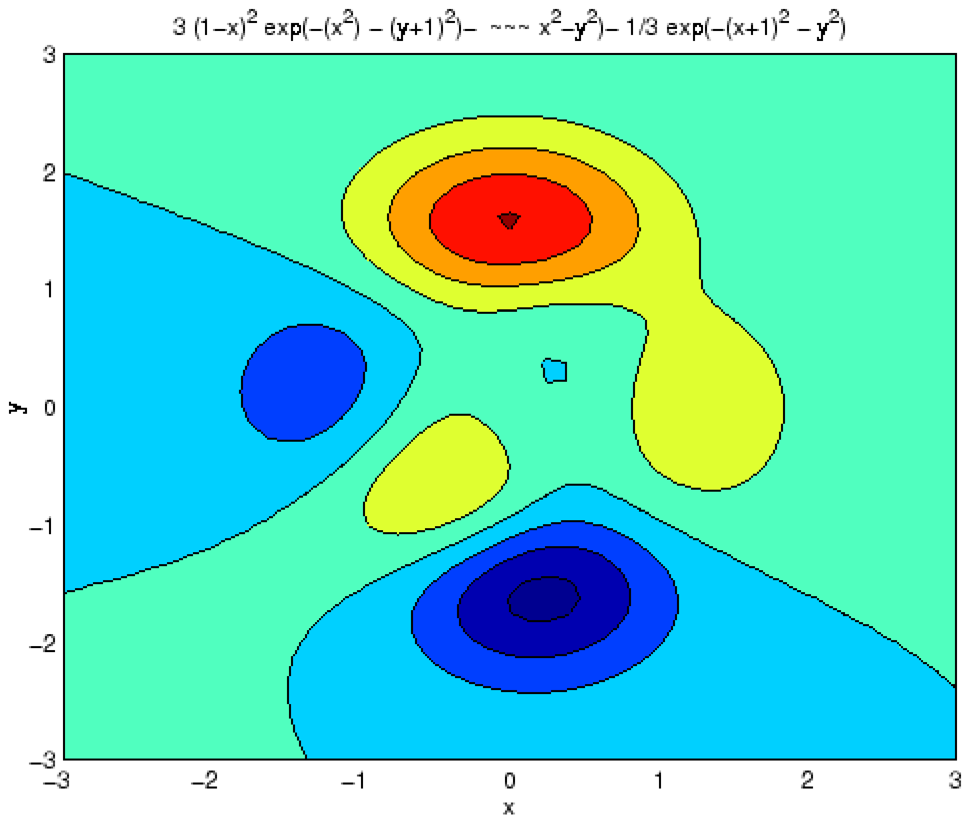
`ezcontourf` requires a string argument that expresses this function using MATLAB syntax to represent exponents, natural logs, etc. This function is represented by the string

```
f = ['3*(1-x)^2*exp(-(x^2)-(y+1)^2)',...
     '- 10*(x/5 - x^3 - y^5)*exp(-x^2-y^2)',...
     '- 1/3*exp(-(x+1)^2 - y^2)'];
```

For convenience, this string is written on three lines and concatenated into one string using square brackets.

Pass the string variable `f` to `ezcontourf` along with a domain ranging from -3 to 3 and specify a grid of 49-by-49:

```
ezcontourf(f,[-3,3],49)
```



In this particular case, the title is too long to fit at the top of the graph, so MATLAB abbreviates the string.

See Also

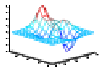
`contourf`, `ezcontour`, `ezmesh`, `ezmeshc`, `ezplot`, `ezplot3`, `ezpolar`, `ezsurf`, `ezsurfc`, `function_handle`

"Contour Plots" on page 1-88 for related functions

ezmesh

Purpose

Easy-to-use 3-D mesh plotter



Syntax

```
ezmesh(fun)
ezmesh(fun,domain)
ezmesh(funx,funy,funz)
ezmesh(funx,funy,funz,[smin,smax,tmin,tmax])
ezmesh(funx,funy,funz,[min,max]
ezmesh(...,n)
ezmesh(...,'circ')
ezmesh(axes_handle,...)
h = ezmesh(...)
```

Description

`ezmesh(fun)` creates a graph of `fun(x,y)` using the `mesh` function. `fun` is plotted over the default domain: $-2\pi < x < 2\pi$, $-2\pi < y < 2\pi$.

`fun` can be a function handle for an M-file function or an anonymous function (see "Function Handles" and Anonymous Functions) or a string (see the Remarks section).

`ezmesh(fun,domain)` plots `fun` over the specified `domain`. `domain` can be either a 4-by-1 vector [`xmin`, `xmax`, `ymin`, `ymax`] or a 2-by-1 vector [`min`, `max`] (where `min` < `x` < `max`, `min` < `y` < `max`).

`ezmesh(funx,funy,funz)` plots the parametric surface `funx(s,t)`, `funy(s,t)`, and `funz(s,t)` over the square: $-2\pi <$ `s` $< 2\pi$, $-2\pi <$ `t` $< 2\pi$.

`ezmesh(funx,funy,funz,[smin,smax,tmin,tmax])` or `ezmesh(funx,funy,funz,[min,max])` plots the parametric surface using the specified domain.

`ezmesh(...,n)` plots `fun` over the default domain using an `n`-by-`n` grid. The default value for `n` is 60.

`ezmesh(...,'circ')` plots `fun` over a disk centered on the domain.

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

`h = ezmesh(...)` returns the handle to a surface object in `h`.

Remarks

Passing the Function as a String

Array multiplication, division, and exponentiation are always implied in the string expression you pass to `ezmesh`. For example, the MATLAB syntax for a mesh plot of the expression

```
sqrt(x.^2 + y.^2);
```

is written as

```
ezmesh('sqrt(x^2 + y^2)')
```

That is, `x^2` is interpreted as `x.^2` in the string you pass to `ezmesh`.

If the function to be plotted is a function of the variables u and v (rather than x and y), then the domain endpoints `umin`, `umax`, `vmin`, and `vmax` are sorted alphabetically. Thus, `ezmesh('u^2 - v^3',[0,1],[3,6])` plots u^2 - v^3 over $0 < u < 1$, $3 < v < 6$.

Passing a Function Handle

Function handle arguments must point to functions that use MATLAB syntax. For example, the following statements define an anonymous function and pass the function handle `fh` to `ezmesh`.

```
fh = @(x,y) sqrt(x.^2 + y.^2);
ezmesh(fh)
```

Note that when using function handles, you must use the array power, array multiplication, and array division operators (`.^, .*, ./`) since `ezmesh` does not alter the syntax, as in the case with string inputs.

Passing Additional Arguments

If your function has additional parameters, for example `k` in `myfun`:

```
function z = myfun(x,y,k)
z = x.^k - y.^k - 1;
```

then you can use an anonymous function to specify that parameter:

```
ezmesh(@(x,y)myfun(x,y,2))
```

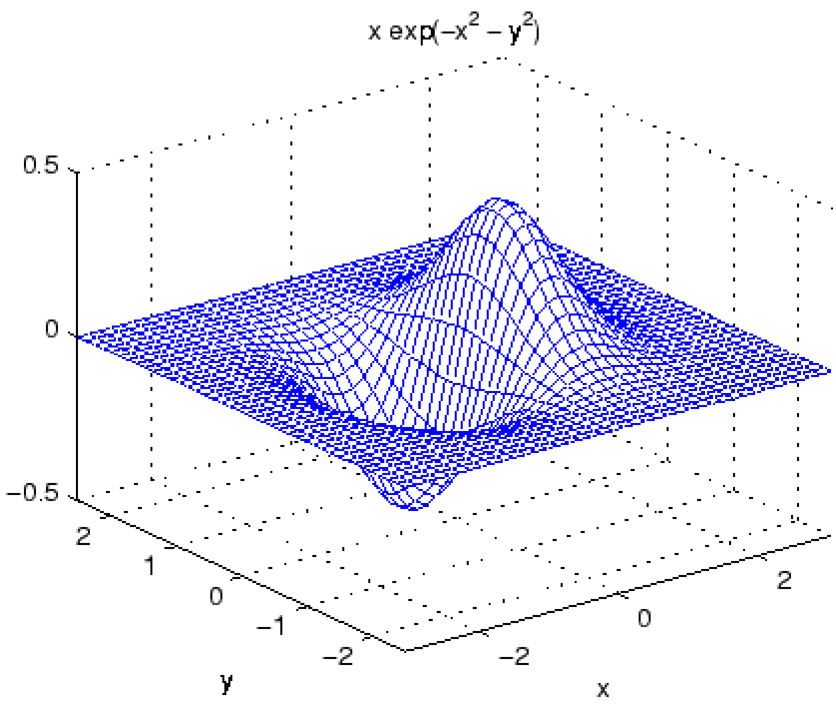
Examples

This example visualizes the function

$$f(x, y) = xe^{-x^2 - y^2}$$

with a mesh plot drawn on a 40-by-40 grid. The mesh lines are set to a uniform blue color by setting the colormap to a single color:

```
fh = @(x,y) x.*exp(-x.^2-y.^2);
ezmesh(fh,40)
colormap([0 0 1])
```



See Also

`ezmeshc`, `function_handle`, `mesh`

"Function Plots" on page 1-88 for related functions

Purpose

Easy-to-use combination mesh/contour plotter

Syntax

```
ezmeshc(fun)
ezmeshc(fun,domain)
ezmeshc(funx,funy,funz)
ezmeshc(funx,funy,funz,[smin,smax,tmin,tmax])
ezmeshc(funx,funy,funz,[min,max])
ezmeshc(...,n)
ezmeshc(...,'circ')
ezmesh(axes_handle,...)
h = ezmeshc(...)
```

Description

`ezmeshc(fun)` creates a graph of `fun(x,y)` using the `meshc` function. `fun` is plotted over the default domain $-2\pi < x < 2\pi$, $-2\pi < y < 2\pi$.

`fun` can be a function handle for an M-file function or an anonymous function (see "Function Handles" and "Anonymous Functions") or a string (see the Remarks section).

`ezmeshc(fun,domain)` plots `fun` over the specified `domain`. `domain` can be either a 4-by-1 vector [`xmin`, `xmax`, `ymin`, `ymax`] or a 2-by-1 vector [`min`, `max`] (where `min` < x < `max`, `min` < y < `max`).

`ezmeshc(funx,funy,funz)` plots the parametric surface `funx(s,t)`, `funy(s,t)`, and `funz(s,t)` over the square: $-2\pi <$ `s` $< 2\pi$, $-2\pi <$ `t` $< 2\pi$.

`ezmeshc(funx,funy,funz,[smin,smax,tmin,tmax])` or `ezmeshc(funx,funy,funz,[min,max])` plots the parametric surface using the specified domain.

`ezmeshc(...,n)` plots `fun` over the default domain using an `n`-by-`n` grid. The default value for `n` is 60.

`ezmeshc(...,'circ')` plots `fun` over a disk centered on the domain.

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

`h = ezmeshc(...)` returns the handle to a surface object in `h`.

Remarks

Passing the Function as a String

Array multiplication, division, and exponentiation are always implied in the string expression you pass to `ezmeshc`. For example, the MATLAB syntax for a mesh/contour plot of the expression

```
sqrt(x.^2 + y.^2);
```

is written as

```
ezmeshc('sqrt(x^2 + y^2)')
```

That is, `x^2` is interpreted as `x.^2` in the string you pass to `ezmeshc`.

If the function to be plotted is a function of the variables u and v (rather than x and y), then the domain endpoints `umin`, `umax`, `vmin`, and `vmax` are sorted alphabetically. Thus, `ezmeshc('u^2 - v^3',[0,1],[3,6])` plots u^2 - v^3 over $0 < u < 1$, $3 < v < 6$.

Passing a Function Handle

Function handle arguments must point to functions that use MATLAB syntax. For example, the following statements define an anonymous function and pass the function handle `fh` to `ezmeshc`.

```
fh = @(x,y) sqrt(x.^2 + y.^2);
ezmeshc(fh)
```

Note that when using function handles, you must use the array power, array multiplication, and array division operators (`.^, .*, ./`) since `ezmeshc` does not alter the syntax, as in the case with string inputs.

Passing Additional Arguments

If your function has additional parameters, for example `k` in `myfun`:

```
function z = myfun(x,y,k)
z = x.^k - y.^k - 1;
```

then you can use an anonymous function to specify that parameter:

```
ezmeshc(@(x,y)myfun(x,y,2))
```

Examples

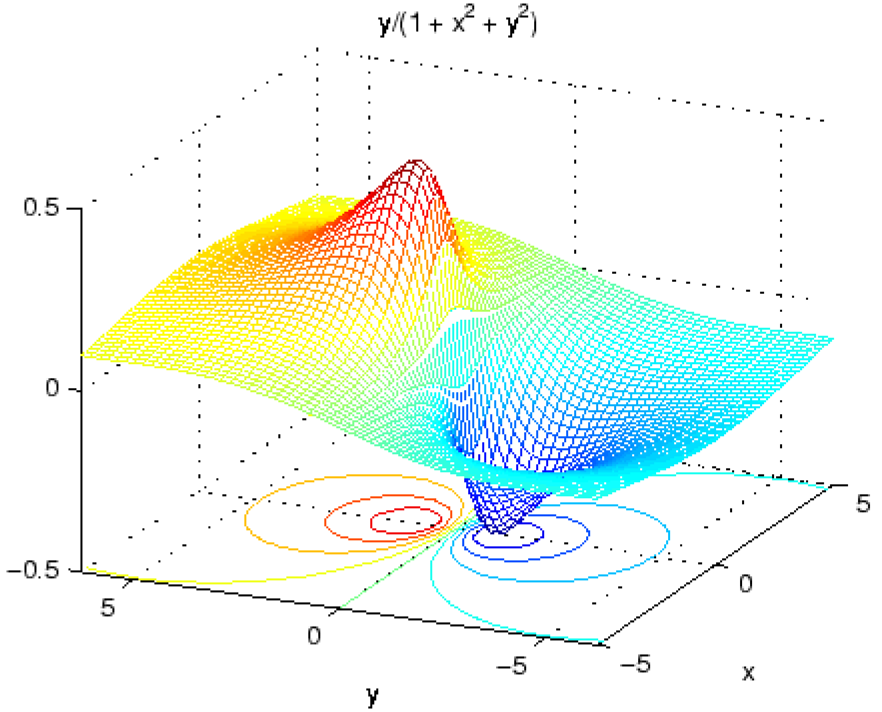
Create a mesh/contour graph of the expression

$$f(x, y) = \frac{y}{1 + x^2 + y^2}$$

over the domain -5 < x < 5, -2*pi < y < 2*pi:

```
ezmeshc('y/(1 + x^2 + y^2)',[-5,5,-2*pi,2*pi])
```

Use the mouse to rotate the axes to better observe the contour lines (this picture uses a view of azimuth = -65.5 and elevation = 26)



See Also

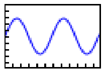
`ezmesh`, `ezsurfc`, `function_handle`, `meshc`

"Function Plots" on page 1-88 for related functions

ezplot

Purpose

Easy-to-use function plotter



Syntax

```
ezplot(fun)
ezplot(fun,[min,max])
ezplot(fun2)
ezplot(fun2,[xmin,xmax,ymin,ymax])
ezplot(fun2,[min,max])
ezplot(funx,funy)
ezplot(funx,funy,[tmin,tmax])
ezplot(...,figure_handle)
ezplot(axes_handle,...)
h = ezplot(...)
```

Description

`ezplot(fun)` plots the expression `fun(x)` over the default domain $-2\pi < x < 2\pi$.

`fun` can be a function handle for an M-file function or an anonymous function (see "Function Handles" and Anonymous Functions) or a string (see the Remarks section).

`ezplot(fun,[min,max])` plots `fun(x)` over the domain: `min` $< x <$ `max`.

For implicitly defined functions, `fun2(x,y)`:

`ezplot(fun2)` plots `fun2(x,y) = 0` over the default domain $-2\pi < x < 2\pi$, $-2\pi < y < 2\pi$.

`ezplot(fun2,[xmin,xmax,ymin,ymax])` plots `fun2(x,y) = 0` over `xmin` < `x` < `xmax` and `ymin` < `y` < `ymax`.

`ezplot(fun2,[min,max])` plots `fun2(x,y) = 0` over `min` < `x` < `max` and `min` < `y` < `max`.

`ezplot(funx,funy)` plots the parametrically defined planar curve `funx(t)` and `funy(t)` over the default domain 0 < `t` < 2π.

`ezplot(funx,funy,[tmin,tmax])` plots `funx(t)` and `funy(t)` over `tmin < t < tmax`.

`ezplot(...,figure_handle)` plots the given function over the specified domain in the figure window identified by the handle `figure`.

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

`h = ezplot(...)` returns the handle to a line objects in `h`.

Remarks

Passing the Function as a String

Array multiplication, division, and exponentiation are always implied in the expression you pass to `ezplot`. For example, the MATLAB syntax for a plot of the expression

```
x.^2 - y.^2
```

which represents an implicitly defined function, is written as

```
ezplot('x^2 - y^2')
```

That is, `x^2` is interpreted as `x.^2` in the string you pass to `ezplot`.

Passing a Function Handle

Function handle arguments must point to functions that use MATLAB syntax. For example, the following statements define an anonymous function and pass the function handle `fh` to `ezplot`,

```
fh = @(x,y) sqrt(x.^2 + y.^2 - 1);
ezplot(fh)
axis equal
```

which plots a circle. Note that when using function handles, you must use the array power, array multiplication, and array division operators (`.^, .*, ./`) since `ezplot` does not alter the syntax, as in the case with string inputs.

Passing Additional Arguments

If your function has additional parameters, for example `k` in `myfun`:

```
function z = myfun(x,y,k)
z = x.^k - y.^k - 1;
```

then you can use an anonymous function to specify that parameter:

```
ezplot(@(x,y)myfun(x,y,2))
```

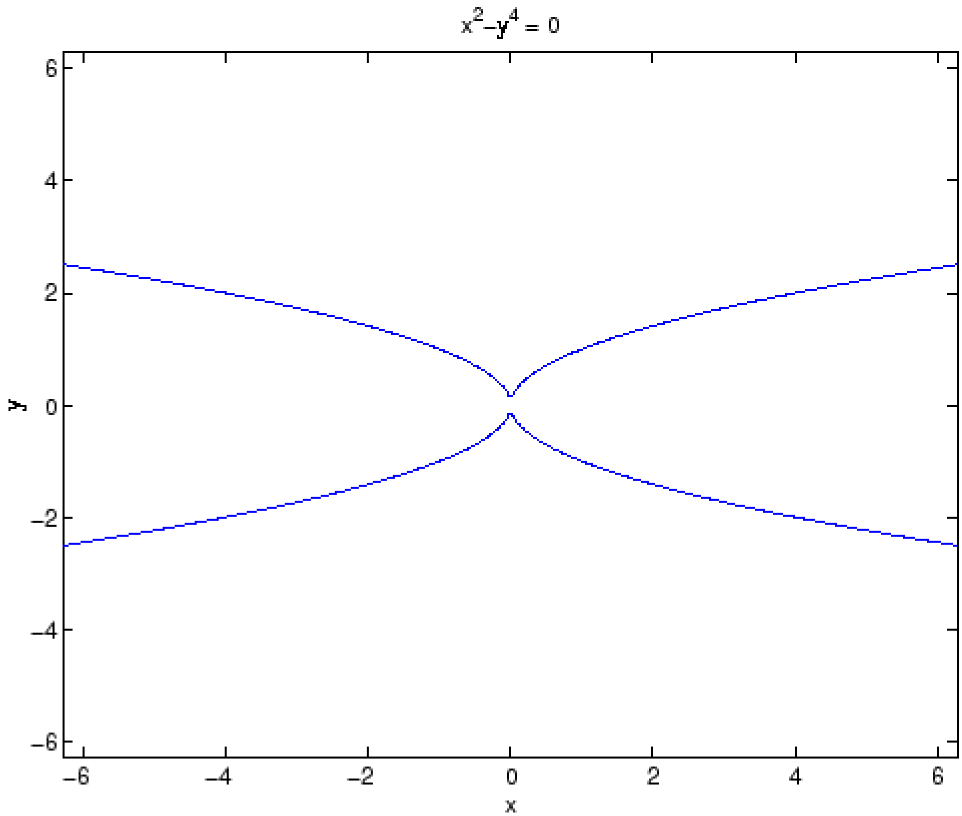
Examples

This example plots the implicitly defined function

$x^2 - y^4 = 0$

over the domain [-2π, 2π]:

```
ezplot('x^2-y^4')
```



See Also

`ezplot3`, `ezpolar`, `function_handle`, `plot`

"Function Plots" on page 1-88 for related functions

Purpose

Easy-to-use 3-D parametric curve plotter

Syntax

```
ezplot3(funx,funy,funz)
ezplot3(funx,funy,funz,[tmin,tmax])
ezplot3(...,'animate')
ezplot3(axes_handle,...)
h = ezplot3(...)
```

Description

`ezplot3(funx,funy,funz)` plots the spatial curve `funx(t)`, `funy(t)`, and `funz(t)` over the default domain $0 < t < 2\pi$.

`funx`, `funy`, and `funz` can be function handles for M-file functions or an anonymous functions (see “Function Handles” and “Anonymous Functions”) or strings (see the Remarks section).

`ezplot3(funx,funy,funz,[tmin,tmax])` plots the curve `funx(t)`, `funy(t)`, and `funz(t)` over the domain `tmin` < `t` < `tmax`.

`ezplot3(...,'animate')` produces an animated trace of the spatial curve.

`ezplot3(axes_handle,...)` plots into the axes with handle `axes_handle` instead of the current axes (`gca`).

`h = ezplot3(...)` returns the handle to the plotted objects in `h`.

Remarks

Passing the Function as a String

Array multiplication, division, and exponentiation are always implied in the expression you pass to `ezplot3`. For example, the MATLAB syntax for a plot of the expression

```
x = s./2, y = 2.*s, z = s.^2;
```

which represents a parametric function, is written as

```
ezplot3('s/2','2*s','s^2')
```

That is, s/2 is interpreted as s./2 in the string you pass to ezplot3.

Passing a Function Handle

Function handle arguments must point to functions that use MATLAB syntax. For example, the following statements define an anonymous function and pass the function handle fh to ezplot3.

```
fh1 = @(s) s./2; fh2 = @(s) 2.*s; fh3 = @(s) s.^2;
ezplot3(fh1,fh2,fh3)
```

Note that when using function handles, you must use the array power, array multiplication, and array division operators (.^, .*, ./) since ezplot does not alter the syntax, as in the case with string inputs.

Passing Additional Arguments

If your function has additional parameters, for example k in myfuntk:

```
function s = myfuntk(t,k)
s = t.^k.*sin(t);
```

then you can use an anonymous function to specify that parameter:

```
ezplot3(@cos,@(t)myfuntk(t,1),@sqrt)
```

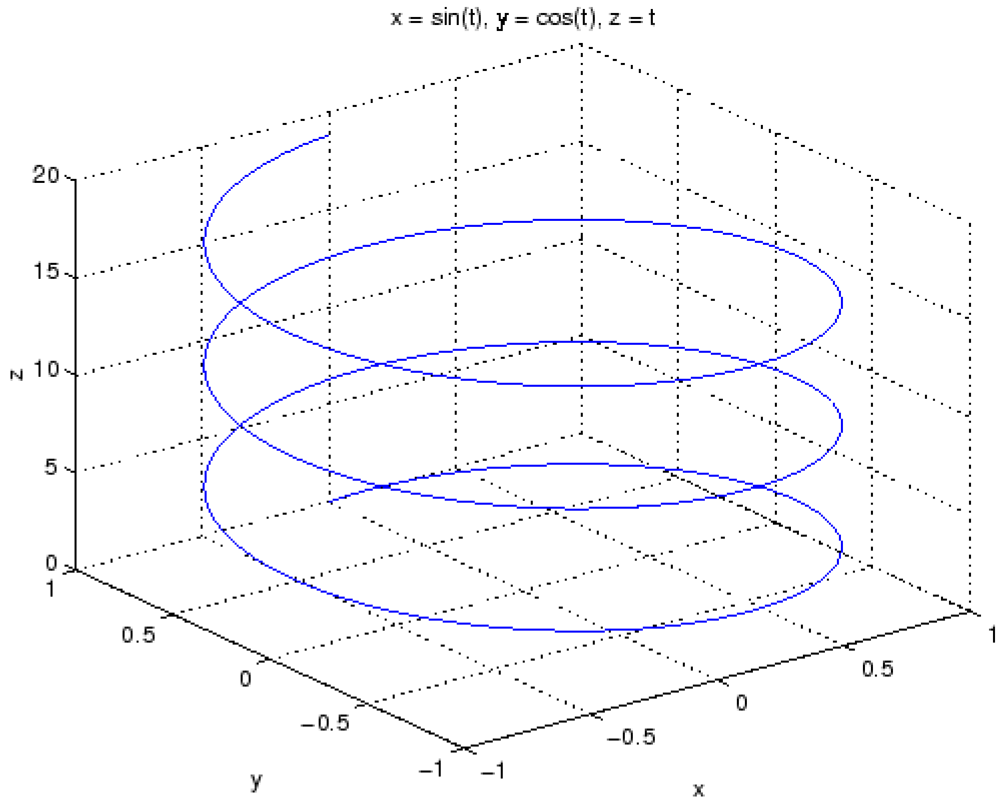
Examples

This example plots the parametric curve

$$x = \sin t, \quad y = \cos t, \quad z = t$$

over the domain [0,6π]:

```
ezplot3('sin(t)','cos(t)','t',[0,6*pi])
```



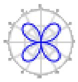
See Also

`ezplot`, `ezpolar`, `function_handle`, `plot3`

“Function Plots” on page 1-88 for related functions

Purpose

Easy-to-use polar coordinate plotter



Syntax

```
ezpolar(fun)
ezpolar(fun,[a,b])
ezpolar(axes_handle,...)
h = ezpolar(...)
```

Description

`ezpolar(fun)` plots the polar curve `rho = fun(theta)` over the default domain 0 < `theta` < 2π.

`fun` can be a function handle for an M-file function or an anonymous function (see "Function Handles" and "Function Handles") or a string (see the Remarks section).

`ezpolar(fun,[a,b])` plots `fun` for `a` < `theta` < `b`.

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

`h = ezpolar(...)` returns the handle to a line object in `h`.

Remarks

Passing the Function as a String

Array multiplication, division, and exponentiation are always implied in the expression you pass to `ezpolar`. For example, the MATLAB syntax for a plot of the expression

```
t.^2.*cos(t)
```

which represents an implicitly defined function, is written as

```
ezpolar('t^2*cos(t)')
```

That is, `t^2` is interpreted as `t.^2` in the string you pass to `ezpolar`.

Passing a Function Handle

Function handle arguments must point to functions that use MATLAB syntax. For example, the following statements define an anonymous function and pass the function handle `fh` to `ezpolar`.

```
fh = @(t) t.^2.*cos(t);
ezpolar(fh)
```

Note that when using function handles, you must use the array power, array multiplication, and array division operators (`.^, .*, ./`) since `ezpolar` does not alter the syntax, as in the case with string inputs.

Passing Additional Arguments

If your function has additional parameters, for example `k1` and `k2` in `myfun`:

```
function s = myfun(t,k1,k2)
s = sin(k1*t).*cos(k2*t);
```

then you can use an anonymous function to specify the parameters:

```
ezpolar(@(t)myfun(t,2,3))
```

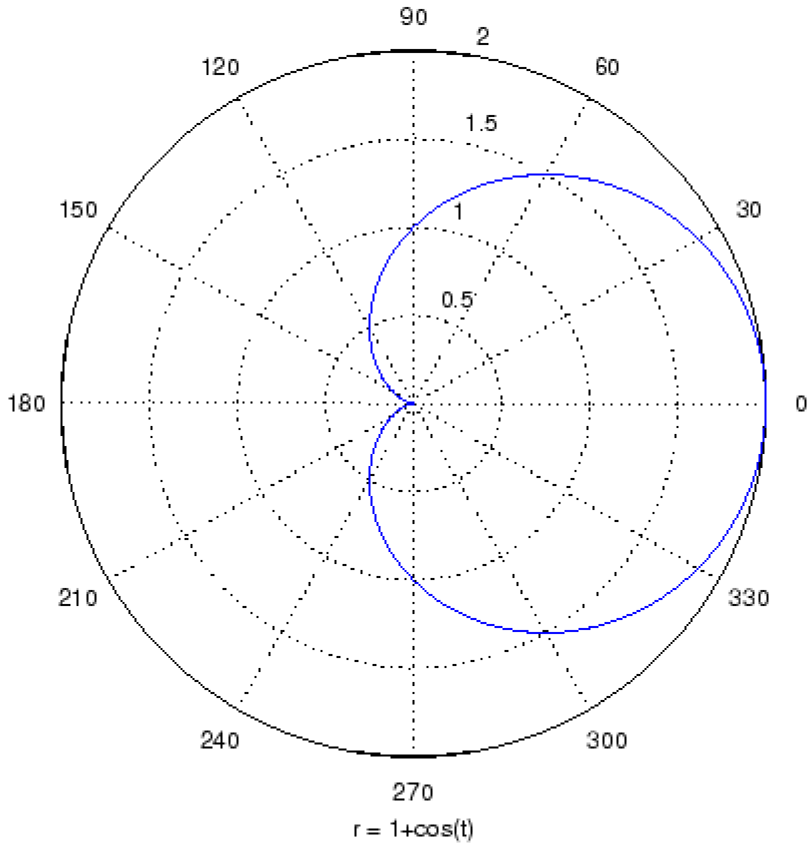
Examples

This example creates a polar plot of the function

$1 + \cos(t)$

over the domain $[0, 2\pi]$:

```
ezpolar('1+cos(t)')
```



See Also

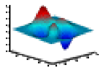
`ezplot`, `ezplot3`, `function_handle`, `plot`, `plot3`, `polar`

"Function Plots" on page 1-88 for related functions

ezsurf

Purpose

Easy-to-use 3-D colored surface plotter



Syntax

```
ezsurf(fun)
ezsurf(fun,domain)
ezsurf(funx,funy,funz)
ezsurf(funx,funy,funz,[smin,smax,tmin,tmax])
ezsurf(funx,funy,funz,[min,max]
ezsurf(...,n)
ezsurf(...,'circ')
ezsurf(axes_handle,...)
h = ezsurf(...)
```

Description

`ezsurf(fun)` creates a graph of `fun(x,y)` using the `surf` function. `fun` is plotted over the default domain: -2π < `x` < 2π, -2π < `y` < 2π.

`fun` can be a function handle for an M-file function or an anonymous function (see “Function Handles” and “Anonymous Functions”) or a string (see the Remarks section).

`ezsurf(fun,domain)` plots `fun` over the specified `domain`. `domain` can be either a 4-by-1 vector [`xmin`, `xmax`, `ymin`, `ymax`] or a 2-by-1 vector [`min`, `max`] (where `min` < `x` < `max`, `min` < `y` < `max`).

`ezsurf(funx,funy,funz)` plots the parametric surface `funx(s,t)`, `funy(s,t)`, and `funz(s,t)` over the square: -2π < `s` < 2π, -2π < `t` < 2π.

`ezsurf(funx,funy,funz,[smin,smax,tmin,tmax])` or `ezsurf(funx,funy,funz,[min,max])` plots the parametric surface using the specified domain.

`ezsurf(...,n)` plots `fun` over the default domain using an `n`-by-`n` grid. The default value for `n` is 60.

`ezsurf(...,'circ')` plots `fun` over a disk centered on the domain.

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

`h = ezsurf(...)` returns the handle to a surface object in `h`.

Remarks

Passing the Function as a String

Array multiplication, division, and exponentiation are always implied in the expression you pass to `ezmesh`. For example, the MATLAB syntax for a surface plot of the expression

```
sqrt(x.^2 + y.^2);
```

is written as

```
ezsurf('sqrt(x^2 + y^2)')
```

That is, `x^2` is interpreted as `x.^2` in the string you pass to `ezsurf`.

If the function to be plotted is a function of the variables u and v (rather than x and y), then the domain endpoints `umin`, `umax`, `vmin`, and `vmax` are sorted alphabetically. Thus, `ezsurf('u^2 - v^3',[0,1],[3,6])` plots u^2 - v^3 over $0 < u < 1$, $3 < v < 6$.

Passing a Function Handle

Function handle arguments must point to functions that use MATLAB syntax. For example, the following statements define an anonymous function and pass the function handle `fh` to `ezsurf`.

```
fh = @(x,y) sqrt(x.^2 + y.^2);
ezsurf(fh)
```

Note that when using function handles, you must use the array power, array multiplication, and array division operators (`.^, .*, ./`) since `ezsurf` does not alter the syntax, as in the case with string inputs.

Passing Additional Arguments

If your function has additional parameters, for example `k` in `myfun`:

```
function z = myfun(x,y,k1,k2,k3)
z = x.*(y.^k1)./(x.^k2 + y.^k3);
```

then you can use an anonymous function to specify that parameter:

```
ezsurf(@(x,y)myfun(x,y,2,2,4))
```

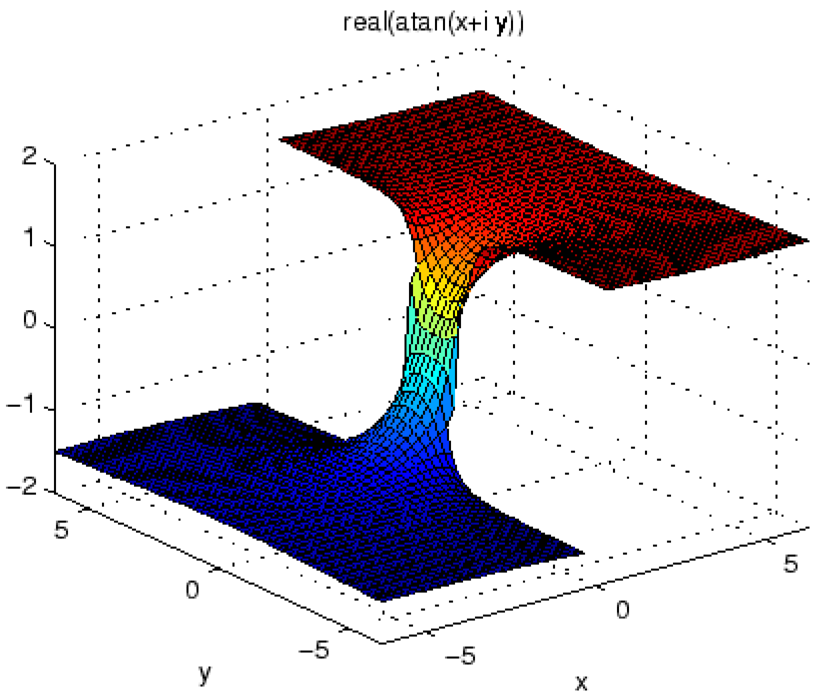
Examples

`ezsurf` does not graph points where the mathematical function is not defined (these data points are set to `NaN`s, which MATLAB does not plot). This example illustrates this filtering of singularities/discontinuous points by graphing the function

$$f(x, y) = real(atan(x + iy))$$

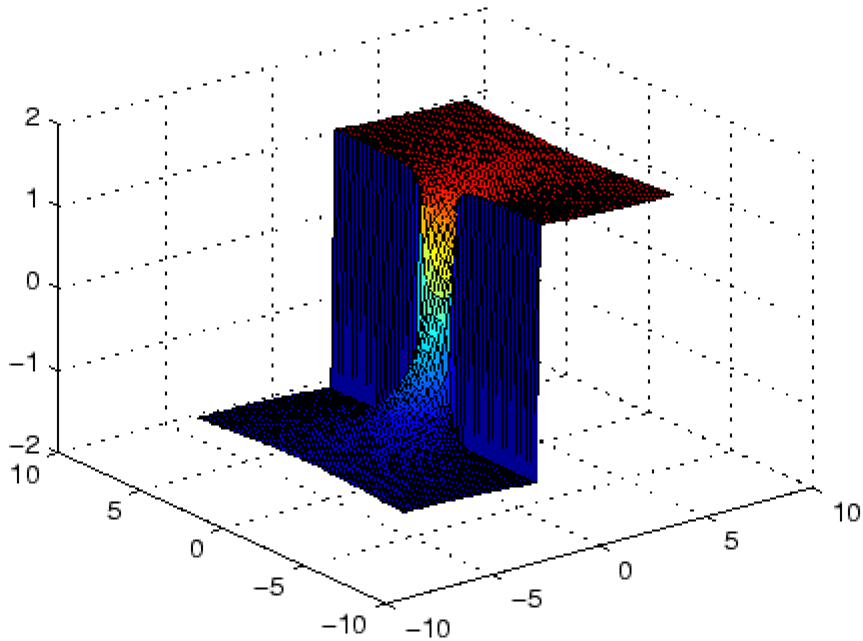
over the default domain $-2\pi < x < 2\pi$, $-2\pi < y < 2\pi$:

```
ezsurf('real(atan(x+i*y))')
```



Using `surf` to plot the same data produces a graph without filtering of discontinuities (as well as requiring more steps):

```
[x,y] = meshgrid(linspace(-2*pi,2*pi,60));
z = real(atan(x+i.*y));
surf(x,y,z)
```



Note also that `ezsurf` creates graphs that have axis labels, a title, and extend to the axis limits.

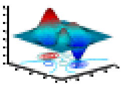
See Also

`ezmesh`, `ezsurfc`, `function_handle`, `surf`

"Function Plots" on page 1-88 for related functions

Purpose

Easy-to-use combination surface/contour plotter



Syntax

```
ezsurfc(fun)
ezsurfc(fun,domain)
ezsurfc(funx,funy,funz)
ezsurfc(funx,funy,funz,[smin,smax,tmin,tmax])
ezsurfc(funx,funy,funz,[min,max]
ezsurfc(...,n)
ezsurfc(...,'circ')
ezsurfc(axes_handle,...)
h = ezsurfc(...)
```

Description

`ezsurfc(fun)` creates a graph of `fun(x,y)` using the `surfc` function. The function `fun` is plotted over the default domain: -2π < `x` < 2π, -2π < `y` < 2π.

`fun` can be a function handle for an M-file function or an anonymous function (see "Function Handles" and "Anonymous Functions") or a string (see the Remarks section).

`ezsurfc(fun,domain)` plots `fun` over the specified `domain`. `domain` can be either a 4-by-1 vector [`xmin`, `xmax`, `ymin`, `ymax`] or a 2-by-1 vector [`min`, `max`] (where `min` < `x` < `max`, `min` < `y` < `max`).

`ezsurfc(funx,funy,funz)` plots the parametric surface `funx(s,t)`, `funy(s,t)`, and `funz(s,t)` over the square: -2π < `s` < 2π, -2π < `t` < 2π.

`ezsurfc(funx,funy,funz,[smin,smax,tmin,tmax])` or `ezsurfc(funx,funy,funz,[min,max])` plots the parametric surface using the specified domain.

`ezsurfc(...,n)` plots *f* over the default domain using an `n`-by-`n` grid. The default value for `n` is 60.

`ezsurfc(...,'circ')` plots *f* over a disk centered on the domain.

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

`h = ezsurfc(...)` returns the handles to the graphics objects in `h`.

Remarks

Passing the Function as a String

Array multiplication, division, and exponentiation are always implied in the expression you pass to `ezsurfc`. For example, the MATLAB syntax for a surface/contour plot of the expression

```
sqrt(x.^2 + y.^2);
```

is written as

```
ezsurfc('sqrt(x^2 + y^2)')
```

That is, `x^2` is interpreted as `x.^2` in the string you pass to `ezsurfc`.

If the function to be plotted is a function of the variables u and v (rather than x and y), then the domain endpoints `umin`, `umax`, `vmin`, and `vmax` are sorted alphabetically. Thus, `ezsurfc('u^2 - v^3',[0,1],[3,6])` plots u^2 - v^3 over $0 < u < 1$, $3 < v < 6$.

Passing a Function Handle

Function handle arguments must point to functions that use MATLAB syntax. For example, the following statements define an anonymous function and pass the function handle `fh` to `ezsurfc`.

```
fh = @(x,y) sqrt(x.^2 + y.^2);
ezsurf(fh)
```

Note that when using function handles, you must use the array power, array multiplication, and array division operators (`.^, .*, ./`) since `ezsurfc` does not alter the syntax, as in the case with string inputs.

Passing Additional Arguments

If your function has additional parameters, for example `k` in `myfun`:

```
function z = myfun(x,y,k1,k2,k3)
```

```
z = x.*(y.^k1)./(x.^k2 + y.^k3);
```

then you can use an anonymous function to specify that parameter:

```
ezsurfc(@(x,y)myfun(x,y,2,2,4))
```

Examples

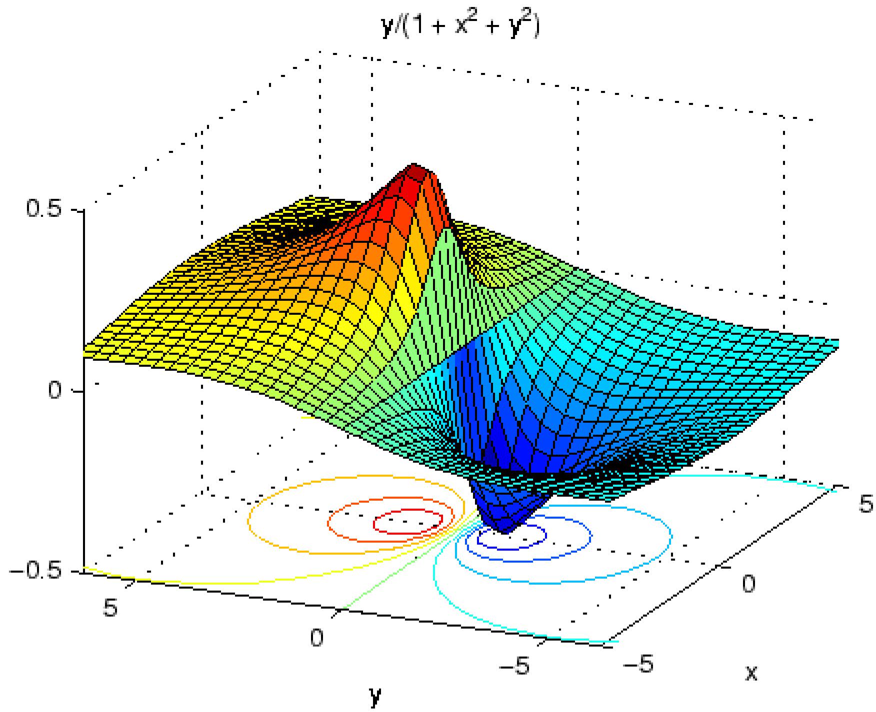
Create a surface/contour plot of the expression

$$f(x, y) = \frac{y}{1 + x^2 + y^2}$$

over the domain -5 < x < 5, -2*pi < y < 2*pi, with a computational grid of size 35-by-35:

```
ezsurfc('y/(1 + x^2 + y^2)',[-5,5,-2*pi,2*pi],35)
```

Use the mouse to rotate the axes to better observe the contour lines (this picture uses a view of azimuth = -65.5 and elevation = 26).



See Also

`ezmesh`, `ezmeshc`, `ezsurf`, `function_handle`, `surfc`

"Function Plots" on page 1-88 for related functions

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`

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