MATLAB® 7

Function Reference: Volume 1 (A-E)

MATLAB®

The MathWorks™
Accelerating the pace of engineering and science

How to Contact The MathWorks

`www.mathworks.com`	Web
`comp.soft-sys.matlab`	Newsgroup
`www.mathworks.com/contact_TS.html`	Technical Support
`suggest@mathworks.com`	Product enhancement suggestions
`bugs@mathworks.com`	Bug reports
`doc@mathworks.com`	Documentation error reports
`service@mathworks.com`	Order status, license renewals, passcodes
`info@mathworks.com`	Sales, pricing, and general information

508-647-7000 (Phone)

508-647-7001 (Fax)

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

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

MATLAB Function Reference

Revision History

December 1996	First printing	For MATLAB 5.0 (Release 8)
June 1997	Online only	Revised for MATLAB 5.1 (Release 9)
October 1997	Online only	Revised for MATLAB 5.2 (Release 10)
January 1999	Online only	Revised for MATLAB 5.3 (Release 11)
June 1999	Second printing	For MATLAB 5.3 (Release 11)
June 2001	Online only	Revised for MATLAB 6.1 (Release 12.1)
July 2002	Online only	Revised for 6.5 (Release 13)
June 2004	Online only	Revised for 7.0 (Release 14)
September 2006	Online only	Revised for 7.3 (Release 2006b)
September 2007	Online only	Revised for 7.5 (Release 2007b)

Contents

1 Function Reference

2 Functions — Alphabetical List

Index

Function Reference

Desktop Tools and Development Environment

Startup and Shutdown

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

`quit`	Terminate the MATLAB program
`startup`	Startup M-file for user-defined options
`userpath`	View or change user portion of search path

Command Window and History

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

Help for Using MATLAB

`builddocsearchdb`	Build searchable documentation database
`demo`	Access product demos via Help browser
`doc`	Reference page in Help browser
`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™ programming language class
`openvar`	Open workspace variable in Variable 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 search path
`genpath`	Generate path string
`partialpath`	Partial pathname description

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

File Operations

See also “File I/O” on page 1-78 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 programming language 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 platform
`matlabroot`	Root directory
`mkdir`	Make new directory
`movefile`	Move file or directory
`pwd`	Identify current directory
`recycle`	Set option to move deleted files to recycle folder
`rehash`	Refresh function and file system path caches
`rmdir`	Remove directory
`toolboxdir`	Root directory for specified toolbox
`type`	Display contents of file
`what`	List MATLAB files in current directory
`which`	Locate functions and files

Programming Tools

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

bench	MATLAB Benchmark
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 a source control system (UNIX platforms)
`checkout`	Check files out of a source control system (UNIX platforms)
`cmopts`	Name of source control system
`customverctrl`	Allow custom source control system (UNIX platforms)
`undocheckout`	Undo previous checkout from source control system (UNIX platforms)
`verctrl`	Source control actions (Windows platforms)

Publishing

`grabcode`	MATLAB code from M-files published to HTML
`notebook`	Open M-book in Microsoft® Word (MicrosoftWindows platforms)
`publish`	Publish M-file containing cells, saving output to a 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 software is running
`dos`	Execute DOS command and return result
`getenv`	Environment variable
`hostid`	MATLAB server host identification number
`maxNumCompThreads`	Controls maximum number of computational threads
`perl`	Call Perl script using appropriate operating system executable
`setenv`	Set environment variable
`system`	Execute operating system command and return result
`unix`	Execute UNIX command and return result
`winqueryreg`	Item from Microsoft Windows registry

MATLAB Version and License

`ismac`	Determine if running MATLAB for Macintosh® OS X platform
`ispc`	Determine if running MATLAB for PC (Windows) platform
`isstudent`	Determine whether Student Version of MATLAB
`isunix`	Determine if running MATLAB for UNIX platform.[1]
`javachk`	Generate error message based on Sun™ Java feature support
`license`	Return license number or perform licensing task
`prefdir`	Directory containing preferences, history, and layout files
`usejava`	Determine whether Sun Java feature is supported in MATLAB software
`ver`	Version information for MathWorks products
`verLessThan`	Compare toolbox version to specified version string
`version`	Version number for the MATLAB software

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

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`	Apply element-by-element binary operation to two arrays with singleton expansion enabled
`cast`	Cast variable to different data type
`cross`	Vector cross product
`cumprod`	Cumulative product
`cumsum`	Cumulative sum
`dot`	Vector dot product
`idivide`	Integer division with rounding option
`kron`	Kronecker tensor product
`prod`	Product of array elements
`sum`	Sum of array elements
`tril`	Lower triangular part of matrix
`triu`	Upper triangular part of matrix

Array Manipulation

`blkdiag`	Construct block diagonal matrix from input arguments
`cat`	Concatenate arrays along specified dimension
`circshift`	Shift array circularly

`diag`	Diagonal matrices and diagonals of matrix
`end`	Terminate block of code, or indicate last array index
`flipdim`	Flip array along specified dimension
`fliplr`	Flip matrix left to right
`flipud`	Flip matrix up to down
`horzcat`	Concatenate arrays horizontally
`inline`	Construct inline object
`ipermute`	Inverse permute dimensions of N-D array
`permute`	Rearrange dimensions of N-D array
`repmat`	Replicate and tile array
`reshape`	Reshape array
`rot90`	Rotate matrix 90 degrees
`shiftdim`	Shift dimensions
`sort`	Sort array elements in ascending or descending order
`sortrows`	Sort rows in ascending order
`squeeze`	Remove singleton dimensions
`vectorize`	Vectorize expression
`vertcat`	Concatenate arrays vertically

Specialized Matrices

`compan`	Companion matrix
`gallery`	Test matrices
`hadamard`	Hadamard matrix
`hankel`	Hankel matrix

`hilb`	Hilbert matrix
`invhilb`	Inverse of Hilbert matrix
`magic`	Magic square
`pascal`	Pascal matrix
`rosser`	Classic symmetric eigenvalue test problem
`toeplitz`	Toeplitz matrix
`vander`	Vandermonde matrix
`wilkinson`	Wilkinson's eigenvalue test matrix

Linear Algebra

Matrix Analysis (p. 1-19)	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, Hessenberg 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`	Finds largest eigenvalues and eigenvectors of a 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

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 nth 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
`padecoef`	Padé approximation of time delays
`pchip`	Piecewise Cubic Hermite Interpolating Polynomial (PCHIP)
`ppval`	Evaluate piecewise polynomial
`spline`	Cubic spline data interpolation
`tsearchn`	N-D closest simplex search
`unmkpp`	Piecewise polynomial details

Delaunay Triangulation and Tessellation

`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

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
`bvp5c`	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
`quadgk`	Numerically evaluate integral, adaptive Gauss-Kronrod quadrature
`quadl`	Numerically evaluate integral, adaptive Lobatto quadrature

`quadv`	Vectorized quadrature
`triplequad`	Numerically evaluate triple integral

Specialized Math

`airy`	Airy functions
`besselh`	Bessel function of third kind (Hankel function)
`besseli`	Modified Bessel function of first kind
`besselj`	Bessel function of first kind
`besselk`	Modified Bessel function of second kind
`bessely`	Bessel function of second kind
`beta`	Beta function
`betainc`	Incomplete beta function
`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

`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`	Finds largest eigenvalues and eigenvectors of a 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 normalized floating-point number

Data Analysis

Basic Operations

`brush`	Interactively mark, delete, modify, and save observations in graphs
`cumprod`	Cumulative product
`cumsum`	Cumulative sum
`linkdata`	Automatically update graphs when variables change
`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 normalized 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`	String handling
`strjust`	Justify character array
`strmatch`	Find possible matches for string
`strread`	Read formatted data from string
`strrep`	Find and replace substring
`strtrim`	Remove leading and trailing white space from string
`strvcat`	Concatenate strings vertically

Structures

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

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

Cell Arrays

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

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

Function Handles

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

Java Classes and Objects

cell	Construct cell array
class	Create object or return class of object

`clear`	Remove items from workspace, freeing up system memory
`depfun`	List dependencies of M-file or P-file
`exist`	Check existence of variable, function, directory, or Java™ programming language class
`fieldnames`	Field names of structure, or public fields of object
`im2java`	Convert image to Java image
`import`	Add package or class to current import list
`inmem`	Names of M-files, MEX-files, Sun™ Java classes in memory
`isa`	Determine whether input is object of given class
`isjava`	Determine whether input is Sun Java object
`javaaddpath`	Add entries to dynamic Sun Java class path
`javaArray`	Construct Sun Java array
`javachk`	Generate error message based on Sun Java feature support
`javaclasspath`	Set and get dynamic Sun Java class path
`javaMethod`	Invoke Sun Java method
`javaObject`	Construct Sun Java object
`javarmpath`	Remove entries from dynamic Sun Java class path
`methods`	Information on class methods
`methodsview`	Information on class methods in separate window

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

Data Type Identification

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

`isstr`	Determine whether input is character array
`isstruct`	Determine whether input is structure array
`validateattributes`	Check validity of array
`who, whos`	List variables in workspace

Data Type Conversion

Numeric (p. 1-57)	Convert data of one numeric type to another numeric type
String to Numeric (p. 1-58)	Convert characters to numeric equivalent
Numeric to String (p. 1-58)	Convert numeric to character equivalent
Other Conversions (p. 1-59)	Convert to structure, cell array, function handle, etc.

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. 1-60)	Equal to, greater than, less than or equal to, etc.
Logical Operators (p. 1-60)	Element-wise and short circuit and, or, not
Special Characters (p. 1-61)	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 1-65 for functions like `xor`, `all`, `any`, etc.

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

Special Characters

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

String Functions

Description of Strings in MATLAB

`strings`	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
`validatestring`	Check validity of text string

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 1-59 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 1-59 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. 1-69)	Evaluate expression in string, apply function to array, run script file, etc.
Timer Functions (p. 1-70)	Schedule execution of MATLAB commands

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, Sun Java classes in memory
`isglobal`	Determine whether input is global variable
`memory`	Display memory information
`mislocked`	Determine whether M-file or MEX-file cannot be cleared from memory
`mlock`	Prevent clearing M-file or MEX-file from memory
`munlock`	Allow clearing M-file or MEX-file from memory
`namelengthmax`	Maximum identifier length
`pack`	Consolidate workspace memory

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

Control Flow

`break`	Terminate execution of `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
`parfor`	Parallel `for`-loop
`return`	Return to invoking function
`switch`	Switch among several cases, based on expression

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

Error Handling

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

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

MEX Programming

`dbmex`	Enable MEX-file debugging
`inmem`	Names of M-files, MEX-files, Sun Java classes in memory
`mex`	Compile MEX-function from C/ C++ or Fortran source code
`mexext`	Binary MEX-file name extension

MATLAB® Classes and Object-Oriented Programming

Classes and Objects

`addlistener (handle)`	Create event listener
`addprop (dynamicprops)`	Add dynamic property
`class`	Create object or return class of object
`classdef`	Class definition key words
`delete (handle)`	Handle object destructor function
`dynamicprops`	Abstract class used to derive handle class with dynamic properties
`event.EventData`	Base class for all data objects passed to event listeners
`event.listener`	Class defining listener objects
`event.PropertyEvent`	Listener for property events
`event.proplistener`	Define listener object for property events
`events`	Display class event names
`fieldnames`	Field names of structure, or public fields of object
`findobj (handle)`	Finds objects matching specified conditions
`findprop (handle)`	Find `meta.property` object associated with property name
`get (hgsetget)`	Query property values of handle objects derived from `hgsetget` class
`getdisp (hgsetget)`	Override to change command window display
`handle`	Abstract class for deriving handle classes

`hgsetget`	Abstract class used to derive handle class with set and get methods
`inferiorto`	Specify inferior class relationship
`isa`	Determine whether input is object of given class
`isobject`	Determine whether input is MATLAB® object
`isvalid (handle)`	Is object valid handle object
`loadobj`	User-defined class method called by `load` function
`meta.class`	`meta.class` class describes MATLAB classes
`meta.class.fromName`	Return `meta.class` object associated with named class
`meta.event`	`meta.event` class describes MATLAB class events
`meta.method`	`meta.method` class describes MATLAB class methods
`meta.package`	`meta.package` class describes MATLAB packages
`meta.package.fromName`	Return `meta.package` object for specified package
`meta.package.getAllPackages`	Get all top-level packages
`meta.property`	`meta.property` class describes MATLAB class properties
`metaclass`	Return `meta.class` object for named class
`methods`	Information on class methods
`methodsview`	Information on class methods in separate window
`notify (handle)`	notify listeners that event is occurring

`properties`	Display class property names
`relationaloperators (handle)`	Equality and sorting of handle objects
`saveobj`	Method called by `save` function for user-defined objects
`set (hgsetget)`	Assign property values to handle objects derived from `hgsetget` class
`setdisp (hgsetget)`	Override to change command window display
`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

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 the MATLAB® software 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. 1-81)	Read and write Microsoft Excel spreadsheet
Lotus 1-2-3 Functions (p. 1-81)	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. 1-84)	Create audio player object, obtain information about multimedia files, convert to/from audio signal
SPARCstation-Specific Sound Functions (p. 1-84)	Access NeXT/SUN (`.au`) 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
`mmreader`	Create multimedia reader object for reading video files
`mu2lin`	Convert mu-law audio signal to linear
`read`	Read video frame data from multimedia reader object
`sound`	Convert vector into sound
`soundsc`	Scale data and play as sound

SPARCstation-Specific Sound Functions

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

Microsoft WAVE Sound Functions

`wavfinfo`	Information about Microsoft WAVE (`.wav`) sound file
`wavplay`	Play recorded sound on PC-based audio output device
`wavread`	Read Microsoft WAVE (`.wav`) sound file
`wavrecord`	Record sound using PC-based audio input device
`wavwrite`	Write Microsoft WAVE (`.wav`) sound file

Audio/Video Interleaved (AVI) Functions

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

Images

`exifread`	Read EXIF information from JPEG and TIFF image files
`im2java`	Convert image to Java™ image

`imfinfo`	Information about graphics file
`imread`	Read image from graphics file
`imwrite`	Write image to graphics file

Internet Exchange

URL, Zip, Tar, E-Mail (p. 1-86)	Send e-mail, read from given URL, extract from tar or zip file, compress and decompress files
FTP Functions (p. 1-86)	Connect to FTP server, download from server, manage FTP files, close server connection

URL, Zip, Tar, E-Mail

`gunzip`	Uncompress GNU zip files
`gzip`	Compress files into GNU zip files
`sendmail`	Send e-mail message to address list
`tar`	Compress files into tar file
`untar`	Extract contents of tar file
`unzip`	Extract contents of zip file
`urlread`	Read content at URL
`urlwrite`	Save contents of URL to file
`zip`	Compress files into zip file

FTP Functions

`ascii`	Set FTP transfer type to ASCII
`binary`	Set FTP transfer type to binary

`cd (ftp)`	Change current directory on FTP server
`close (ftp)`	Close connection to FTP server
`delete (ftp)`	Remove file on FTP server
`dir (ftp)`	Directory contents on FTP server
`ftp`	Connect to FTP server, creating FTP object
`mget`	Download file from FTP server
`mkdir (ftp)`	Create new directory on FTP server
`mput`	Upload file or directory to FTP server
`rename`	Rename file on FTP server
`rmdir (ftp)`	Remove directory on FTP server

Graphics

Basic Plots and Graphs

`box`	Axes border
`errorbar`	Plot error bars along curve
`hold`	Retain current graph in figure
`LineSpec`	Line specification string syntax
`loglog`	Log-log scale plot
`plot`	2-D line plot
`plot3`	3-D line plot
`plotyy`	2-D line plots with y-axes on both left and right side
`polar`	Polar coordinate plot

`semilogx, semilogy`	Semilogarithmic plots
`subplot`	Create axes in tiled positions

Plotting Tools

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

Annotating Plots

`annotation`	Create annotation objects
`clabel`	Contour plot elevation labels
`datacursormode`	Enable or disable interactive data cursor mode
`datetick`	Date formatted tick labels
`gtext`	Mouse placement of text in 2-D view
`legend`	Graph legend for lines and patches
`line`	Create line object
`rectangle`	Create 2-D rectangle object
`texlabel`	Produce TeX format from character string

`title`	Add title to current axes
`xlabel, ylabel, zlabel`	Label *x*-, *y*-, and *z*-axis

Specialized Plotting

Area, Bar, and Pie Plots (p. 1-90)	1-D, 2-D, and 3-D graphs and charts
Contour Plots (p. 1-91)	Unfilled and filled contours in 2-D and 3-D
Direction and Velocity Plots (p. 1-91)	Comet, compass, feather and quiver plots
Discrete Data Plots (p. 1-91)	Stair, step, and stem plots
Function Plots (p. 1-91)	Easy-to-use plotting utilities for graphing functions
Histograms (p. 1-92)	Plots for showing distributions of data
Polygons and Surfaces (p. 1-92)	Functions to generate and plot surface patches in two or more dimensions
Scatter/Bubble Plots (p. 1-93)	Plots of point distributions
Animation (p. 1-93)	Functions to create and play movies of plots

Area, Bar, and Pie Plots

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

Contour Plots

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

Direction and Velocity Plots

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

Discrete Data Plots

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

Function Plots

`ezcontour`	Easy-to-use contour plotter
`ezcontourf`	Easy-to-use filled contour plotter
`ezmesh`	Easy-to-use 3-D mesh plotter

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

Histograms

hist	Histogram plot
histc	Histogram count
rose	Angle histogram plot

Polygons and Surfaces

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

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

Scatter/Bubble Plots

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

Animation

`frame2im`	Convert movie frame to indexed image
`getframe`	Capture movie frame
`im2frame`	Convert image to movie frame

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

Bit-Mapped Images

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

Printing

`frameedit`	Edit print frames for Simulink® and Stateflow® block diagrams
`hgexport`	Export figure
`orient`	Hardcopy paper orientation
`print, printopt`	Print figure or save to file and configure printer defaults
`printdlg`	Print dialog box

`printpreview`	Preview figure to print
`saveas`	Save figure or Simulink block diagram using specified format

Handle Graphics

Finding and Identifying Graphics Objects

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

`gcbo`	Handle of object whose callback is executing
`gco`	Handle of current object
`get`	Query object properties
`ishandle`	Is valid Handle Graphics® handle
`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`	Flush event queue and update figure window
`gcf`	Current figure handle
`hgload`	Load Handle Graphics object hierarchy from file

`hgsave`	Save Handle Graphics object hierarchy to file
`newplot`	Determine where to draw graphics objects
`opengl`	Control OpenGL rendering
`refresh`	Redraw current figure
`saveas`	Save figure or Simulink block diagram using specified format

Axes Operations

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

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. 1-101)	Orbiting, dollying, pointing, rotating camera positions and setting fields of view
Setting the Aspect Ratio and Axis Limits (p. 1-102)	Specifying what portions of axes to view and how to scale them
Object Manipulation (p. 1-102)	Panning, rotating, and zooming views
Selecting Region of Interest (p. 1-103)	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 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 MATLAB C and Fortran API Reference for functions you can use in external routines that interact with MATLAB programs and the data in MATLAB workspaces.

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® software
`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 import list
`inspect`	Open Property Inspector
`isa`	Determine whether input is object of given class
`isjava`	Determine whether input is Sun™ Java™ object
`ismethod`	Determine whether input is object method
`isprop`	Determine whether input is object property
`javaaddpath`	Add entries to dynamic Sun Java class path
`javaArray`	Construct Sun Java array
`javachk`	Generate error message based on Sun Java feature support
`javaclasspath`	Set and get dynamic Sun Java class path
`javaMethod`	Invoke Sun Java method
`javaObject`	Construct Sun Java object

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

Component Object Model and ActiveX

`actxcontrol`	Create Microsoft® ActiveX® control in figure window
`actxcontrollist`	List all currently installed Microsoft ActiveX controls
`actxcontrolselect`	Open GUI to create Microsoft ActiveX control
`actxGetRunningServer`	Get handle to running instance of Automation server
`actxserver`	Create COM server
`addproperty`	Add custom property to COM object
`class`	Create object or return class of object
`delete (COM)`	Remove COM control or server
`deleteproperty`	Remove custom property from COM object
`enableservice`	Enable, disable, or report status of Automation server
`eventlisteners`	List all event handler functions registered for COM object
`events (COM)`	List of events COM object can trigger
`Execute`	Execute MATLAB command in 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`	True if COM object 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 Microsoft® 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 for COM object event at run-time
`release`	Release interface
`save (COM)`	Serialize control object to file
`set (COM)`	Set object or interface property to specified value
`unregisterallevents`	Unregister all event handlers for COM object event at run-time
`unregisterevent`	Unregister event handler for COM object event at run-time

Web Services

`callSoapService`	Send SOAP message 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 types

Serial Port Devices

`clear (serial)`	Remove serial port object from MATLAB workspace
`delete (serial)`	Remove serial port object from memory
`disp (serial)`	Serial port object summary information
`fclose (serial)`	Disconnect serial port object from device
`fgetl (serial)`	Read line of text from device and discard terminator
`fgets (serial)`	Read line of text from device and include terminator
`fopen (serial)`	Connect serial port object to device
`fprintf (serial)`	Write text to device
`fread (serial)`	Read binary data from device
`fscanf (serial)`	Read data from device, and format as text
`fwrite (serial)`	Write binary data to device
`get (serial)`	Serial port object properties
`instrcallback`	Event information when event occurs
`instrfind`	Read serial port objects from memory to MATLAB workspace
`instrfindall`	Find visible and hidden serial port objects
`isvalid (serial)`	Determine whether serial port objects are valid
`length (serial)`	Length of serial port object array
`load (serial)`	Load serial port objects and variables into MATLAB workspace

`readasync`	Read data asynchronously from device
`record`	Record data and event information to file
`save (serial)`	Save serial port objects and variables to MAT-file
`serial`	Create serial port object
`serialbreak`	Send break to device connected to serial port
`set (serial)`	Configure or display serial port object properties
`size (serial)`	Size of serial port object array
`stopasync`	Stop asynchronous read and write operations

2

Functions — Alphabetical List

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

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

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

delaunay3
delaunayn
delete
delete (COM)
delete (ftp)
delete (handle)
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 (memmapfile)
disp (MException)
disp (serial)
disp (timer)
display
divergence
dlmread
dlmwrite
dmperm
doc

event.EventData
event.PropertyEvent
event.listener
event.proplistener
eventlisteners
events
events (COM)
Execute
exifread
exist
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

flipud
floor
flow
fminbnd
fminsearch
fopen
fopen (serial)
for
format
fplot
fprintf
fprintf (serial)
frame2im
frameedit
fread
fread (serial)
freqspace
frewind
fscanf
fscanf (serial)
fseek
ftell
ftp
full
fullfile
func2str
function
function_handle (@)
functions
funm
fwrite
fwrite (serial)
fzero
gallery
gamma, gammainc, gammaln
gca
gcbf

gcbo
gcd
gcf
gco
ge
genpath
genvarname
get
get (COM)
get (hgsetget)
get (memmapfile)
get (serial)
get (timer)
get (timeseries)
get (tscollection)
getabstime (timeseries)
getabstime (tscollection)
getappdata
GetCharArray
getdatasamplesize
getdisp (hgsetget)
getenv
getfield
getframe
GetFullMatrix
getinterpmethod
getpixelposition
getpref
getqualitydesc
getReport (MException)
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
handle
hankel
hdf
hdf5
hdf5info
hdf5read
hdf5write
hdfinfo
hdfread
hdftool
help
helpbrowser
helpdesk

Image Properties
imagesc
imfinfo
imformats
import
importdata
imread
imwrite
ind2rgb
ind2sub
Inf
inferiorto
info
inline
inmem
inpolygon
input
inputdlg
inputname
inputParser
inspect
instrcallback
instrfind
instrfindall
int2str
int8, int16, int32, int64
interfaces
interp1
interp1q
interp2
interp3
interpft
interpn
interpstreamspeed
intersect
intmax
intmin

isnan
isnumeric
isobject
isocaps
isocolors
isonormals
isosurface
ispc
ispref
isprime
isprop
isreal
isscalar
issorted
isspace
issparse
isstr
isstrprop
isstruct
isstudent
isunix
isvalid (handle)
isvalid (serial)
isvalid (timer)
isvarname
isvector
j
javaaddpath
javaArray
javachk
javaclasspath
javaMethod
javaObject
javarmpath
keyboard
kron
last (MException)

lasterr
lasterror
lastwarn
lcm
ldl
ldivide, rdivide
le
legend
legendre
length
length (serial)
length (timeseries)
length (tscollection)
libfunctions
libfunctionsview
libisloaded
libpointer
libstruct
license
light
Light Properties
lightangle
lighting
lin2mu
line
Line Properties
Lineseries Properties
LineSpec
linkaxes
linkdata
linkprop
linsolve
linspace
listdlg
listfonts
load
load (COM)

load (serial)
loadlibrary
loadobj
log
log10
log1p
log2
logical
loglog
logm
logspace
lookfor
lower
ls
lscov
lsqnonneg
lsqr
lt
lu
luinc
magic
makehgtform
mat2cell
mat2str
material
matlabcolon (matlab:)
matlabrc
matlabroot
matlab (UNIX)
matlab (Windows)
max
max (timeseries)
MaximizeCommandWindow
maxNumCompThreads
mean
mean (timeseries)
median

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
ne (MException)
newplot
nextpow2
nnz
noanimate
nonzeros
norm
normest
not
notebook
notify (handle)
now
nthroot

pascal
patch
Patch Properties
path
path2rc
pathdef
pathsep
pathtool
pause
pbaspect
pcg
pchip
pcode
pcolor
pdepe
pdeval
peaks
perl
perms
permute
persistent
pi
pie
pie3
pinv
planerot
playshow
plot
plot (timeseries)
plot3
plotbrowser
plotedit
plotmatrix
plottools
plotyy
pol2cart
polar

rehash
release
relationaloperators (handle)
rem
removets
rename
repmat
resample (timeseries)
resample (tscollection)
reset
reshape
residue
restoredefaultpath
rethrow
rethrow (MException)
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

settimeseriesnames
setxor
shading
shiftdim
showplottool
shrinkfaces
sign
sin
sind
single
sinh
size
size (serial)
size (timeseries)
size (tscollection)
slice
smooth3
sort
sortrows
sound
soundsc
spalloc
sparse
spaugment
spconvert
spdiags
specular
speye
spfun
sph2cart
sphere
spinmap
spline
spones
spparms
sprand
sprandn

sprandsym
sprank
sprintf
spy
sqrt
sqrtm
squeeze
ss2tf
sscanf
stairs
Stairseries Properties
start
startat
startup
std
std (timeseries)
stem
stem3
Stemseries Properties
stop
stopasync
str2double
str2func
str2mat
str2num
strcat
strcmp, strcmpi
stream2
stream3
streamline
streamparticles
streamribbon
streamslice
streamtube
strfind
strings
strjust

uitable
Uitable Properties
uitoggletool
Uitoggletool Properties
uitoolbar
Uitoolbar Properties
undocheckout
unicode2native
union
unique
unix
unloadlibrary
unmkpp
unregisterallevents
unregisterevent
untar
unwrap
unzip
upper
urlread
urlwrite
usejava
userpath
validateattributes
validatestring
vander
var
var (timeseries)
varargin
varargout
vectorize
ver
verctrl
verLessThan
version
vertcat
vertcat (timeseries)

xlswrite
xmlread
xmlwrite
xor
xslt
zeros
zip
zoom

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® software 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 2-2253 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 software 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 Classes”, under “Built-In Classes (Data Types)” in the MATLAB Programming Fundamentals 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 NaNs or Infs 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.

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.

Inputs		and	or	not	xor
A	B	A & B	A | B	~A	xor(A,B)
0	0	0	0	1	0
0	1	0	1	1	1
1	0	0	1	0	1
1	1	1	1	0	0

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

Operator	Operation	Priority
~	NOT	Highest
&	Elementwise AND	
|	Elementwise OR	
&&	Short-circuit AND	
||	Short-circuit OR	Lowest

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)`

Short-Circuiting in Elementwise Operators

When used in the context of an `if` or `while` expression, and only in this context, the elementwise | and & operators use short-circuiting in evaluating their expressions. That is, `A|B` and `A&B` ignore the second operand, `B`, if the first operand, `A`, is sufficient to determine the result.

So, although the statement `1|[]` evaluates to `false`, the same statement evaluates to `true` when used in either an `if` or `while` expression:

```
A = 1;   B = [];
if(A|B) disp 'The statement is true',  end;
   The statement is true
```

while the reverse logical expression, which does not short-circuit, evaluates to `false`

```
if(B|A) disp 'The statement is true',  end;
```

Another example of short-circuiting with elementwise operators shows that a logical expression such as the following, which under most circumstances is invalid due to a size mismatch between `A` and `B`,

```
A = [1 1];   B = [2 0 1];
```

```
A|B        % This generates an error.
```

works within the context of an `if` or `while` expression:

```
if (A|B) disp 'The statement is true',  end;
   The statement is true
```

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 < > <= >= == ~=`

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 < > <= >= == ~=

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 the MATLAB® software 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 & | ~,`

colon (:)

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
```

Using a colon with characters to iterate a for-loop,

```
for x='a':'d',x,end
```

results in

```
x =
    a
x =
    b
x =
    c
x =
    d
```

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

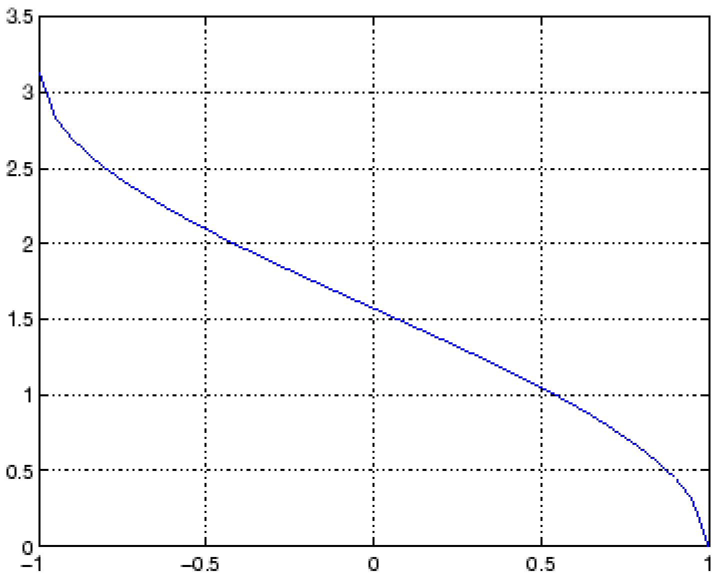
`Y = acos(X)` returns the inverse cosine (arccosine) for each element of `X`. For real elements of `X` in the domain $[-1, 1]$, `acos(X)` is real and in the range $[0, \pi]$. For real elements of `X` outside the domain $[-1, 1]$, `acos(X)` is complex.

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

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

Algorithm

acos uses FDLIBM, which was developed at SunSoft, a Sun Microsystems™ 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

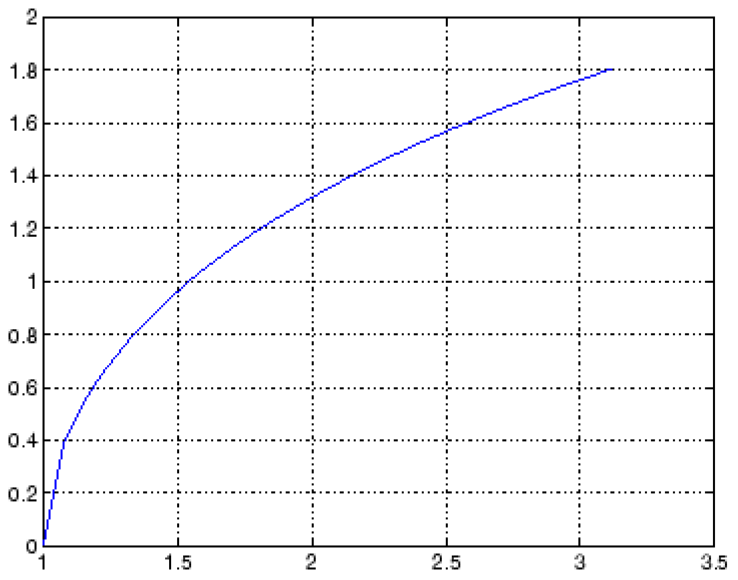
`Y = acosh(X)` returns the inverse hyperbolic cosine for each element of `X`.

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™ 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

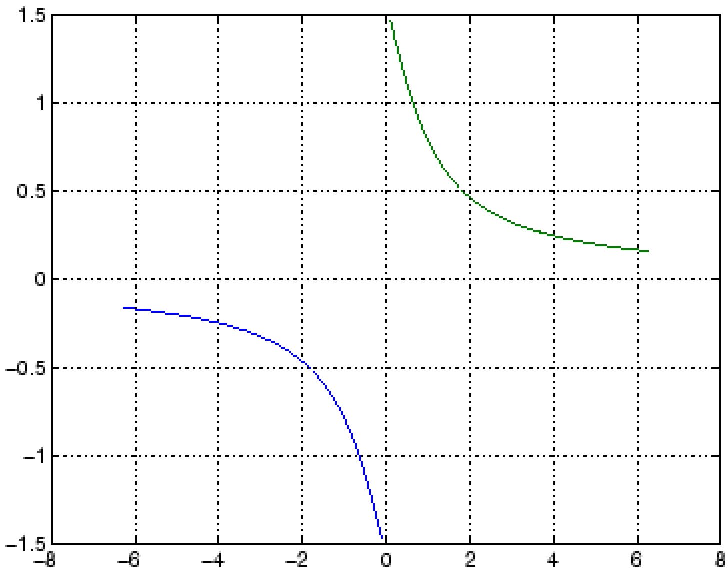
`Y = acot(X)` returns the inverse cotangent (arccotangent) for each element of `X`.

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™ 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`

Purpose Inverse hyperbolic cotangent

Syntax

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

Description

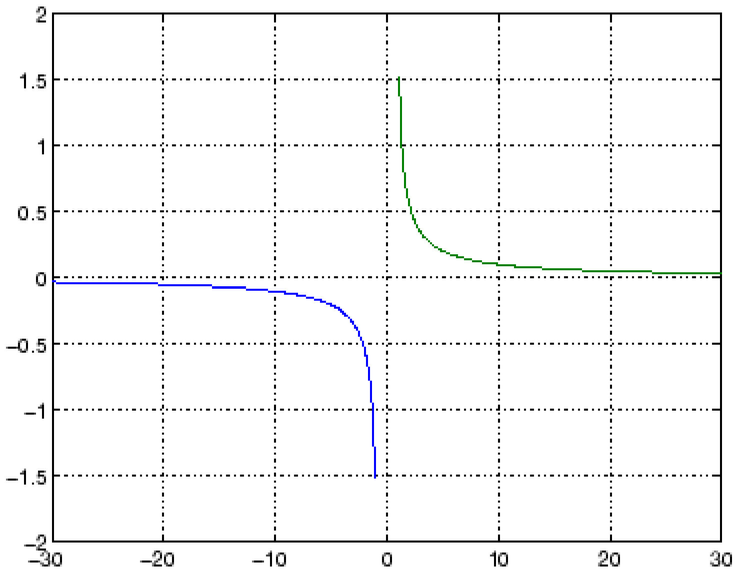
`Y = acoth(X)` returns the inverse hyperbolic cotangent for each element of `X`.

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 $-30 \leq x < -1$ and $1 < x \leq 30$.

```
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™ 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

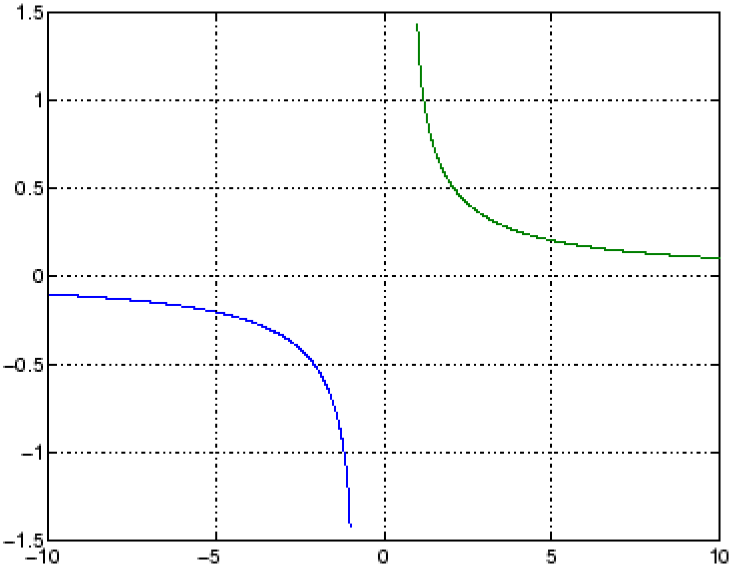
```
Y = acsc(X)
```

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™ 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

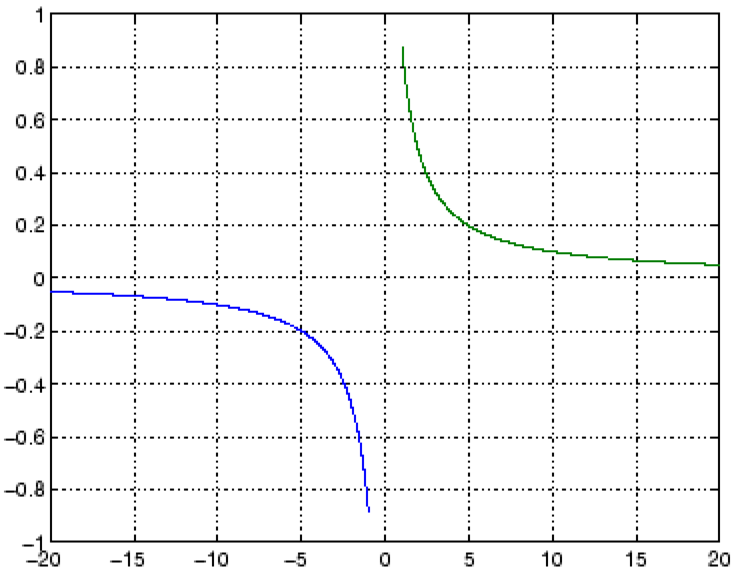
`Y = acsch(X)` returns the inverse hyperbolic cosecant for each element of `X`.

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™ business, by Kwok C. Ng, and others. For information about FDLIBM, see http://www.netlib.org.

See Also

acsc, csch

Purpose

Create Microsoft® 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 programmatic identifier (`progid`) for the control determines the type of control created. (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 2-87 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 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 software 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 software.

See Also

`actxserver`, `release`, `delete (COM)`, `save (COM)`, `load (COM)`, `interfaces`

actxcontrollist

Purpose

List all currently installed Microsoft® 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 Microsoft® ActiveX® control

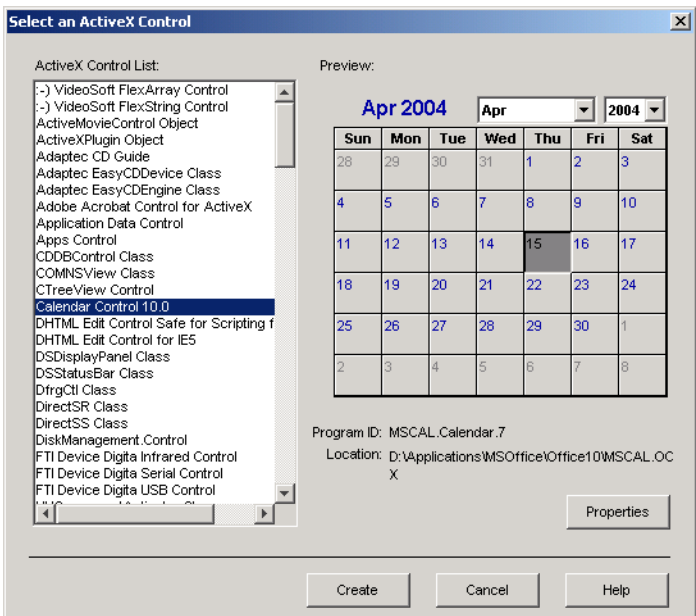
Syntax

```
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.

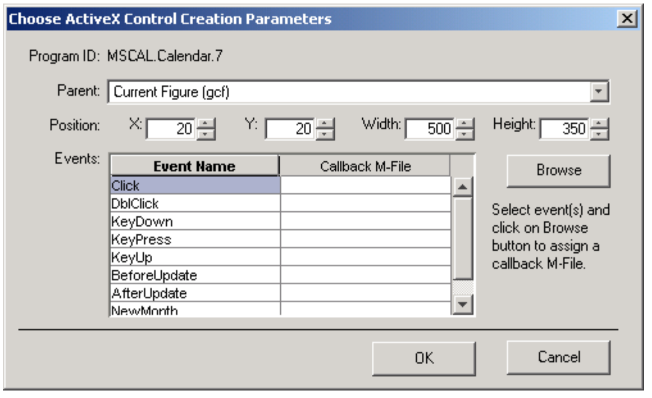


The `actxcontrolselect` interface has a selection pane at the left of the window and a preview pane at the right. Click on one of the control names in the selection pane to see a preview of the control displayed. (If MATLAB cannot create the control, an error message is displayed in the preview pane.) 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 software 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('matlab.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 "COM 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.

Microsoft® Excel® Example

This example creates an OLE Automation server, 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`, `actxGetRunningServer`, `release`, `delete (COM)`, `save (COM)`, `load (COM)`, `interfaces`

Purpose

Append MException objects

Syntax

```
new_ME = addCause(base_ME, cause_ME)
base_ME = addCause(base_ME, cause_ME)
```

Description

new_ME = addCause(base_ME, cause_ME) creates a new MException object new_ME from two existing MException objects, base_ME and cause_ME. addCause constructs new_ME by making a copy of the base_ME object and appending cause_ME to the cause property of that object.

If other errors have contributed to the exception currently being thrown, you can add the MException objects that represent these errors to the cause field of the current MException to provide further information for diagnosing the error at hand. All objects of the MException class have a property called cause which is defined as a vector of additional MException objects that can be added onto a base object of that class.

base_ME = addCause(base_ME, cause_ME) modifies existing MException object base_ME by appending cause_ME to the cause property of that object.

Examples

Example 1

This example attempts to assign data from array D. If D does not exist, the code attempts to recreate D by loading it from a MAT-file. The code constructs a new MException object new_ME to store the causes of the first two errors, cause1_ME and cause2_ME:

```
try
    x = D(1:25);
catch cause1_ME
    try
        filename = 'test204';
        testdata = load(filename);
        x = testdata.D(1:25)
    catch cause2_ME
        base_ME = MException('MATLAB:LoadErr', ...
               'Unable to load from file %s', filename);
```

```
        new_ME = addCause(base_ME, cause1_ME);
        new_ME = addCause(new_ME, cause2_ME);
        throw(new_ME);
    end
end
```

When you run the code, the MATLAB® software displays the following message:

```
??? Unable to load from file test204
```

There are two exceptions in the cause field of `new_ME`:

```
new_ME.cause
ans =
    [1x1 MException]
    [1x1 MException]
```

Examine the `cause` field of `new_ME` to see the related errors:

```
new_ME.cause{:}
ans =

 MException object with properties:

    identifier: 'MATLAB:UndefinedFunction'
       message: 'Undefined function or method 'D' for input
            arguments of type 'double'.'
         stack: [0x1 struct]
         cause: {}
ans =

 MException object with properties:

    identifier: 'MATLAB:load:couldNotReadFile'
       message: 'Unable to read file test204: No such file
            or directory.'
         stack: [0x1 struct]
```

```
         cause: {}
```

Example 2

This example attempts to open a file in a directory that is not on the MATLAB path. It uses a nested `try-catch` block to give the user the opportunity to extend the path. If the still cannot be found, the program issues an exception with the first error appended to the second using `addCause`:

```
function data = read_it(filename);
try
   fid = fopen(filename, 'r');
   data = fread(fid);
catch ME1
   if strcmp(ME1.identifier, 'MATLAB:FileIO:InvalidFid')
      msg = sprintf('\n%s%s%s', 'Cannot open file ', ...
         filename, '. Try another location?  ');
      reply = input(msg, 's')
      if reply(1) == 'y'
          newdir = input('Enter directory name:  ', 's');
      else
          throw(ME1);
      end
      addpath(newdir);
      try
         fid = fopen(filename, 'r');
         data = fread(fid);
      catch ME2
         ME3 = addCause(ME2, ME1)
         throw(ME3);
      end
      rmpath(newdir);
   end
end
fclose(fid);
```

If you run this function in a try-catch block at the command line, you can look at the MException object by assigning it to a variable (e) with the catch command.

```
try
   d = read_it('anytextfile.txt');
catch e
end

e
e =
 MException object with properties:

    identifier: 'MATLAB:FileIO:InvalidFid'
       message: 'Invalid file identifier.  Use fopen to
generate a valid file identifier.'
         stack: [1x1 struct]
         cause: {[1x1 MException]}

  Cannot open file anytextfile.txt. Try another location?y
Enter directory name:  xxxxxxx
Warning: Name is nonexistent or not a directory: xxxxxxx.
> In path at 110
  In addpath at 89
```

See Also

try, catch, error, assert, , MException, throw(MException), rethrow(MException), throwAsCaller(MException), getReport(MException), disp(MException), isequal(MException), eq(MException), ne(MException), last(MException)

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

Create event listener

Syntax

```
lh = addlistener(Hsource,'EventName',callback)
lh = addlistener(Hsource,property,'EventName',callback)
```

Description

`lh = addlistener(Hsource,'EventName',callback))` creates a listener for the specified event.

`lh = addlistener(Hsource,property,'EventName',callback)` creates a listener for one of the predefined property events. There are four property events:

- `PreSet` — triggered just before the property value is set, before calling its set access method.
- `PostSet` — triggered just after the property value is set.
- `PreGet` — triggered just before a property value query is serviced, before calling its get access method.
- `PostGet` — triggered just after returning the property value to the query

See "Defining Events and Listeners — Syntax and Techniques" for more information.

Arguments

`Hsource`
: Handle of the object that is the source of the event, or an array of source handles.

`EventName`
: Name of the event, which is triggered by the source objects.

`callback`
: Function handle referencing a function to execute when the event is triggered.

`property`
: Character string that can be:

- the name of the property
- a cell array of strings where each string is the name of a property that exists in object array `Hsource`
- a `meta.property` object or an array of `meta.property` objects
- a cell array of `meta.property` objects

If `Hsource` is a scalar, then any of the properties can be dynamic properties. If `Hsource` is non-scalar, then the properties must belong to the class of `Hsource` and can not include dynamic properties (which are not part of the class definition).

For more information, see the following sections:

- The `GetObservable` and `SetObservable` property attributes in the "Property Attributes" table.
- "Creating Property Listeners"
- "Dynamic Properties — Adding Properties to an Instance"

`lh`

Handle of the `event.listener` object returned by `addlistener`.

See Also

`handle`, `notify (handle)`

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.

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

Examples

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

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.

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

Examples

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

addprop (dynamicprops)

Purpose Add dynamic property

Syntax

```
P = addprop(Hobj,'PropName')
```

Description

`P = addprop(Hobj,'PropName')` adds a property named `PropName` to each object in array `Hobj`. The class definition is not affected by the addition of dynamic properties. Note that you can add dynamic properties only to objects derived from the `dynamicprops` class. You can set and retrieve the data in dynamic properties as you would any property.

The output argument `P` is an array the same size as `Hobj` of `meta.DynamicProperty` objects, which you can use to assign `SetMethod` and `GetMethod` functions to the property. These functions operate just like property set and get access methods.

See "Dynamic Properties — Adding Properties to an Instance" for more information and examples.

See Also `handle`, `dynamicprops`

Purpose

Add custom property to COM 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 (COM)`, `set (COM)`, `inspect`

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 Fundamentals documentation.

Examples

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

```
Time Series Collection Object: unnamed

Time vector characteristics

      Start time            1 seconds
      End time              5 seconds

Member Time Series Objects:

      acceleration
      speed
```

The members of `tsc` are listed by name at the bottom: `acceleration` and `speed`. These are the `Name` properties of 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, $Ai'(Z)$
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)
```

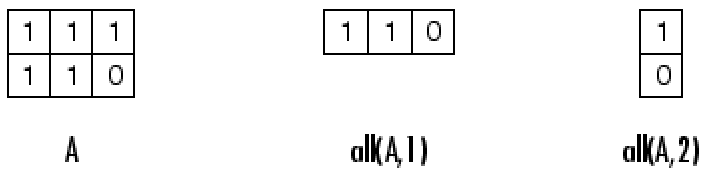
Description `B = all(A)` tests whether *all* the elements along various dimensions of an array are nonzero or logical `1` (`true`).

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 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® software 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 software 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 the MATLAB® software. 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 "Working in 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)
```

For more information see "Positioning Annotations in Data Space" in the MATLAB Graphics documentation.

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

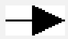
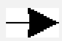
Length of the arrowhead. Specify this property in points (1 point = 1/72 inch). See also `HeadWidth`.

`HeadStyle`

select string from list

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

Annotation Arrow Properties

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

`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`.

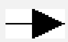
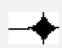
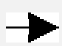
The first arrowhead is located at the end defined by the point `x(end)`, `y(end)`. See also the `X` and `Y` properties.

`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

`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

`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

`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

`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`

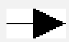
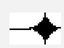
Weight of text characters. MATLAB uses this property to select a font from those available on your system. Generally, setting this property to `bold` or `demi` causes MATLAB to use a bold font.

`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			

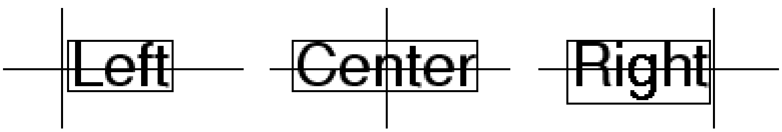
HeadWidth
scalar value in points

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

`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		\omega	ω	\diamondsuit	♦
\zeta	ζ	\Gamma	Γ	\heartsuit	♥
\eta	η	\Delta	Δ	\spadesuit	♠

Character Sequence	Symbol	Character Sequence	Symbol	Character Sequence	Symbol
\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	ℵ
\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	´

Character Sequence	Symbol	Character Sequence	Symbol	Character Sequence	Symbol
\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

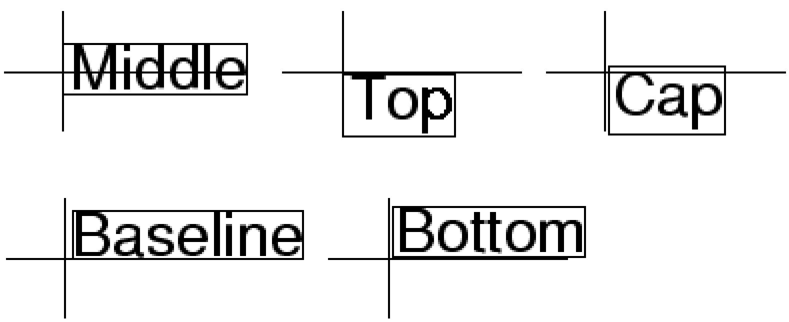
top | cap | {middle} | baseline | bottom

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`.

`FitBoxToText`

`on | off`

Automatically adjust text box width and height to fit text. When this property is `on` (the default), MATLAB automatically resizes textboxes to fit the *x*-extents and *y*-extents of the text strings they contain. When it is `off`, text strings are wrapped to fit the width of their textboxes, which can cause them to extend below the bottom of the box.

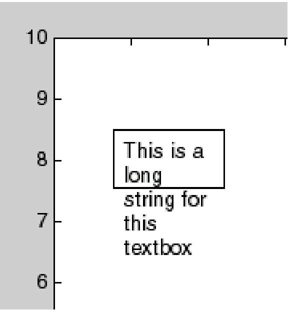
If you resize a textbox in plot edit mode or change the width or height of its `position` property directly, MATLAB sets the object's `FitBoxToText` property to `'off'`. You can toggle this property with `set`, with the Property Inspector, or in plot edit mode via the object's context menu.

`FitHeightToText`

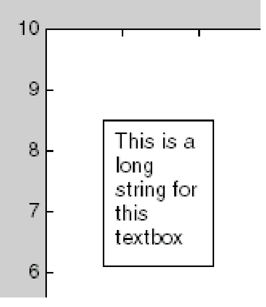
`on | off`

Automatically adjust text box width and 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 can extend beyond the bottom of the text box.

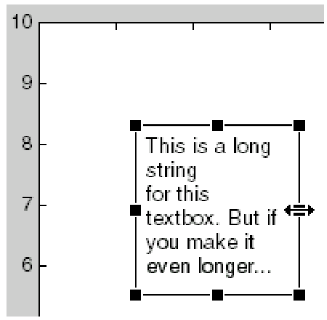
Note The `FitHeightToText` property is obsolete. To control line wrapping behavior in textboxes, use `fitBoxToText` instead.



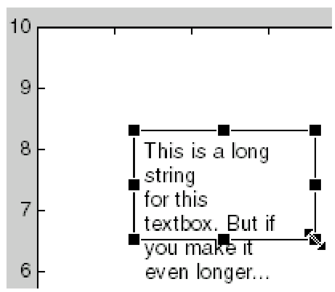
When you set this mode to `on`, MATLAB automatically adjusts the height of the text box to accommodate the string, doing so as you create or edit the string.



The fit-size-to-text behavior turns off if you resize the text box programmatically or manually in plot edit mode.



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).

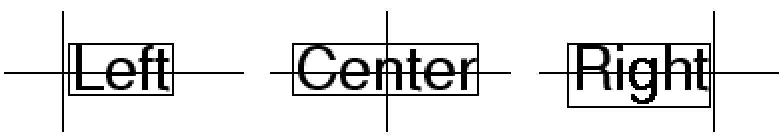
FontWeight
light | {normal} | demi | bold

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 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

`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	≤

Character Sequence	Symbol	Character Sequence	Symbol	Character Sequence	Symbol
\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	↓
\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	ℵ
\Im	ℑ	\Re	ℜ	\wp	℘
\otimes	⊗	\oplus	⊕	\oslash	∅
\cap	∩	\cup	∪	\supseteq	⊇

Character Sequence	Symbol	Character Sequence	Symbol	Character Sequence	Symbol
\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`

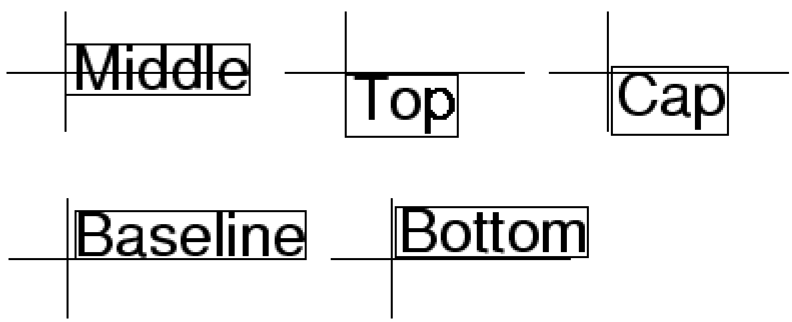
`top | cap | {middle} | baseline | bottom`

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 The MATLAB® software 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

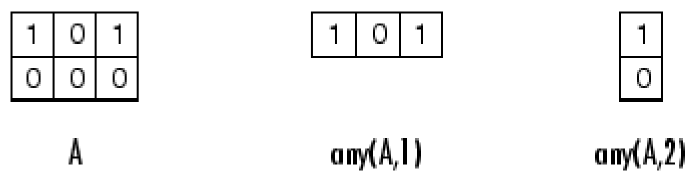
`B = any(A)` tests whether *any* of the elements along various dimensions of an array is a nonzero number or is logical `1` (`true`). `any` ignores entries that are `NaN` (Not a Number).

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
```

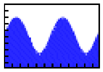
See Also

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 and Development Environment 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.

Note The `v6` option enables users of MATLAB Version 7.x of to create FIG-files that previous versions can open. It is obsolete and will be removed in a future version of MATLAB.

See Plot Objects and Backward Compatibility for more information.

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.

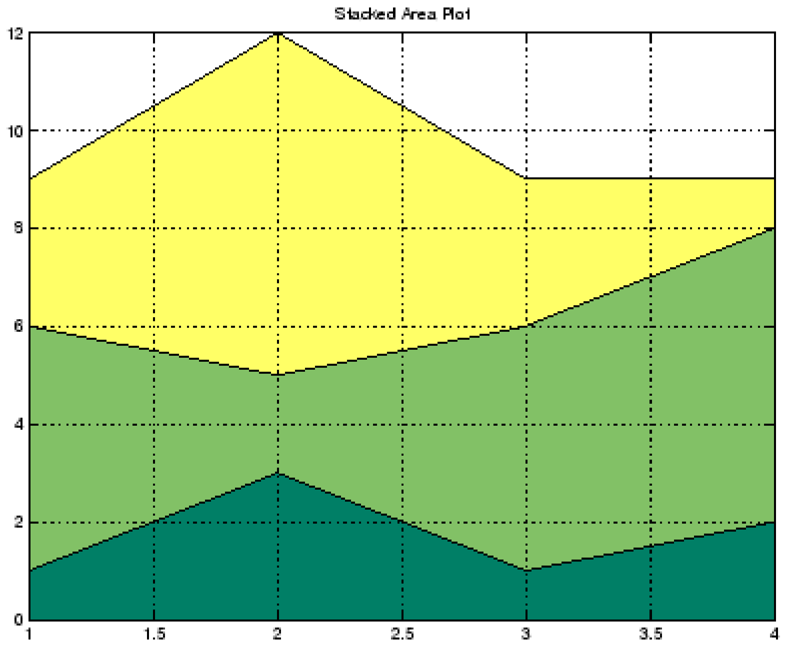
Some areaseries object properties that you set on an individual areaseries object set the values for all areaseries objects in the graph. See the property descriptions for information on specific properties.

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'
```

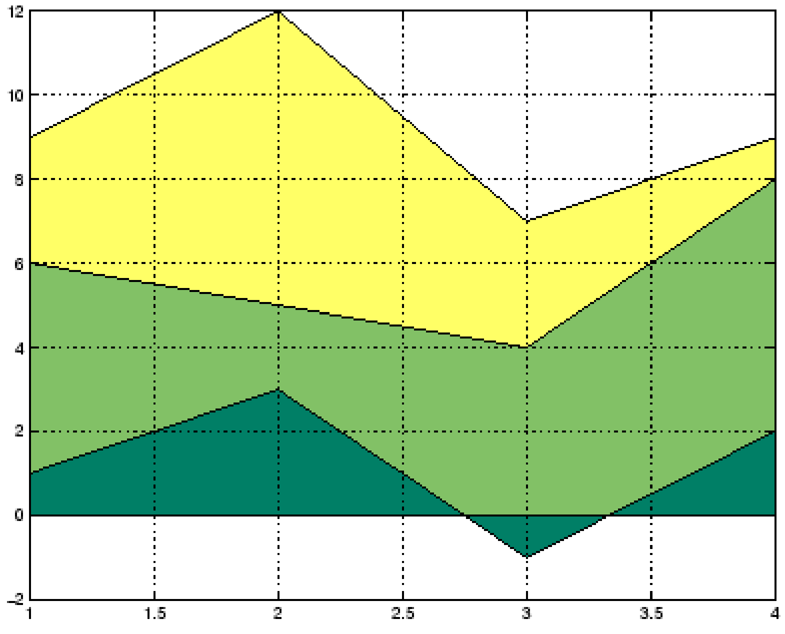


Adjusting the Base Value

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
```

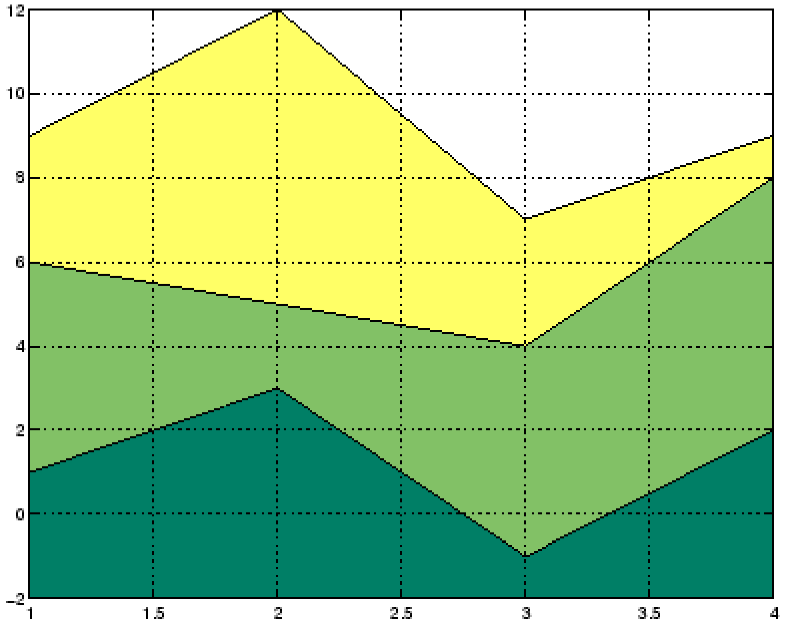
The area graph now looks like this:



Adjusting the `BaseValue` property improves the appearance of the graph:

```
set(h,'BaseValue',-2)
```

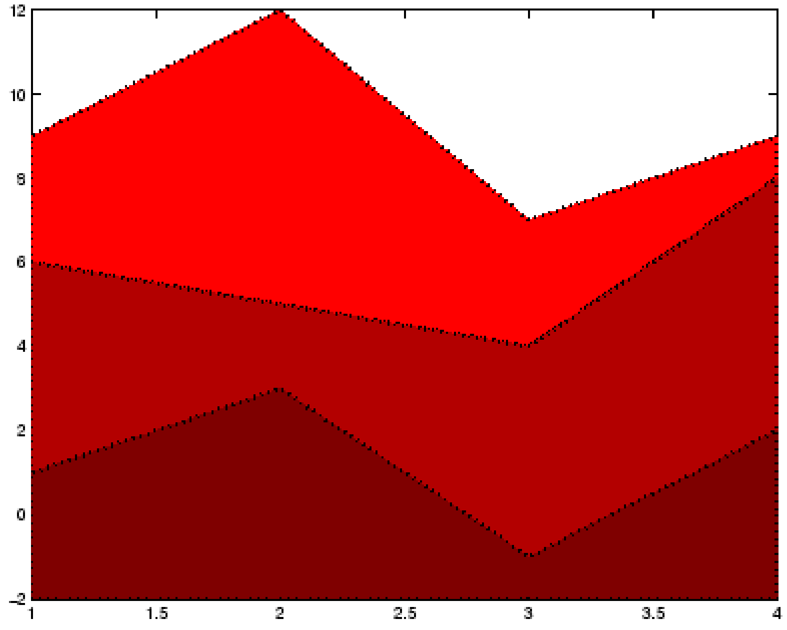
Setting the `BaseValue` property on one areaseries object sets the values of all objects.



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 1-90 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.

`Annotation`

`hg.Annotation` object Read Only

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

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

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

IconDisplayStyle Value	Purpose
`on`	Include the areaseries object in a legend as one entry, but not its children objects
`off`	Do not include the areaseries or its children in a legend (default)
`children`	Include only the children of the areaseries as separate entries in the legend

Setting the `IconDisplayStyle` property

These commands set the `IconDisplayStyle` of a graphics object with handle `hobj` to `children`, which causes each child object to have an entry in the legend:

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

Using the `IconDisplayStyle` property

See “Controlling Legends” for more information and examples.

`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 (default is empty string)

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

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

See "Controlling Legends" for more examples.

`EdgeColor`

`{[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

`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 2-662 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.

---

arrayfun

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

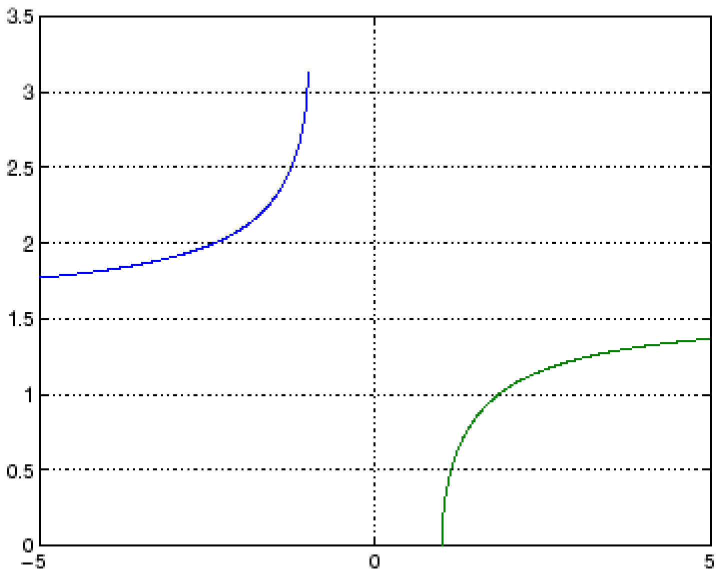
`Y = asec(X)` returns the inverse secant (arcsecant) for each element of `X`.

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™ business, by Kwok C. Ng, and others. For information about FDLIBM, see `http://www.netlib.org`.

See Also

`asecd`, `asech`, `sec`

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

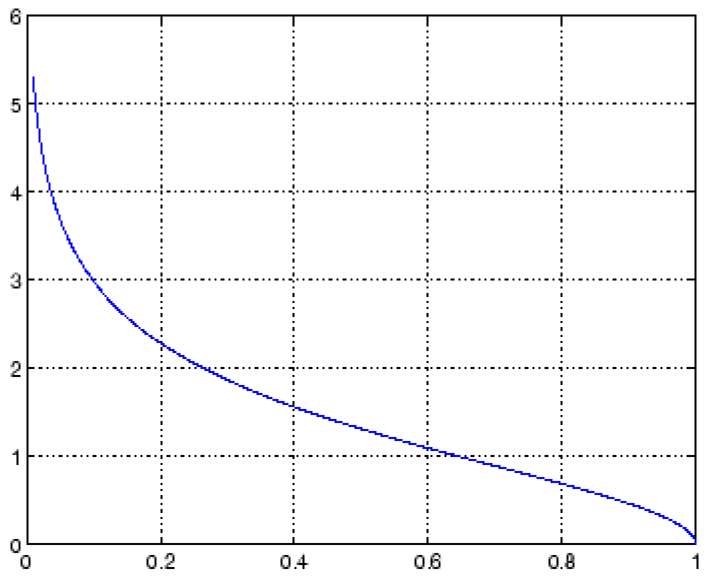
Y = asech(X) returns the inverse hyperbolic secant for each element of X.

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

$$\text{sech}^{-1}(z) = \cosh^{-1}\left(\frac{1}{z}\right)$$

Algorithm

asech uses FDLIBM, which was developed at SunSoft, a Sun Microsystems™ business, by Kwok C. Ng, and others. For information about FDLIBM, see http://www.netlib.org.

See Also

asec, sech

asin

Purpose Inverse sine; result in radians

Syntax

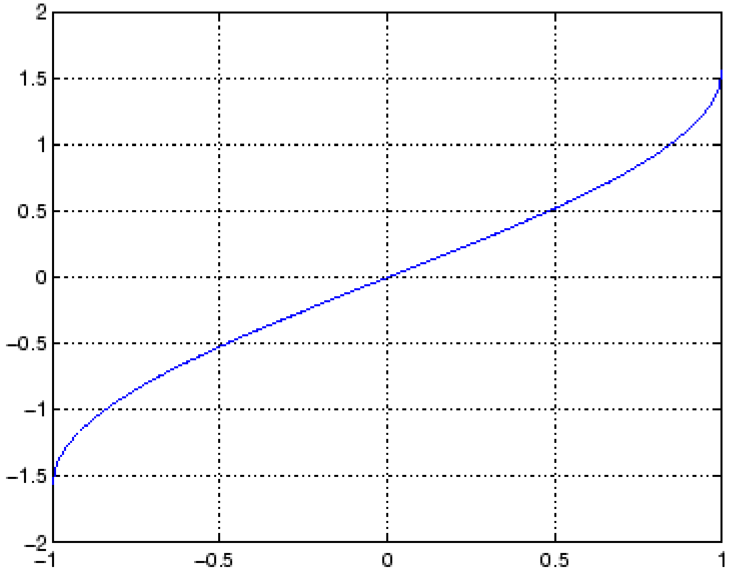
```
Y = asin(X)
```

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

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

Algorithm

`asin` uses FDLIBM, which was developed at SunSoft, a Sun Microsystems™ business, by Kwok C. Ng, and others. For information about FDLIBM, see `http://www.netlib.org`.

See Also

`asind`, `asinh`, `sin`, `sind`, `sinh`

asind

Purpose Inverse sine; result in degrees

Syntax

```
Y = asind(X)
```

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

See Also `asin`, `asinh`, `sin`, `sind`, `sinh`

Purpose Inverse hyperbolic sine

Syntax

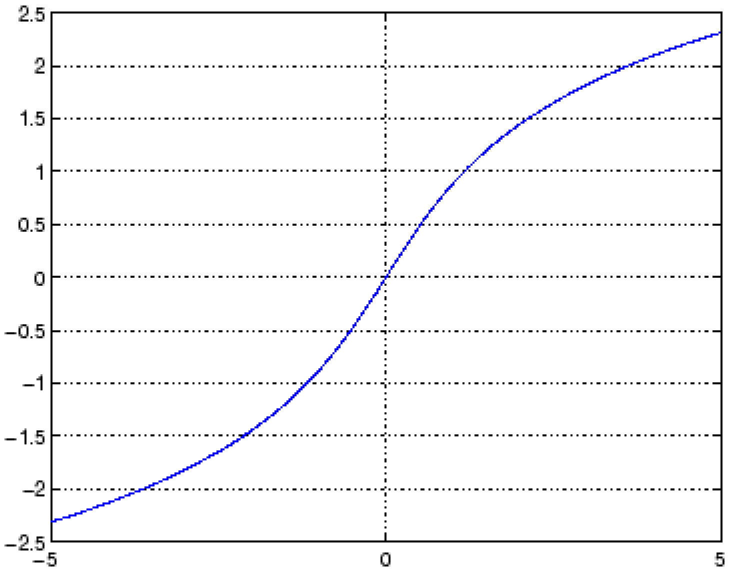
```
Y = asinh(X)
```

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 $-5 \le x \le 5$.

```
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™ business, by Kwok C. Ng, and others. For information about FDLIBM, see http://www.netlib.org.

See Also

asin, asind, sin, sinh, sind

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`, the MATLAB® software 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 Fundamentals 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 Fundamentals 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

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.

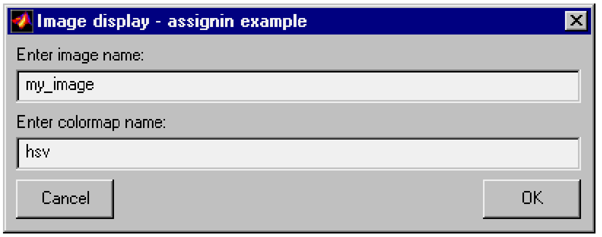
The `assignin` function is particularly useful for these tasks:

- 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

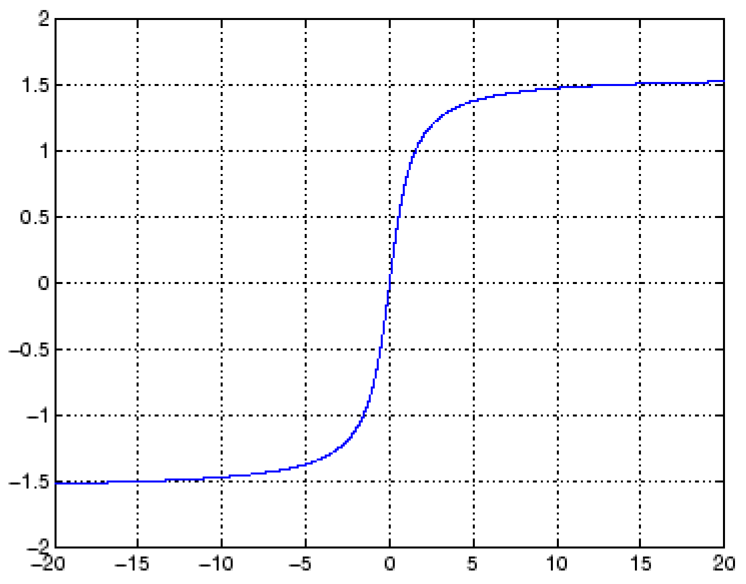
`Y = atan(X)` returns the inverse tangent (arctangent) for each element of `X`. For real elements of `X`, `atan(X)` is in the range $[-\pi/2, \pi/2]$.

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™ business, by Kwok C. Ng, and others. For information about FDLIBM, see `http://www.netlib.org`.

See Also

`atan2`, `tan`, `atand`, `atanh`

Purpose Four-quadrant inverse tangent

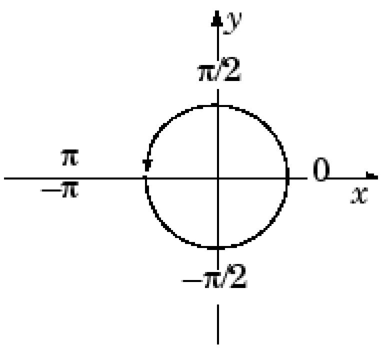
Syntax

```
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 software 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™ 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`

atanh

Purpose

Inverse hyperbolic tangent

Syntax

```
Y = atanh(X)
```

Description

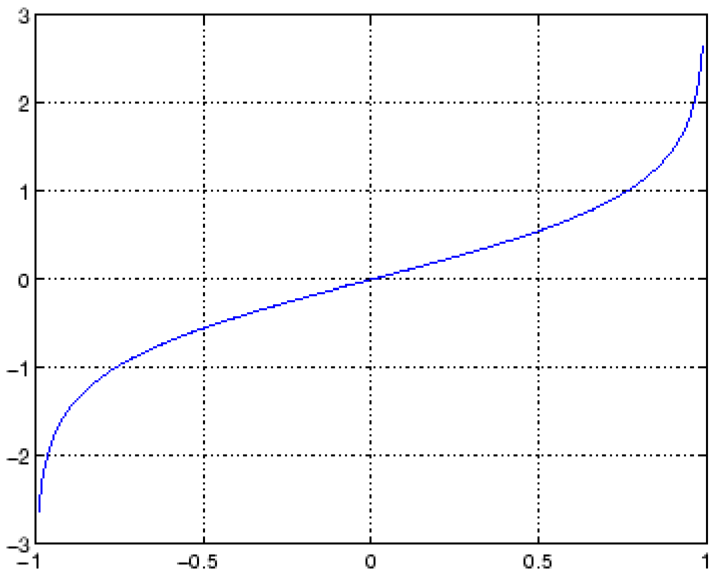
The `atanh` function operates element-wise on arrays. The function's domains and ranges include complex values. All angles are in radians.

`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™ business, by Kwok C. Ng, and others. For information about FDLIBM, see `http://www.netlib.org`.

See Also

`atan2`, `atan`, `tanh`

audioplayer

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

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 (only 44100 on Macintosh® systems). The value of `nbits` must be `8`, `16`, or `24`, on Microsoft® 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

Using a microphone, record your voice, using a sample rate of 44100 Hz, 16 bits per sample, and one channel. Speak into the microphone, then pause the recording. Play back what you have recorded so far. Record some more, then stop the recording. Finally, return the recorded data to MATLAB® as an int16 array.

```
r = audiorecorder(44100, 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`.
`getplayer(y)`	Creates an `audioplayer` and returns a handle to the created `audioplayer`.

Method	Description
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

Property	Description	Type
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
StartFcn	Handle to a user-specified callback function that is executed once when recording starts.	User-settable

Property	Description	Type
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

aufinfo

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`

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`

auwrite

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. This parameter can be specified only when the `'compression'` parameter is set to `'MSVC'`, `'RLE'`, or `'None'`	There is no default colormap.

Parameter	Value	Default
'compression'	A text string specifying the compression codec to use. • On Windows: 'Indeo3' 'Indeo5' 'Cinepak' 'MSVC' 'RLE' 'None' • On UNIX: 'None' 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.	'Indeo5' on Windows. 'None' on UNIX.
'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`

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.

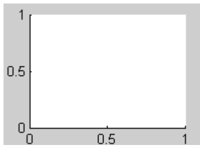
Note If you are using MATLAB on a Windows platform, consider using the new `mmreader` function, which adds support for more video formats and codecs.

See also

`avifile`, `aviinfo`, `mmreader`, `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.

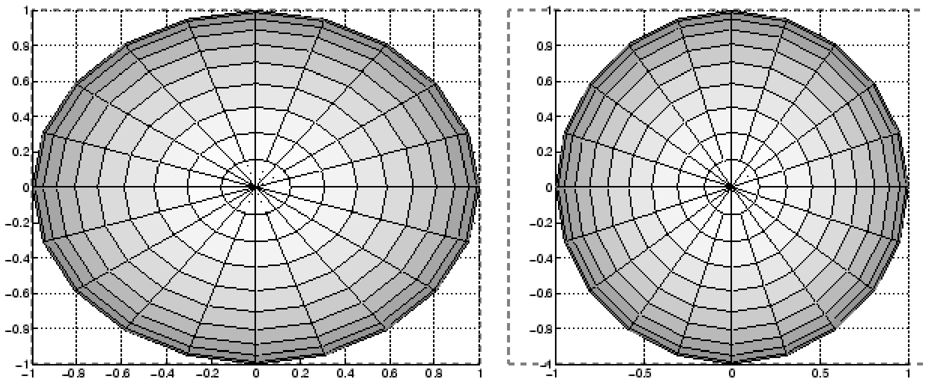
While the basic purpose of an axes object is to provide a coordinate system for plotted data, axes properties provide considerable control over the way MATLAB displays data.

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,

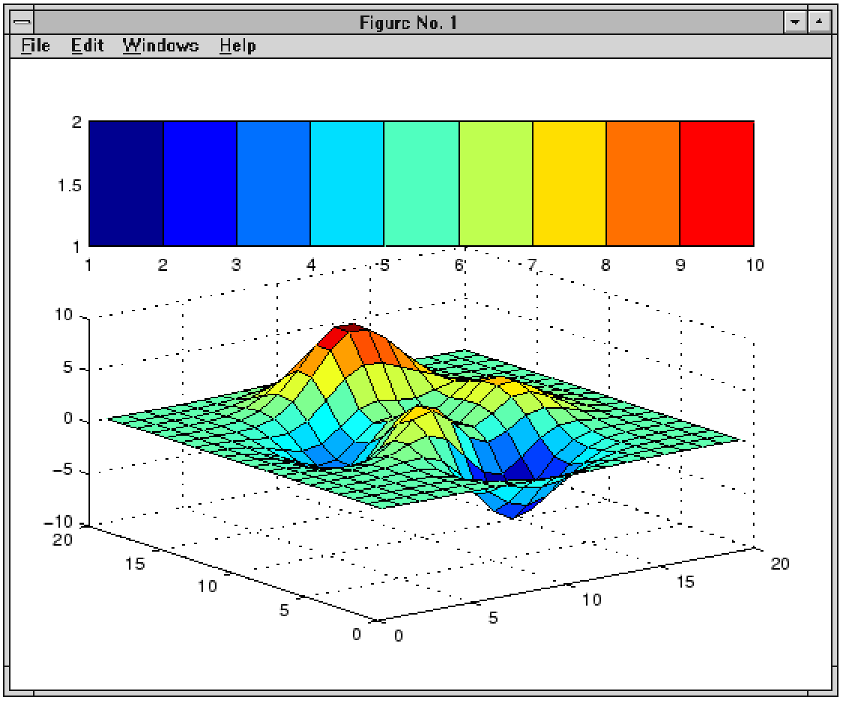
```
position_rectangle = [left, bottom, width, height];
```

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.

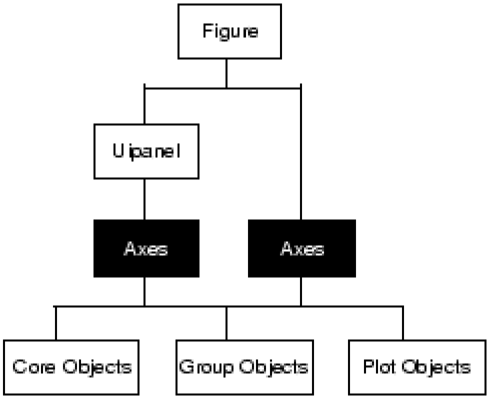
You can define multiple axes in a single figure window:

```
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 1-98 for related functions

"Axes Properties" for more examples

See "Types of Graphics Objects" for information on core, group, plot, and annotation objects.

Axes Properties

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 and the title are also children of axes, but their HandleVisibility properties are set to off. 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.

See the figure CurrentPoint property for more information.

`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 theline 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.

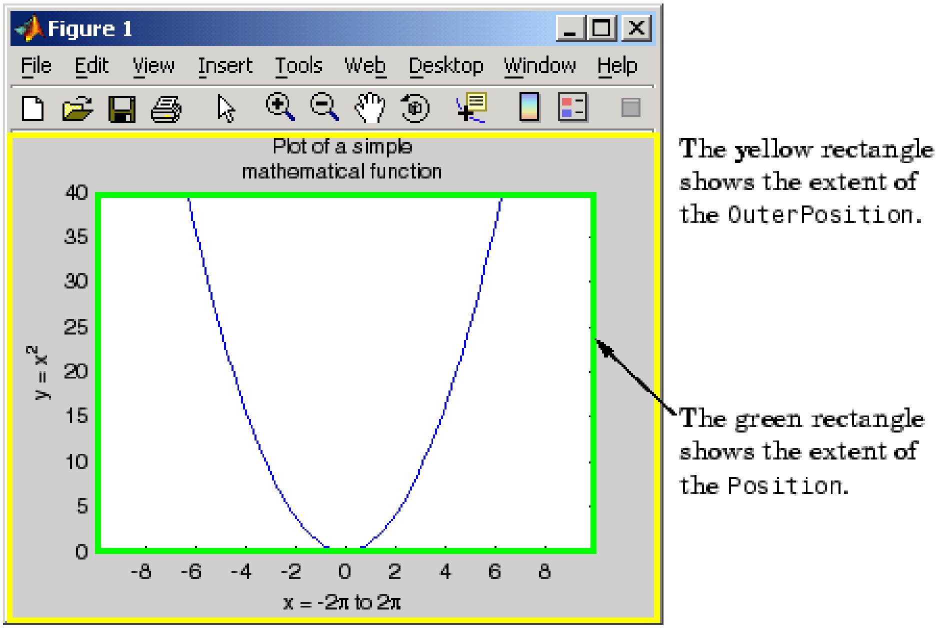
`OuterPosition`
: four-element vector

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` property 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® default behavior to computie 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). This option 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.

Remarks

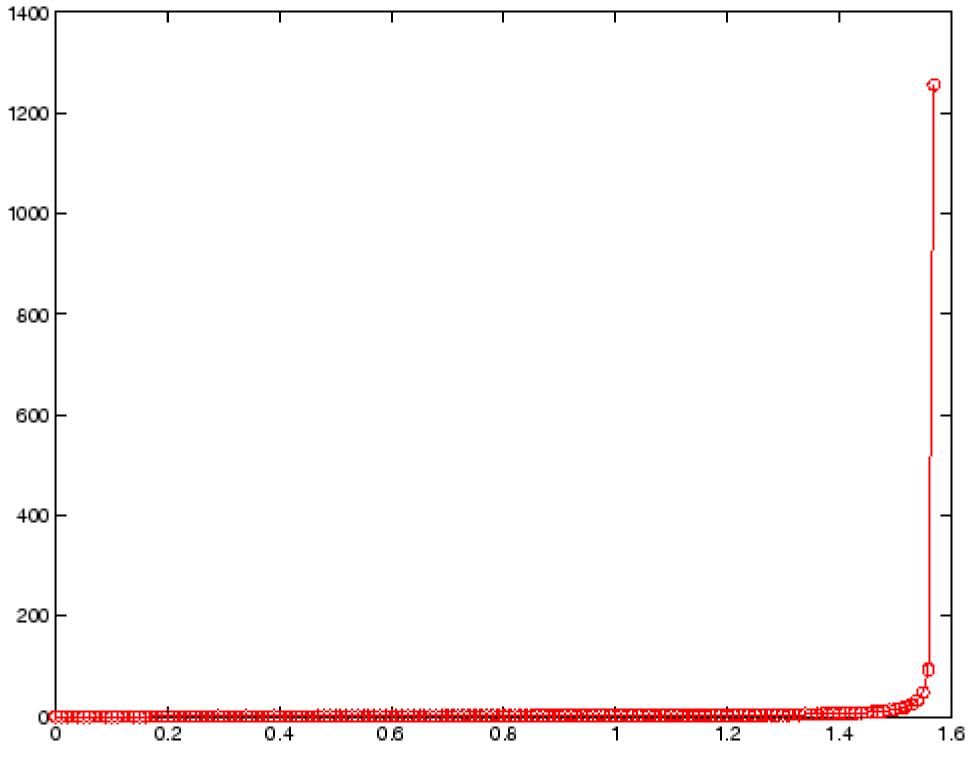
You can create an axes (and a figure for it) if none exists with the `axis` command. However, if you specify non-default limits or formatting for the axes when doing this, such as `[4 8 2 9]`, `square`, `equal`, or `image`, the property is ignored because there are no axis limits to adjust in the absence of plotted data. To use `axis` in this manner, you can set `hold on` to keep preset axes limits from being overridden.

Examples

The statements

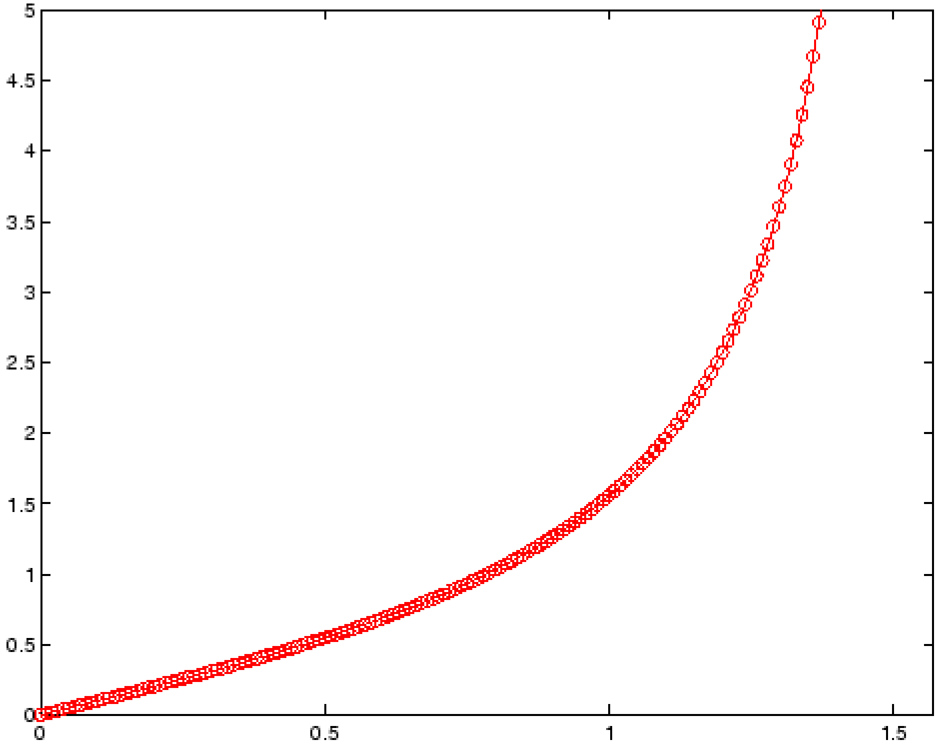
```
x = 0:.025:pi/2;
plot(x,tan(x),'-ro')
```

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 1-98 for related functions

For aspect ratio behavior, see in the axes properties reference page.

balance

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`

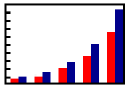
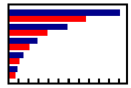
References

[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.

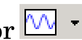
bar, barh

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 and Development Environment documentation.

Syntax

```
bar(Y)
bar(x,Y)
bar(...,width)
bar(...,'style')
bar(...,'bar_color')
bar(...,'PropertyName',PropertyValue,...)
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.
- `'histc'` displays the graph in histogram format, in which bars touch one another.
- `'hist'` also displays the graph in histogram format, but centers each bar over the *x*-ticks, rather than making bars span *x*-ticks as the `histc` option does.

Note When you use either the `hist` or `histc` option, you cannot also use parameter/value syntax. These two options create graphic objects that are patches rather than barseries. See "Backward-Compatible Versions" on page 2-328 for details.

`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(...,'PropertyName',PropertyValue,...)` set the named property or properties to the specified values. Properties cannot be specified when the `hist` or `histc` options are used. See the barseries property descriptions for information on what properties you can set.

`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. Patch objects are also created when the `hist` and `histc` options are used, even if the `V6` option is not. See patch object properties for a discussion of the properties you can set to control the appearance of these bar graphs.

Note The v6 option enables users of MATLAB Version 7.x of to create FIG-files that previous versions can open. It is obsolete and will be removed in a future version of MATLAB.

See

Plot Objects and Backward Compatibility for more information.

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).

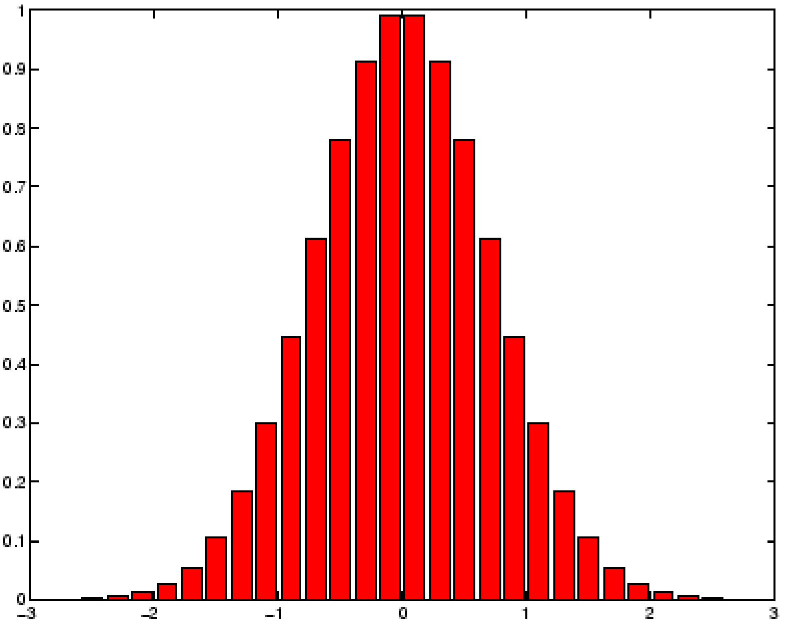
Note that some barseries object properties set on an individual barseries object set the values for all barseries objects in the graph. See the barseries property descriptions for information on specific properties.

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.

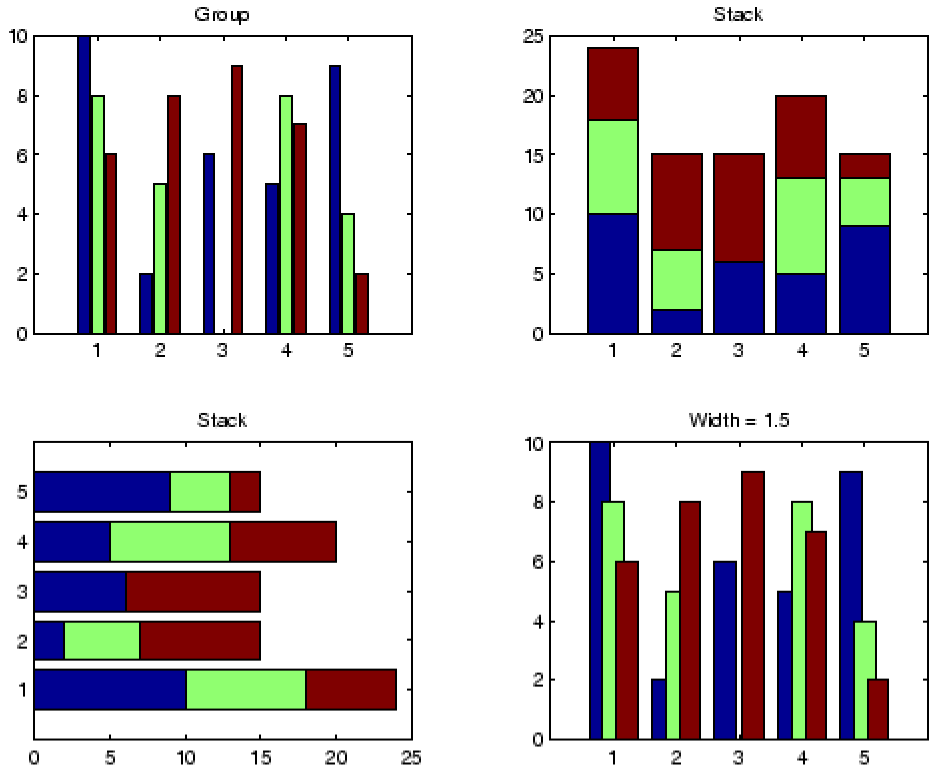
```
x = -2.9:0.2:2.9;
bar(x,exp(-x.*x),'r')
```



Bar Graph Options

This example illustrates some bar graph options.

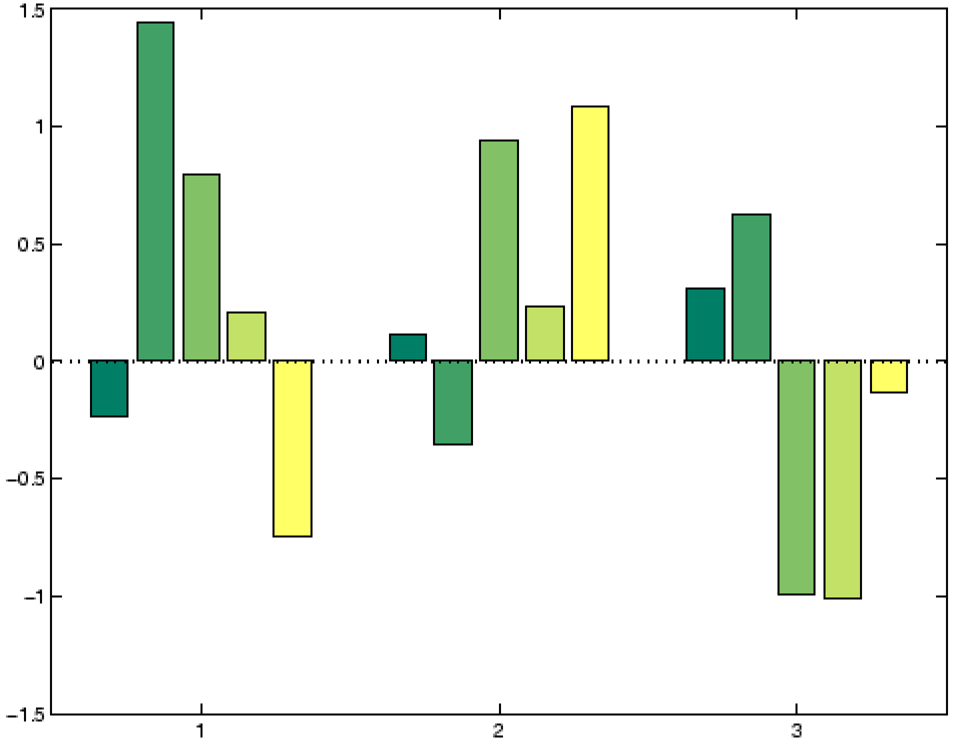
```
Y = round(rand(5,3)*10);
subplot(2,2,1)
bar(Y,'group')
title 'Group'
subplot(2,2,2)
bar(Y,'stack')
title 'Stack'
subplot(2,2,3)
barh(Y,'stack')
title 'Stack'
subplot(2,2,4)
bar(Y,1.5)
title 'Width = 1.5'
```



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

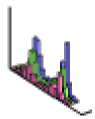
"Area, Bar, and Pie Plots" on page 1-90 for related functions

Barseries Properties

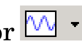
"Bar and Area Graphs" for more examples

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 and Development Environment 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).

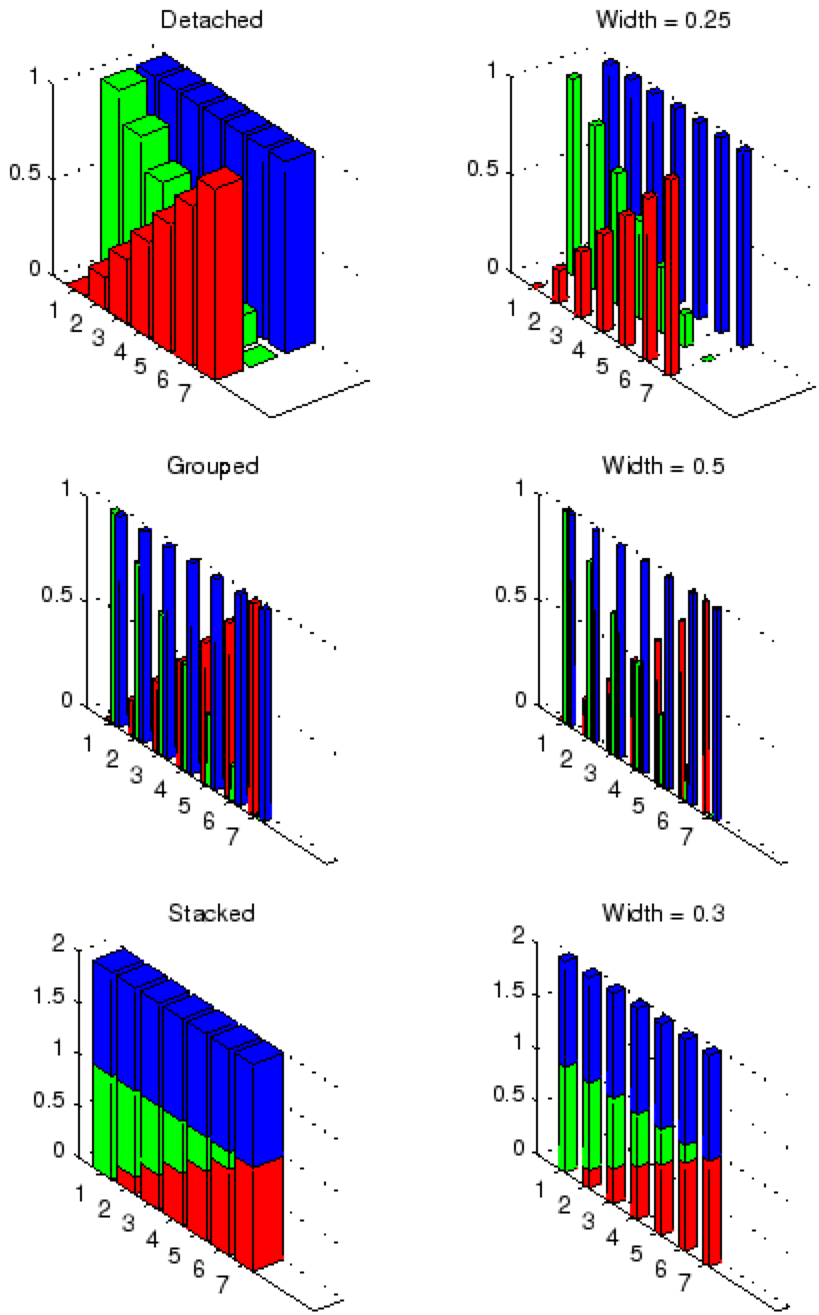
h = bar3(...) returns a vector of handles to patch graphics objects, one for each created. bar3 creates one patch object per column in Y. When Y is a matrix, bar3 creates one patch graphics object per column in Y.

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 1-90 for related functions

"Bar and Area Graphs" for more examples

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.

`Annotation`

`hg.Annotation` object Read Only

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

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

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

IconDisplayStyle Value	Purpose
`on`	Include the barseries object in a legend as one entry, but not its children objects
`off`	Do not include the barseries or its children in a legend (default)
`children`	Include only the children of the barseries as separate entries in the legend

Setting the `IconDisplayStyle` property

These commands set the `IconDisplayStyle` of a graphics object with handle `hobj` to `children`, which causes each child object to have an entry in the legend:

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

Using the `IconDisplayStyle` property

See "Controlling Legends" for more information and examples.

`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 (default is empty string)

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

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

See "Controlling Legends" for more examples.

EdgeColor
{[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

`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” in the `bar, barh` reference page 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.

---

base2dec

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`).

bench

Purpose

MATLAB Benchmark

Syntax

```
bench
bench(N)
bench(0)
t = bench(N)
```

Description

`bench` times six different MATLAB tasks and compares the execution speed with the speed of several other computers. The six tasks are:

Test	Description	Performance Factors
LU	Perform LU of a full matrix	Floating-point, regular memory access
FFT	Perform FFT of a full vector	Floating-point, irregular memory access
ODE	Solve van der Pol equation with ODE45	Data structures and M-files
Sparse	Solve a symmetric sparse linear system	Mixed integer and floating-point
2-D	Plot Bernstein polynomial graph	2-D line drawing graphics
3-D	Display animated L-shape membrane logo	3-D animated OpenGL graphics

A final bar chart shows speed, which is inversely proportional to time. The longer bars represent faster machines, and the shorter bars represent the slower ones.

`bench(N)` runs each of the six tasks N times.

`bench(0)` just displays the results from other machines.

`t = bench(N)` returns an N-by-6 array with the execution times.

Remarks

The comparison data for other computers is stored in the following text file. Updated versions of this file are available from MATLAB Central:

```
http://www.mathworks.com/matlabcentral/fileexchange/loadFile.do?objectId=1836&objectType;=file#
```

This benchmark is intended to compare performance of one particular version of MATLAB on different machines. It does not offer direct comparisons between different versions of MATLAB. The tasks and problem sizes change from version to version.

The LU and FFT tasks involve large matrices and long vectors. Machines with less than 64 megabytes of physical memory or without optimized Basic Linear Algebra Subprograms may show poor performance.

The 2-D and 3-D tasks measure graphics performance, including software or hardware support for OpenGL. The command

```
OpenGL info
```

describes the OpenGL support available on a particular machine.

Fluctuations of five or ten percent in the measured times of repeated runs on a single machine are not uncommon. Your own mileage may vary.

See Also

`profile`, `profsave`, `mlint`, `mlintrpt`, `memory`, `pack`, `tic`, `cputime`, `rehash`

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

$$z^2\frac{d^2y}{dz^2} + z\frac{dy}{dz} + (z^2 - \nu^2)y = 0$$

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`.

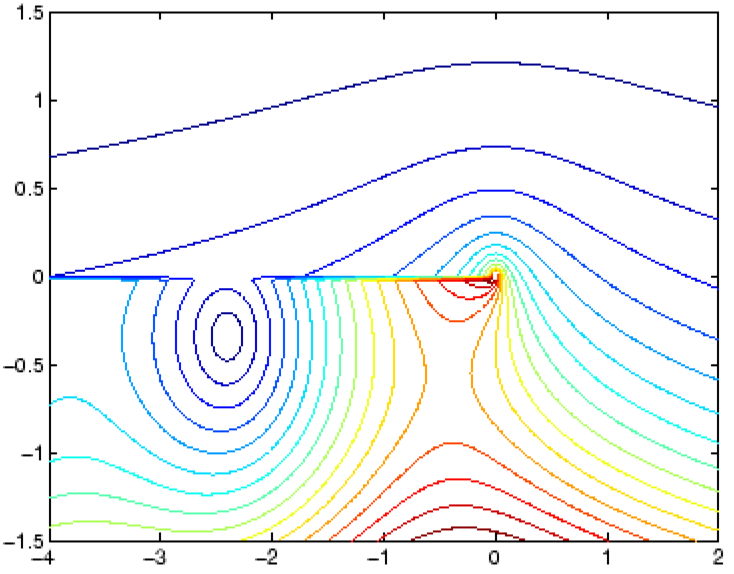
ierr	Description
0	`besselh` successfully computed the Hankel function for this element.
1	Illegal arguments.
2	Overflow. Returns `Inf`.
3	Some loss of accuracy in argument reduction.
4	Unacceptable loss of accuracy, `Z` or `nu` too large.
5	No convergence. Returns `NaN`.

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*.

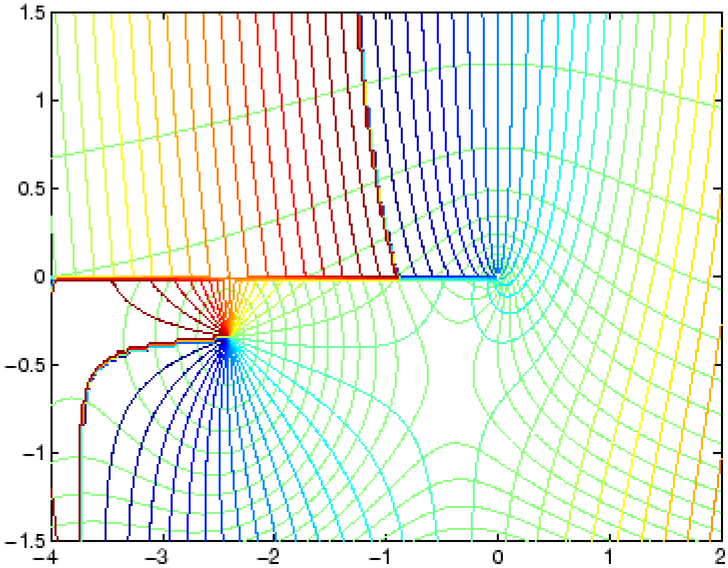
It first generates the modulus contour plot

```
[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.

besseli

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

$$z^2\frac{d^2y}{dz^2} + z\frac{dy}{dz} - (z^2 + \nu^2)y = 0$$

where ν is a real constant, is called the *modified Bessel's equation*, and its solutions are known as *modified Bessel functions*.

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)
I = betainc(X,Z,tail)
```

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.

`I = betainc(X,Z,tail)` specifies the tail of the incomplete beta function. Choices are:

`'lower'` (the default)	Computes the integral from `0` to `x`
`'upper'`	Computes the integral from `x` to `1`

These functions are related as follows:

```
1-betainc(X,Z,W) = betainc(X,Z,W,'upper')
```

Note that especially when the upper tail value is close to `0`, it is more accurate to use the `'upper'` option than to subtract the `'lower'` value from `1`.

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.

, 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 software 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.

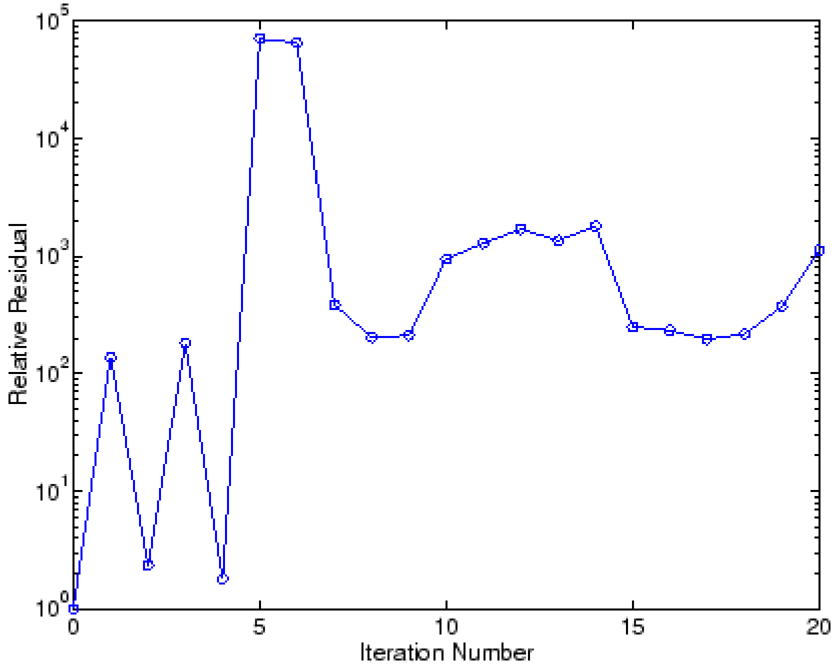
```
x = A \ b;
norm(b-A*x) / norm(b)

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
```

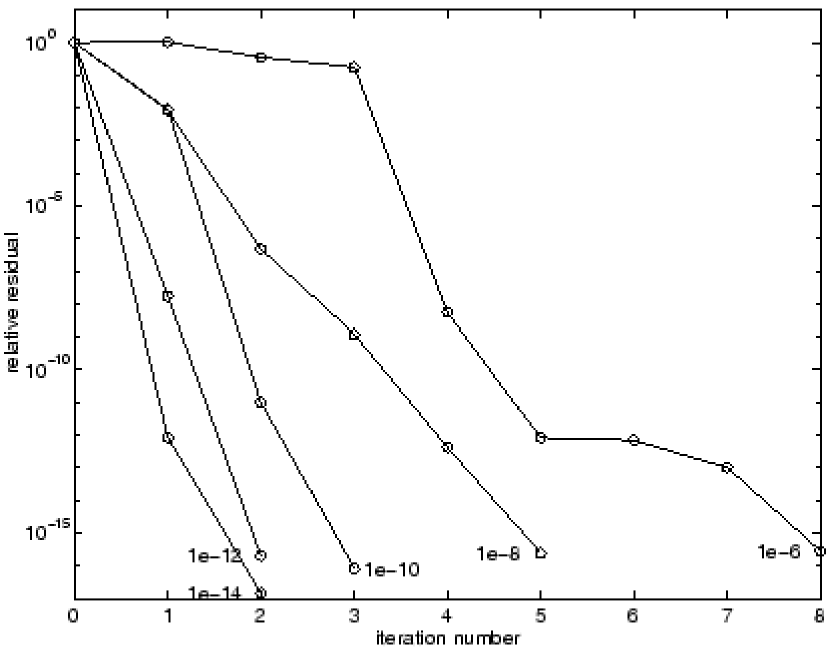
This time U2 is nonsingular and may be an appropriate preconditioner.

```
[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.

, 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 software 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.

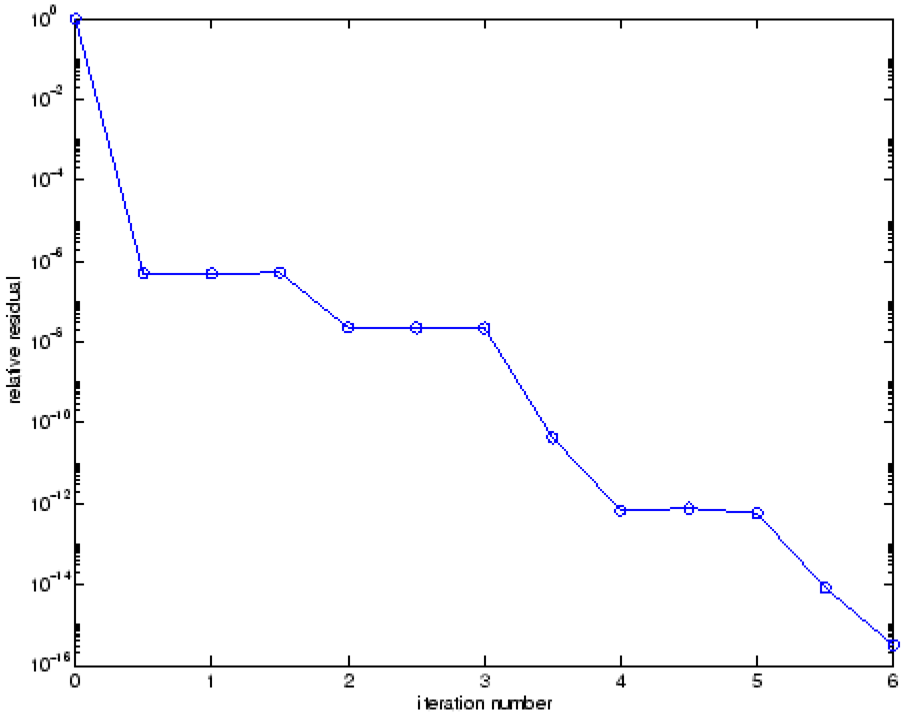
```
[L1,U1] = luinc(A,1e-5);
[x1,flag1] = bicgstab(A,b,1e-6,20,L1,U1)
```

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

$$\begin{bmatrix} a & 0 & 0 & 0 & 0 \\ 0 & b & 0 & 0 & 0 \\ 0 & 0 & c & 0 & 0 \\ 0 & 0 & 0 & d & 0 \\ 0 & 0 & 0 & 0 & \dots \end{bmatrix}$$

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 1-98 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 1-100 for related functions

"Altering Colormaps" for more information

Purpose

Interactively mark, delete, modify, and save observations in graphs

GUI Alternatives

To turn data brushing on or off, use the Data Brushing tool  in the figure toolbar, the right side of which drops down as a color palette for changing the current brushing color. For details, see "Marking Up Graphs with Data Brushing" in the MATLAB® Data Analysis documentation.

Syntax

```
brush on
brush off
brush
brush color
brush(figure_handle,...)
brushobj = brush(figure_handle)
```

Description

Data brushing is a mode for interacting with graphs in figure windows in which you can click data points or drag a selection rectangle around data points to highlight observations in a color of your choice. Highlighting takes different forms for different types of graphs, and brushing marks persist—even in other interactive modes—until removed by deselecting them.

`brush on` turns on interactive data brushing mode.

`brush off` turns brushing mode off, leaving any brushed observations still highlighted.

`brush` by itself toggles the state of the data brushing tool.

`brush color` sets the current color used for brushing graphics to the specified `ColorSpec`. Changing brush color affects subsequent brushing, but does not change the color of observations already brushed or the brush tool's state.

`brush(figure_handle,...)` applies the function to the specified figure handle.

`brushobj = brush(figure_handle)` returns a *brush mode object* for that figure, useful for controlling and customizing the figure's brushing state. The following properties of such objects can be modified using `get` and `set`:

`Enable 'on' | {'off'}`	Specifies whether this figure mode is currently enabled on the figure.
`FigureHandle`	The associated figure handle. This property supports `get` only.
`Color`	Specifies the color to be used for brushing.

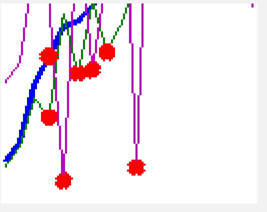
`brush` cannot return a brush mode object at the same time you are calling it to set a brushing option.

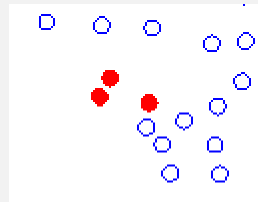
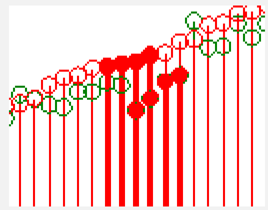
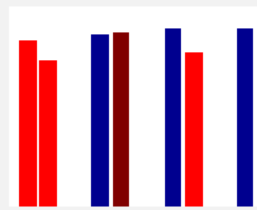
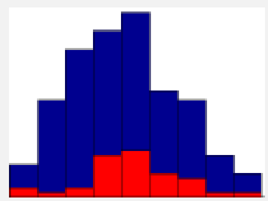
Remarks

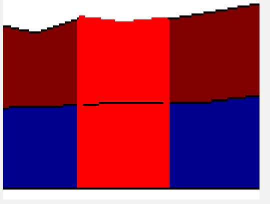
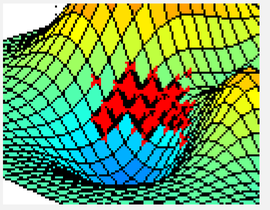
- "Types of Plots You Can Brush" on page 2-418
- "Plot Types You Cannot Brush" on page 2-420
- "Mode Exclusivity and Persistence" on page 2-421
- "How Data Linking Affects Data Brushing" on page 2-422
- "Mouse Gestures for Data Brushing" on page 2-423

Types of Plots You Can Brush

Data brushing places lines and patches on plots to create highlighting, marking different types of graphs as follows (brushing marks are shown in red):

Graph Type	Brushing Annotation	Overlays?	Example
lineseries	Colored lines slightly wider than those in the lineseries with a marker distinct from those on the lineseries (filled circles if none) to identify brushed vertices. Only those line segments that connect brushed vertices are highlighted	Y	

Graph Type	Brushing Annotation	Overlays?	Example
scattergroup	Line with `LineStyle 'none'` and a marker with a color distinct from and slightly larger than the base scattergroup marker.	Y	
stemseries	The brushed stems and stem heads are shaded in the brushing color.	Y	
barseries	The interior of selected bars is filled in the brushing color.	N	
histogram	The bars to which brushed observations contribute are proportionately filled from the bottom up with the brushing color.	N	

Graph Type	Brushing Annotation	Overlays?	Example
areaseries	Patches filling the region between selected points and the *x*-axis in the brushing color.	N	
surfaceplot	Patches with edges slightly wider than the surfaceplot line width and with a marker distinct from that of the surfaceplot (**X** if none) to identify brushed vertices. Patches are plotted only when all four vertices that define them are brushed. The brushed observations are the set of marked vertices, not the patches.	N	

When using the linked plots feature, a graph can become brushed when you brush another graph that displays some of the same data, potentially brushing the same observations more than once. The overlaid brushing marks (whether lines or markers) are slightly wider than the brushing marks that they overlay; this makes multiply brushed observations visually distinct. The wider brushing marks are placed under the narrower ones, so that if they happen to have different colors, you can see all the colors. See the subsection "How Data Linking Affects Data Brushing" on page 2-422 for more information about brushing linked figures.

As the above table indicates, only lineseries, scatterseries, and stemseries brushing marks can be overlaid in this manner. Although you can brush them, you cannot overlay brushing marks on areaseries, barseries, histograms, or surfaceplots.

Plot Types You Cannot Brush

Currently, not all plot types enable data brushing. Graph functions that *do not* support brushing are:

- Line plots created with `line`
- Scatter plots created with `spy`
- Contour plots created with `contour`, `contourf`, or `contour3`
- Pie charts created with `pie` or `pie3`
- Radial graphs created with `polar`, `compass`, or `rose`
- Direction graphs created with `feather`, `quiver`, or `comet`
- Area and image plots created with `fill`, `image`, `imagesc`, or `pcolor`
- Bar graphs created with `pareto` or `errorbar`
- Functional plots created with `ezcontour` or `ezcontourf`
- 3-D plot types *other than* `plot3`, `stem3`, `scatter3`, `mesh`, `meshc`, `surf`, `surfl`, and `surfc`

You can use some of these functions to display base data that do not need to be brushable. For example, use `line` to plot mean *y*-values as horizontal lines that you do not need or want to brush.

Mode Exclusivity and Persistence

Data brushing mode is *exclusive*, like zoom, pan, data cursor, or plot edit mode. However, brush marks created in data brushing mode *persist* through all changes in mode. Brush marks that appear in other graphs while they are linked via `linkdata` also persist even when data linking is subsequently turned off. That is, severing connections to a graph's data sources does not remove brushing marks from it. The only ways to remove brushing marks are (in brushing mode):

- Brush an empty area in a brushed graph.
- Right-click and select **Clear all brushing** from the context menu.

Changing the brushing color for a figure does not recolor brushing marks on it until you brush it again. If you hold down the **Shift** key, all existing brush marks change to the new color. All brush marks that appear on linked plots in the same or different figure also change to the new color if the brushing action affects them. The behavior is the same whether you select a brushing color from the Brush Tool dropdown palette, set it by calling `brush(colorspec)`, or by setting the `Color` property of a brush mode object (e.g., `set(brushobj,'Color',`*`colorspec`*`)`.

How Data Linking Affects Data Brushing

When you use the Data Linking tool or call the `linkdata` function, brushing marks that you make on one plot appear on other plots that depict the same variable you are brushing—if they are also linked. This happens even if the affected plot is not in Brushing mode. That is, brushing marks appear on a linked plot *in any mode* when you brush another plot linked to it via a common variable or brush that variable in the Variable Editor. Two limiting conditions apply, however:

- The graph type must support data brushing (see "Types of Plots You Can Brush" on page 2-418 and "Plot Types You Cannot Brush" on page 2-420)
- The graphed variable should not be complex; if you can plot a complex variable you can brush it, but such graphs do not respond when you brush the complex variable in another linked plot.

For more information about linking complex variables, see Example 3 in the `linkdata` reference page.

Brush marks on a an unlinked graph can change color when data linking is turned on for that figure. They can, in fact, vanish and be replaced by marks in the same or different color when the plot enters a linked state. This happens because in the linked state, the variables (data sources) are brushed, not just the graphics. If different observations for the same variable on a linked figure are brushed, those brushed variables override the brushed graphics on the newly linked plot. In other words, the newly linked graph loses all its previous brush marks when it "joins the club" of common data sources.

Mouse Gestures for Data Brushing

You can brush graphs in several ways. The basic operation is to drag the mouse to highlight all observations within the rectangle you define. The following table lists data brushing gestures and their effects.

Action	Gesture	Result
Select data using a region of interest	ROI mouse drag	Region of interest (ROI) rectangle (or rectangular prism for 3-D axes) appears during the gesture and all brushable observations within the rectangle are highlighted. All other brushing marks in the axes are removed. The ROI rectangle disappears when the mouse button is released.
Select a single point	Single left-click on a graphic object that supports data brushing	Produces an equivalent result to ROI rectangle, brushing where the rectangle encloses only the single vertex on the graphical object closest to the mouse. All other brushing annotations in the figure are removed.
Add a point to the selection or remove a highlighted one	Single left-click on a graphic object that supports data brushing, with the **Shift** key down	Equivalent brushing by dragging an ROI rectangle that encloses only the single vertex on the graphic object closest to the mouse. All other brushed regions in the figure remain brushed.
Select all data associated with a graphic object	Double left-click on a graphic object that supports data brushing	All vertices for the graphic object are brushed.

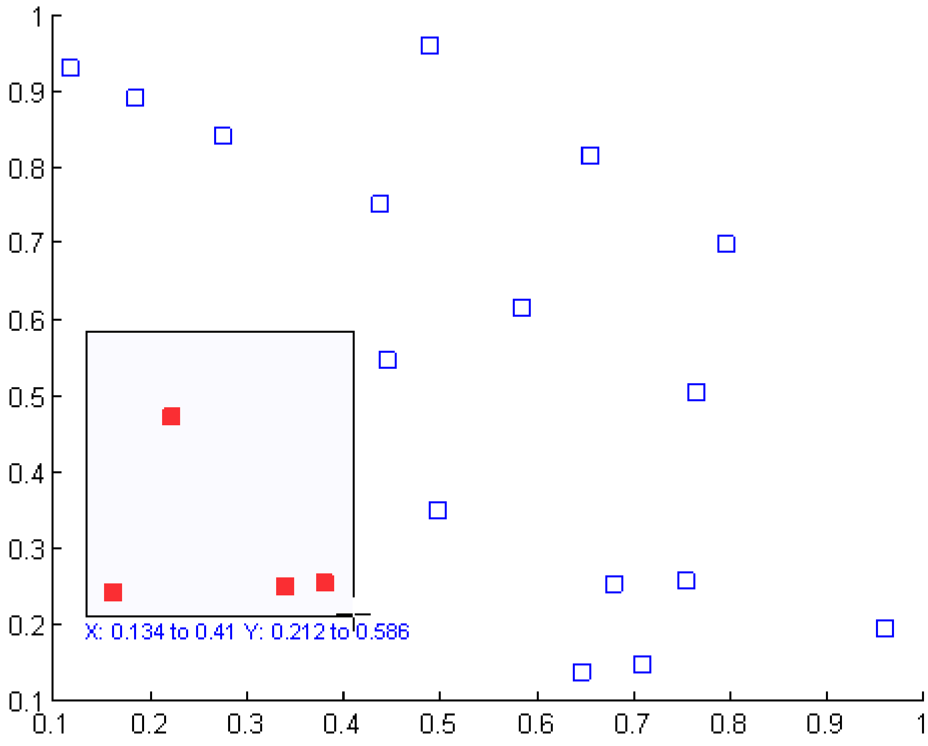
Action	Gesture	Result
Add to or subtract from region of interest	Click or ROI drag with the **Shift** or **Ctrl** keys down	Region of interest grows; all unbrushed vertices within the rectangle become brushed and all brushed observations in it become unbrushed. All brushed vertices outside the ROI remain brushed.
Copy brushed data to Editor, Command Window, Variable Editor, or Workspace Browser	Drag brushed data to another window or to a program/icon on the system desktop	Equivalent to copying brushed data and pasting into other window or an existing/new variable.

Examples

Example 1

On a scatterplot, drag out a rectangle to brush the graph:

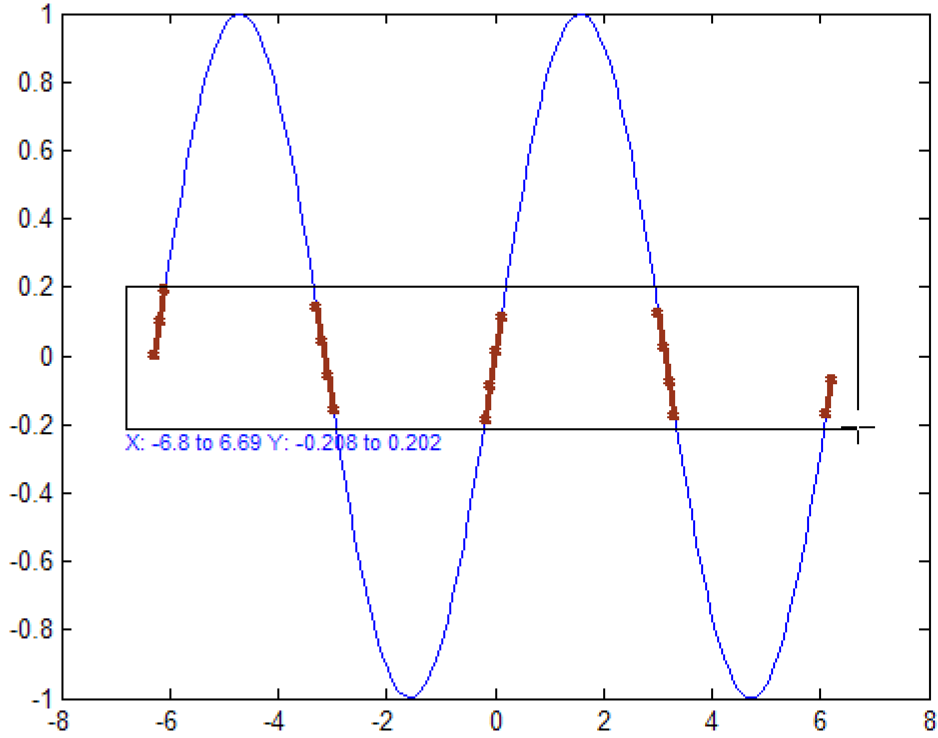
```
x = rand(20,1);
y = rand(20,1);
scatter(x,y,80,'s')
brush on
```



Example 2

Brush observations from -.2 to .2 on a lineseries plot in dark red:

```
x = [-2*pi:.1:2*pi];
y = sin(x);
plot(x,y);
h = brush;
set(h,'Color',[.6 .2 .1],'Enable','on');
```



See Also `linkaxes`, `linkdata`, `pan`, `rotate3d`, `zoom`

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® software used to create it.

For a full discussion of this process, refer to "Adding HTML Help Files for Your Own Toolboxes to 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

Apply 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 2-434 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.

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 2-434. 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.

Note The `bvp5c` function is used exactly like `bvp4c`, with the exception of the meaning of error tolerances between the two solvers. If *S(x)* approximates the solution *y(x)*, `bvp4c` controls the residual |*S'(x)* - *f(x,S(x))*|. This controls indirectly the true error |*y(x)* - *S(x)*|. `bvp5c` controls the true error directly. `bvp5c` is more efficient than `bvp4c` for small error tolerances.

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 software 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

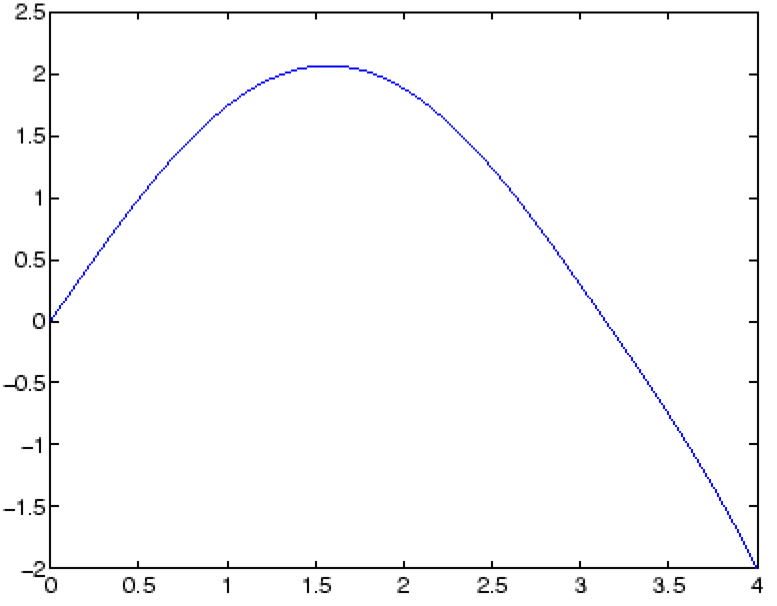
```
solinit = bvpinit(linspace(0,4,5),[1 0]);
```

Now solve the problem with

```
sol = bvp4c(@twoode,@twobc,solinit);
```

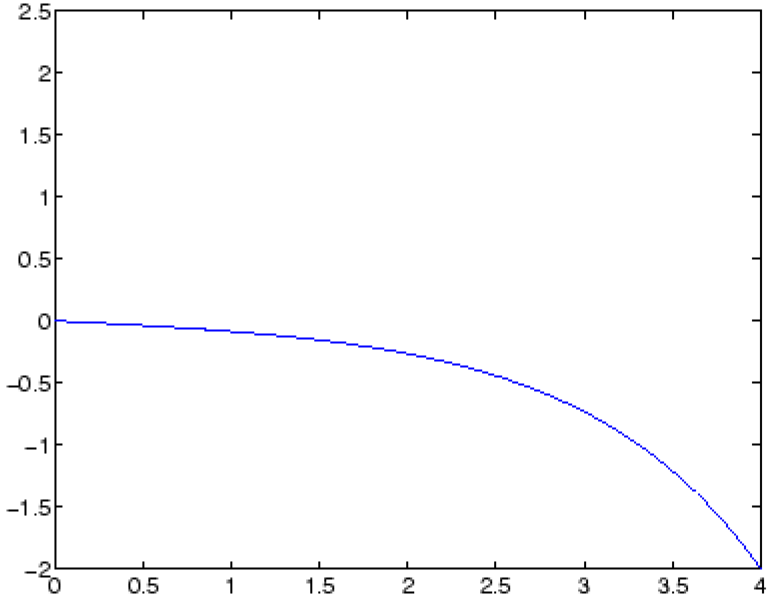
Evaluate the numerical solution at 100 equally spaced points and plot $y(x)$ with

```
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
```

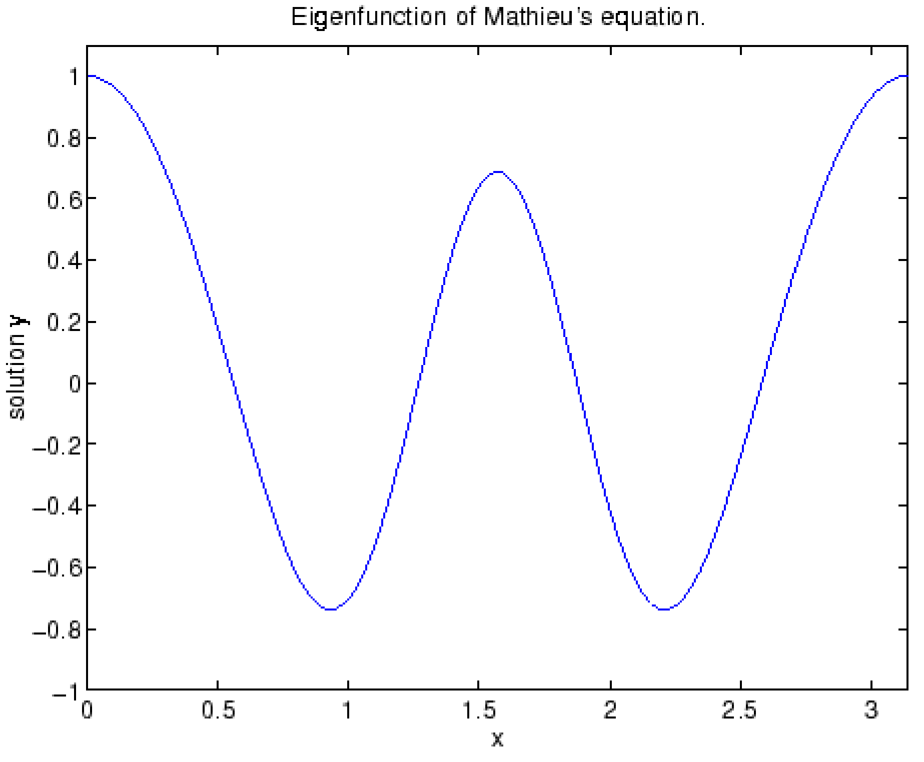
```
lambda = 15;
solinit = bvpinit(linspace(0,pi,10),@mat4init,lambda);
sol = bvp4c(@mat4ode,@mat4bc,solinit);

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 (@), bvp5c,bvpget, bvpinit, bvpset, bvpxtend, deval

Purpose

Solve boundary value problems for ordinary differential equations

Syntax

```
sol = bvp5c(odefun,bcfun,solinit)
sol = bvp5c(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.	

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 = bvp5c(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.

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. 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 `bvp5c` 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 `bvp5c` an initial guess for any unknown parameters in `solinit.parameters`. The `bvp5c` solver returns the final values of these unknown parameters in `sol.parameters`.

`bvp5c` 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 `bvp5c` to evaluate the solution at specific points `xint` in the interval `[a,b]`.

```
sxint = deval(sol,xint)
```

The structure `sol` returned by `bvp5c` has the following fields:

`sol.x`	Mesh selected by `bvp5c`
`sol.y`	Approximation to $y(x)$ at the mesh points of `sol.x`
`sol.parameters`	Values returned by `bvp5c` for the unknown parameters, if any
`sol.solver`	'bvp5c'

The structure `sol` can have any name, and `bvp5c` creates the fields `x`, `y`, `parameters`, and `solver`.

`sol = bvp5c(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.

Note The `bvp5c` function is used exactly like `bvp4c`, with the exception of the meaning of error tolerances between the two solvers. If *S(x)* approximates the solution *y(x)*, `bvp4c` controls the residual |*S'(x)* - *f(x,S(x))*|. This controls indirectly the true error |*y(x)* - *S(x)*|. `bvp5c` controls the true error directly. `bvp5c` is more efficient than `bvp4c` for small error tolerances.

Singular Boundary Value Problems

`bvp5c` 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.

Algorithms

`bvp5c` is a finite difference code that implements the four-stage Lobatto IIIa formula. This is a collocation formula and the collocation polynomial provides a C^1-continuous solution that is fifth-order accurate uniformly in `[a,b]`. The formula is implemented as an implicit Runge-Kutta formula. `bvp5c` solves the algebraic equations directly; `bvp4c` uses analytical condensation. `bvp4c` handles unknown parameters directly; while `bvp5c` augments the system with trivial differential equations for unknown parameters.

References

[1] Shampine, L.F., M.W. Reichelt, and J. Kierzenka “Solving Boundary Value Problems for Ordinary Differential Equations in MATLAB with

bvp4c" http://www.mathworks.com/bvp_tutorial. Note that this tutorial uses the bvp4c function, however in most cases the solvers can be used interchangeably.

See Also

function_handle (@), bvp4c, bvpget, bvpinit, bvpset, bvpxtend, deval

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`, `bvp5c`, `bvpinit`, `bvpset`, `deval`

bvpinit

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`,`bvp5c`, `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 2-452
- "Vectorization" on page 2-453
- "Analytical Partial Derivatives" on page 2-454
- "Singular BVPs" on page 2-457

- "Mesh Size Property" on page 2-457
- "Solution Statistic Property" on page 2-458

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 `i`th 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.

$$\|(\mathrm{res(i)/max(abs(f(i)),AbsTol(i)/RelTol)})\| \leq \mathrm{RelTol}$$

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 $S'(x) = F(x, S(x)) + res(x)$. On each subinterval of the mesh, the residual $res(x)$ satisfies $\|(res(i)/max(abs(F(i)),AbsTol(i)/RelTol))\| \le RelTol$
`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`,`bvp5c`, `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`, `bvp5c`, `bvpinit`

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`

calllib

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',[]);
```

Remove the library from memory:

```
unloadlibrary shrlibsample
```

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 Sun™ Java™ document object model (DOM), to the `soapAction` service at the `endpoint`.

See Also `createClassFromWsdl`, `CreateSoapMessage`, `parseSoapResponse`

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 the camera moves:

- `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 1-101 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 1-103 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 1-101 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 1-101 for related functions

"Defining Scenes with Camera Graphics" for more information

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 1-101 for related functions

“Defining Scenes with Camera Graphics” for more information

campos

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 1-101 for related functions

"Defining Scenes with Camera Graphics" for more information

camproj

Purpose

Set or query projection type

Syntax

```
camproj
camproj('projection_type')
camproj(axes_handle,...)
```

Description

The projection type determines whether MATLAB® 3-D views use a perspective or orthographic projection.

`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 1-101 for related functions

"Defining Scenes with Camera Graphics" for more information

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 1-101 for related functions

“Defining Scenes with Camera Graphics” for more information

camtarget

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`, the camera target is 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 1-101 for related functions

"Defining Scenes with Camera Graphics" for more information

camup

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, `[0 1 0]` is the up vector of for 2-D views. This means the *z*-axis points up.

`camup('manual')` sets the camera up vector mode to `manual`. In `manual` mode, the value of the camera up vector does not change unless you set it.

`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 1-101 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`, the camera view angle adjusts so that the scene fills the available space in the window. If you move the camera to a different position, the camera view angle changes 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 1-101 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 1-101 for related functions

"Defining Scenes with Camera Graphics" for more information

Purpose

Transform Cartesian coordinates to polar or cylindrical

Syntax

```
[THETA,RHO,Z] = cart2pol(X,Y,Z)
[THETA,RHO] = cart2pol(X,Y)
```

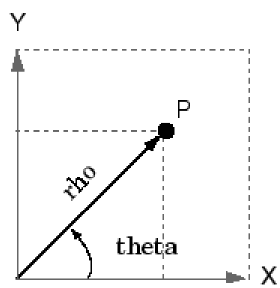
Description

`[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.

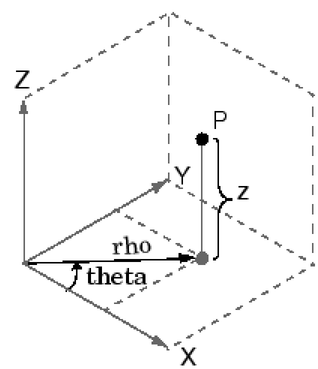
Algorithm

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`

cart2sph

Purpose Transform Cartesian coordinates to spherical

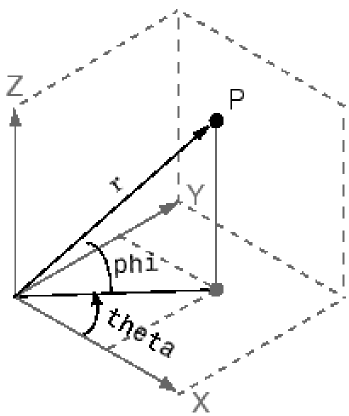
Syntax

```
[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 (or any of them can be scalar).

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

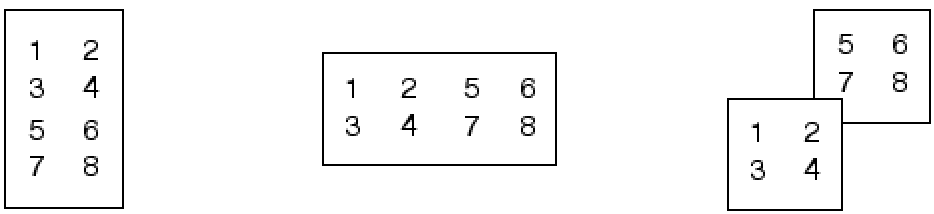
When used with comma-separated list syntax, `cat(dim, C{:})` or `cat(dim, C.field)` is a convenient way to concatenate a cell or structure array containing numeric matrices into a single matrix.

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

`vertcat`, `horzcat`, `strcat`, `strvcat`, `num2cell`, `special character []`

catch

Purpose

Specify how to respond to error in `try` statement

Syntax

```
catch ME
catch
```

Description

`catch ME` marks the start of a *catch block* in a `try-catch` statement. It returns object `ME`, which is an instance of the MATLAB® class `MException`. This object contains information about an error caught in the preceding *try block* and can be useful in helping your program respond to the error appropriately.

A `try-catch` statement is a programming device that enables you to define how certain errors are to be handled in your program. This bypasses the default MATLAB error-handling mechanism when these errors are detected. The `try-catch` statement consists of two blocks of MATLAB code, a *try block* and a *catch block*, delimited by the keywords `try`, `catch`, and `end`:

```
try
   MATLAB commands     % Try block
catch ME
   MATLAB commands     % Catch block
end
```

Each of these blocks consists of one or more MATLAB commands. The `try` block is just another piece of your program code; the commands in this block execute just like any other part of your program. Any errors MATLAB encounters in the `try` block are dealt with by the respective `catch` block. This is where you write your error-handling code. If the `try` block executes without error, MATLAB skips the `catch` block entirely. If an error occurs while executing the `catch` block, the program terminates unless this error is caught by another `try-catch` block.

`catch` marks the start of a catch block but does not return an `MException` object. You can obtain the error string that was generated by calling the `lasterror` function.

Specifying the `try`, `catch`, and `end` commands, as well as the commands that make up the `try` and `catch` blocks, on separate lines is recommended. If you combine any of these components on the same line, separate them with commas:

```
try, surf, catch ME, ME.stack, end
ans =
    file: 'matlabroot\toolbox\matlab\graph3d\surf.m'
    name: 'surf'
    line: 54
```

Examples

The `catch` block in this example checks to see if the specified file could not be found. If this is the case, the program allows for the possibility that a common variation of the filename extension (e.g., `jpeg` instead of `jpg`) was used by retrying the operation with a modified extension. This is done using a `try-catch` statement that is nested within the original `try-catch`.

```
function d_in = read_image(filename)
[path name ext] = fileparts(filename);
try
   fid = fopen(filename, 'r');
   d_in = fread(fid);
catch ME1
   % Get last segment of the error message identifier.
   idSegLast = regexp(ME1.identifier, '(?<=:)\w+$', 'match');

   % Did the read fail because the file could not be found?
   if strcmp(idSegLast, 'InvalidFid') && ~exist(filename, 'file')

      % Yes. Try modifying the filename extension.
      switch ext
      case '.jpg'    % Change jpg to jpeg
          filename = strrep(filename, '.jpg', '.jpeg')
      case '.jpeg'   % Change jpeg to jpg
          filename = strrep(filename, '.jpeg', '.jpg')
      case '.tif'    % Change tif to tiff
```

```
        filename = strrep(filename, '.tif', '.tiff')
    case '.tiff'   % Change tiff to tif
        filename = strrep(filename, '.tiff', '.tif')
    otherwise
       fprintf('File %s not found\n', filename);
       rethrow(ME1);
    end

    % Try again, with modifed filenames.
    try
       fid = fopen(filename, 'r');
       d_in = fread(fid);
    catch ME2
       fprintf('Unable to access file %s\n', filename);
       ME2 = addCause(ME2, ME1);
       rethrow(ME2)
    end
  end
end
```

See Also

`try`, `rethrow`, `end`, `lasterror`, `eval`, `evalin`

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` computes 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. The following linear transformation is performed 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
```

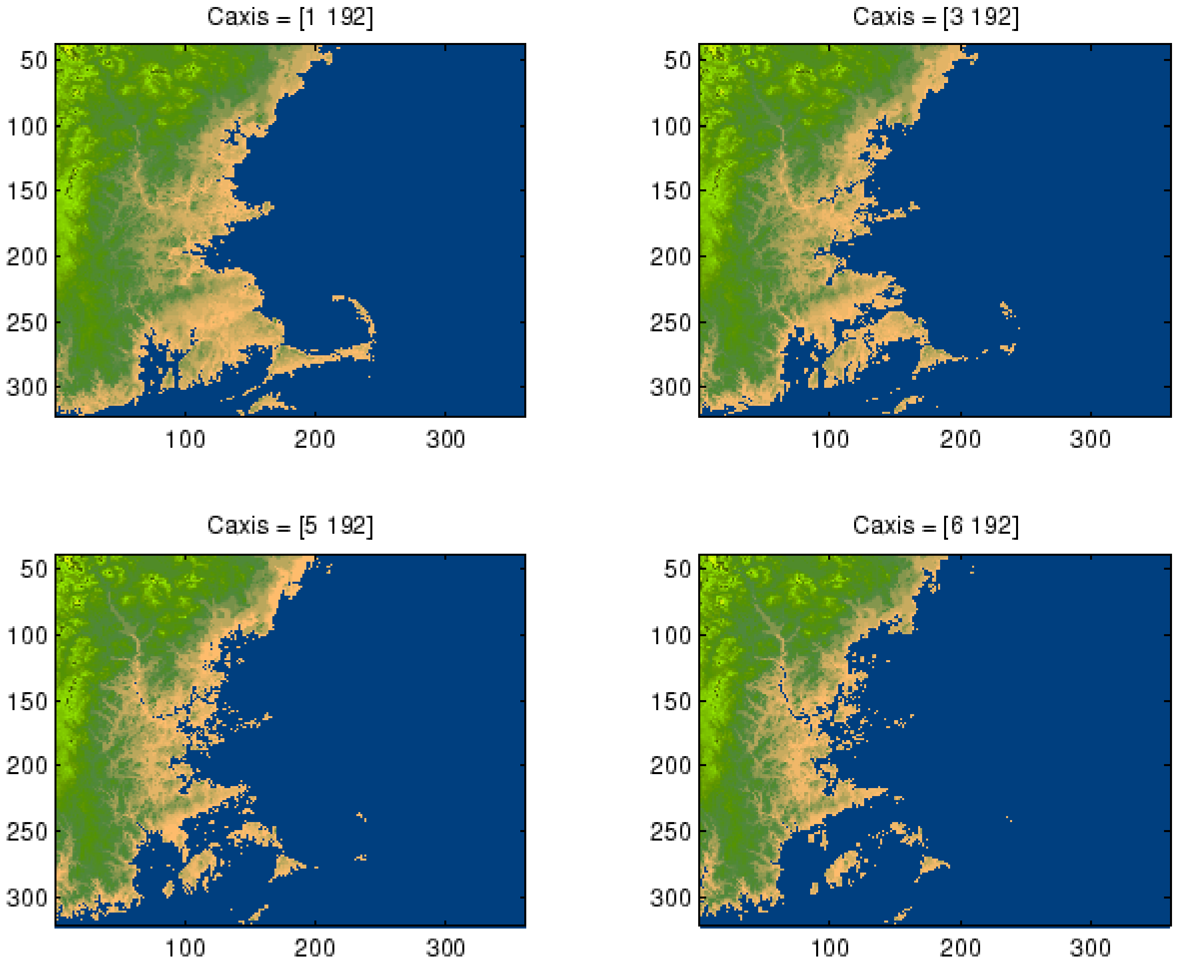
This command loads the image's data `X` and the image's colormap `map` into the workspace. Now display the image with `CDataMapping` set to `scaled` and install the image's colormap.

```
image(X,'CDataMapping','scaled')colormap(map)
```

This adjusts 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 1-100 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 platforms,

```
cd('/usr/local/matlab/toolbox/control/ctrldemos')
```

changes the current working directory to `ctrldemos` for the Control System Toolbox.

On Windows® platforms,

```
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`

cd (ftp)

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`

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`

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".

cdfwrite

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 invalid in your MATLAB® application, 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`

cell2mat

Purpose Convert cell array of matrices to single matrix

Syntax

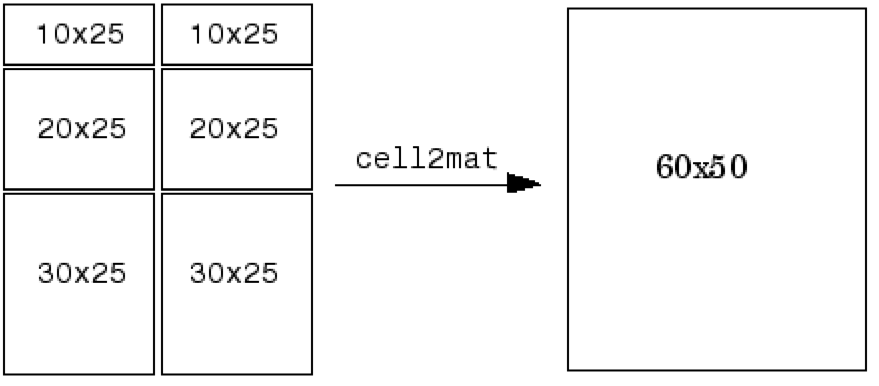
```
m = cell2mat(c)
```

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

celldisp

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 2-528 below.
ErrorHandler	Function handle, specifying the function that cellfun is to call if the call to fun fails. See "ErrorHandler Parameter" on page 2-528 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

The MATLAB® software 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

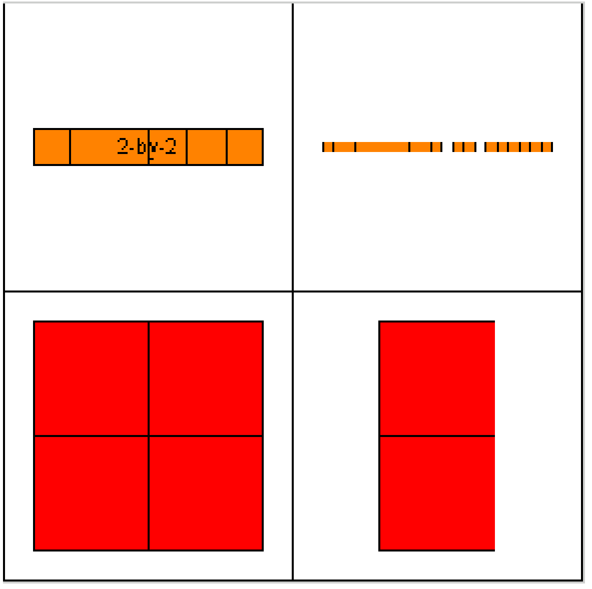
The `cellplot` function can display only two-dimensional cell arrays.

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.

, 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 software 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)
```

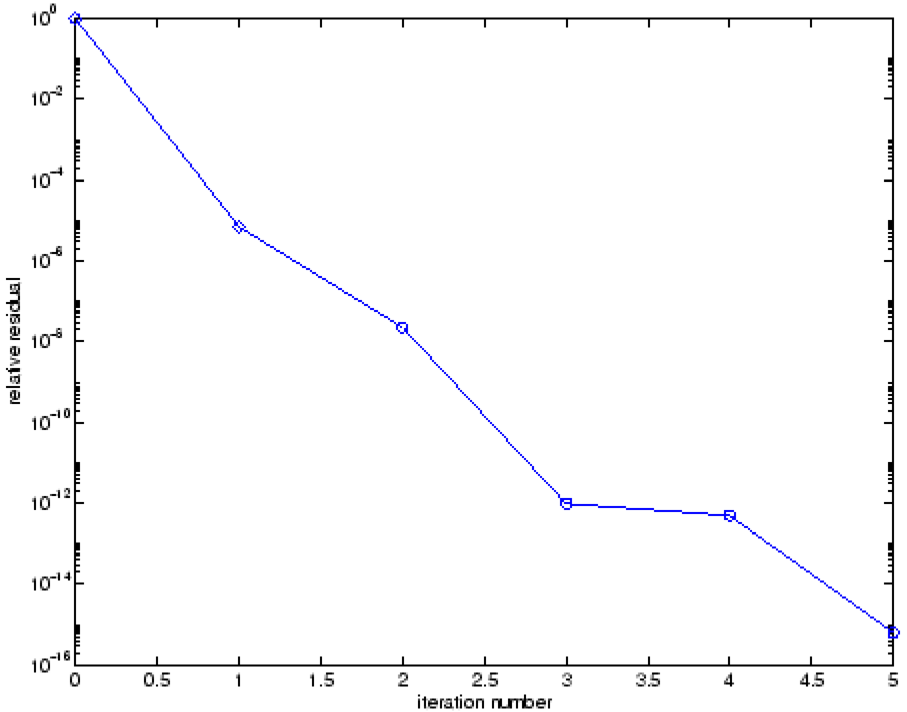
`flag1` is `2` because the upper triangular `U1` has a zero on its diagonal, and `cgs` fails in the first iteration when it tries to solve a system such as `U1*y = r` for `y` with backslash.

```
[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.

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 a source control system (UNIX® platforms)

GUI Alternatives As an alternative to the `checkin` function, use **File > Source Control > Check In** in the Editor, the Simulink® product, or the Stateflow® product, or in the context menu of the Current Directory browser. For more information, see "Checking Files Into the Source Control System on UNIX Platforms".

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 file names, use an array of strings instead of `filename`, that is, `{'filename1','filename2',...}`. Options apply to all file names. 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.

option Argument	value Argument	Purpose
'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 Microsoft® Windows® platforms, use verctrl.

Purpose

Check files out of a source control system (UNIX® platforms)

GUI Alternatives

As an alternative to the `checkout` function, select **Source Control > Check Out** from the **File** menu in the MATLAB® Editor, the Simulink® product, or the Stateflow® product, or in the context menu of the Current Directory browser. For details, see "Checking Files Out of the Source Control System on UNIX".

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 file names, use an array of strings instead of `filename`, that is, `{'filename1','filename2', ...}`. Options apply to all file names. 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 the MATLAB desktop 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 Microsoft® Windows® platforms, use `verctrl`.

chol

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® software 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 software 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`

cholinc

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).

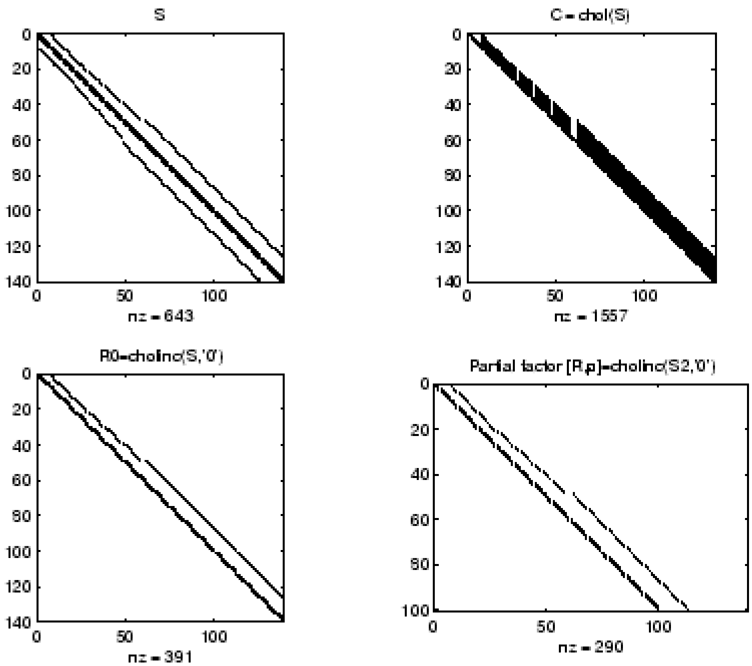
Compute the Cholesky factorization and the incomplete Cholesky factorization of level 0 to compare the fill-in. Make S singular by zeroing out a diagonal entry and compute the (partial) incomplete Cholesky factorization of level 0.

```
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.

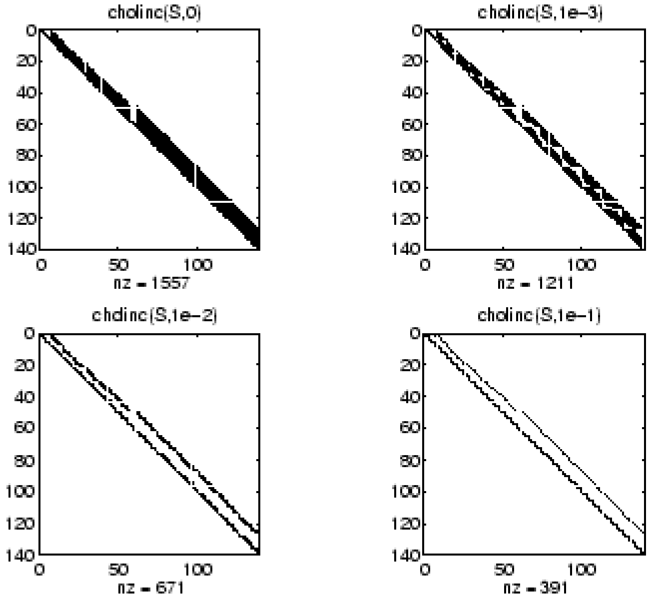
```
D1 = (R0'*R0).*spones(S)-S;
D2 = (R'*R).*spones(S2)-S2;
```

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).

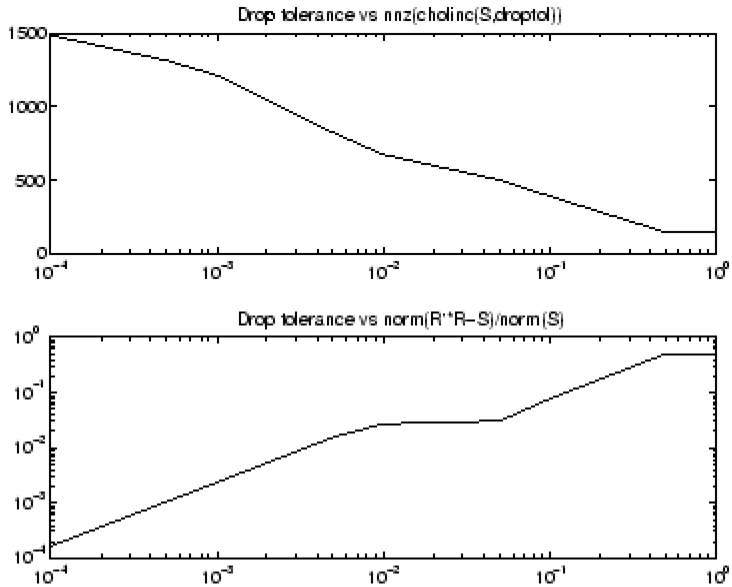


Example 2

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

cholupdate

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.

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`

cla

Purpose

Clear current axes

GUI Alternatives

Remove axes and clear objects from them in *plot edit* mode. For details, see "Working in 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 1-98 for related functions

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).

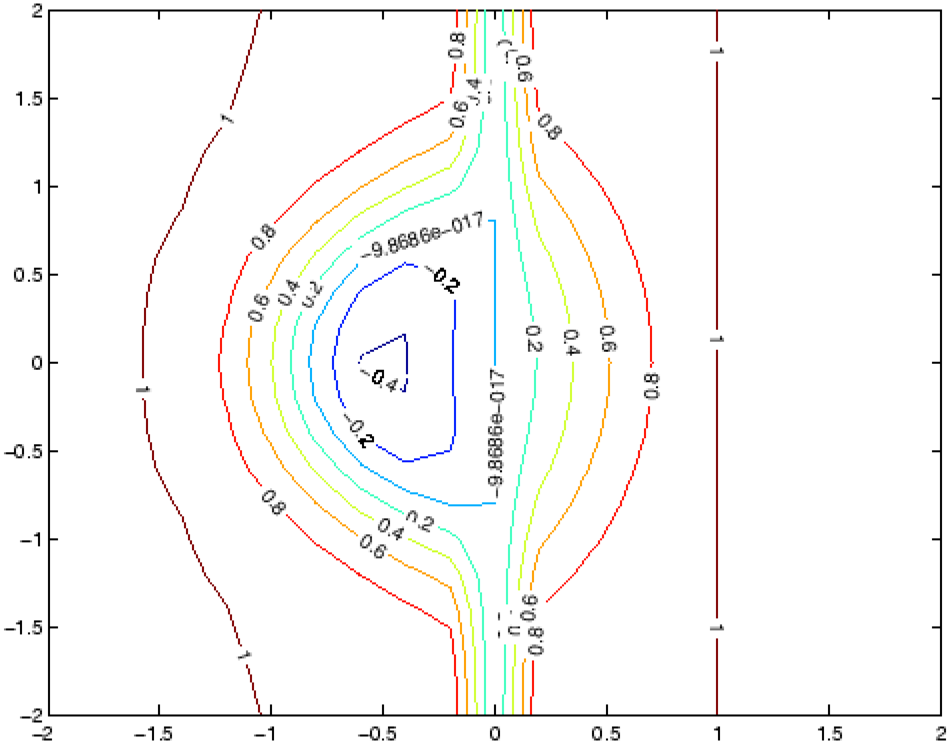
Remarks

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

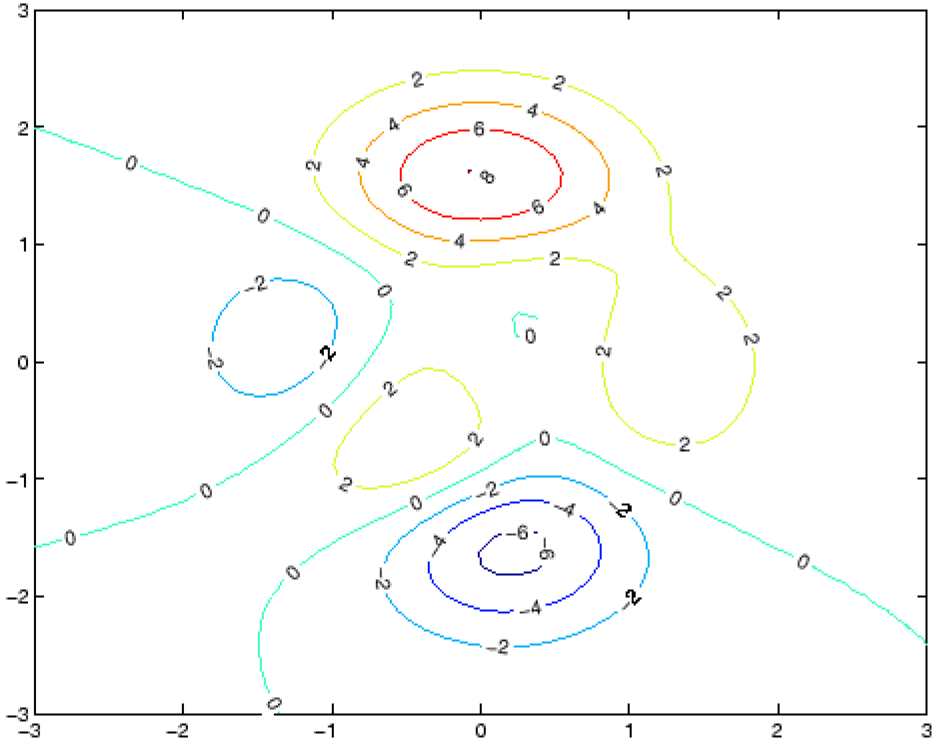
Generate, draw, and label a simple contour plot.

```
[x,y] = meshgrid(-2:.2:2);
z = x.^exp(-x.^2-y.^2);
[C,h] = contour(x,y,z);
clabel(C,h);
```



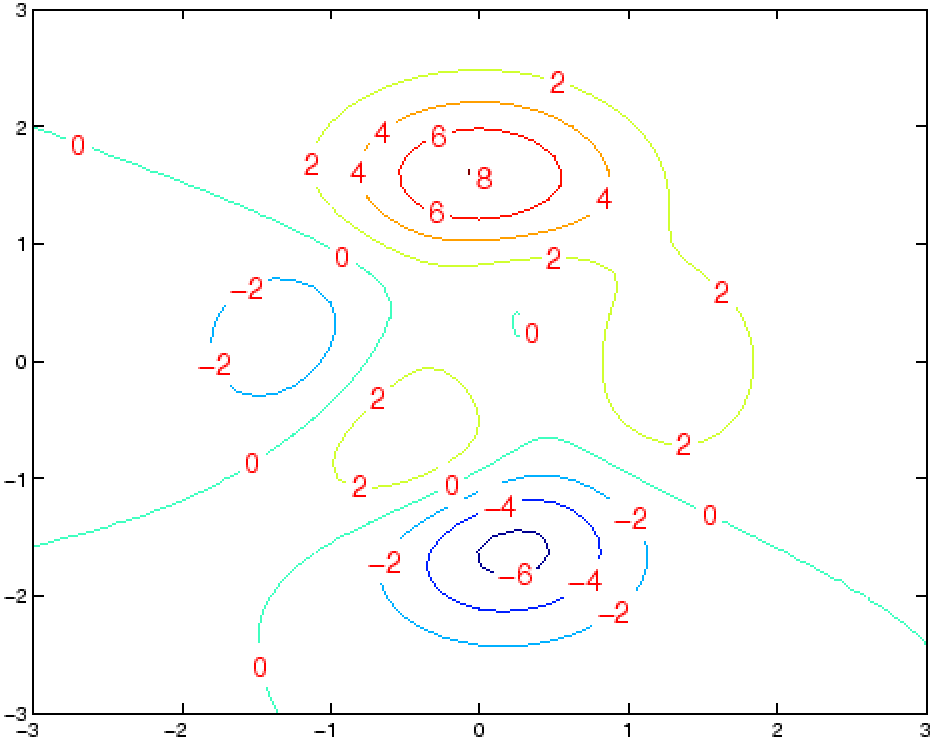
Label a contour plot with label spacing set to 72 points (one inch).

```
[x,y,z] = peaks;
[C,h] = contour(x,y,z);
clabel(C,h,'LabelSpacing',72)
```



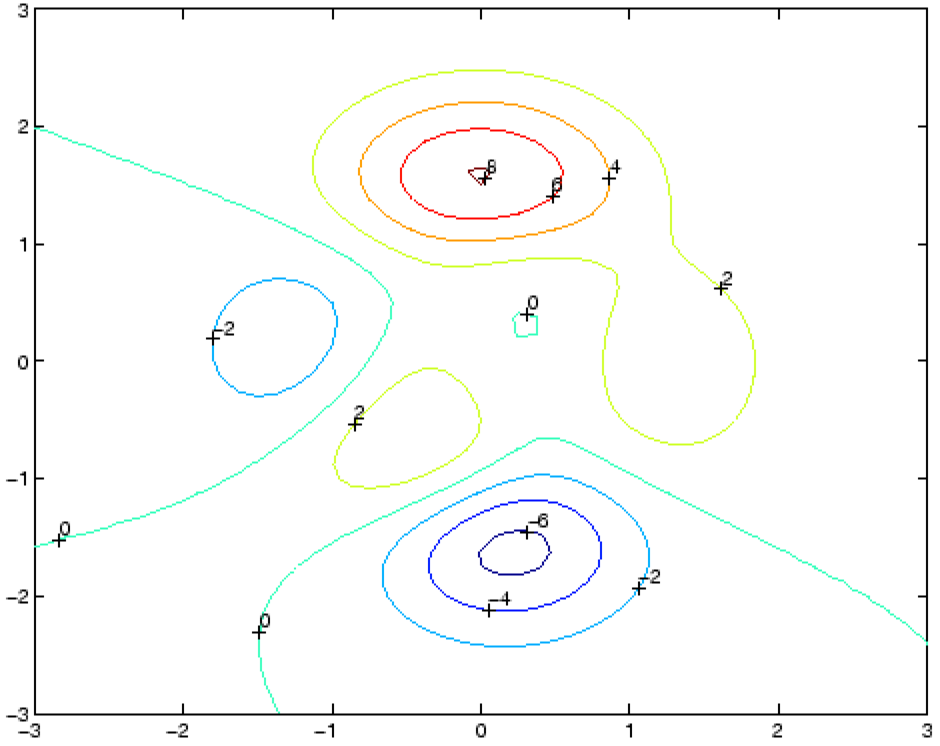
Label a contour plot with 15 point red text.

```
[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 1-89 for related functions

"Drawing Text in a Box" for an example that illustrates the use of contour labels

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,...)
obj_struct = class(struct_array,'class_name',parent_array)
```

Description `str = class(object)` returns a string specifying the class of `object`.

The following table lists the 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*'	User–defined MATLAB® class
'*Java_class_name*'	Java™ class

Using the class function within a class constructor (pre MATLAB Version 7.6)

The following usage of the `class` function is restricted to pre MATLAB Version 7.6 class constructors (classes defined without a `classdef` statement). It can be used only within a function named *class_name*.m, which is in a directory named @*class_name* (where *class_name* is the same as the string passed to `class` and is the name of the class being constructed).

See "Class Constructor Methods" for information on implementing class constructor methods in MATLAB Version 7.6 and after.

`obj = class(s,'`*class_name*`')` creates an object of class *class_name* using the `struct` `s` as a pattern to determine the size of `obj`.

`obj = class(s,'`*class_name*`',parent1,parent2,...)` creates an object of class *class_name* that inherits the methods and fields of the parent objects `parent1`, `parent2`, and so on. The `struct` `s` is used as a pattern to determine the size of `obj`. The size of the parent objects must match the size of `s` or be a scalar (1–by-1), in which case, MATLAB performs scalar expansion.

`obj = class(struct([]),'`*class_name*`',parent1,parent2,...)` creates an object of 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. All parents must have the same, nonzero size, which determines the size of the returned object `obj`.

Arrays of objects

`obj_struct = class(struct_array,'`*class_name*`',parent_array)` `struct_array` is an array of `structs` and `parrent_array` is an array of parent objects. Every element of the parrent_array is mapped to a corresponding element in the struct_array to produce the output array of objects, obj_struct. All arrays must be of the same size or, if either the struct_array or the parrent_array is of size 1–by1, then MATLAB performs scalar expansion to match the array sizes.

Note that you can create an object array of size 0–by-0 by setting the size of the struct_array and parrent_array to 0–by-0.

Examples

To return in nameStr the class of Java object j,

```
nameStr = class(j)
```

Obtain the full name of a package-based Java class,

```
import java.lang.*;
obj = String('mystring');
class(obj)
```

See Also

inferiorto, isa, struct, superiorto

MATLAB Classes and Object-Oriented Programming

classdef

Purpose

Class definition key words

Syntax

```
classdef
properties
methods
events
```

Description

`classdef` begins the class definition, which is terminated by an `end` key word. Only blank lines and comments can precede `classdef`. You must place a class definition in a file having the same name as the class, with a filename extension of `.m`.

See "Defining Classes — Syntax" for more information on classes.

`properties` begins a property definition block, which is terminated by an `end` key word. Class definitions can contain multiple property definition blocks, each specifying different attribute settings that apply to the properties in that particular block.

See "Defining Properties" for more information.

`methods` begins a methods definition block, which is terminated by an `end` key word. This block contains functions that implement class methods. Class definitions can contain multiple method blocks, each specifying different attribute settings that apply to the methods in that particular block. It is possible for method functions to be defined in separate files.

See "Class Methods" for more information.

`events` begins an events definition block, which is terminated by an `end` key word. This block contains event names defined by the class. Class definitions can contain multiple event blocks, each specifying different attribute settings that apply to the events in that particular block.

See "Defining Events and Listeners — Syntax and Techniques" for more information.

Table of Attributes

Display the attributes of all class component in a popup window, click this link: Attribute Tables

Examples

Here is the basic structure of a class definition.

```
classdef class_name
   properties
      PropertyName
   end
   methods
      function obj = methodName(obj,arg2,...)
         ...
      end
   end
   events
      EventName
   end
end
```

See Also

MATLAB® Classes and Object-Oriented Programming

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

On UNIX® systems, `clear` does not affect the amount of memory allocated to the MATLAB process. (UNIX is a registered trademark of The Open Group in the United States and other countries.)

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`

clearvars

Purpose

Clear variables from memory

Syntax

```
clearvars v1 v2 ...
clearvars -global
clearvars -global v1 v2 ...
clearvars -regexp p1 p2 ...
clearvars -except v1 v2 ...
clearvars -except -regexp p1 p2 ...
clearvars v1 v2 ... -except -regexp p1 p2 ...
clearvars -regexp p1 p2 ... -except v1 v2 ...
```

Description

`clearvars v1 v2 ...` clears variables `v1`, `v2`, and so on from the currently active workspace. Each input must be an unquoted string specifying the variable to be cleared. This string may include the wildcard character (`*`) to clear all variables that match a pattern. For example, `clearvars X*` clears all the variables in the current workspace that start with the letter `X`.

If any of the variables `v1`, `v2`, and so on, are global, `clearvars` removes these variables from the current workspace only, leaving them accessible to any functions that declare them as global.

`clearvars -global` removes all global variables, including those made global within functions.

`clearvars -global v1 v2 ...` completely removes the specified global variables.

The `-global` flag may be used with any of the following syntaxes. When used in this way, it must immediately follow the function name.

`clearvars -regexp p1 p2 ...` clears all variables that match regular expression patterns `p1`, `p2`, and so on.

`clearvars -except v1 v2 ...` clears all variables except for those specified following the `-except` flag. Use the wildcard character '*' in a variable name to exclude variables that match a pattern from being cleared. `clearvars -except X*` clears all the variables in the current workspace, except for those that start with `X`, for instance.

`clearvars -except -regexp p1 p2 ...` clears all variables except those that regular expression patterns `p1`, `p2`. If used in this way, the `-regexp` flag must immediately follow the `-except` flag.

`clearvars v1 v2 ...  -except -regexp p1 p2 ...` can be used to specify variables to clear that do not match specified regular expression patterns.

`clearvars -regexp p1 p2 ...  -except v1 v2 ...` clears variables that match `p1`, `p2`, ..., except for variables `v1`, `v2`, ...

Examples

Clear variables starting with `a`, except for the variable `ab`:

```
clearvars a* -except ab
```

Clear all global variables except those starting with `x`:

```
clearvars -global -except x*
```

Clear variables that start with `b` and are followed by 3 digits, for the variable `b106`:

```
clearvars -regexp ^b\d{3}$ -except b106
```

Clear variables that start with `a`, except those ending with `a`:

```
clearvars a* -except -regexp a$
```

See Also

`clear`, `who`, `whos`, `persistent`, `global`, `exist`

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 "MATLAB® Shortcuts — 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 1-97 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® platforms, and Java™ on other platforms. (UNIX is a registered trademark of The Open Group in the United States and other countries).

See Also

`load`, `uiimport`

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 an error that terminates the execution of a `CloseRequestFcn` occurs, 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 1-97 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 1-97 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® platforms only)
- `customverctrl` (UNIX platforms only)
- `cvs` (UNIX platforms only)
- `pvcs` (UNIX platforms only, used for PVCS® and ChangeMan® software)
- `rcs` (UNIX platforms only)
- `sourcesafe` (Windows® platforms only)

If you have not selected a source control system, `cmopts` displays

```
none
```

For more information, see “Specify Source Control System with MATLAB® Software” for PC platforms, and “Specifying the Source Control System on UNIX Platforms” 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:

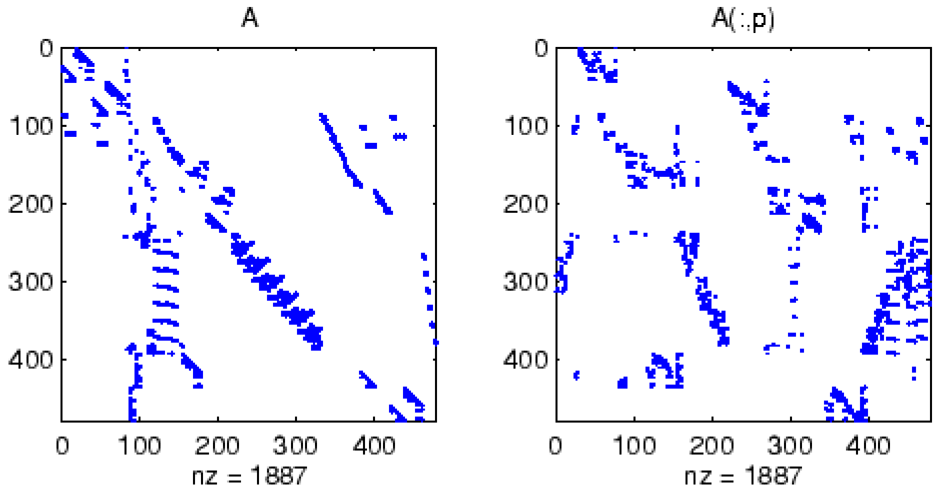
- If a row index appears two or more times in the same column, `colamd` ignores the duplicate entries, continues processing, and provides information about the duplicate entries in `stats(4:7)`.
- If row indices in a column are out of order, `colamd` sorts each column of its internal copy of the matrix `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.

Examples

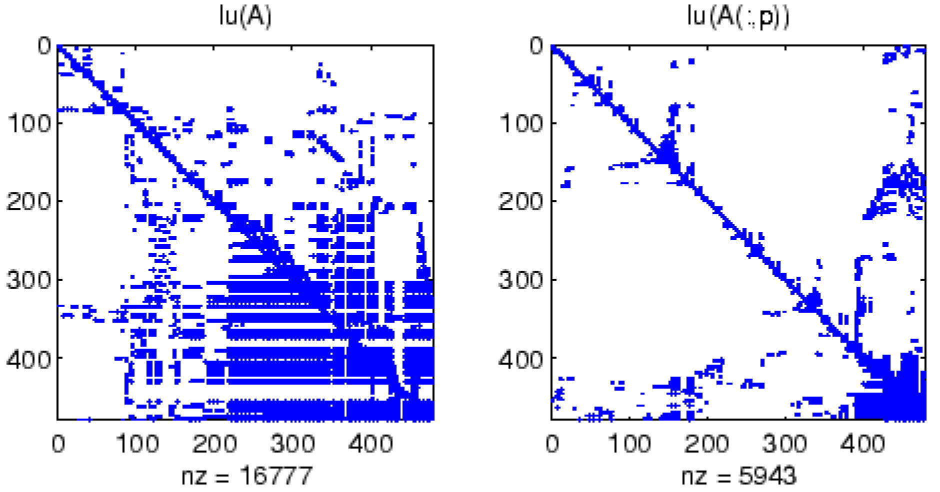
The Harwell-Boeing collection of sparse matrices and the MATLAB demos directory include a test matrix `west0479`. It is a matrix of order 479 resulting from a model due to Westerberg of an eight-stage chemical distillation column. The spy plot shows evidence of the eight stages. The `colamd` ordering 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

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 “Working in Plot Edit Mode” in the MATLAB® Graphics documentation.

Syntax

```
colorbar
colorbar('off')
colorbar('hide')
colorbar('delete')
colorbar(...,'peer',axes_handle)
colorbar(...,'location')
colorbar(...,'PropertyName',propertyvalue)
cbar_axes = colorbar(...)
colorbar(cbar_handle, PropertyName',propertyvalue,...)
```

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('off')`, `colorbar('hide')`, and `colorbar('delete')` delete all colorbars associated with the current axes.

`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 a new colorbar object, which is a child of the current figure. If a colorbar exists, a new one is still created.

`colorbar(cbar_handle,` *`PropertyName`*`',propertyvalue,...)` sets properties for the existing colorbar having the handle `cbar_handle`. To obtain the handle to an existing colorbar, use the command

```
cbar_handle = findobj(figure_handle,'tag','Colorbar')
```

where `figure_handle` is the handle of the figure containing the colorbar you want to modify. If the figure contains more than one colorbar, `cbar_handle` is returned as a vector, and you must choose which of the handles to specify to `colorbar`.

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.

Note The `v6` option enables MATLAB Version 7.x users to create FIG-files that previous versions can open. It is obsolete and will be removed in a future version of MATLAB.

See Plot Objects and Backward Compatibility for more information.

Remarks

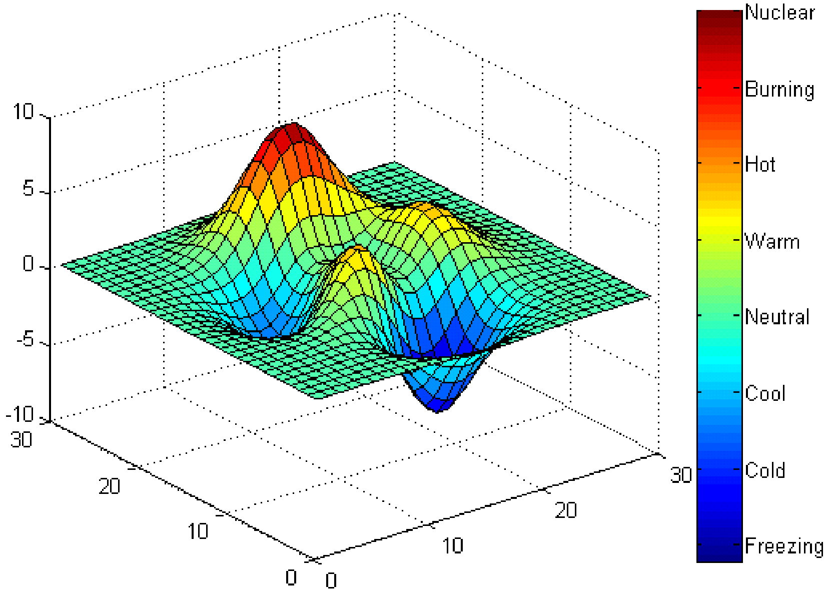
You can use `colorbar` with 2-D and 3-D plots.

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".

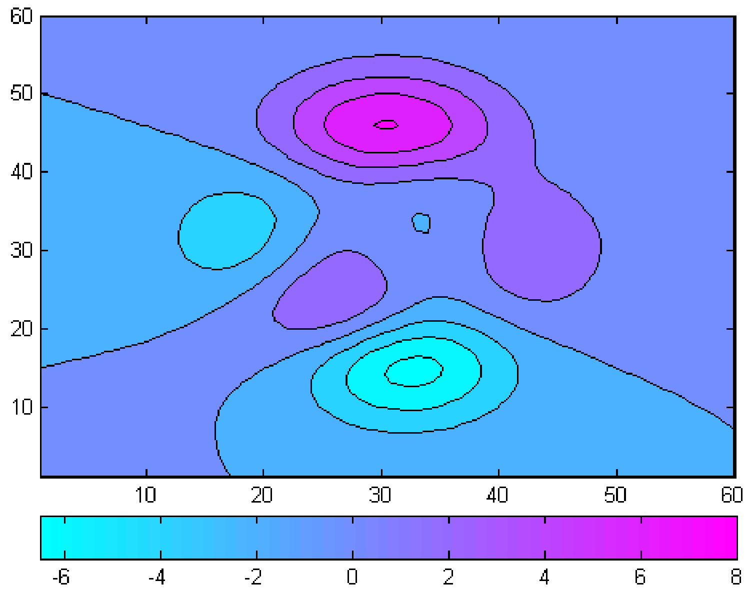
```
surf(peaks(30))
colorbar('YTickLabel',...
    {'Freezing','Cold','Cool','Neutral',...
     'Warm','Hot','Burning','Nuclear'})
```



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 1-100 for related functions

colordef

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 1-100 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], you receive 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, a colormap the same size as the current colormap is created.

Supported Colormaps

The built-in MATLAB® colormaps are 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 2-608 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.

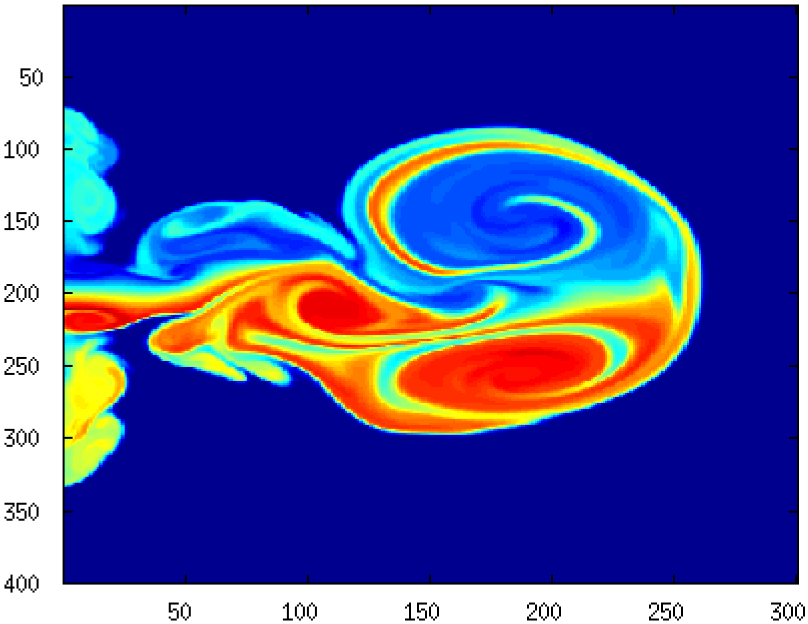
Examples

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.

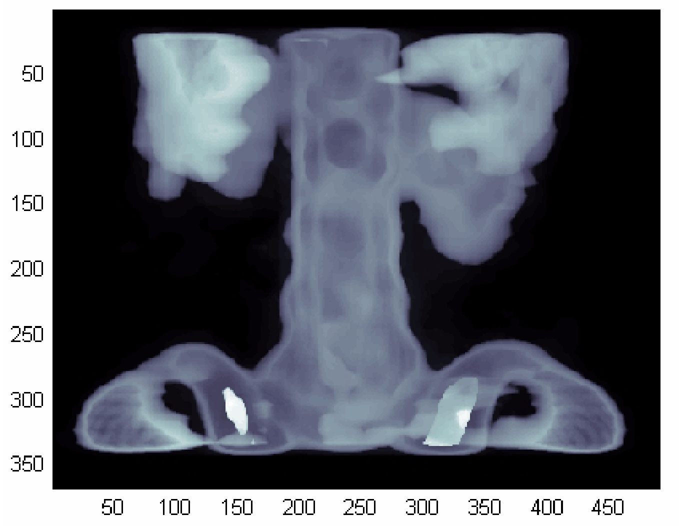
```
load flujet
image(X)
colormap(jet)
```



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 1-100 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. A color picker box appears, from which you can select a new color. After you select a new color at a node, the colors between nodes are reinterpolated.

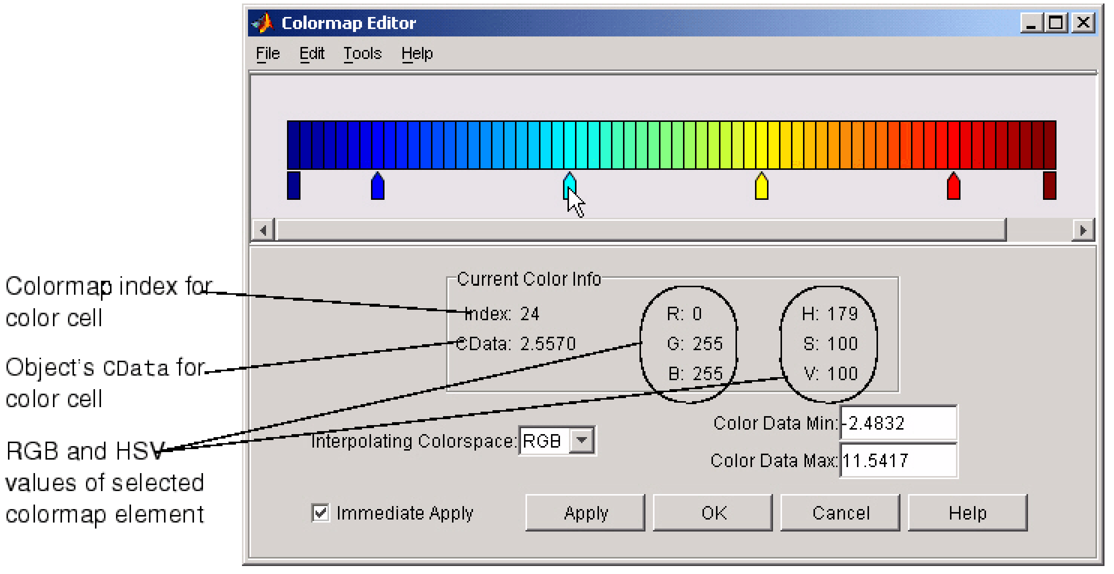
Operation	How to Perform
Add a node	Click below the corresponding cell in the colormap strip.
Select a node	Left-click the node.
Select multiple nodes	Adjacent: left-click first node, **Shift+click** the last node. Nonadjacent: left-click first node, **Ctrl+click** subsequent nodes.
Move a node	Select and drag with the mouse or select and use the left and right arrow keys.

Operation	How to Perform
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

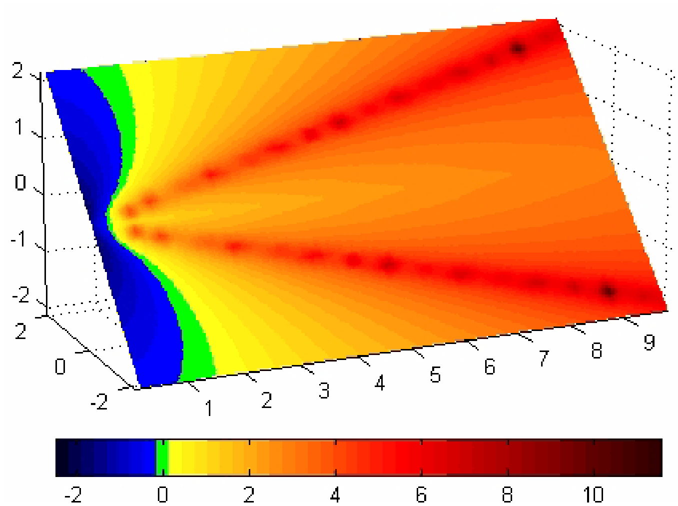
This example modifies a default MATLAB® colormap so that ranges of data values are displayed in specific ranges of color. The graph is a slice plane illustrating a cross section of fluid flow through a jet nozzle. See the `slice` reference page for more information on this type of graph.

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).

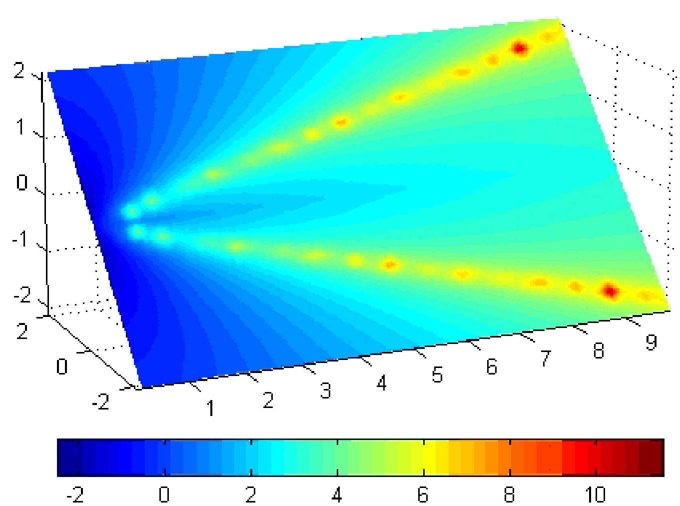
The following picture shows the desired coloring of the slice plane. The colorbar shows the data to color mapping.



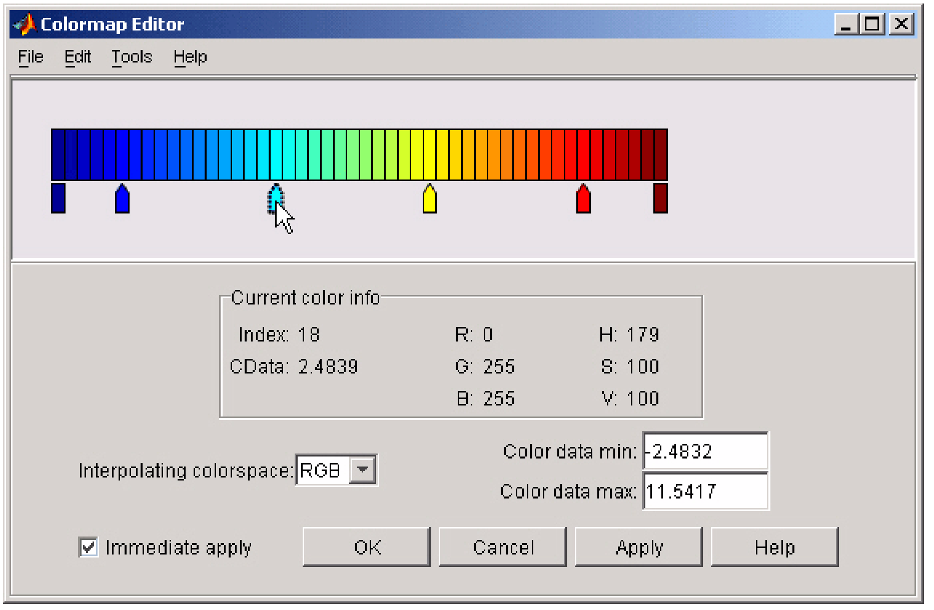
Running the Example

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).

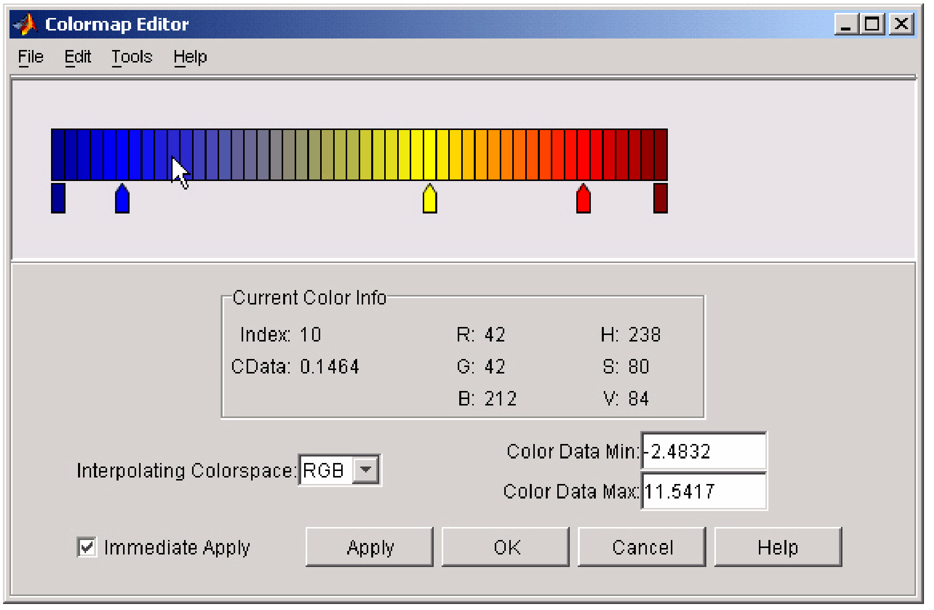
Initially, the default colormap (`jet`) colored the slice plane, as illustrated in the following picture. Note that this example uses a colormap that is 48 elements to display wider bands of color (the default is 64 elements).



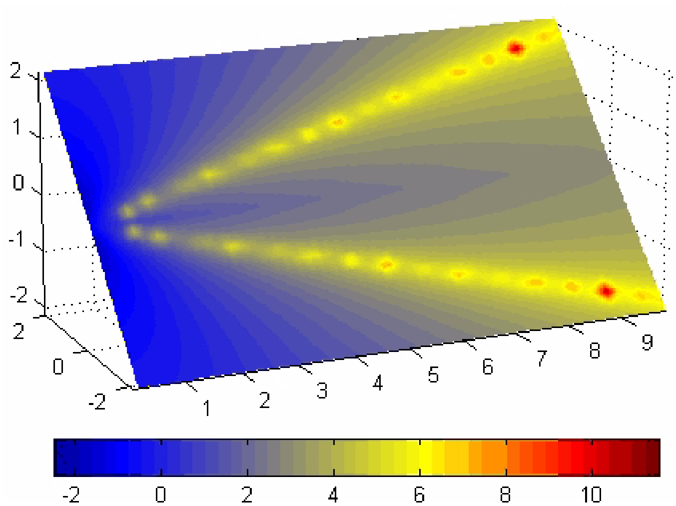
1 Start the colormap editor using the `colormapeditor` command. The color map editor displays the current figure’ s colormap, as shown in the following picture.



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.

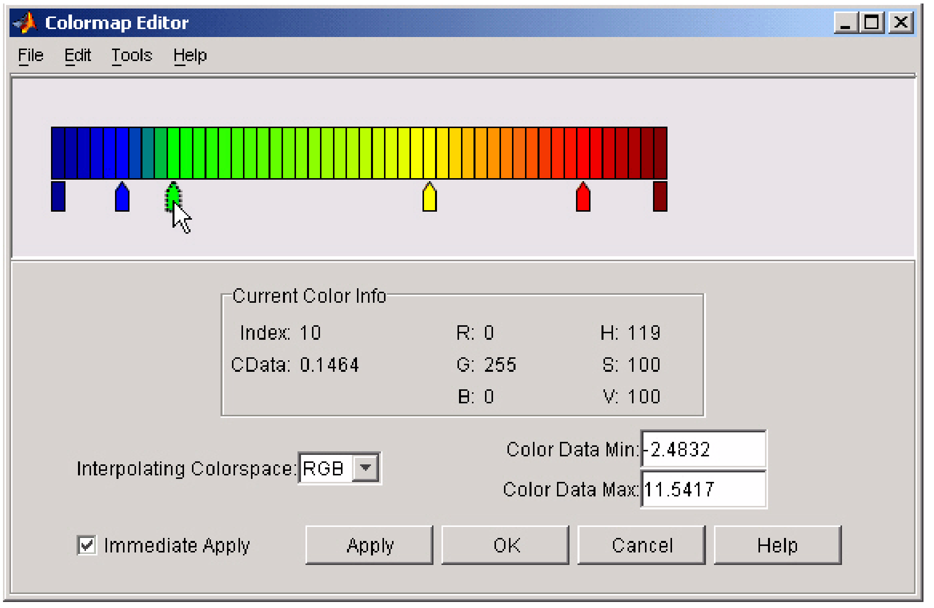


The **Immediate Apply** box is checked, so the graph displays the results of the changes made to the colormap.

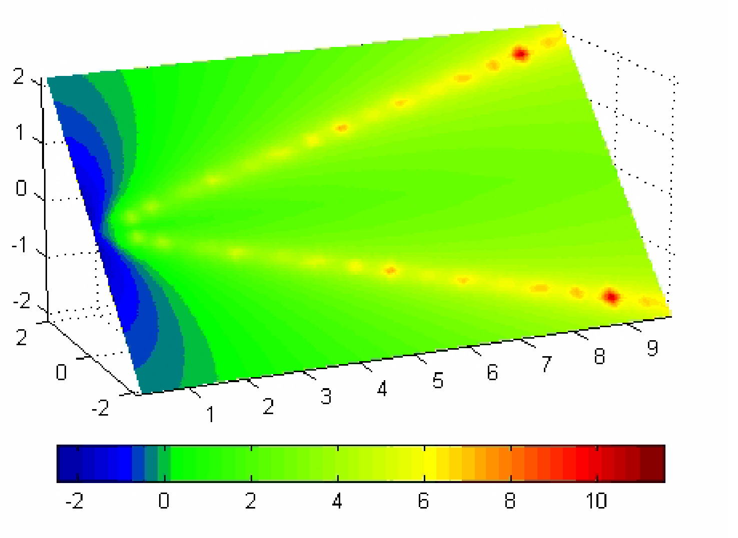


3 We want the fluid speed values around zero to stand out, so we need to find the color cell where the negative-to-positive transition occurs. Dragging the cursor over the color strip enables you to read the data values in the **Current Color Info** panel.

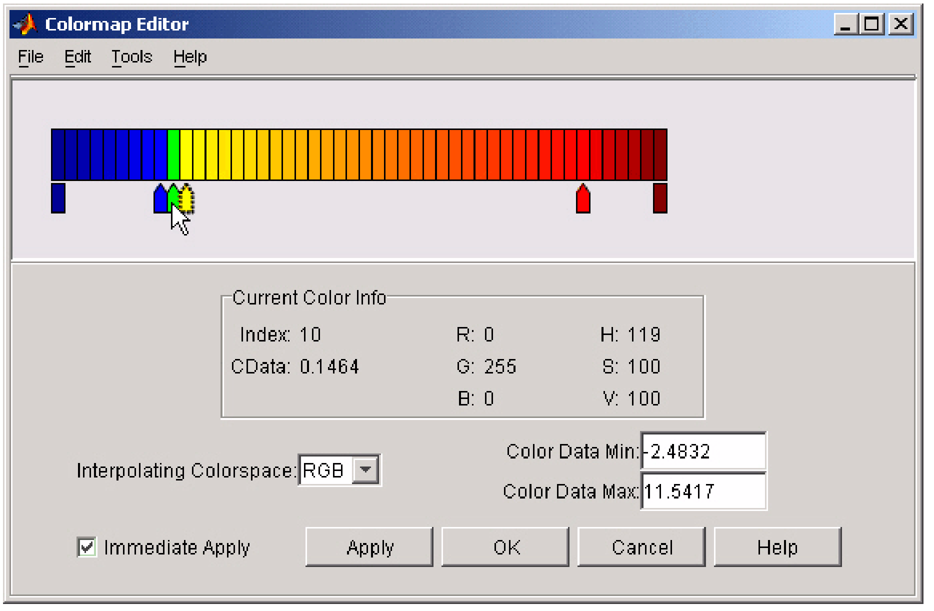
In this case, cell 10 is the first positive value, so we click below that cell and create a node pointer. Double-clicking the node pointer displays the color picker. Set the color of this node to green.



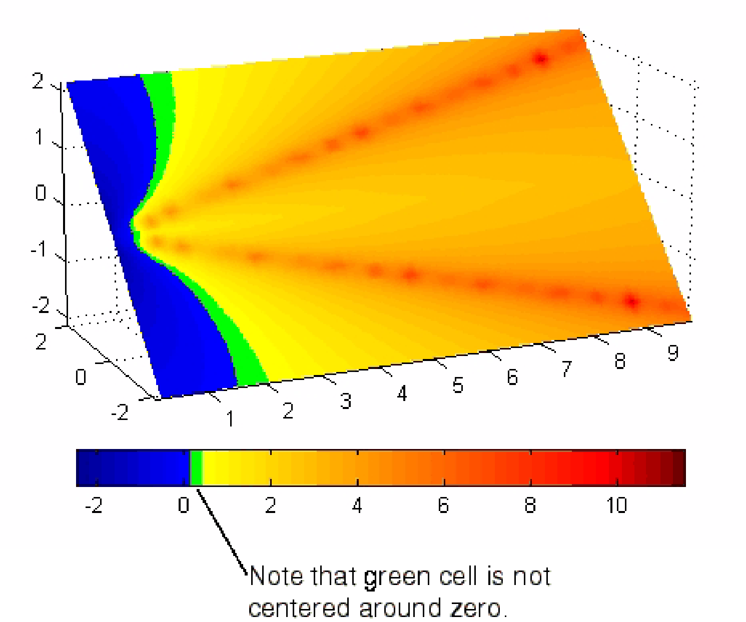
The graph continues to update to the modified colormap.



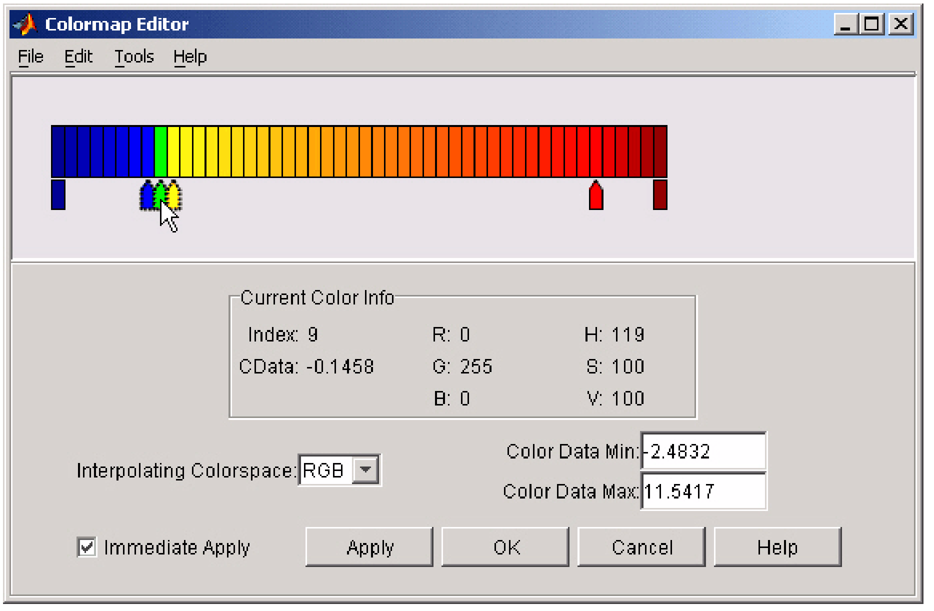
4 In the current state, the colormap colors are interpolated from the green node to the yellowish node about 20 cells away. We actually want only the single cell that is centered around zero to be colored green. To limit the color green to one cell, move the blue and yellow node pointers next to the green pointer.



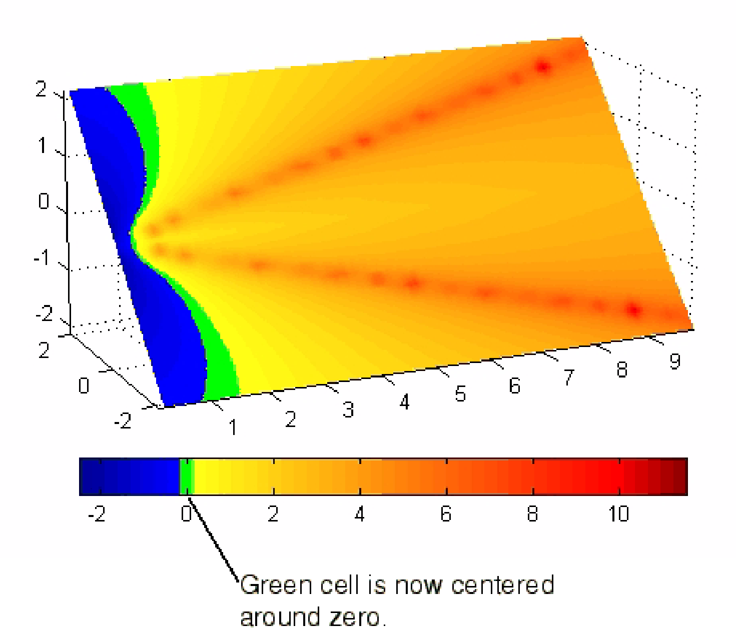
5 Before making further adjustments to the colormap, we need to move the green cell so that it is centered around zero. Use the colorbar to locate the green cell.



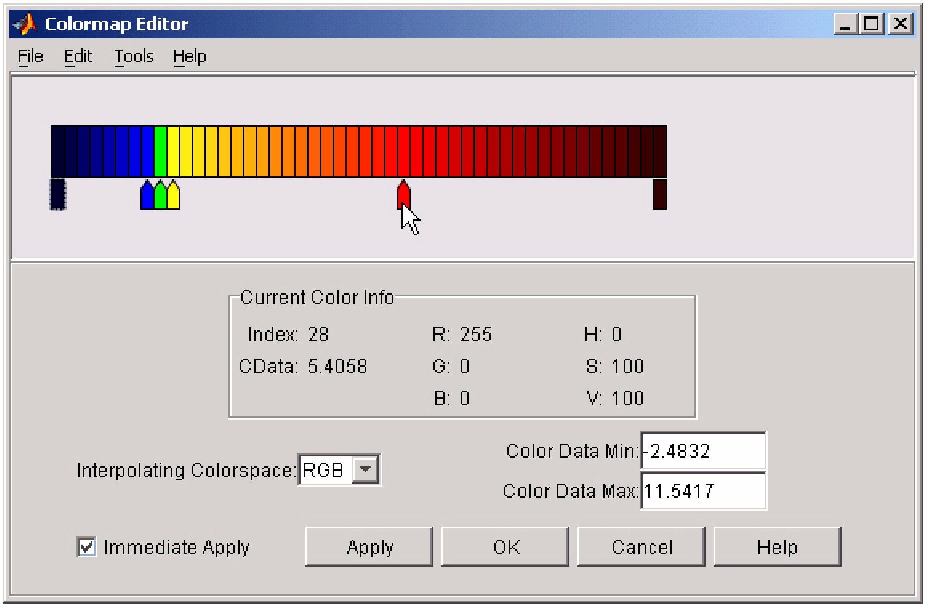
To recenter the green cell around zero, select the blue, green, and yellow node pointers (left-click blue, **Shift+click** yellow) and move them as a group using the left arrow key. Watch the colorbar in the figure window to see when the green color is centered around zero.



The slice plane now has the desired range of colors for negative, zero, and positive data.

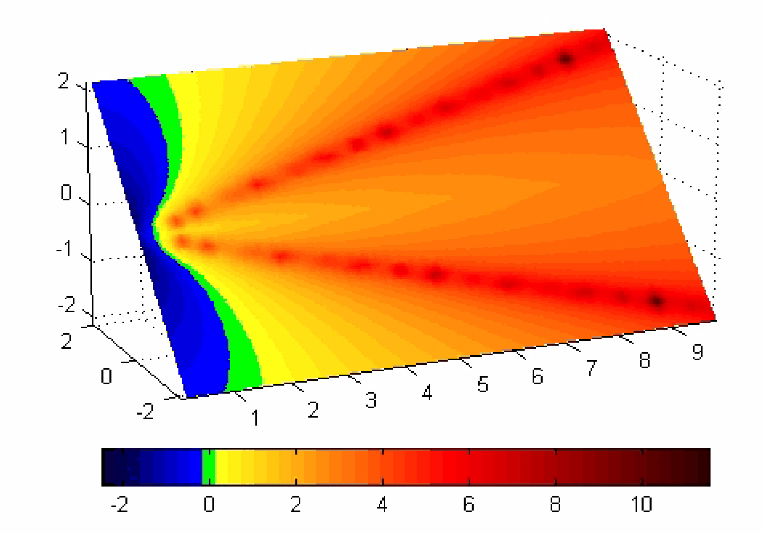


6 Increase the orange-red coloring in the slice by moving the red node pointer toward the yellow node.



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.

Purpose

Color specification

Description

`ColorSpec` is not a function; it refers to the three ways in which you specify color for MATLAB® graphics:

- 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 1-100 for related functions

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,

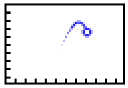
```
B = bucky
```

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.

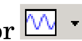
See Also chol, colamd, lu, spparms, symamd, symrcm

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 and Development Environment 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);
```

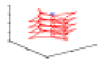
See Also

comet3

"Direction and Velocity Plots" on page 1-91 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 and Development Environment 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 1-91 for related functions

Purpose

Open Command History window, or select it if already open

GUI Alternatives

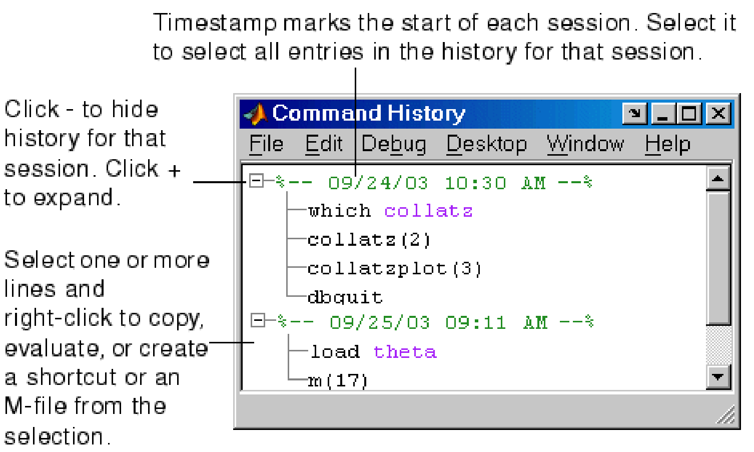
As an alternative to `commandhistory`, select **Desktop > Command History** to open it, or **Window > Command History** to select it.

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 Window"

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
```

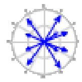
This is also `roots(u)`.

See Also

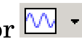
`eig`, `poly`, `polyval`, `roots`

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 and Development Environment 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`.

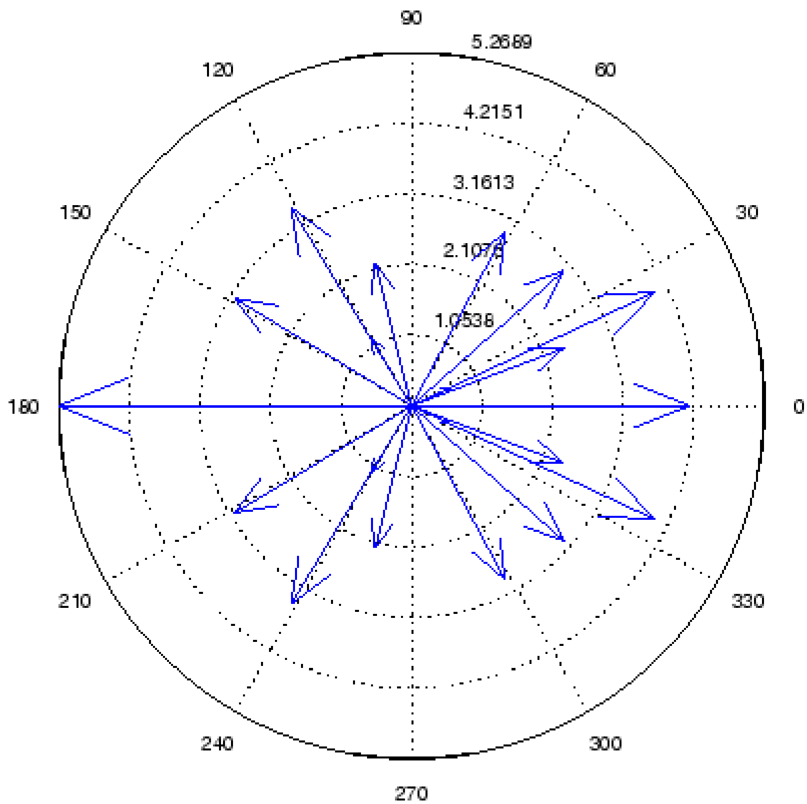
`compass(axes_handle,...)` plots into the axes with the handle `axes_handle` instead of into the current axes (`gca`).

`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 1-91 for related functions

“Compass Plots” for another example

complex

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® software is running

Syntax

```
str = computer
[str,maxsize] = computer
[str,maxsize,endian] = computer
archstr = computer('arch')
```

Description

`str = computer` returns the string `str` with the computer type on which MATLAB software 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 software.

`[str,maxsize,endian] = computer` also returns either 'L' for little-endian byte ordering or 'B' for big-endian byte ordering.

`archstr = computer('arch')` returns the string `archstr` which is the architecture of the build platform. This string can be used for the term `arch` in the `mex` command switch `-<arch>`.

The list of supported computers changes as new computers are added and others become obsolete. A typical list follows.

32–bit Platforms

Computer	str	archstr	ispc	isunix	ismac
GNU on x86	GLNX86	glnx86	0	1	0
Apple® Macintosh® OS X on x86	MACI	maci	0	1	1
Microsoft® Windows® on x86	PCWIN	win32	1	0	0

64–bit Platforms

Computer	str	archstr	ispc	isunix	ismac
GNU Linux® on x86_64	GLNXA64	glnxa64	0	1	0
Microsoft Windows on x64	PCWIN64	win64	1	0	0
Sun™ Solaris™ on SPARC®	SOL64	sol64	0	1	0

Remarks

In some cases, both 32-bit and 64-bit versions of MATLAB can run on the same platform. In this case, the value returned by `computer` reflects which of these is running. For example, if you run a 32-bit version of MATLAB on a Windows x64 platform, `computer` returns `PCWIN`, indicating that the 32-bit version is running.

See Also

`getenv`, `setenv`, `ispc`, `isunix`, `ismac`

cond

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.

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`

condest

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

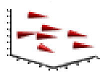
[1] William W. Hager, “Condition Estimates,” *SIAM J. Sci. Stat. Comput. 5*, 1984, 311-316, 1984.

[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.

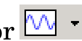
coneplot

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 and Development Environment 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) 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, a value of 1 is used. 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 to automatically 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`).

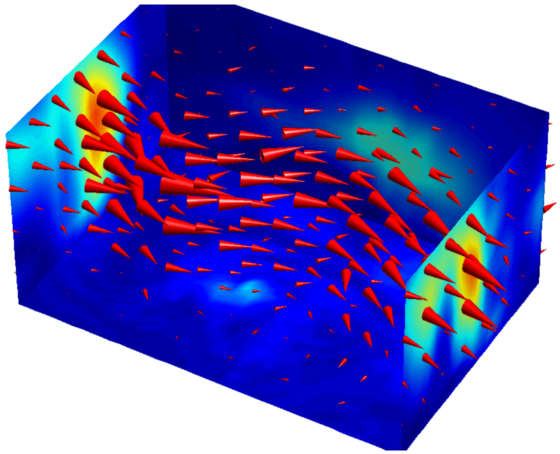
```
axis tight; view(30,40); axis off
camproj perspective; camzoom(1.5)
```

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 1-104 for related functions

conj

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`

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. The same holds true for `continue` statements in nested loops. That is, execution continues at the beginning of the loop in which the `continue` statement was encountered.

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.

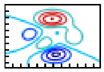
```
fid = fopen('magic.m','r');
count = 0;
while ~feof(fid)
    line = fgetl(fid);
    if isempty(line) | strncmp(line,'%',1)
        continue
    end
    count = count + 1;
end
disp(sprintf('%d lines',count));
```

See Also `for`, `while`, `end`, `break`, `return`

contour

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 and Development Environment 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).

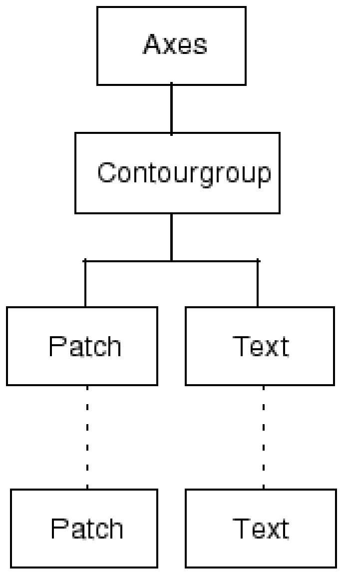
Note The `v6` option enables users of MATLAB Version 7.x to create FIG-files that previous versions can open. It is obsolete and will be removed in a future version of MATLAB.

See Plot Objects and Backward Compatibility for more information.

Remarks

Use 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

$$z = xe^{(-x^2 - y^2)}$$

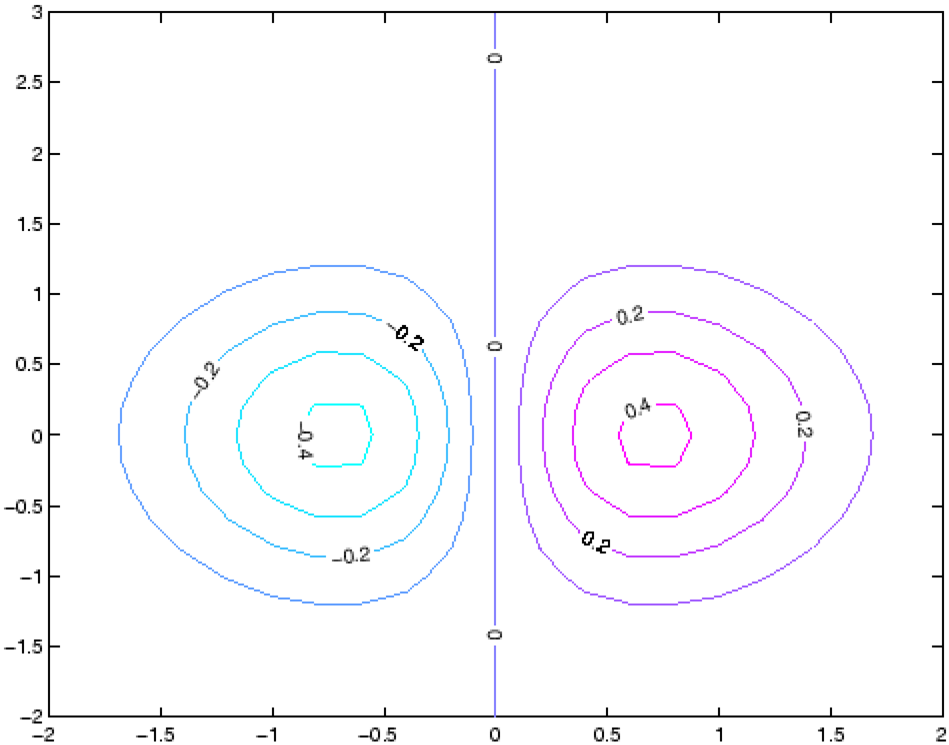
over the range $-2 \le x \le 2$, $-2 \le y \le 3$, create matrix Z using the statements

```
[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.

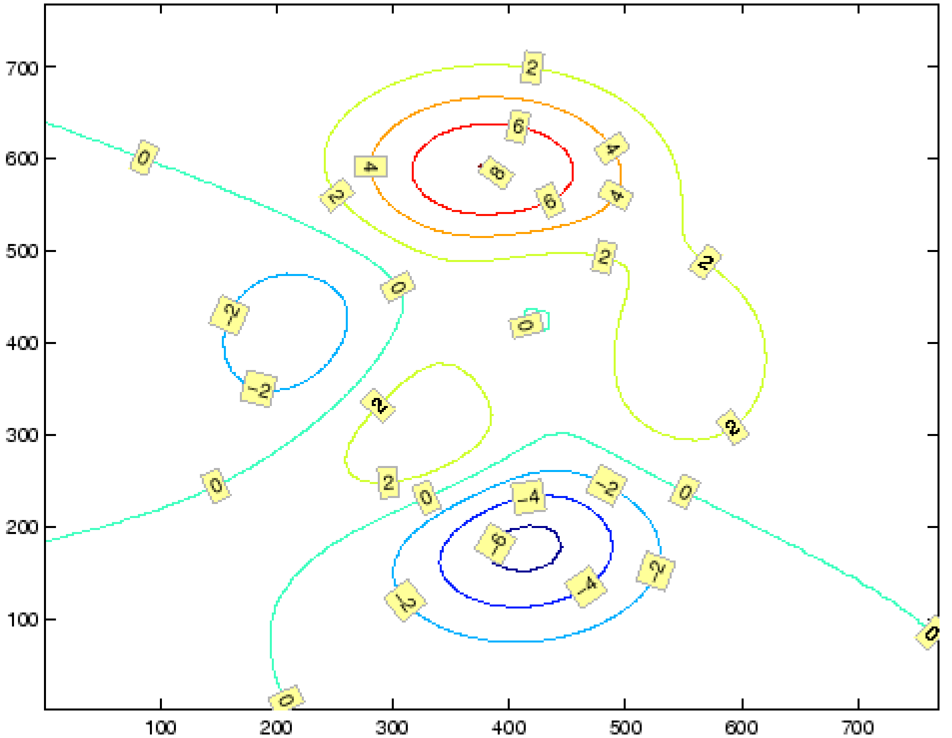
```
[C,h] = contour(X,Y,Z);
set(h,'ShowText','on','TextStep',get(h,'LevelStep')*2)
colormap cool
```



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

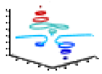
contour3, contourc, contourf, contourslice

See Contourgroup Properties for property descriptions.

contour3

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 and Development Environment 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:

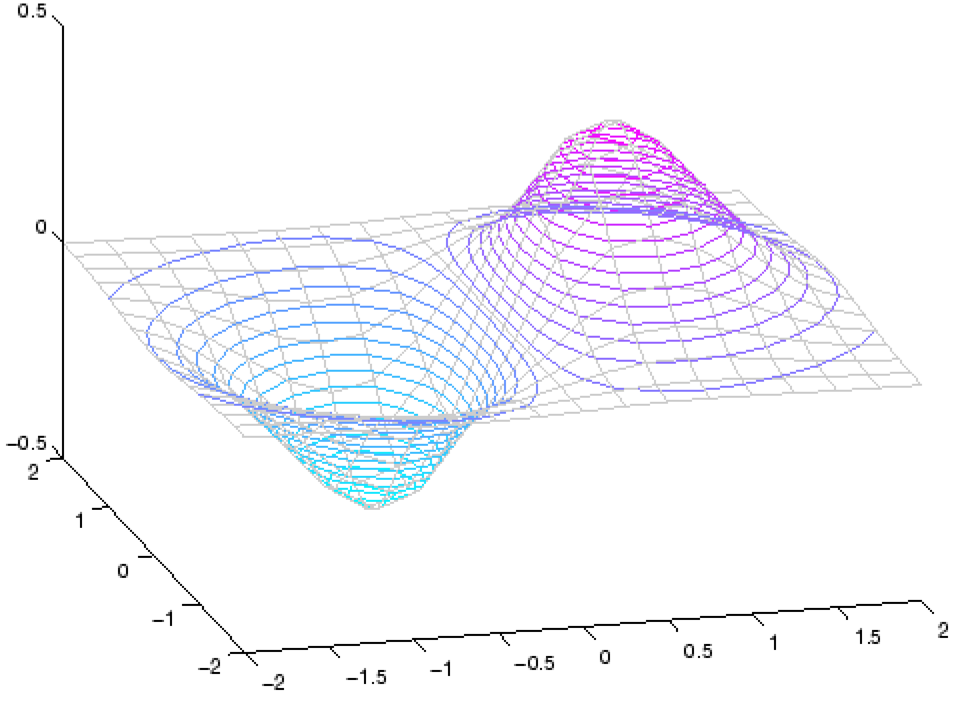
- The contours are drawn at their corresponding Z level.
- Multiple `patch` objects are created instead of a `contourgroup`.
- Calling `contour3` with trailing property-value pairs is not allowed.

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 1-91 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

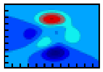
`clabel`, `contour`, `contour3`, `contourf`

"Contour Plots" on page 1-91 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 and Development Environment 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 Version 6.5 and earlier) and a contour matrix CF for the filled areas.

Note The v6 option enables users of MATLAB Version 7.x to create FIG-files that previous versions can open. It is obsolete and will be removed in a future version of MATLAB.

See Plot Objects and Backward Compatibility for more information.

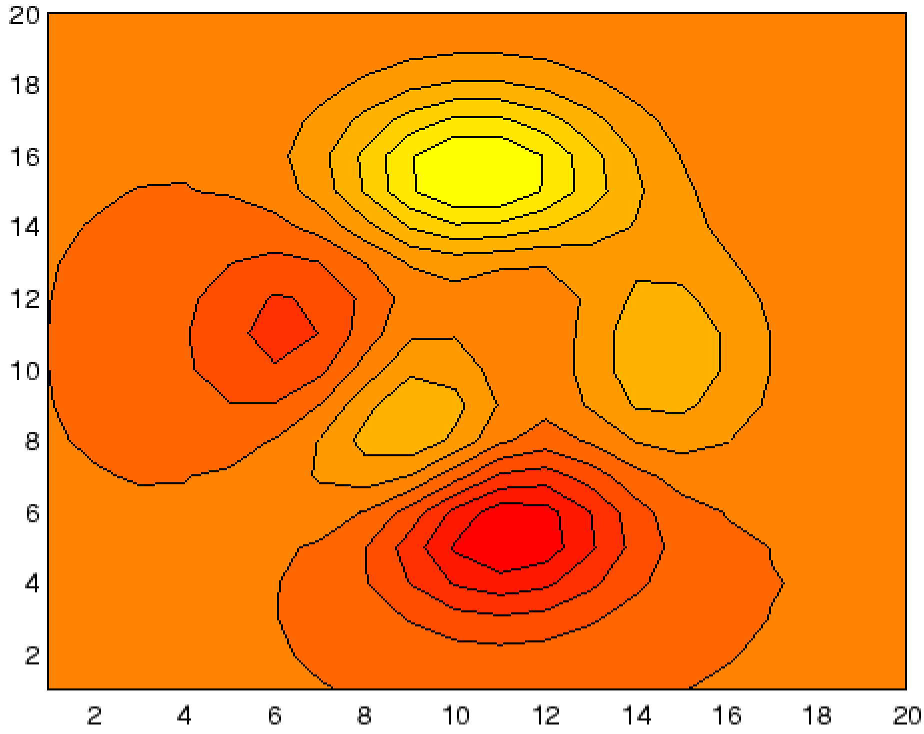
Remarks

If 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 1-91 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.

`Annotation`

`hg.Annotation` object Read Only

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

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

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

IconDisplayStyle Value	Purpose
`on`	Include the contourgroup object in a legend as one entry, but not its children objects
`off`	Do not include the contourgroup or its children in a legend (default)
`children`	Include only the children of the contourgroup as separate entries in the legend

Setting the `IconDisplayStyle` property

These commands set the `IconDisplayStyle` of a graphics object with handle `hobj` to `children`, which causes each child object to have an entry in the legend:

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

Using the `IconDisplayStyle` property

See "Controlling Legends" for more information and examples.

`BeingDeleted`

`on | {off}` Read Only

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

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

`BusyAction`

`cancel | {queue}`

Callback routine interruption. The `BusyAction` property enables you to control how MATLAB handles events that potentially interrupt executing callbacks. If there is a callback function executing, callbacks invoked subsequently always attempt to interrupt it.

If the `Interruptible` property of the object whose callback is executing is set to `on` (the default), then interruption occurs at the next point where the event queue is processed. If the `Interruptible` property is `off`, the `BusyAction` property (of the object owning the executing callback) determines how MATLAB handles the event. The choices are

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

`ButtonDownFcn`
string or function handle

Button press callback function. A callback that executes whenever you press a mouse button while the pointer is over this object, but not over another graphics object. See the `HitTestArea` property for information about selecting objects of this type.

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

This property can be

- A string that is a valid MATLAB expression
- The name of an M-file
- 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 (default is empty string)

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

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

See "Controlling Legends" for more examples.

`EraseMode`
`{normal} | none | xor | background`

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

- `normal` — Redraw the affected region of the display, performing the three-dimensional analysis necessary to ensure that all objects are rendered correctly. This mode produces the most accurate picture, but is the slowest. The other modes are faster, but do not perform a complete redraw and are therefore less accurate.
- `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

`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 2-660.

`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 2-660 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 2-660 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 2-662 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 2-662 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`.

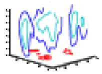
You can use the `refreshdata` function to force an update of the object's data. `refreshdata` also enables you to specify that the data source variable be evaluated in the workspace of a function from which you call `refreshdata`.

See the `refreshdata` reference page for more information.

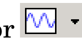
Note If you change one data source property to a variable that contains data of a different dimension, you might cause the function to generate a warning and not render the graph until you have changed all data source properties to appropriate values.

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 and Development Environment 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.

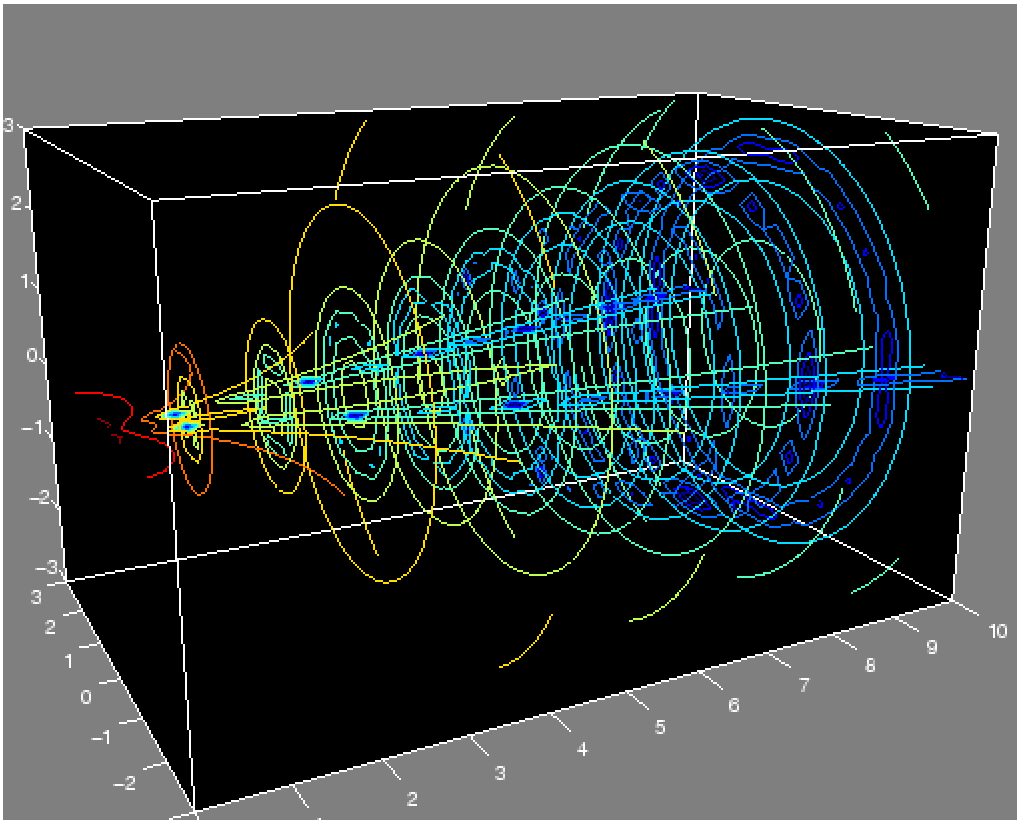
Examples

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 1-104 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 1-101 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

conv2

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 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® software 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
```

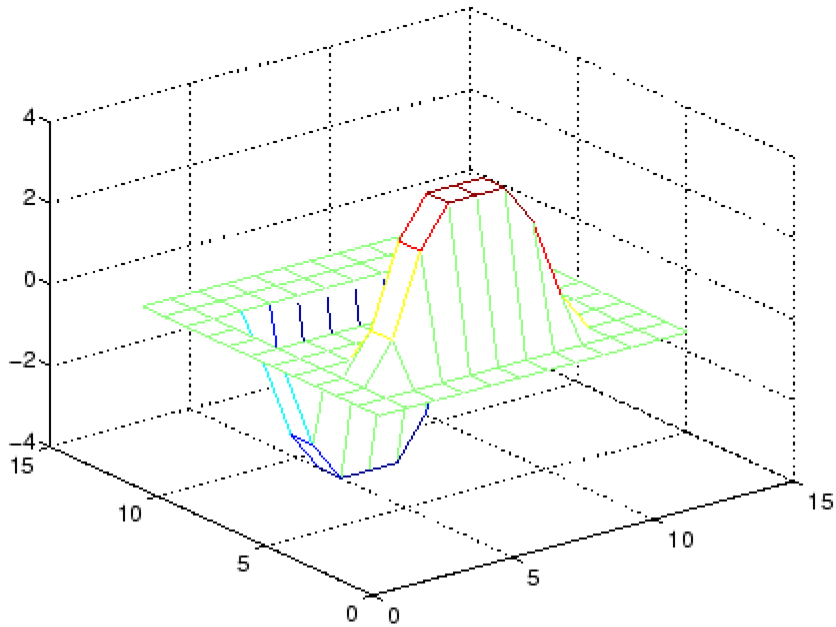
Example 2

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];
```

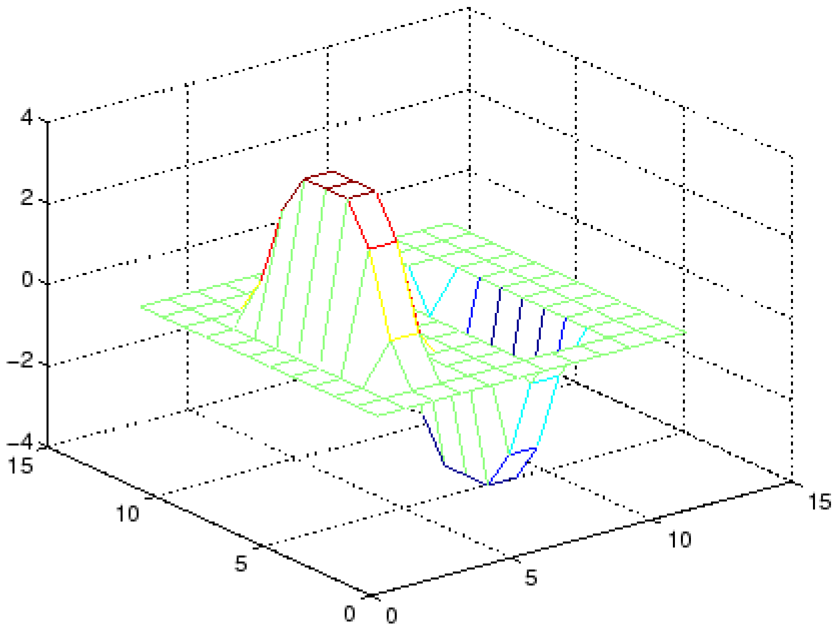
These commands extract the horizontal edges from a raised pedestal.

```
A = zeros(10);
A(3:7,3:7) = ones(5);
H = conv2(A,s);
mesh(H)
```



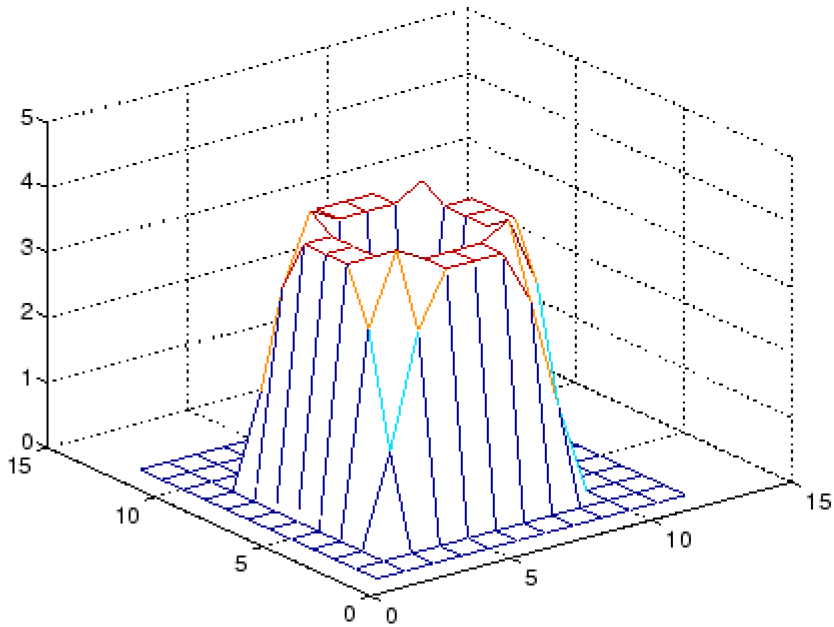
Transposing the filter s extracts the vertical edges of A.

```
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`.

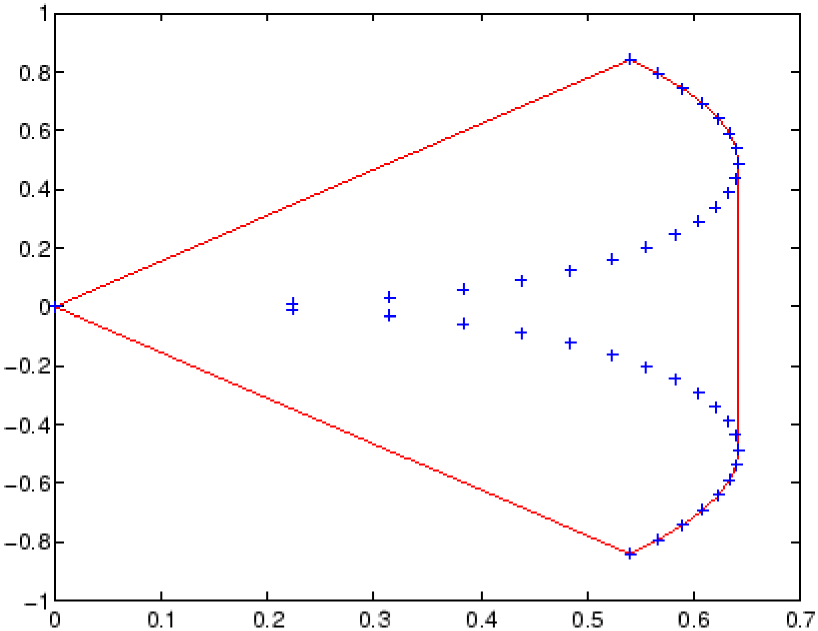
`[K,a] = convhull(...)` also returns the area of the convex hull.

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 "Convex Hulls" 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 the UNIX® and Windows® platforms when using the wildcard `*` or copying directories. (UNIX is a registered trademark of The Open Group in the United States and other countries).

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`

copyobj

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 1-95 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])`. If `x` and `y` are not column vectors, `corrcoef` converts them to column vectors. For example, in this case `R=corrcoef(x,y)` is equivalent to `R=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

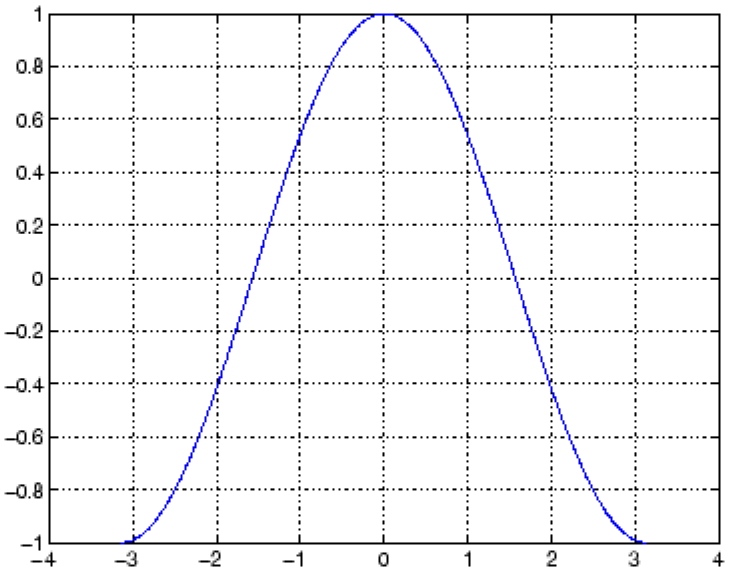
The `cos` function operates element-wise on arrays. The function's domains and ranges include complex values. All angles are in radians.

`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™ 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

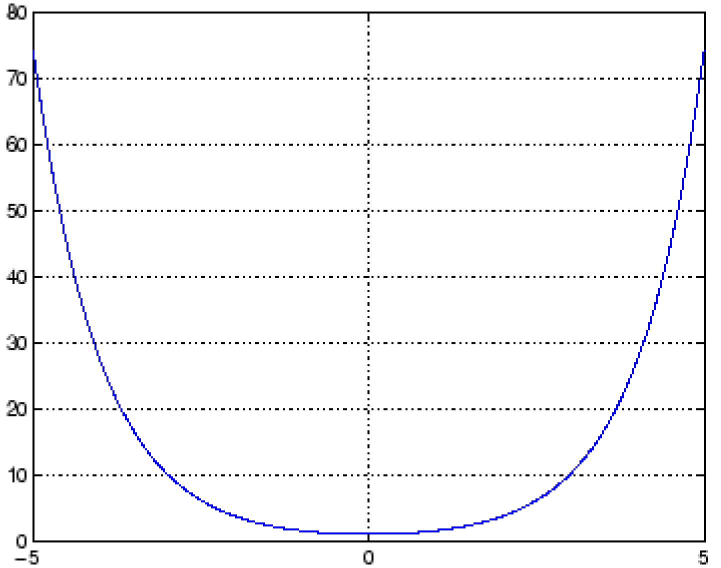
The `cosh` function operates element-wise on arrays. The function's domains and ranges include complex values. All angles are in radians.

`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™ 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

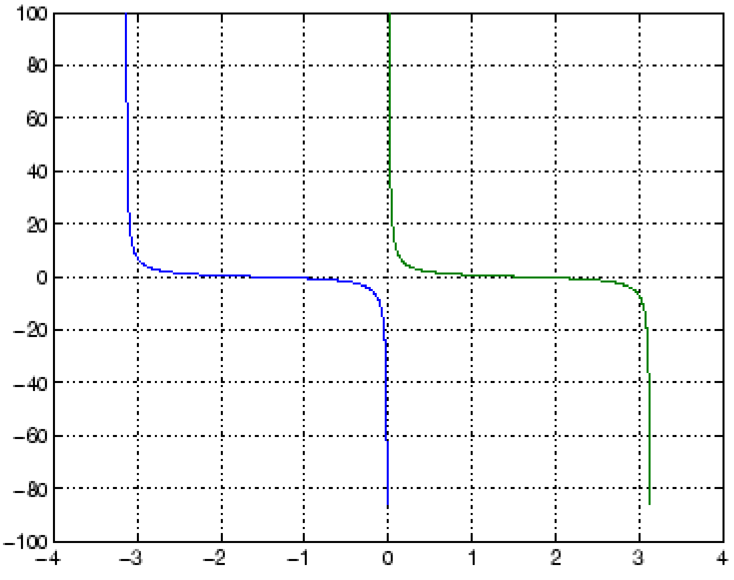
```
Y = cot(X)
```

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

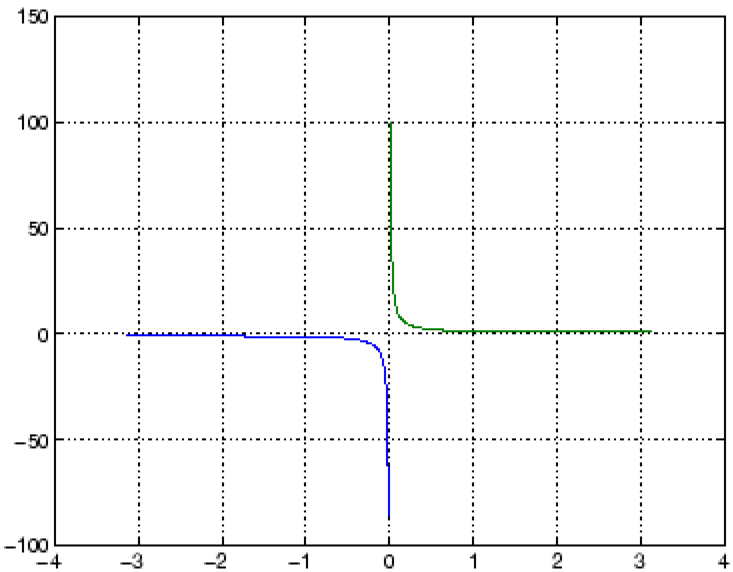
The `coth` function operates element-wise on arrays. The function's domains and ranges include complex values. All angles are in radians.

`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 your MATLAB® application 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 Fundamentals 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

See Also

`callSoapService`, `createSoapMessage`, `parseSoapResponse`

createCopy (inputParser)

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.

For more information on the inputParser class, see “Parsing Inputs with inputParser”in the MATLAB Programming Fundamentals documentation.

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

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

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

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

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)`

createSoapMessage

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.

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

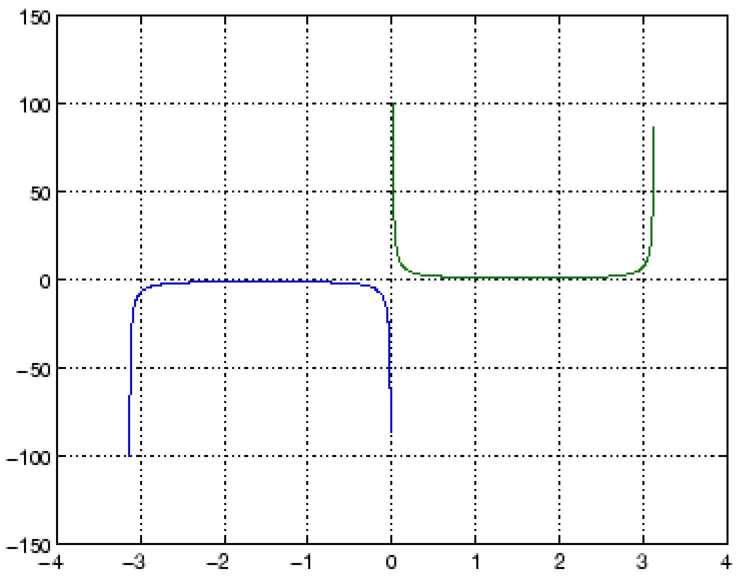
The `csc` function operates element-wise on arrays. The function's domains and ranges include complex values. All angles are in radians.

`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™ 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

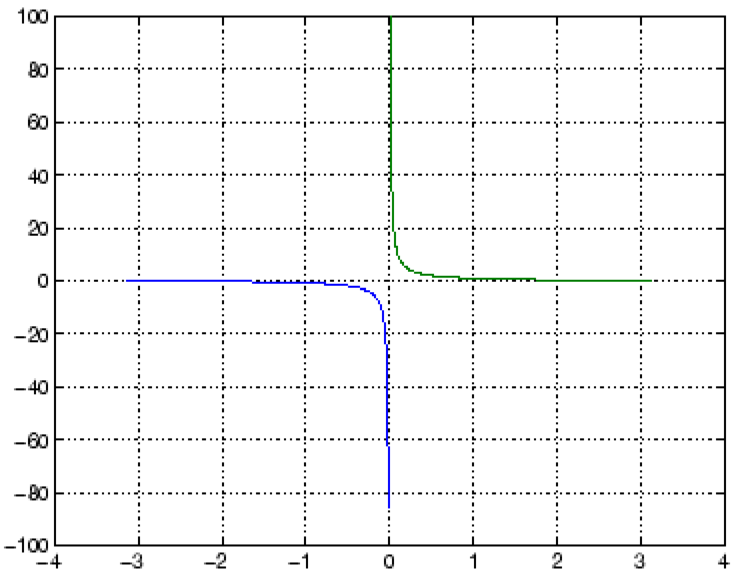
```
Y = csch(x)
```

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

$$\operatorname{csch}(z) = \frac{1}{\sinh(z)}$$

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`

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

<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

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`

csvwrite

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`

ctranspose (timeseries)

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 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`

cumprod

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 column index, thus working along the columns of `A`. Thus, `cumprod(A,1)` and `cumprod(A)` will return the same thing. To increment the row index, use `cumprod(A,2)`.

Examples

```
cumprod(1:5)
ans =
     1   2   6   24   120

A = [1 2 3; 4 5 6];

cumprod(A,1)
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 along the first dimension (the columns); `cumsum(A,2)` works along the second dimension (the rows).

Examples

```
cumsum(1:5)
ans =
       [1   3   6   10   15]

A = [1 2 3; 4 5 6];

cumsum(A,1)
ans =
       1      2      3
       5      7      9

cumsum(A,2)
ans =
       1      3      6
       4      9     15
```

See Also `cumprod`, `prod`, `sum`

cumtrapz

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)`.

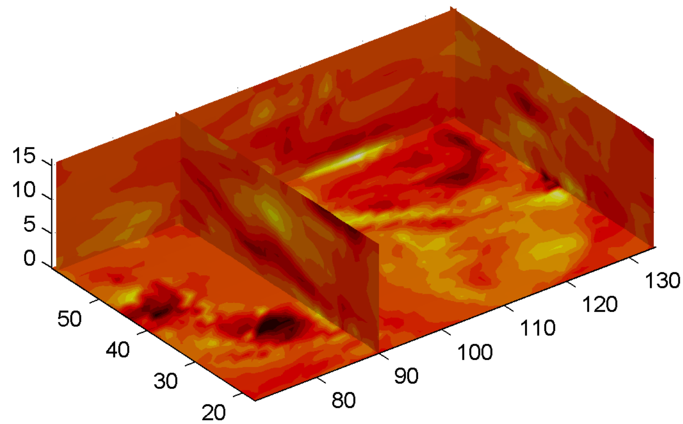
`[curlx,curly,curlz] = curl(...), curlx,curly] = curl(...)` returns only the curl.

`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.

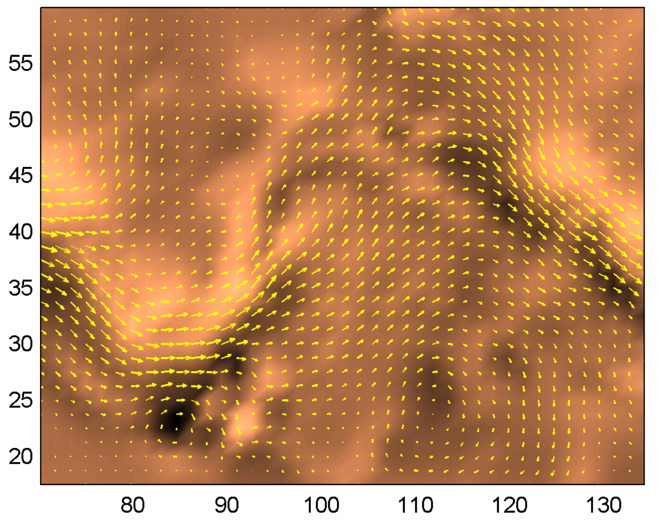
```
load wind
cav = curl(x,y,z,u,v,w);
slice(x,y,z,cav,[90 134],[59],[0]);
shading interp
daspect([1 1 1]); axis tight
colormap hot(16)
camlight
```



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 1-104 for related functions

"Example — Displaying Curl with Stream Ribbons" for another example

Purpose

Allow custom source control system (UNIX® platforms)

Syntax

`customerverctrl`

Description

`customerverctrl` function is for customers who want to integrate a source control system that is not supported for use with MATLAB® software. 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

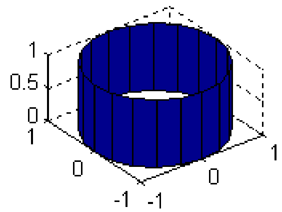
`checkin`, `checkout`, `cmopts`, `undocheckout`

For Microsoft®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`.

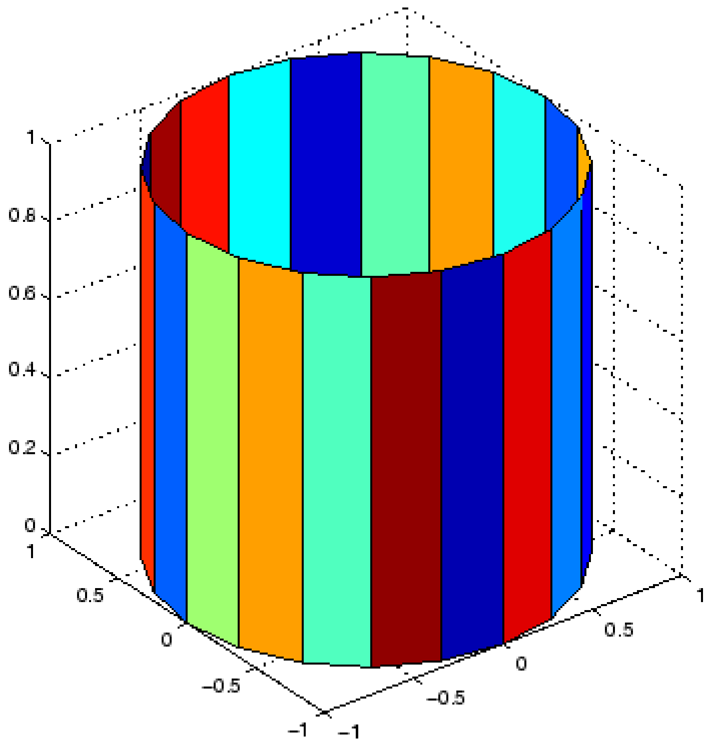
Remarks

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.

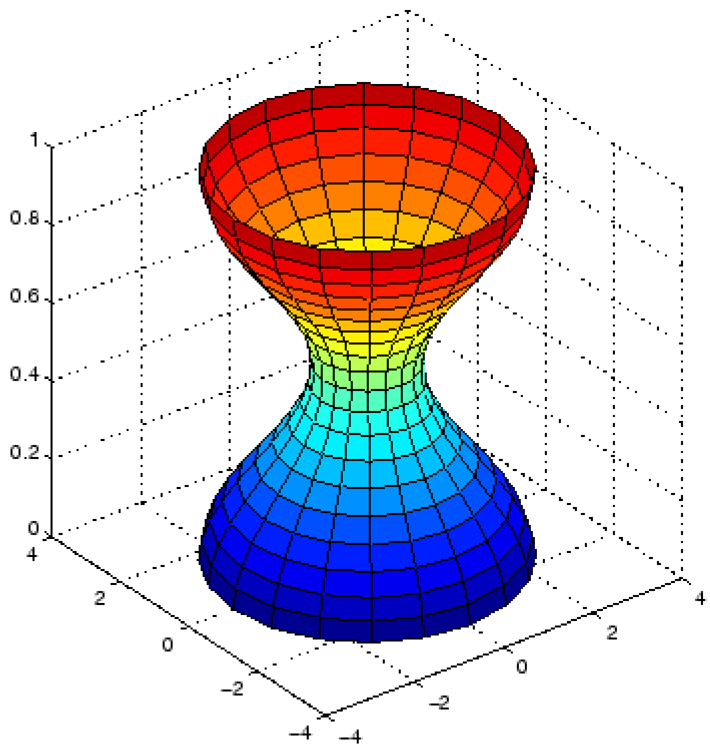
```
cylinder
axis square
h = findobj('Type','surface');
set(h,'CData',rand(size(get(h,'CData'))))
```



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 1-92 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`, the data aspect ratio adjusts 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,

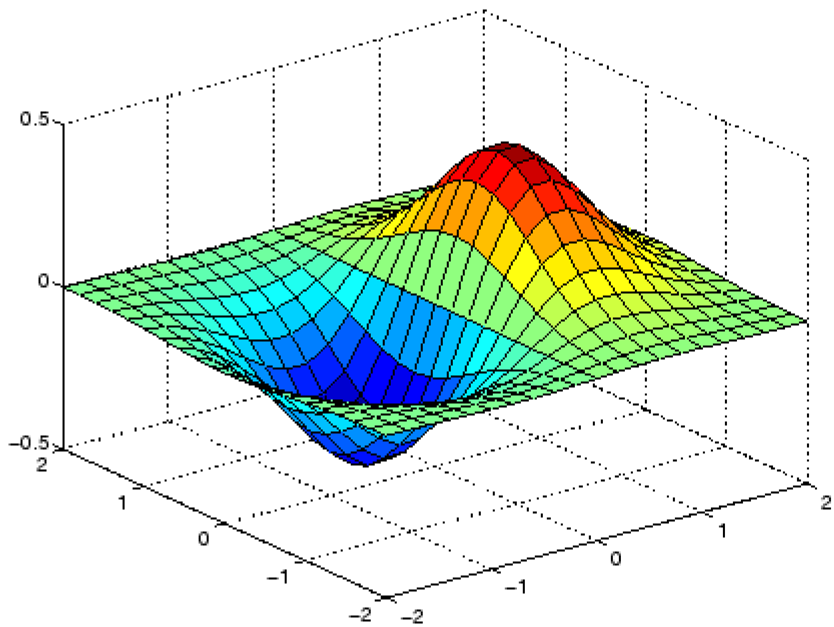
```
daspect(daspect)
```

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)
```



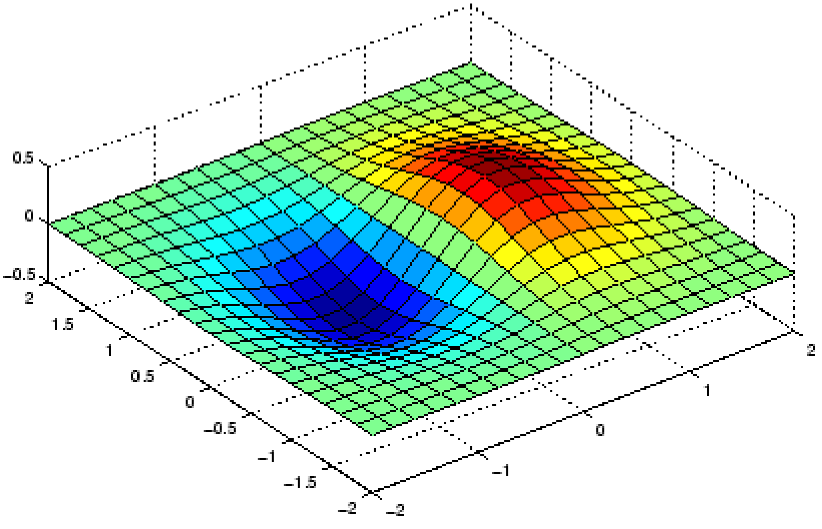
daspect

Querying the data aspect ratio shows how the surface is drawn.

```
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 1-102 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 2-773.

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 when it 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 2-777 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
```

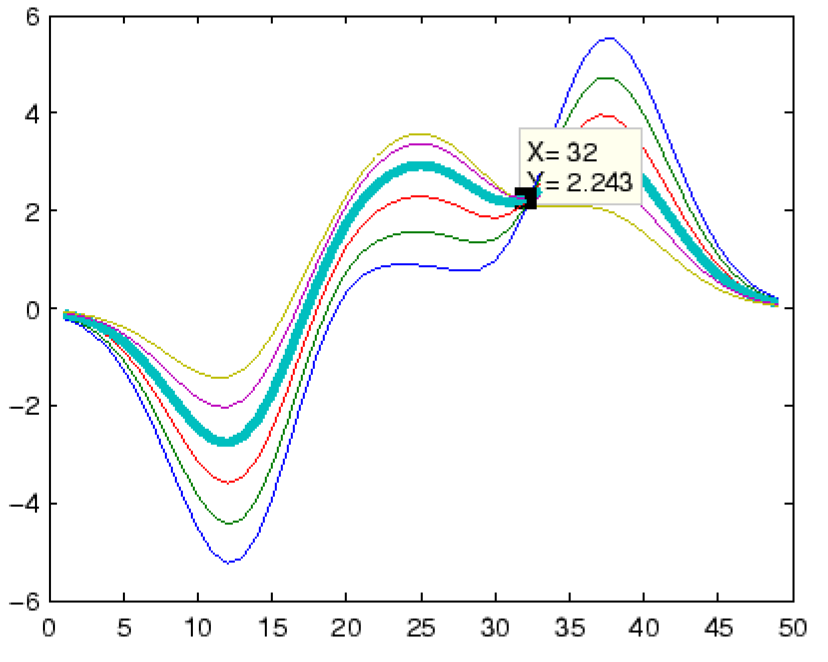
Setting Data Cursor Mode Options

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))]};
```

See Also

`brush`, `pan`, `zoom`

“Example — Visually Exploring Demographic Statistics” for a further example of a data cursor update function

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`

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`

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 your MATLAB® application: 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 your MATLAB® application: 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 2-785, 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 2-788, 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. All date strings in `S1` must have the same format.

`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

Standard MATLAB Date Format Definitions (Continued)

dateform (number)	dateform (string)	Example
5	'mm'	03
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

Standard MATLAB Date Format Definitions (Continued)

dateform (number)	dateform (string)	Example
27	'QQ-YYYY'	Q1-2001
28	'mmmyyyy'	Mar2000
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`

Free-Form Date Format Specifiers (Continued)

Symbol	Interpretation	Example
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
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 2-788 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

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.

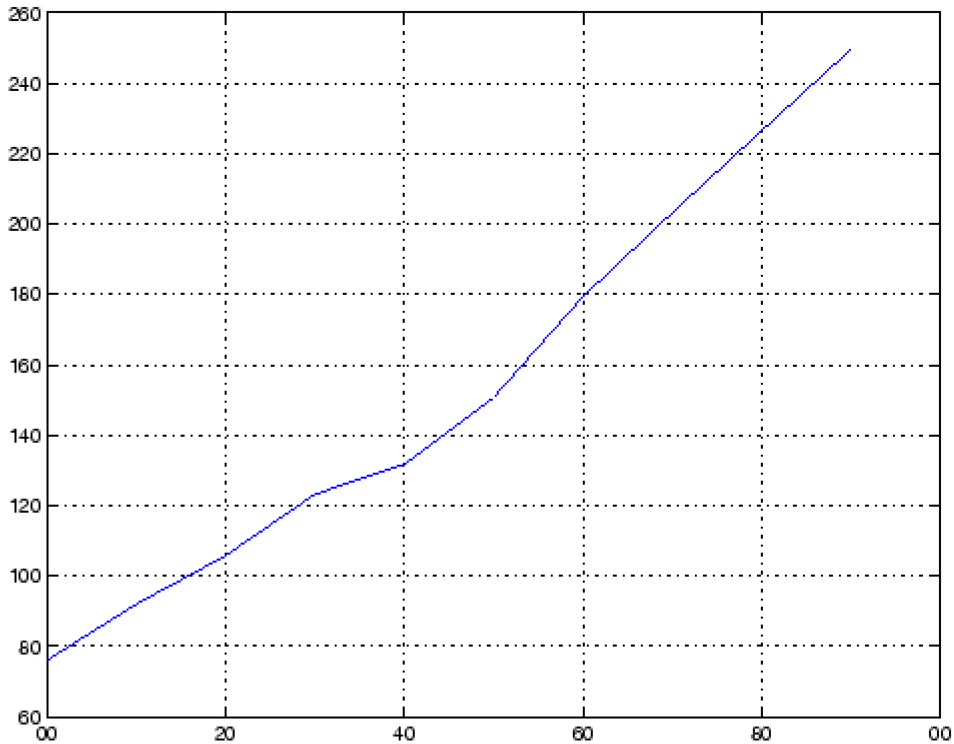
To change the tick spacing and locations, set the appropriate axes property (i.e., `XTick`, `YTick`, or `ZTick`) before calling `datetick`.

Calling `datetick` sets the `TickMode` of the specified axis to `'manual'`. This means that after zooming, panning or otherwise changing axis limits, you should call `datetick` again to update the ticks and labels.

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 years
```



See Also

The axes properties `XTick`, `YTick`, and `ZTick`

`datenum`, `datestr`

"Annotating Plots" on page 1-89 for related functions

datevec

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 your MATLAB® application: 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`

dbclear

Purpose

Clear breakpoints

GUI Alternatives

In the Editor, 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`. `mfile` must be the name of an M-file, and can include a MATLAB® `partialpath`. If the command includes the `-completenames` option, then `mfile` need not be on the path, as long as it is a fully qualified file name. (On Microsoft® Windows® platforms, this is a file name that begins with `\\` or with a drive `%` letter followed by a colon. On UNIX® platforms, this is a file name that begins with `/` or `~`.) `mfile` can include a `filemarker` to specify the path to a particular subfunction or to a nested function within an M-file.
`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`.

Format	Action
`dbclear in mfile at lineno@n`	Removes the breakpoint set in the nthe 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` on Windows platforms.

See Also

`dbcont`, `dbdown`, `dbquit`, `dbstack`, `dbstatus`, `dbstep`, `dbstop`, `dbtype`, `dbup`, `filemarker`,`partialpath`

Purpose

Resume execution

GUI Alternatives

Select **Debug > Continue** from most desktop tools, or in the Editor, 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`

dbdown

Purpose Change local workspace context when in debug mode

GUI Alternatives Use the **Stack** field 

in the Editor or in the 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`

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.

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, quadgk, quadl, triplequad, function_handle (@), "Anonymous Functions"

Purpose

Enable MEX-file debugging

Syntax

```
dbmex on
dbmex off
dbmex stop
```

dbmex

Description

`dbmex` **`on`** enables MEX-file debugging for UNIX®[2] platforms. It is not supported on the Sun™ Solaris™ platform.

To use this option, first start the MATLAB® software from 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 Solaris, `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`

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

Purpose

Quit debug mode

GUI Alternative

From most desktop tools, select **Debug > Exit Debug Mode**, or in the Editor, 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® software 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.

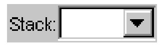
See Also

`dbclear`, `dbcont`, `dbdown`, `dbstack`, `dbstatus`, `dbstep`, `dbstop`, `dbtype`, `dbup`

Purpose

Function call stack

GUI Alternatives

Use the **Stack** field 

in the Editor or in the 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. 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`

MATLAB® Desktop Tools and Development Environment Documentation

- "Editing and Debugging M-Files"
- "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.

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 path. Each line number is a hyperlink you can click to go directly to that line in the Editor.

`dbstatus(` **`-completenames`** `)` displays, for each breakpoint, the absolute file name 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 path 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 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® software 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. 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 the running `mfile` at the first executable line, putting MATLAB® software in debug mode. `mfile` must be the name of an M-file, and can include a MATLAB `partialpath`. If the command includes the `-completenames` option, then `mfile` need not be on the path, as long as it is a fully qualified file name. (On Microsoft® Windows®, this is a file name that begins with `\\` or with a drive `%` letter followed by a colon. On UNIX® platforms, this is a file name that begins with `/` or `~`.) `mfile` can include a `filemarker` to specify the path to a particular subfunction or to a nested function within an M-file. 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 nthe 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 `n`the 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 2-826 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 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 paths 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`, `filemarker`,`keyboard`, `partialpath`, `return`, `whos`

dbtype

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.

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 path name 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`

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 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`

dde23

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.

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 "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`.

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`

ddesd

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 $d(j) \leq t$ 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 $t \leq t_0$ 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.

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 "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 $t \leq 0$ 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

<table>
<tr><th>Property</th><th>Value</th><th>Description</th></tr>
<tr><td><code>OutputFcn</code></td><td>Function handle
<code>{@odeplot}</code></td><td>The output function is a function that the solver calls after every successful integration step. To specify an output function, set <code>'OutputFcn'</code> to a function handle. For example,

<code>options = ddeset('OutputFcn',...</code>
<code>@myfun)</code>

sets ’<code>OutputFcn</code>’ to @myfun, a handle to the function <code>myfun</code>. See “Function Handles” in the MATLAB® Programming documentation for more information.

The output function must be of the form

<code>status = myfun(t,y,flag)</code>

in the MATLAB Mathematics documentation, explains how to provide additional parameters to <code>myfun</code>, 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:</td></tr>
</table>

DDE Solver Output Properties (Continued)

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 ith column of y corresponds to the ith 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

DDE Solver Output Properties (Continued)

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`.

DDE Step Size Properties (Continued)

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 2-842 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:

DDE Events Property (Continued)

String	Value	Description
		• value(i) is the value of the ith 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 "Event Location" (ballode) and "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 (@)

deal

Purpose

Distribute inputs to outputs

Note Beginning with MATLAB® Version 7.0 software, 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

Beginning with MATLAB Version 7.0 software, 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`

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`

Purpose

List M-file debugging functions

GUI Alternatives

Use the **Debug** menu in most desktop tools, or use the Editor.

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® software encounters a breakpoint during execution, it enters debug mode, the Editor 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 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

dec2base

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`

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.

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`

del2

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® software 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`

Purpose

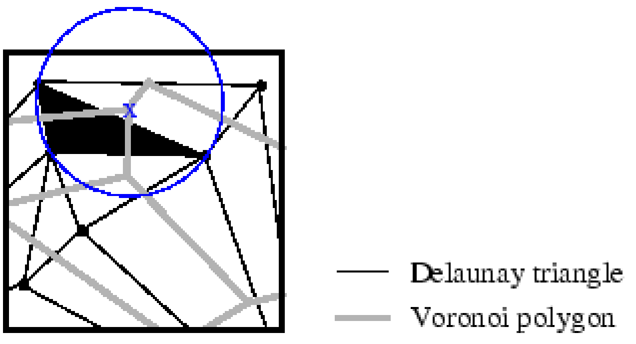
Delaunay triangulation

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

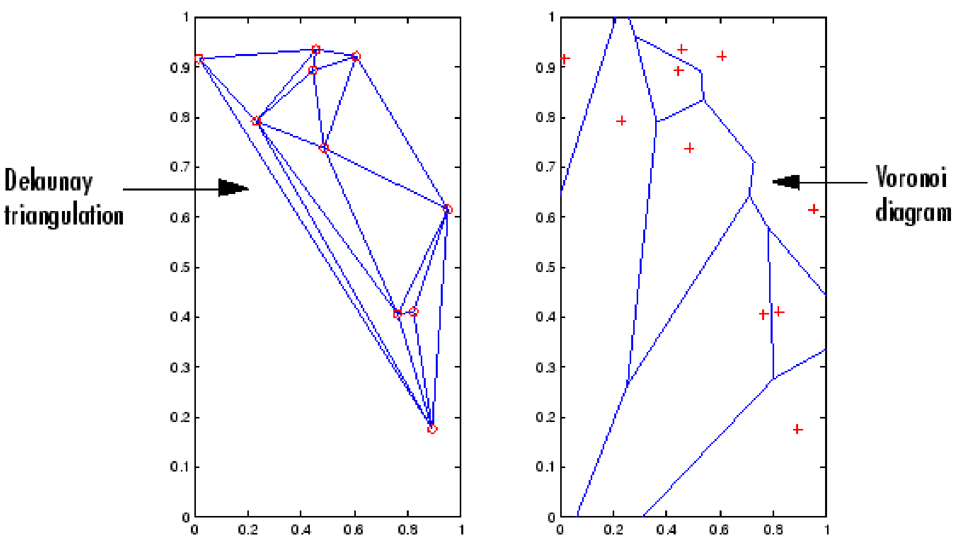
Plot the Delaunay triangulation for 10 randomly generated points.

```
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])
```

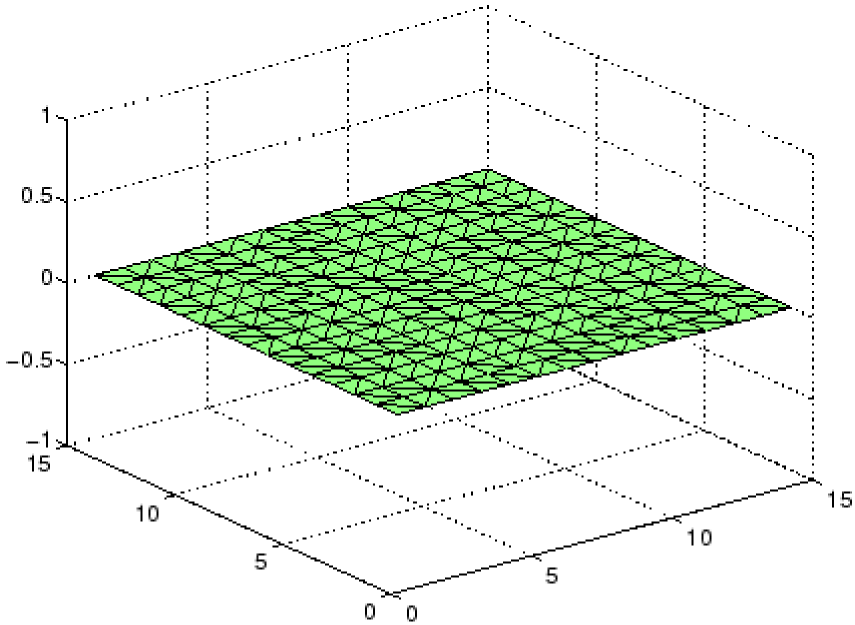


Example 2

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.

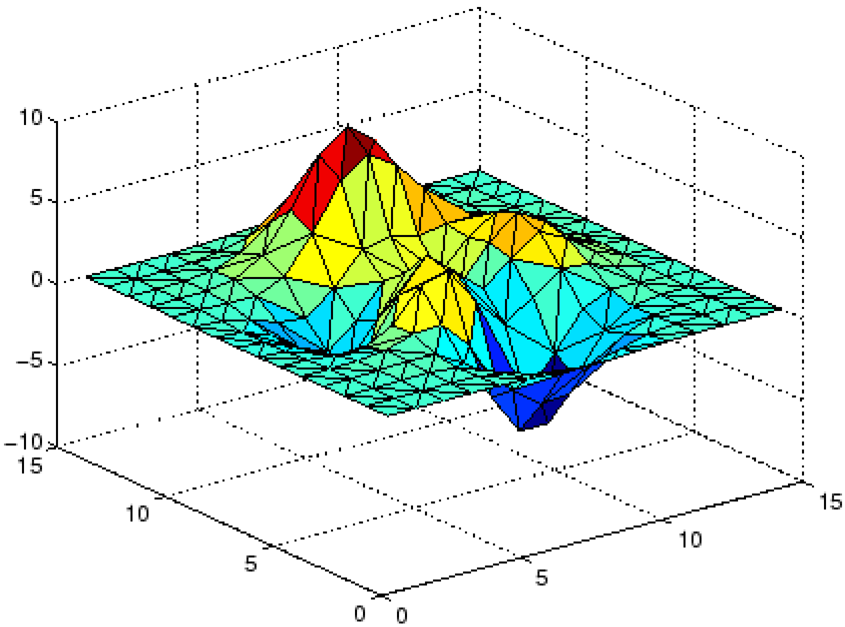
```
[x,y] = meshgrid(1:15,1:15);
```

```
tri = delaunay(x,y);
trisurf(tri,x,y,zeros(size(x)))
```



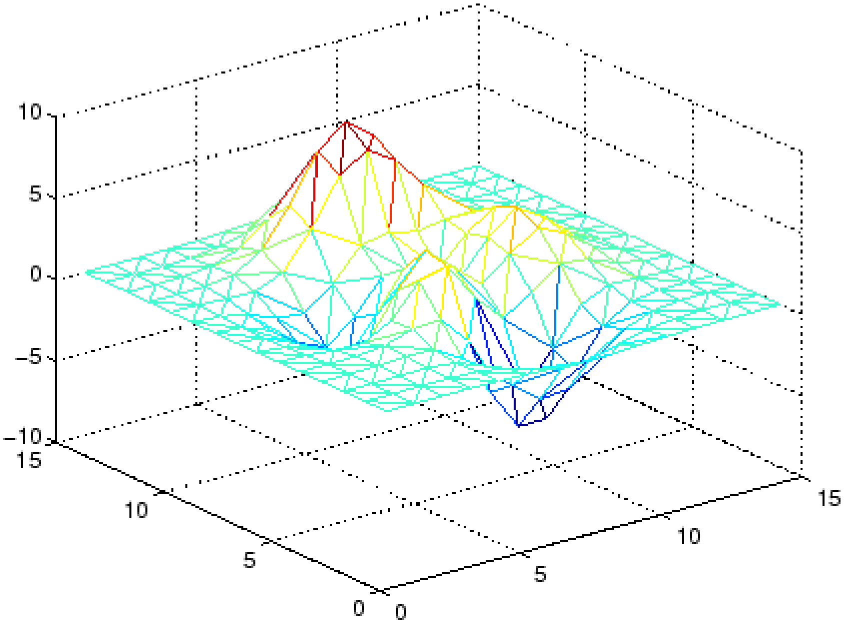
Next, generate peaks data as a 15-by-15 matrix, and use that data with the Delaunay triangulation to produce a surface in 3-D space.

```
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.

delaunay3

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`.

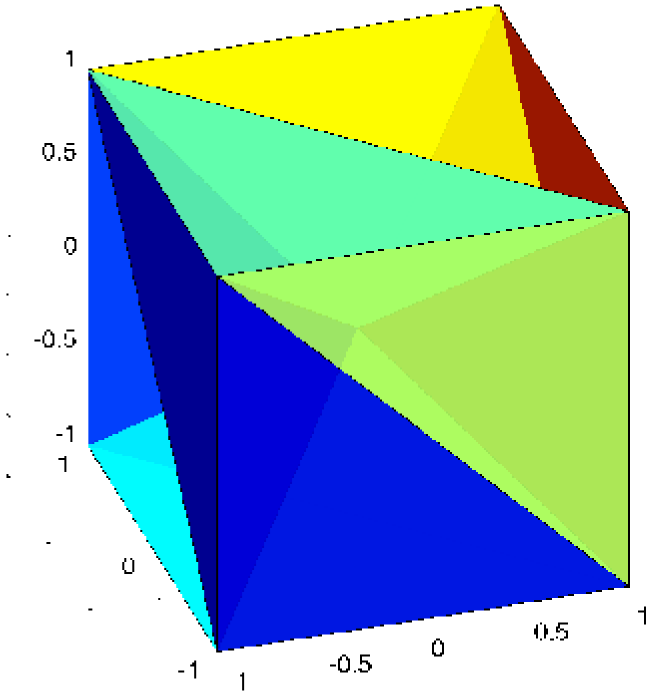
Examples

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.

delaunayn

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 in the MATLAB® documentation.
- You cannot plot `delaunayn` output for `n > 3`.

Examples

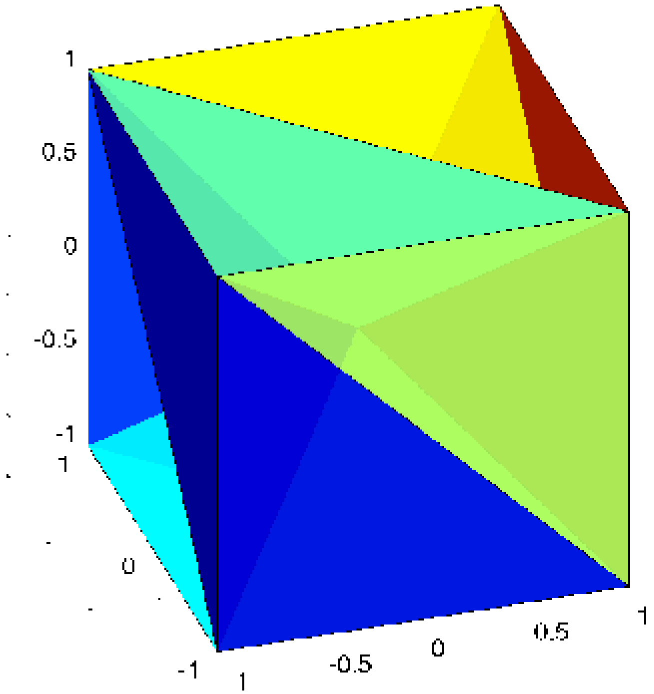
Example 1

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.

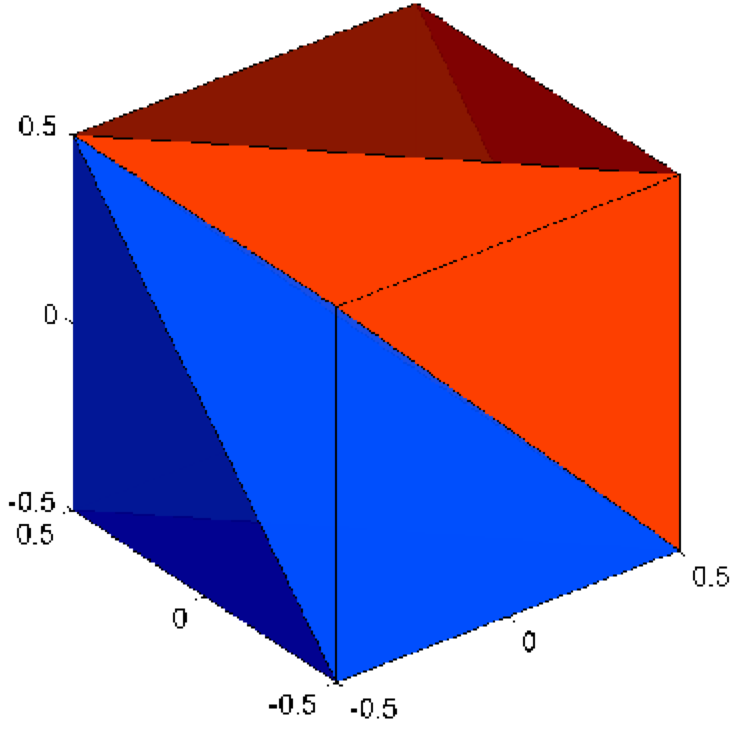
??? qhull input error: can not scale last coordinate. Input is cocircular or cospherical. Use option 'Qz' to add a point at infinity.

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 The MATLAB® software 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

Application"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`

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 (COM), load (COM), actxcontrol, actxserver

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`

delete (handle)

Purpose

Handle object destructor function

Syntax

```
delete(h)
```

Description

`delete(h)` optional method you can implement to perform cleanup tasks just before the handle object is destroyed. The MATLAB® runtime calls the `delete` method of any handle object (if it exists) when the object is destroyed. `h` is a scalar handle object.

A `delete` method should not generate errors or create new handles to the object being destroyed. If the `delete` method has a different signature (having output arguments or more than one input argument) it is not called when the handle objects is destroyed.

See "Handle Class Delete Methods" for more information.

See Also

`handle`, `isvalid`

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 COM 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 (COM), set (COM), 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`

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, listing demos for all installed products that are selected in the Help browser product filter preference. To access demos from the **Demos** 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 Mathematics). 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 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, blockset, and links and targets. If no products in subtopic are installed, or if none are selected in the Help browser product filter preference, an error page appears.

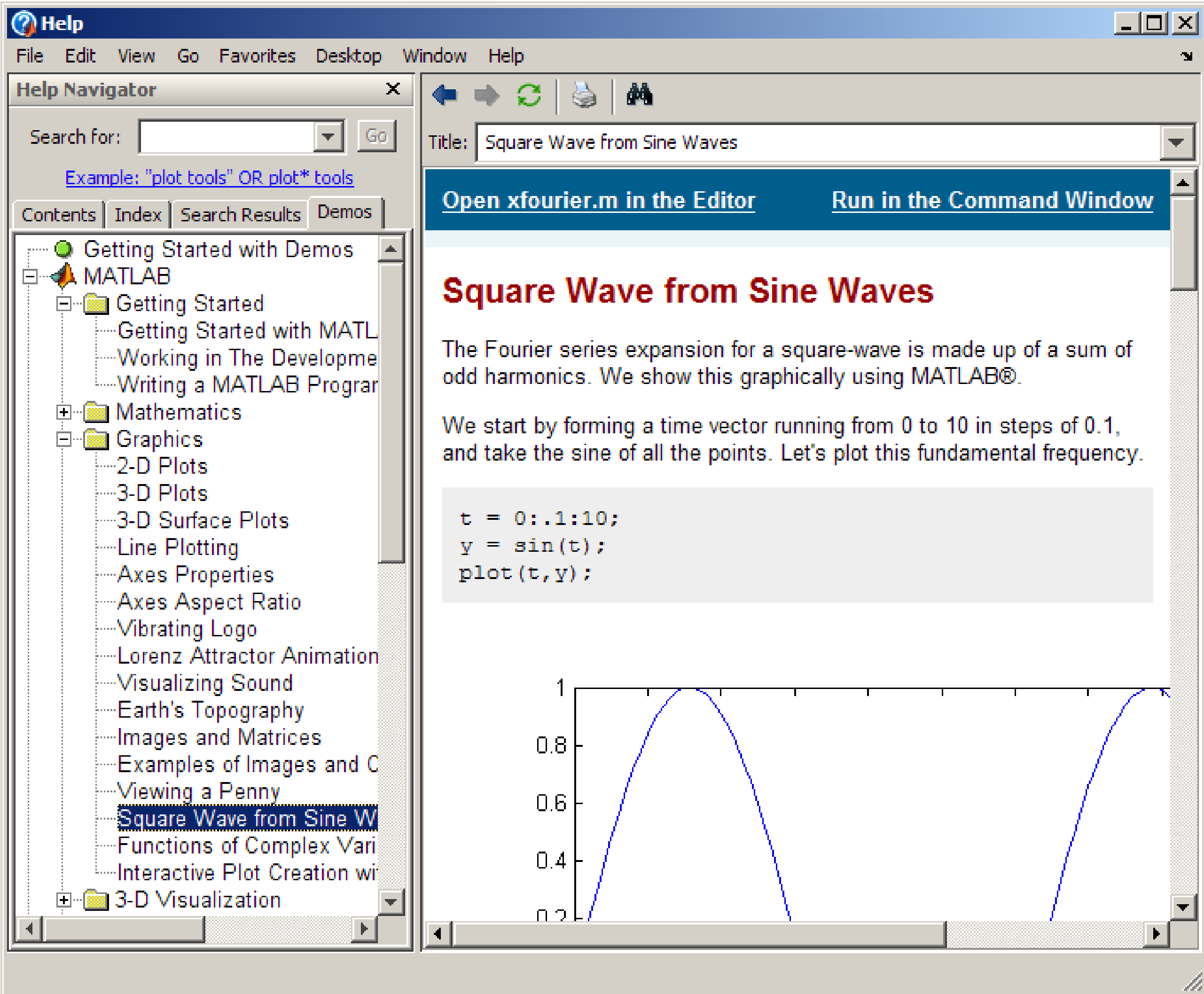
demo '*subtopic category*' opens the **Demos** pane in the Help browser to the specified product or category within the subtopic. The demo function uses the full name displayed in the **Demo** pane for category. If the product specified by category is not installed, or is not selected in the Help browser product filter preference, an error page appears.

`demo('subtopic', 'category')` is the function form of the syntax.

This illustration shows the result of running

```
demo matlab graphics
```

and then selecting the Square Wave from Sine Waves example.



Examples

Accessing Toolbox Demos

To find the demos relating to Communications Toolbox™, product type

```
demo toolbox communications
```

The Help browser opens to the **Demos** pane with the Toolbox subtopic expanded and with the Communications entry highlighted and expanded to show the available demos.

Accessing Simulink® Demos

To access the demos within the Simulink product, type

```
demo simulink automotive
```

The **Demos** pane opens with the subtopic for Simulink open and the 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 Project Desktop Window Help
Help Navigator
Search for:
Go
Example: "plot tools" OR plot* tools
Contents
Index
Search Results
Demos
Getting Started with Demos
MATLAB
Toolboxes
Simulink
General Applications
Automotive Applications
Aerospace Applications
Modeling Features
Simulink Parameter Estimatio
Parameter Estimation GUI
Command-Line Estimation
Adaptive Lookup Table De
Blocksets
Links and Targets
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
Engine Throttle Parameter Estimation
Model
Muscle Reflex Model
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.

It displays a link in the Command Window: `View the published version of this demo`. Click the link to view and run the demo from the Help browser.

You can view the M-file, `quake.m`, 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. You can step through the demo cell-by-cell, from the Editor—select **Cell > Evaluate Current Cell and Advance**.

Alternatively, run

```
echodemo quake
```

and the `quake` demo runs step-by-step in the Command Window.

See Also

`echodemo`, `grabcode`, `help`, `helpbrowser`

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`

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 `\`, `/`

Purpose

Remove linear trends

Syntax

```
y = detrend(x)
y = detrend(x,'constant')
y = detrend(x,'linear',bp)
```

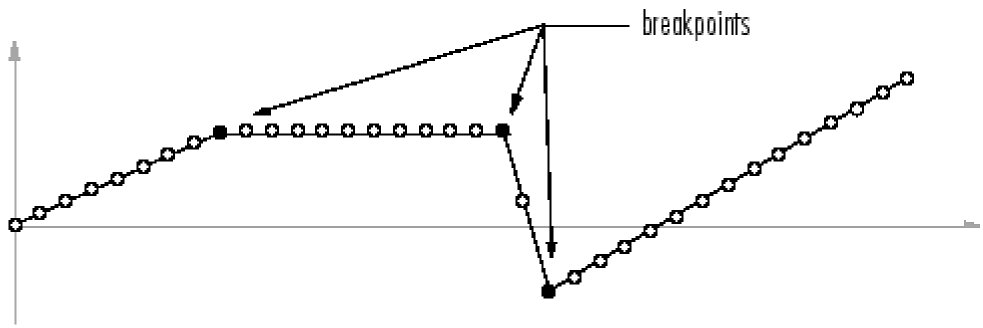
Description

`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`

Purpose

Subtract mean or best-fit line and all NaNs 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.

deval

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`.

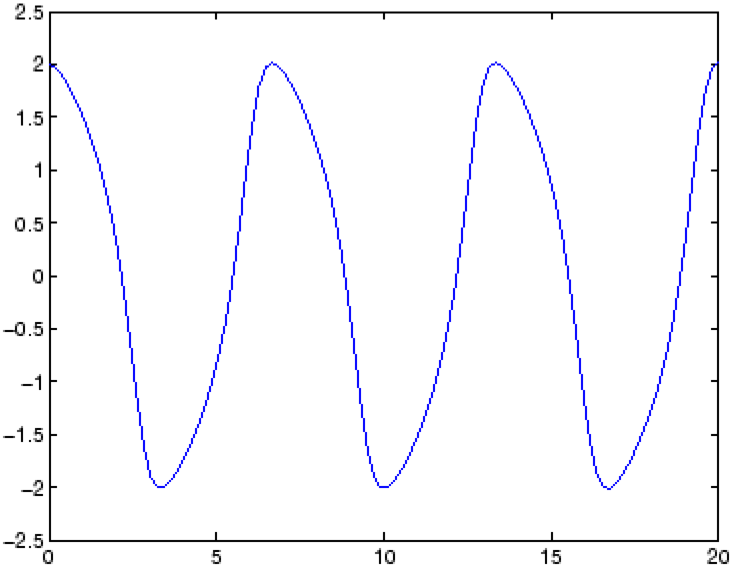
`[sxint, spxint] = deval(...)` also returns `spxint`, the value of the first derivative of the polynomial interpolating the solution.

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`

diag

Purpose

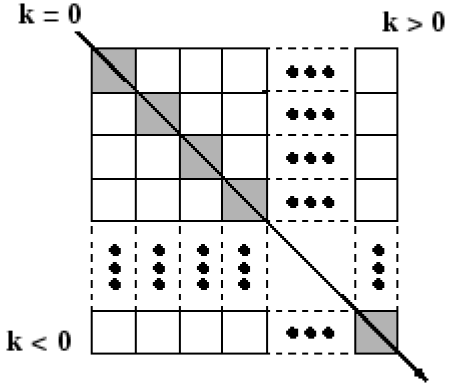
Diagonal matrices and diagonals of matrix

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(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.

See Also

`errordlg`, `helpdlg`, `inputdlg`, `listdlg`, `msgbox`, `questdlg`, `warndlg`

`figure`, `uiwait`, `uiresume`

"Predefined Dialog Boxes" on page 1-106 for related functions

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 2-917 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`, the MATLAB® software 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 Window" 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	double

Remarks

Listing Drives

On Windows® systems, 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 =
24x1 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`

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 also can 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>')
```

which generates this hyperlink in the Command Window:

```
The MathWorks Web Site
```

Click the link to display The MathWorks home page in a MATLAB® Web browser.

See Also `format`, `int2str`, `matlabcolon`, `num2str`, `rats`, `sprintf`

disp (memmapfile)

Purpose

Information about memmapfile object

Syntax

`disp(obj)`

Description

`disp(obj)` displays all properties and their values for `memmapfile` object `obj`.

The MATLAB® software also displays this information when you construct a `memmapfile` object or set any of the object's property values, provided you do not terminate the command to do so with a semicolon.

Examples

Construct an object `m` of class `memmapfile`:

```
m = memmapfile('records.dat',                          ...
               'Offset', 2048,                         ...
               'Format', {                             ...
                  'int16'  [2 2] 'model';              ...
                  'uint32' [1 1] 'serialno';           ...
                  'single' [1 3] 'expenses'});
```

Use `disp` to display all the object's current properties:

```
disp(m)
    Filename: 'd:\matlab\mfiles\records.dat'
    Writable: false
      Offset: 2048
      Format: {'int16' [2 2] 'model'
               'uint32' [1 1] 'serialno'
               'single' [1 3] 'expenses'}
      Repeat: Inf
        Data: 753x1 struct array with fields:
            model
         serialno
         expenses
```

See Also

`memmapfile`, `get(memmapfile)`

Purpose

Display `MException` object

Syntax

```
disp(ME)
disp(ME.property)
```

Description

`disp(ME)` displays all properties (fields) of `MException` object `ME`.

`disp(ME.property)` displays the specified property of `MException` object `ME`.

Examples

Using the `surf` command without input arguments throws an exception. Use `disp` to display the `identifier`, `message`, `stack`, and `cause` properties of the `MException` object:

```
try
   surf
catch ME
   disp(ME)
end

 MException object with properties:

    identifier: 'MATLAB:nargchk:notEnoughInputs'
       message: 'Not enough input arguments.'
         stack: [1x1 struct]
         cause: {}
```

Display only the `stack` property:

```
disp(ME.stack)
    file: 'X:\bat\Akernel\perfect\matlab\toolbox\matlab\
graph3d\surf.m'
    name: 'surf'
    line: 54
```

See Also

`try`, `catch`, `error`, `assert`, `MException`, `getReport(MException)`, `throw(MException)`, `rethrow(MException)`, throwAsCaller(MException), addCause(MException), isequal(MException), eq(MException), ne(MException), last(MException),

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`. The MATLAB® software 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

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

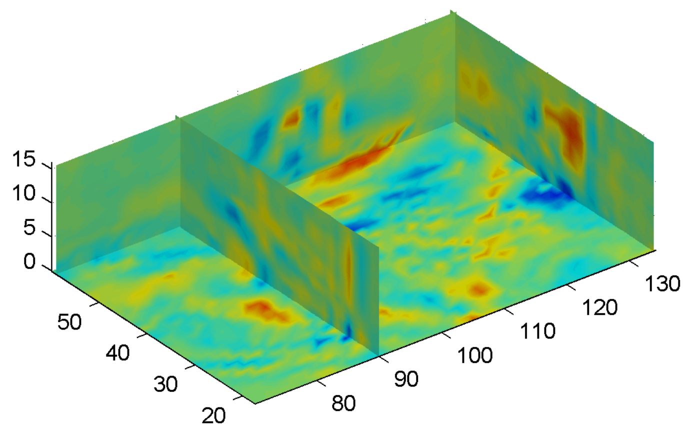
```
[X Y] = meshgrid(1:n,1:m)
```

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 1-104 for related functions

"Example — 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

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

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,cc,rr] = dmperm(A)
```

Description

`p = dmperm(A)` finds a vector `p` such that `p(j) = i` if column `j` is matched to row `i`, or zero if column `j` is unmatched. If `A` is a square matrix with full structural rank, `p` is a maximum matching row permutation and `A(p,:)` has a zero-free diagonal. The structural rank of `A` is `sprank(A) = sum(p>0)`.

`[p,q,r,s,cc,rr] = dmperm(A)` where `A` need not be square or full structural rank, finds the Dulmage-Mendelsohn decomposition of `A`. `p` and `q` are row and column permutation vectors, respectively, such that `A(p,q)` has a block upper triangular form. `r` and `s` are index vectors indicating the block boundaries for the fine decomposition. `cc` and `rr` are vectors of length five indicating the block boundaries of the coarse decomposition.

`C = A(p,q)` is split into a 4-by-4 set of coarse blocks:

```
A11  A12  A13  A14
0      0  A23  A24
0      0    0  A34
0      0    0  A44
```

where `A12`, `A23`, and `A34` are square with zero-free diagonals. The columns of `A11` are the unmatched columns, and the rows of `A44` are the unmatched rows. Any of these blocks can be empty. In the coarse decomposition, the `(i,j)th` block is `C(rr(i):rr(i+1)-1,cc(j):cc(j+1)-1)`. For a linear system,

- `[A11 A12]` is the underdetermined part of the system—it is always rectangular and with more columns and rows, or `0`-by-`0`,
- `A23` is the well-determined part of the system—it is always square, and

- `[A34 ; A44]` is the overdetermined part of the system—it is always rectangular with more rows than columns, or `0`-by-`0`.

The structural rank of `A` is `sprank(A) = rr(4)-1`, which is an upper bound on the numerical rank of `A`. `sprank(A) = rank(full(sprand(A)))` with probability 1 in exact arithmetic.

The `A23` submatrix is further subdivided into block upper triangular form via the fine decomposition (the strongly connected components of `A23`). If `A` is square and structurally nonsingular, `A23` is the entire matrix.

`C(r(i):r(i+1)-1,s(j):s(j+1)-1)` is the `(i,j)`th block of the fine decomposition. The `(1,1)` block is the rectangular block `[A11 A12]`, unless this block is `0`-by-`0`. The `(b,b)` block is the rectangular block `[A34 ; A44]`, unless this block is `0`-by-`0`, where `b = length(r)-1`. All other blocks of the form `C(r(i):r(i+1)-1,s(i):s(i+1)-1)` are diagonal blocks of `A23`, and are square with a zero-free diagonal.

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].

`dmperm` uses CSparse [2].

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.

[2] T.A. Davis *Direct Methods for for Sparse Linear Systems*. SIAM, Philadelphia: 2006. Software available at:http://www.cise.ufl.edu/research/sparse/CSparse.

See Also `sprank`

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 search path MATLAB uses, `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/matlabunix` displays the reference page for the `matlab` startup function for The Open Group UNIX® platforms, which is in MATLAB.

Examples

Type `doc abs` to display the reference page for the `abs` function. If the Simulink® and Signal Processing Toolbox™ products 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 the Signal Processing Toolbox product.

Type `doc signal` to display the roadmap page for Signal Processing Toolbox product.

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`

"Getting Help in MATLAB Software" in the MATLAB Desktop Tools and Development Environment documentation.

Purpose

Web browser for UNIX® platforms

Syntax

```
docopt
doccmd = docopt
```

Description

`docopt` displays the Web browser used with the MATLAB® software when running on The Open Group UNIX platforms, except for the Apple® Macintosh® platform, with the default being `netscape` (for Netscape Navigator®). For UNIX platforms (other than the Macintosh platform), 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`

docsearch

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, the MATLAB® software always waits 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`

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.

dragrect

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 1-103 for related functions

Purpose

Flush event queue and update figure window

Syntax

```
drawnow
drawnow expose
drawnow update
```

Description

`drawnow` causes figure windows and their children to update and flushes the system event queue. Any callbacks generated by incoming events (e.g. mouse or key events) are dispatched before `drawnow` returns.

`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.

`drawnow update` causes only non-graphics objects to refresh, if needed. It does not allow callbacks to execute and does not process other events in the queue.

You can combine the `expose` and `update` options to obtain both effects.

```
drawnow expose update
```

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
  - `figure`
  - `getframe`
  - `input`
  - `keyboard`
  - `pause`
- Functions that wait for user input (i.e., `waitforbuttonpress`, `waitfor`, `ginput`)

- Any code that causes one of the above functions to be executed. For example, suppose h is the handle of an axes. Calling axes(h) causes its parent figure to be made the current figure and brought to the front of all displayed figures, which results in the event queue being flushed.

Examples

Using drawnow in a loop causes the display to update while the loop executes:

```
t = 0:pi/20:2*pi;
y = exp(sin(t));
h = plot(t,y,'YDataSource','y');
for k = 1:.1:10
 y = exp(sin(t.*k));
 refreshdata(h,'caller') % Evaluate y in the function workspace
 drawnow; pause(.1)
end
```

See Also

waitfor, waitforbuttonpress

"Figure Windows" on page 1-97 for related functions

dsearch

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/`

dynamicprops

Purpose

Abstract class used to derive handle class with dynamic properties

Syntax

```
classdef myclass < dynamicprops
```

Description

`classdef` *`myclass`* `< dynamicprops` makes *`myclass`* a subclass of the `dynamicprops` class, which is a subclass of the `handle` class.

Use the `dynamicprops` class to derive classes that can define dynamic properties (instance properties), which are associated with a specific objects, but have no effect on the objects class definition. Dynamic properties are useful for attaching temporary data to one or more objects.

dynamicprops Methods

This class defines one method `addprop` and, as a subclass of the `handle` class, inherits all the `handle` class methods.

- `addprop` — adds the named property to the specified handle objects. See "Dynamic Properties — Adding Properties to an Instance" for more information.

See Also

`handle`

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
echodemo('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 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. To end the demo, click the **Stop** link.

`echodemo('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

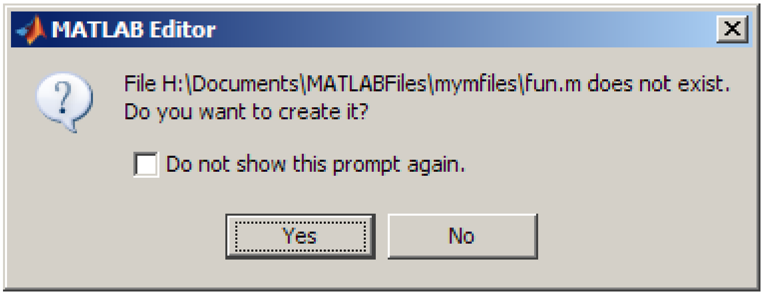
```
edit
edit fun.m
edit file.ext
edit fun1 fun2 fun3 ...
edit classname/fun
edit private/fun
edit classname/private/fun
edit +packagename/classname/fun
edit('my file.m')
```

Description

`edit` opens a new editor window.

`edit fun.m` opens the M-file `fun.m` in the default editor. The `fun.m` file specification can include a MATLAB `partialpath`, complete path, relative path, or no path. Be aware of the following:

- If you do not specify a path, the current directory is the default.
- If you specify a path, the directory must exist; otherwise MATLAB returns an error.
- If you specify a path and the directory exits, but the specified file does not, a prompt opens such as shown in the following image:



To create a blank file named `fun.m` in the specified directory, click **Yes**. To suppress the prompt, select **Do not show this prompt again**. To reinstate the prompt after suppressing it, open the Preferences dialog box by selecting **File > Preferences > General > Confirmation Dialogs** and then selecting **Prompt when editing files that do not exist** in the pane on the right.

`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` *`classname`*`/fun`, or `edit private/fun`, or `edit` *`classname`*`/private/fun` opens a method, private function, or private method for the named class.

`edit +`*`packagename`*`/`*`classname`*`/fun` opens a method for the named class in the named package.

`edit('my file.m')` opens the M-file `my file.m` in the default editor. This form of the `edit` function is useful when a file name contains a space; you cannot use the command form in such a case.

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 editor.

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, 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 file name 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 return 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. This may give more accurate results for certain problems with unusual scaling. 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.

Also note that if `A` is symmetric, `eig(A,'nobalance')` ignores the `nobalance` option since `A` is already balanced.

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*. TheMATLAB® 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 software 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 software 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

Finds largest eigenvalues and eigenvectors of a 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. `A` should be large and sparse, though `eigs` will work on full matrices as well. See "Remarks" below.

`[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'	Formerly largest algebraic ('lr')
'sa'	Formerly smallest algebraic ('sr')
'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)

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
```

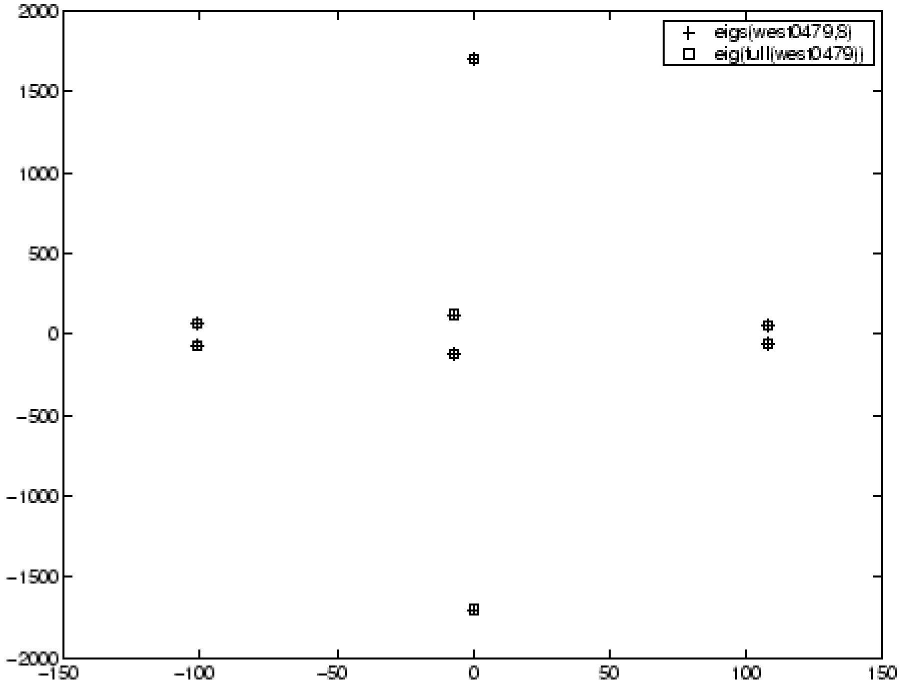
Example 3

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))')
```

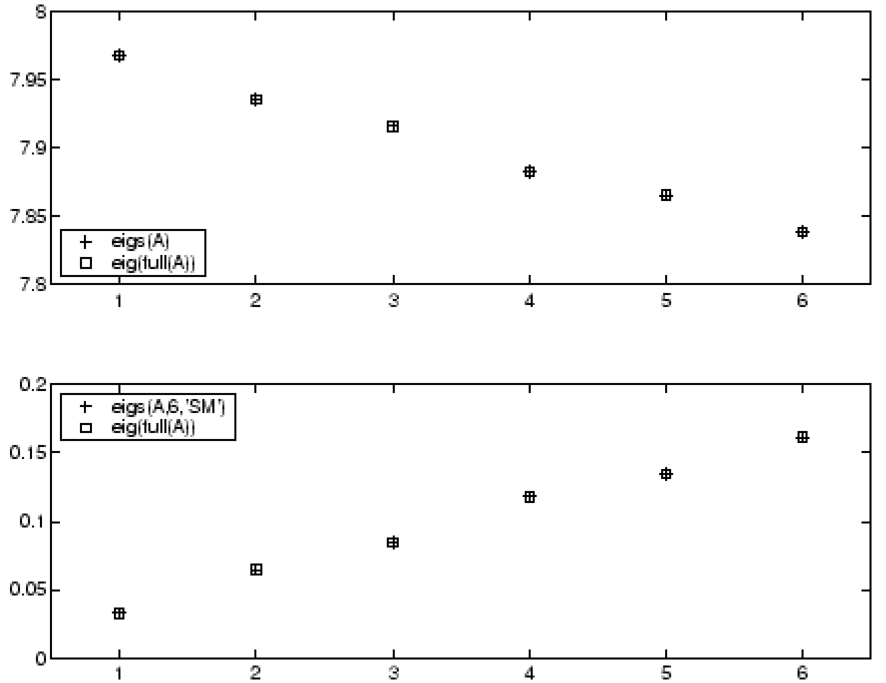


Example 4

`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');
```

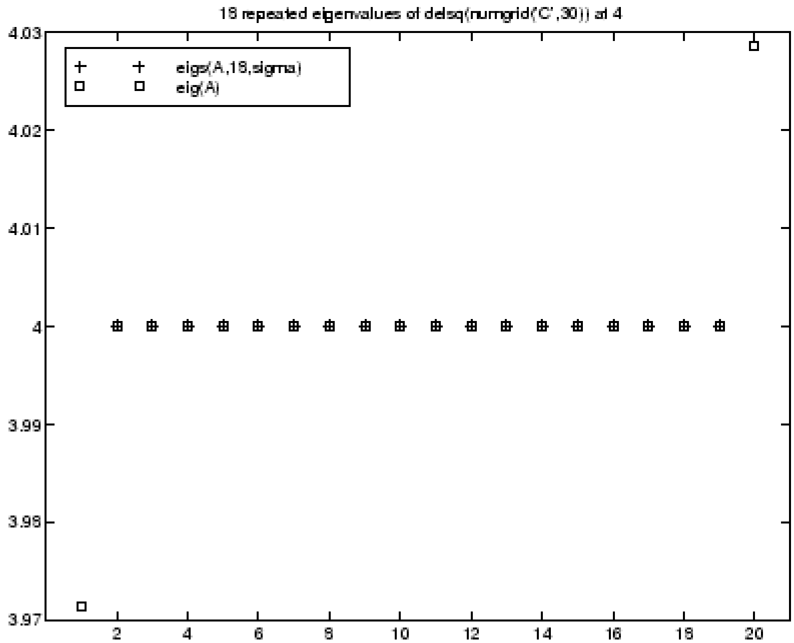
```
subplot(2,1,1)
plot(dlm,'k+')
hold on
plot(d(ind(end:-1:end-5)),'ks')
hold off
legend('eigs(A)','eig(full(A))',3)
set(gca,'XLim',[0.5 6.5])

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.

ellipke

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

$$a_i = \frac{1}{2}(a_{i-1} + b_{i-1})$$
$$b_i = (a_{i-1}b_{i-1})^{\frac{1}{2}}$$
$$c_i = \frac{1}{2}(a_{i-1} - b_{i-1})$$

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`

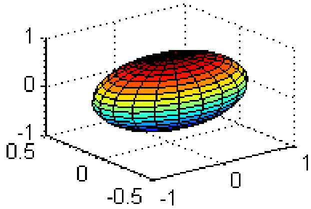
References

[1] Abramowitz, M. and I.A. Stegun, *Handbook of Mathematical Functions*, Dover Publications, 1965, 17.6.

ellipsoid

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:

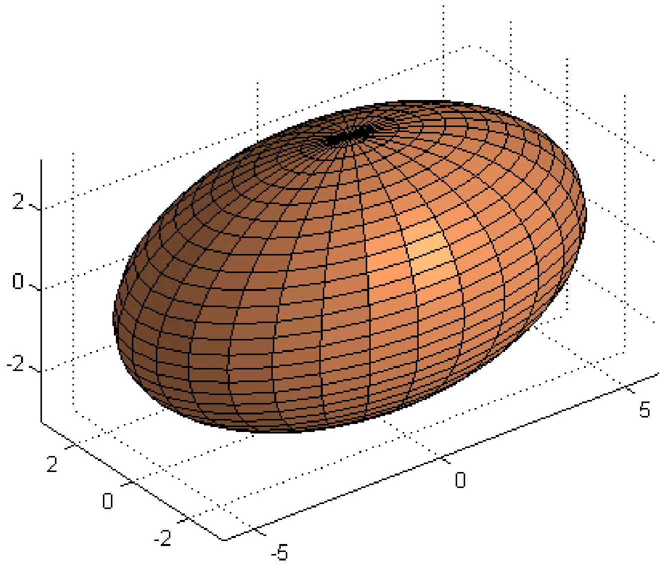
$$\frac{(x-xc)^2}{xr^2} + \frac{(y-yc)^2}{yr^2} + \frac{(z-zc)^2}{zr^2}$$

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 1-92 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 Fundamentals 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)

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 Fundamentals documentation for more information on controlling the flow of your program code.

Remarks

`elseif` , 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                               if A
   x = 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)

Purpose

Enable, disable, or report status of Automation server

Syntax

```
state = enableservice('AutomationServer',enable)
state = enableservice('AutomationServer')
```

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.

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.

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,:)
```

The MATLAB® software calls 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 the twentieth century, try:

```
y = 1900:1999;
E = eomday(y, 2);
y(find(E == 29))

ans =
  Columns 1 through 8
     1904     1908     1912     1916     1920     1924     1928

  Columns 9 through 16
     1936     1940     1944     1948     1952     1956     1960

  Columns 17 through 24
     1968     1972     1976     1980     1984     1988     1992
```

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 the MATLAB® software 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

eq (MException)

Purpose Compare `MException` objects for equality

Syntax

```
eObj1 == eObj2
```

Description `eObj1 == eObj2` tests scalar `MException` objects `eObj1` and `eObj2` for equality, returning logical 1 (`true`) if the two objects are identical, otherwise returning logical 0 (`false`).

See Also `try`, `catch`, `error`, `assert`, `MException`, `isequal(MException)`, `ne(MException)`, `getReport(MException)`, `disp(MException)`, `throw(MException)`, `rethrow(MException)`, `throwAsCaller(MException)`, `addCause(MException)`, `last(MException)`

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 $1/2$.

$$\mathrm{erf}(x) = \frac{2}{\sqrt{\pi}}\int_0^x e^{-t^2}dt$$

The complementary error function `erfc(X)` is defined as

$$\mathrm{erfc}(x) = \frac{2}{\sqrt{\pi}}\int_x^\infty e^{-t^2}dt = 1 - \mathrm{erf}(x)$$

The scaled complementary error function `erfcx(X)` is defined as

$$\mathrm{erfcx}(x) = e^{x^2}\,\mathrm{erfc}(x)$$

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 $y = \mathrm{erf}(x)$ 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" 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.) When the `message_struct` input includes a `stack` field, the `stack` field of the error will be set according to the contents of the stack input. When specifying a stack input, use the absolute file name and the entire sequence of functions that nests the function in the stack frame. (This is the same as the string returned by dbstack('-completenames')). If message_struct 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('-completenames'). 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.
```

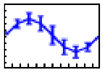
But, when more than one argument is specified, MATLAB does convert special characters. This holds true regardless of whether the additional argument supplies conversion values or is a message identifier:

```
error('ErrorTests:convertTest', ...
      'In this case, the newline \n is converted.')
??? In this case, the newline
 is converted.
```

See Also `lasterror`, `rethrow`, `assert`, `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.

Note The v6 option enables users of Version 7.x of MATLAB to create FIG-files that previous versions can open. It is obsolete and will be removed in a future version of MATLAB.

See Plot Objects and Backward Compatibility for more information.

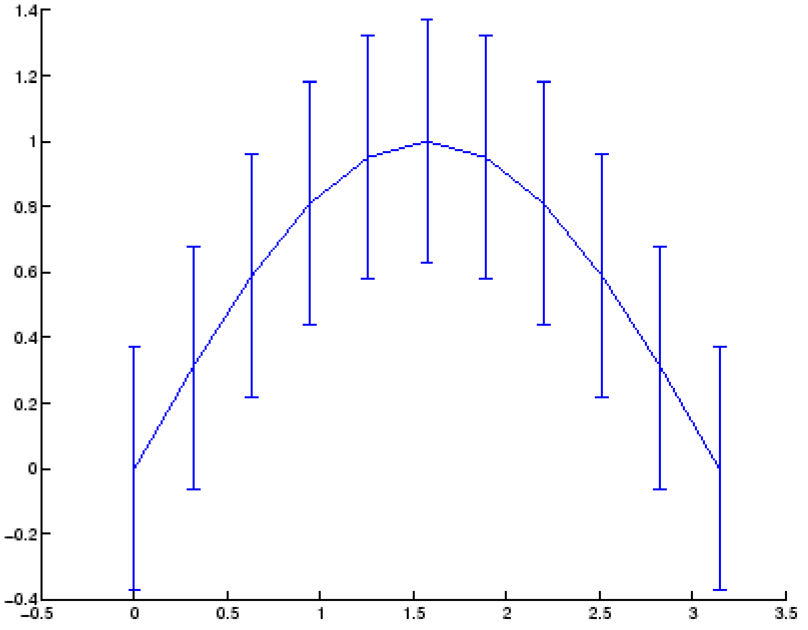
Remarks

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 1-88 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.

`Annotation`

`hg.Annotation` object Read Only

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

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

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

IconDisplayStyle Value	Purpose
`on`	Include the errorbarseries object in a legend as one entry, but not its children objects

IconDisplayStyle Value	Purpose
off	Do not include the errorbarseries or its children in a legend (default)
children	Include only the children of the errorbarseries as separate entries in the legend

Setting the `IconDisplayStyle` property

These commands set the `IconDisplayStyle` of a graphics object with handle `hobj` to `children`, which causes each child object to have an entry in the legend:

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

Using the `IconDisplayStyle` property

See "Controlling Legends" for more information and examples.

`BeingDeleted`

`on | {off}` Read Only

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

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

`BusyAction`

`cancel | {queue}`

Callback routine interruption. The `BusyAction` property enables you to control how MATLAB handles events that potentially interrupt executing callbacks. If there is a callback function executing, callbacks invoked subsequently always attempt to interrupt it.

If the `Interruptible` property of the object whose callback is executing is set to `on` (the default), then interruption occurs at the next point where the event queue is processed. If the `Interruptible` property is `off`, the `BusyAction` property (of the object owning the executing callback) determines how MATLAB handles the event. The choices are

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

`ButtonDownFcn`

string or function handle

Button press callback function. A callback that executes whenever you press a mouse button while the pointer is over this object, but not over another graphics object. See the `HitTestArea` property for information about selecting objects of this type.

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

This property can be

- A string that is a valid MATLAB expression

- The name of an M-file
- 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 (default is empty string)

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

- If you specify string arguments with the `legend` function, `DisplayName` is set to this errorbarseries object's corresponding string and that string is used for the legend.

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

See "Controlling Legends" for more examples.

`EraseMode`

`{normal} | none | xor | background`

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

- `normal` — Redraw the affected region of the display, performing the three-dimensional analysis necessary to ensure that all objects are rendered correctly. This mode produces the most accurate picture, but is the slowest. The other modes are faster, but do not perform a complete redraw and are therefore less accurate.
- `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.

errordlg

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 the Figure 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.

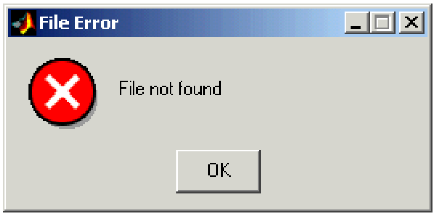
The appearance of the dialog box depends on the platform you use.

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 1-106 for related functions

etime

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. Use the second syntax instead:

```
% Not recommended
  eval('[a1, a2, a3, ...] = function(var)')

% Recommended syntax
  [a1, a2, a3, ...] = eval('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, except for error messages, 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

Purpose

Base class for all data objects passed to event listeners

Description

The `event` package contains the `event.EventData` class, which defines the data objects passed to event listeners. If you want to provide additional information to event listeners, you can do so by subclassing `event.EventData`. See "Defining Event-Specific Data" for more information.

Properties

The `event.EventData` class defines two properties and no methods:

- `EventName` — The name of the event described by this data object.
- `Source` — The source object whose class defines the event described by the data object.

See Also

`event.ClassInstanceEvent`, `event.PropertyEvent`

"Events — Sending and Responding to Messages"

Purpose

Listener for property events

Description

The `event.PropertyEvent` class defines the data objects passed to listeners of the `meta.property` events `PreGet`, `PostGet`, `PreSet`, and `PostSet`. `event.PropertyEvent` is a sealed subclass of `event.EventData` (i.e., you cannot subclass `event.PropertyEvent`).

Properties

`event.PropertyEvent` inherits the `EventName` and `Source` properties from `event.EventData` and defines one new property:

- `AffectedObject` — The instance of the class to which this event refers.

See Also

`event.EventData`, `meta.property`

"Listening for Changes to Property Values"

event.listener

Purpose

Class defining listener objects

Syntax

`lh = event.listener(Hobj,'`*`EventName`*`',@`*`CallbackFunction`*`)`

Description

`lh = event.listener(Hobj,'`*`EventName`*`',@`*`CallbackFunction`*`)` creates a listener object for the named event on the specified object.

Listener objects respond to events. The `event.listener` class defines listener objects as a subclass of the `handle` class.

If `delete` is called on the listener object, the listener ceases to exist, which means the event no longer causes the listener callback function to execute. The listener can also be enabled or disabled by setting the value of the listener's `Enabled` property.

You can call the `event.listener` constructor instead of calling `addlistener` to create a listener. However, when you do not use `addlistener`, the listener's lifecycle is not tied to the object(s) being listened to.

Properties

Property	Purpose
`Source`	Cell array of source objects
`EventName`	Name of the event
`Callback`	Function to execute when the event is triggered and the `Enabled` property is set to `true`
`Enabled`	callback executes when the event occurs if and only if `Enabled` is set to `true` (the default).
`Recursive`	When this property is set to `true` (the default), a listener can cause the same event that triggered the callback. This can lead to infinite recursion and the MATLAB®recursion limit eventually triggers an error to end the recursion. When set to `false`, this listener does not execute recursively. Therefore, if the callback triggers its own event, the listener does not execute again.

See Also

`addlistener`, `event.proplistener`

"Creating Listeners"

event.proplistener

Purpose

Define listener object for property events

Syntax

```
lh =
event.proplistener(Hobj,'PropertyName','PropertyEvent',
   @CallbackFunction)
```

Description

`lh = event.proplistener(Hobj,'PropertyName','PropertyEvent',@CallbackFunction)` creates a property listener object for the specified property event.

The `event.proplistener` class defines property event listener objects. It is a subclass of the `event.listener` class and adds one property to those defined by `event.listener`:

- `Object` — Cell array of objects whose property events are being listened to.

You can call the `event.proplistener` constructor instead of calling `addlistener` to create a property listener. However, when you do not use `addlistener`, the listener's lifecycle is not tied to the object(s) being listened to.

See Also

`event.listener`, `addlistener`

Purpose

List all event handler functions registered for COM object

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 COM object, `h`. The function returns a cell array of strings `C`, with each row containing the name of a registered event and the handler routine for that event. If the object 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 =
     {}
```

Microsoft® Excel® Workbook Example

```
myApp = actxserver('Excel.Application');
wbs = myApp.Workbooks;
wb = wbs.Add;
wb.registerevent({'Activate' 'EvtActivateHandler'})
wb.eventlisteners

ans =

    'Activate'    'EvtActivateHandler'
```

See Also

`events (COM)`, `registerevent`, `unregisterevent`, `unregisterallevents`, `isevent`

Purpose Display class event names

Syntax

```
events('classname')
events(obj)
e = events(...)
```

Description

`events('classname')` displays the names of the public events for the MATLAB® class *`classname`*, including events inherited from superclasses.

`events(obj)` displays the names of the public events for the class of the object `obj`, where `obj` is an instance of a MATLAB class. `obj` can be either a scalar object or an array of objects.

`e = events(...)` returns the event names in a cell array of strings.

An event is public when its `ListenAccess` attribute is set to `public` and its `Hidden` attribute is set to `false` (default values for both attributes). See “Event Attributes” for a complete list of attributes.

Note `events` is also a keyword used in MATLAB class definition. See `classdef` for more information on class definition keywords.

See “Events — Sending and Responding to Messages” for information on using events and listeners.

Examples

Get the names of the public events for the `handle` class:

```
events('handle')
Events for class handle:

    ObjectBeingDestroyed
```

See Also

`properties`, `methods`

events (COM)

Purpose

List of events COM object 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 COM object, 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.

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 Workbook Events Example

Open a Microsoft® Excel® application and list all events for a `Workbook` object:

```
myApp = actxserver('Excel.Application');
wbs = myApp.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)
```

Microsoft® 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 software 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™ programming language 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® program (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 session of MATLAB 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.

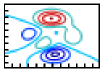
See Also

`ones`, `rand`, `randn`, `zeros`

ezcontour

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.

$$f(x, y) = 3(1-x)^2 e^{-x^2-(y+1)^2} - 10\left(\frac{x}{5} - x^3 - y^5\right)e^{-x^2-y^2} - \frac{1}{3}e^{-(x+1)^2-y^2}$$

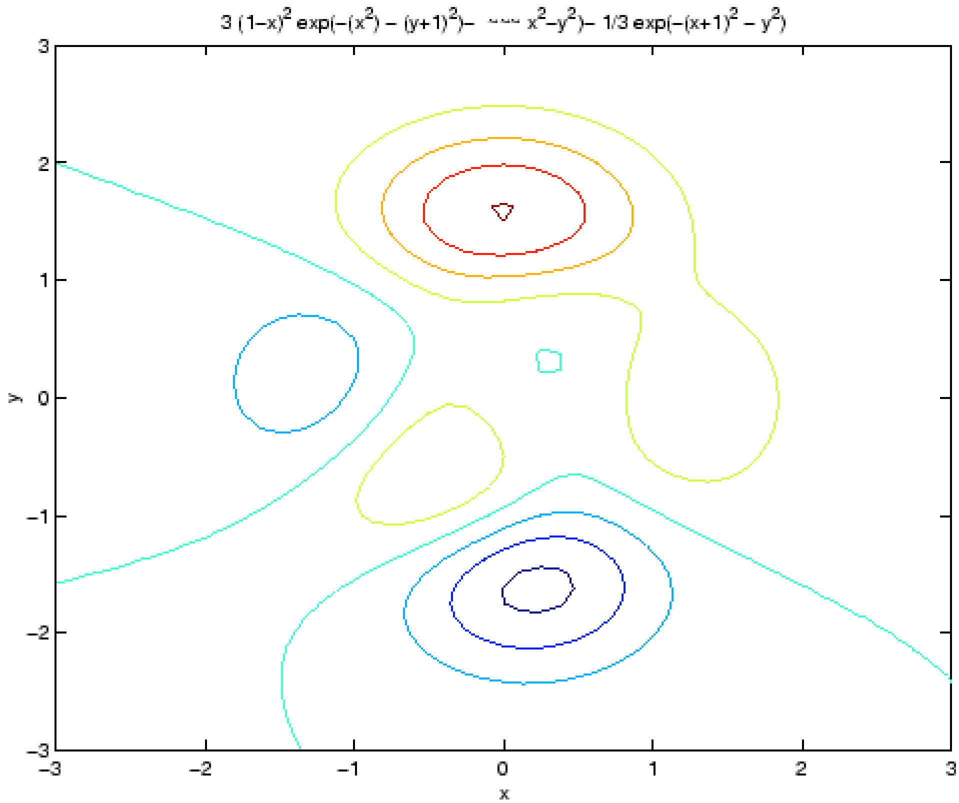
ezcontour requires a function handle argument that expresses this function using MATLAB syntax. This example uses an anonymous function, which you can define in the command window without creating an M-file.

```
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

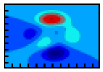
`contour`, `ezcontourf`, `ezmesh`, `ezmeshc`, `ezplot`, `ezplot3`, `ezpolar`, `ezsurf`, `ezsurfc`, `function_handle`

"Contour Plots" on page 1-91 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.

$$f(x, y) = 3(1-x)^2 e^{-x^2-(y+1)^2} - 10\left(\frac{x}{5} - x^3 - y^5\right)e^{-x^2-y^2} - \frac{1}{3}e^{-(x+1)^2-y^2}$$

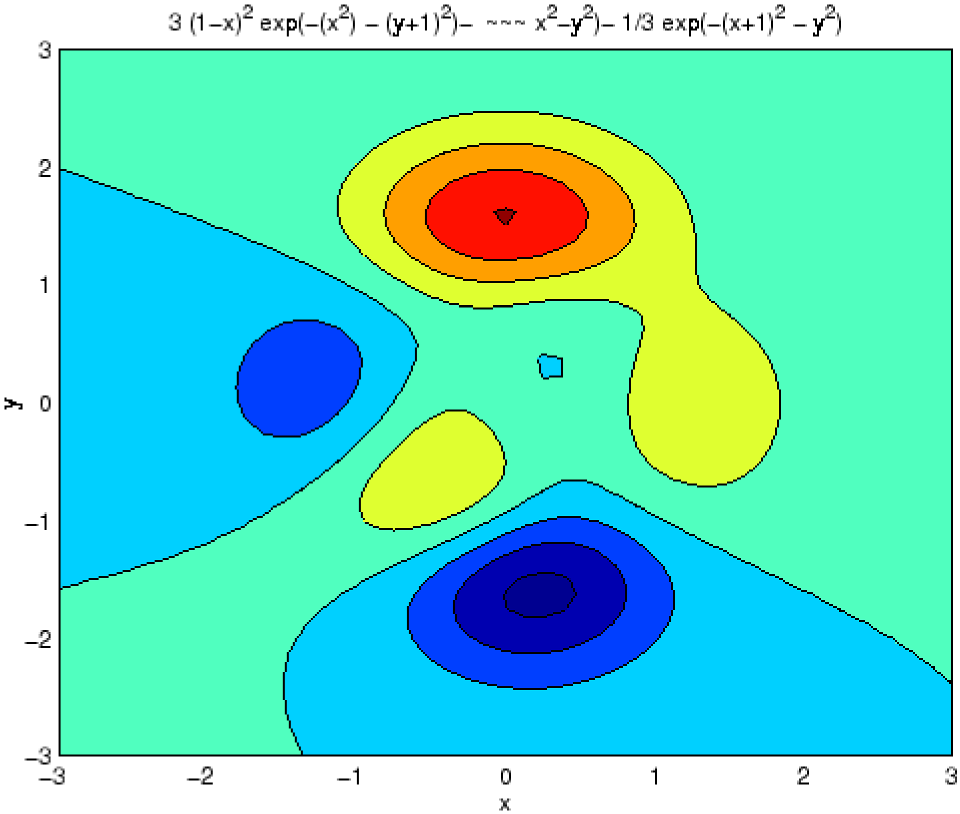
ezcontourf requires a string argument that expresses this function using MATLAB syntax to represent exponents, natural logs, etc. This function is represented by the string

```
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

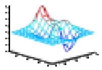
`contourf`, `ezcontour`, `ezmesh`, `ezmeshc`, `ezplot`, `ezplot3`, `ezpolar`, `ezsurf`, `ezsurfc`, `function_handle`

"Contour Plots" on page 1-91 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))
```

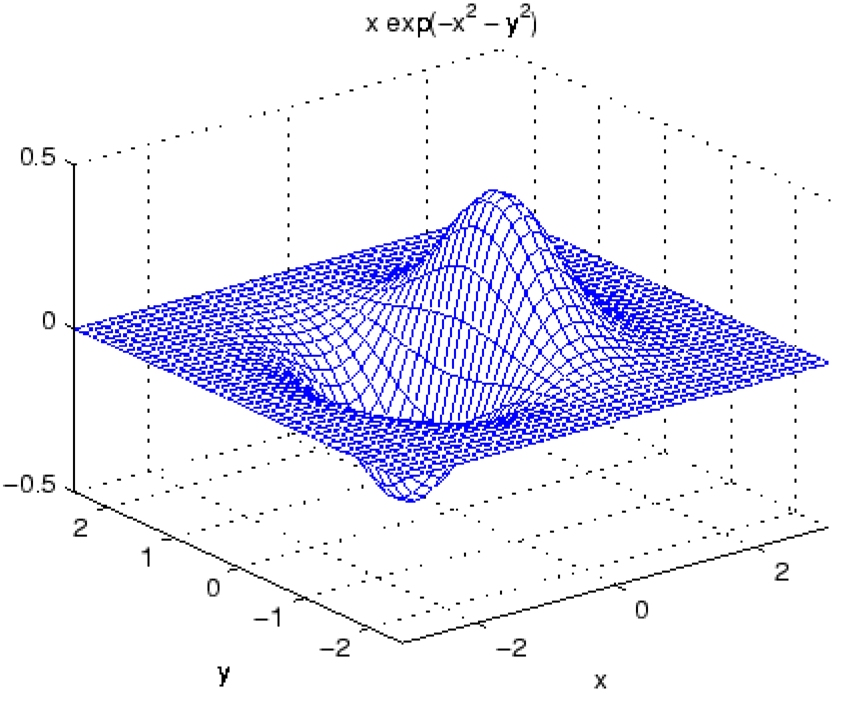
Examples

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 1-91 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

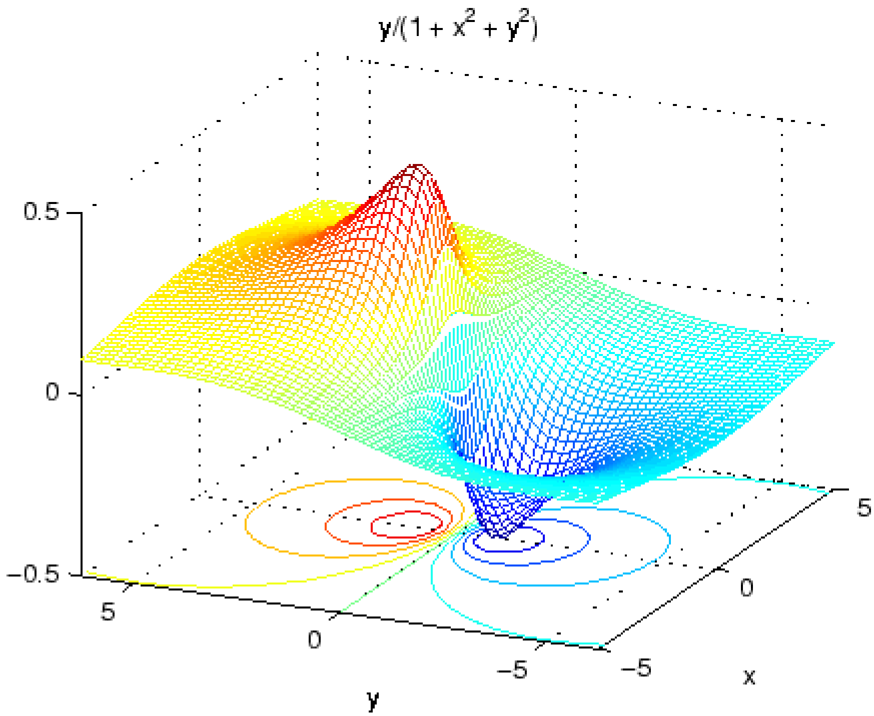
Create a mesh/contour graph of the expression

$$f(x, y) = \frac{y}{1 + x^2 + y^2}$$

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

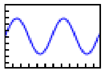
`ezmesh`, `ezsurfc`, `function_handle`, `meshc`

"Function Plots" on page 1-91 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))
```

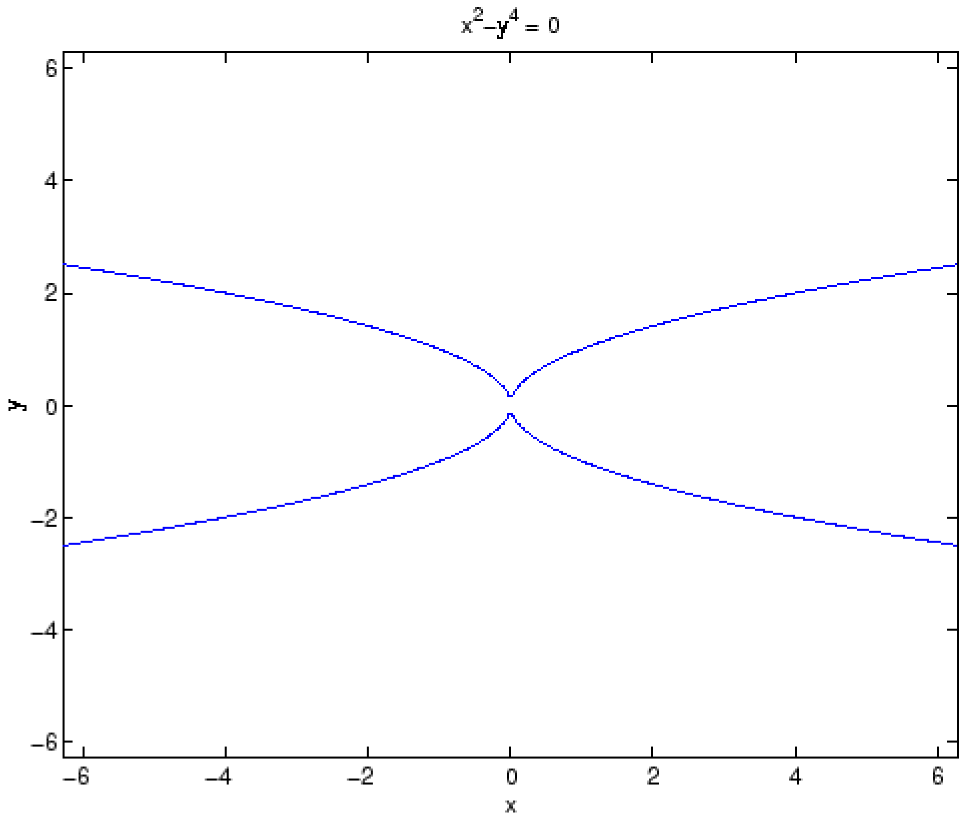
Examples

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 1-91 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)
```

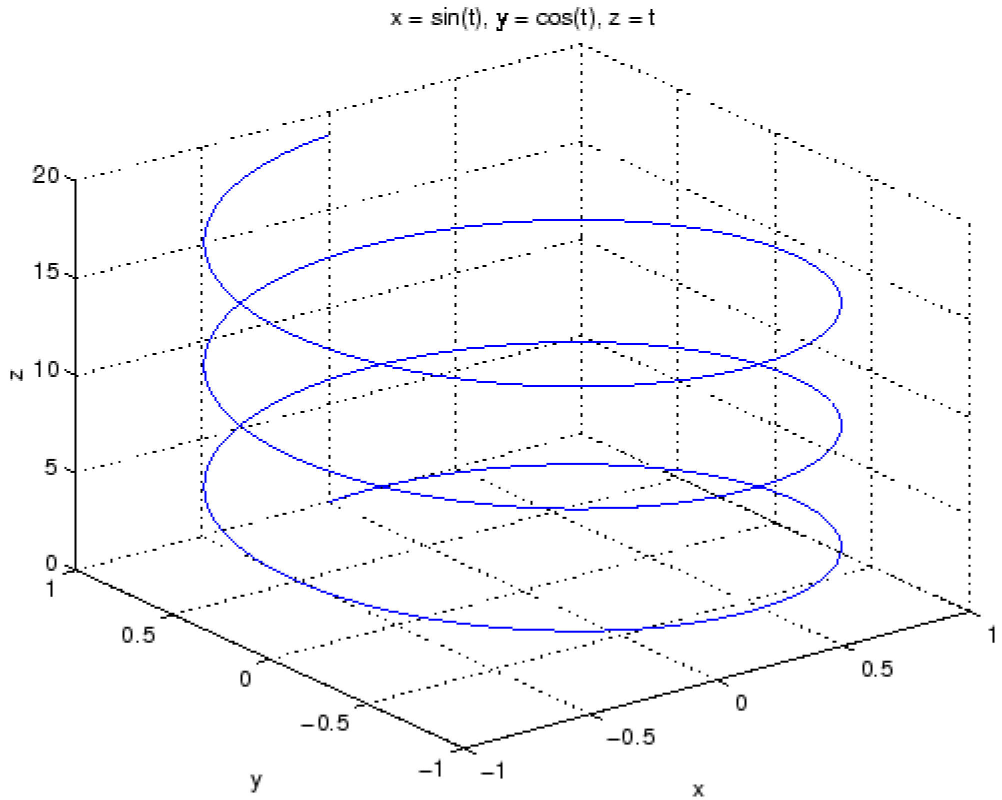
Examples

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])
```



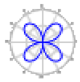
See Also

`ezplot`, `ezpolar`, `function_handle`, `plot3`

"Function Plots" on page 1-91 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))
```

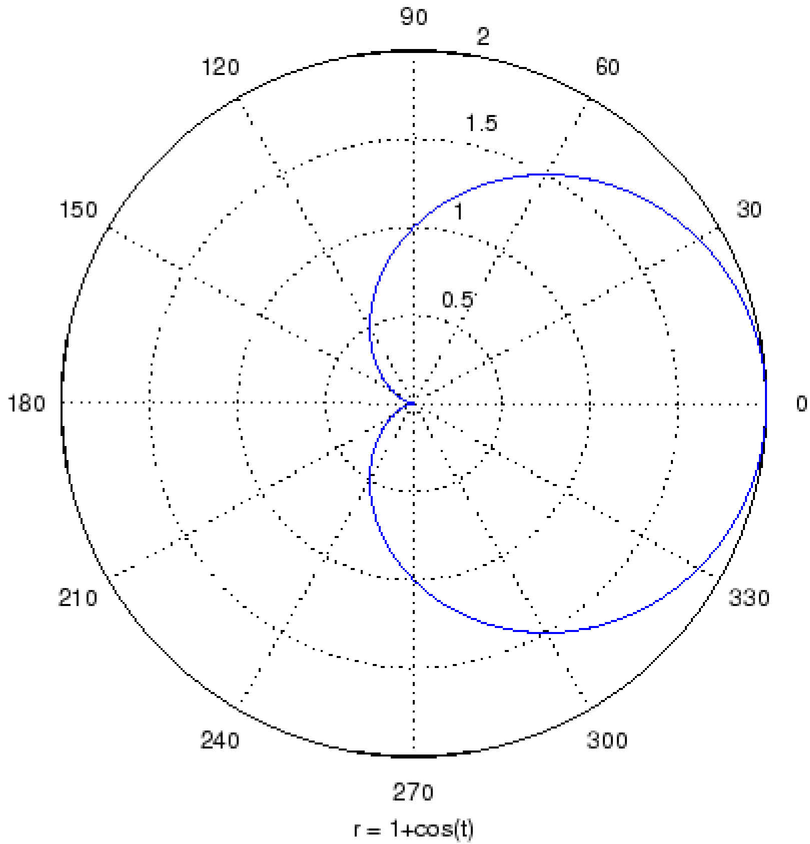
Examples

This example creates a polar plot of the function

$1 + cos(t)$

over the domain $[0, 2\pi]$:

```
ezpolar('1+cos(t)')
```



See Also

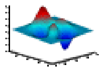
`ezplot`, `ezplot3`, `function_handle`, `plot`, `plot3`, `polar`

"Function Plots" on page 1-91 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

`ezsurf` and `ezsurfc` do not accept complex inputs.

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))
```

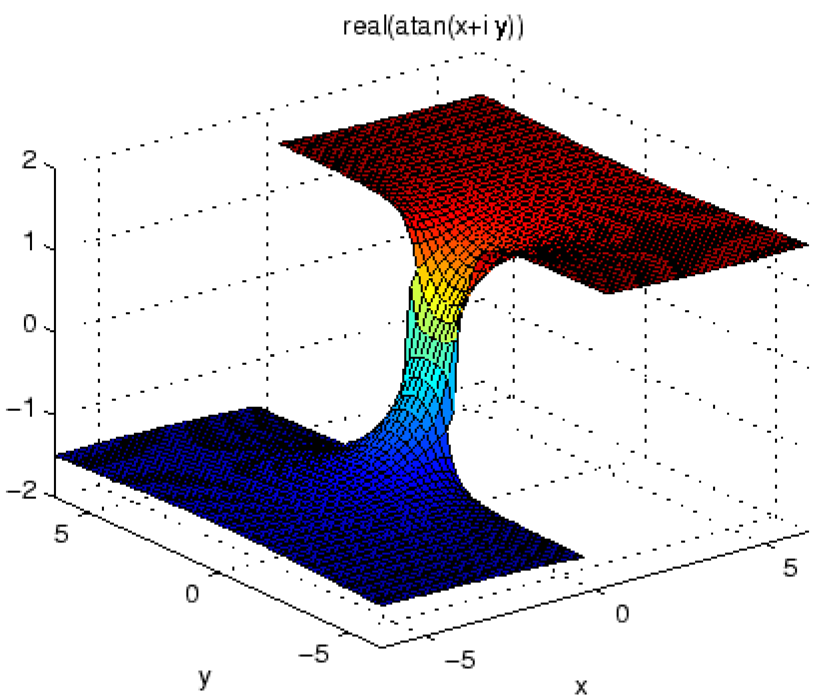
Examples

ezsurf does not graph points where the mathematical function is not defined (these data points are set to NaNs, which do not plot). This example illustrates this filtering of singularities/discontinuous points by graphing the function

$$f(x, y) = real(atan(x + iy))$$

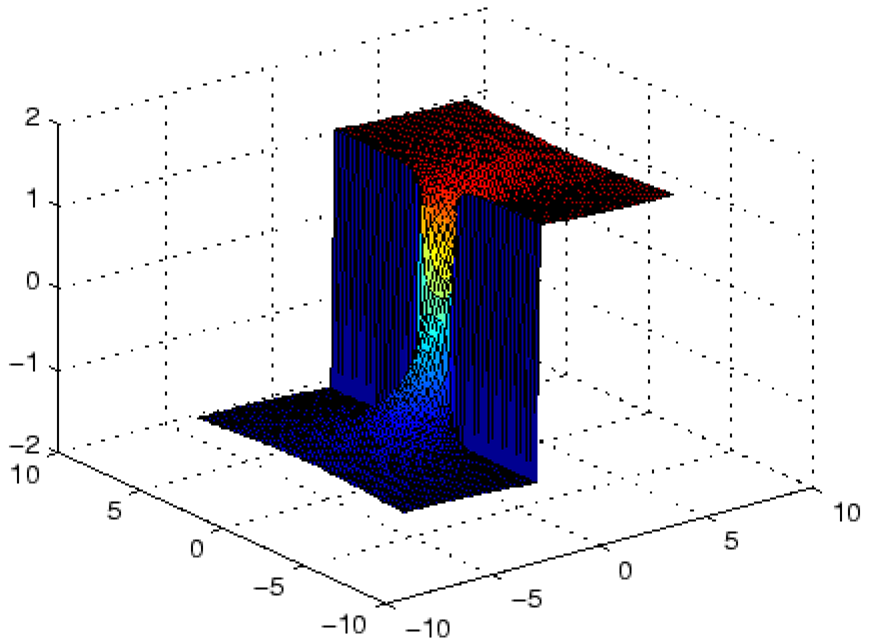
over the default domain $-2\pi < x < 2\pi$, $-2\pi < y < 2\pi$:

```
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.

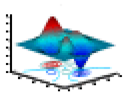
See Also

ezmesh, ezsurfc, function_handle, surf

"Function Plots" on page 1-91 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

`ezsurf` and `ezsurfc` do not accept complex inputs.

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

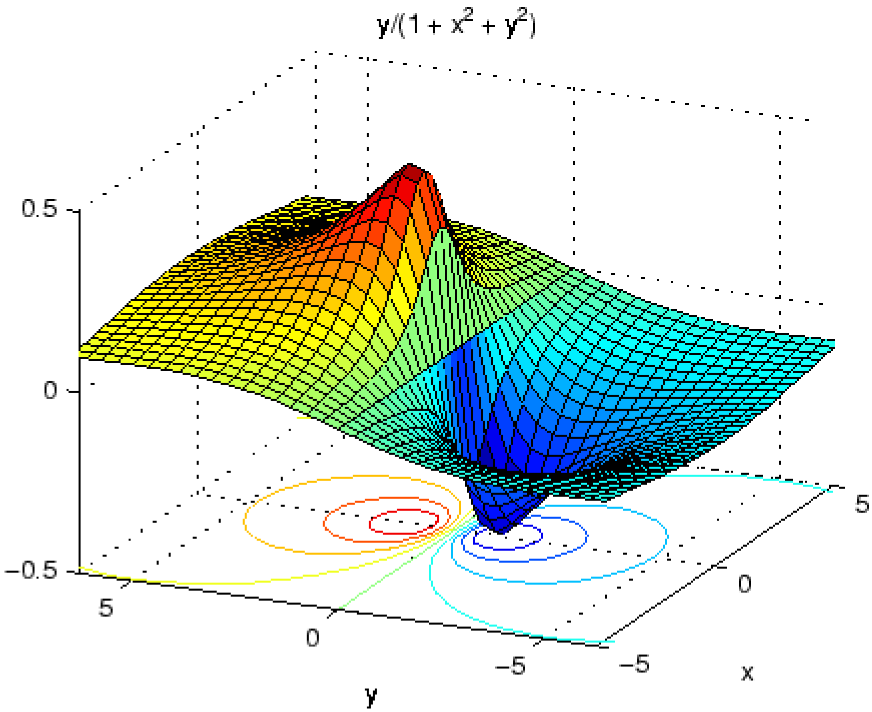
Create a surface/contour plot of the expression

$$f(x, y) = \frac{y}{1 + x^2 + y^2}$$

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 1-91 for related functions

Index

Symbols and Numerics

A

C

E

F

H

J

M

O

Q

S

U

W

Y

Z