MATLAB® 7
Function Reference: P - Z

MATLAB®

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MATLAB Function Reference

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Function Reference

Desktop Tools and Development Environment

Startup and Shutdown

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

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

Command Window and History

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

Help for Using MATLAB

`builddocsearchdb`	Build searchable documentation database
`demo`	Access product demos via Help browser
`doc`	Reference page in Help browser
`docopt`	Web browser for UNIX platforms
`docsearch`	Open Help browser and search for specified term
`echodemo`	Run M-file demo step-by-step in Command Window
`help`	Help for functions in Command Window
`helpbrowser`	Open Help browser to access all online documentation and demos
`helpwin`	Provide access to M-file help for all functions
`info`	Information about contacting The MathWorks
`lookfor`	Search for keyword in all help entries
`playshow`	Run M-file demo (deprecated; use `echodemo` instead)
`support`	Open MathWorks Technical Support Web page
`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
`who, whos`	List variables in workspace
`workspace`	Open Workspace browser to manage workspace

Search Path

`addpath`	Add directories to search path
`genpath`	Generate path string

`partialpath`	Partial pathname description
`path`	View or change search path
`path2rc`	Save current search path to `pathdef.m` file
`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
`userpath`	View or change user portion of search path

File Operations

See also "File I/O" on page 1-79 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
`matlabroot`	Root directory
`mkdir`	Make new directory
`movefile`	Move file or directory
`pwd`	Identify current directory
`recycle`	Set option to move deleted files to recycle folder
`rehash`	Refresh function and file system path caches
`rmdir`	Remove directory
`toolboxdir`	Root directory for specified toolbox
`type`	Display contents of file
`visdiff`	Compare two text files, MAT-Files, or binary files
`what`	List MATLAB files in current directory
`which`	Locate functions and files

Programming Tools

M-File Editing and Debugging

`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

M-File Performance

`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 software (on Microsoft Windows platforms)
`publish`	Publish M-file containing cells, saving output to a file of specified type
`snapnow`	Force snapshot of image for inclusion in published document

System

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

Operating System Interface

`clipboard`	Copy and paste strings to and from system clipboard
`computer`	Information about computer on which MATLAB software is running
`dos`	Execute DOS command and return result
`getenv`	Environment variable
`hostid`	Server host identification number
`maxNumCompThreads`	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 Windows registry

MATLAB Version and License

`ismac`	Determine if version is for Mac OS® X platform
`ispc`	Determine if version is for Windows (PC) platform
`isstudent`	Determine if version is Student Version
`isunix`	Determine if version is for UNIX platform.
`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

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
`create (RandStream)`	Create random number streams
`diag`	Diagonal matrices and diagonals of matrix
`eye`	Identity matrix
`freqspace`	Frequency spacing for frequency response
`get (RandStream)`	Random stream properties
`getDefaultStream (RandStream)`	Default random number stream
`ind2sub`	Subscripts from linear index
`linspace`	Generate linearly spaced vectors
`list (RandStream)`	Random number generator algorithms
`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
`rand (RandStream)`	Uniformly distributed random numbers

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

Array Operations

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

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

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

Array Manipulation

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

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

Specialized Matrices

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

Linear Algebra

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

Matrix Analysis

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

`subspace`	Angle between two subspaces
`trace`	Sum of diagonal elements

Linear Equations

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

Eigenvalues and Singular Values

`balance`	Diagonal scaling to improve eigenvalue accuracy
`cdf2rdf`	Convert complex diagonal form to real block diagonal form
`condeig`	Condition number with respect to eigenvalues
`eig`	Eigenvalues and eigenvectors
`eigs`	Largest eigenvalues and eigenvectors of 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 of argument in degrees
`cosh`	Hyperbolic cosine
`cot`	Cotangent of argument in radians
`cotd`	Cotangent of argument in degrees
`coth`	Hyperbolic cotangent
`csc`	Cosecant of argument in radians
`cscd`	Cosecant of argument in degrees
`csch`	Hyperbolic cosecant
`hypot`	Square root of sum of squares
`sec`	Secant of argument in radians
`secd`	Secant of argument in degrees
`sech`	Hyperbolic secant
`sin`	Sine of argument in radians
`sind`	Sine of argument in degrees
`sinh`	Hyperbolic sine of argument in radians
`tan`	Tangent of argument in radians

`tand`	Tangent of argument in degrees
`tanh`	Hyperbolic tangent

Exponential

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

Complex

`abs`	Absolute value and complex magnitude
`angle`	Phase angle

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

Rounding and Remainder

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

Discrete Math

`factor`	Prime factors
`factorial`	Factorial function
`gcd`	Greatest common divisor

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

Polynomials

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

Interpolation and Computational Geometry

Interpolation

`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 (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. 1-34)	Solve boundary value problems for ordinary differential equations, set solver options, evaluate solution
Partial Differential Equations (p. 1-34)	Solve initial-boundary value problems for parabolic-elliptic PDEs, evaluate solution
Optimization (p. 1-34)	Find minimum of single and multivariable functions, solve nonnegative least-squares constraint problem
Numerical Integration (Quadrature) (p. 1-35)	Evaluate Simpson, Lobatto, and vectorized quadratures, evaluate double and triple integrals

Ordinary Differential Equations

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

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

Delay Differential Equations

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

Boundary Value Problems

`bvp4c`	Solve boundary value problems for ordinary differential equations
`bvp5c`	Solve boundary value problems for ordinary differential equations
`bvpget`	Extract properties from options structure created with `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

Linear Equations (Iterative Methods) (p. 1-39)	Methods for conjugate and biconjugate gradients, residuals, lower quartile
Tree Operations (p. 1-40)	Elimination trees, tree plotting, factorization analysis

Elementary Sparse Matrices

`spdiags`	Extract and create sparse band and diagonal matrices
`speye`	Sparse identity matrix
`sprand`	Sparse uniformly distributed random matrix
`sprandn`	Sparse normally distributed random matrix
`sprandsym`	Sparse symmetric random matrix

Full to Sparse Conversion

`find`	Find indices and values of nonzero elements
`full`	Convert sparse matrix to full matrix
`sparse`	Create sparse matrix
`spconvert`	Import matrix from sparse matrix external format

Sparse Matrix Manipulation

`issparse`	Determine whether input is sparse
`nnz`	Number of nonzero matrix elements
`nonzeros`	Nonzero matrix elements

`nzmax`	Amount of storage allocated for nonzero matrix elements
`spalloc`	Allocate space for sparse matrix
`spfun`	Apply function to nonzero sparse matrix elements
`spones`	Replace nonzero sparse matrix elements with ones
`spparms`	Set parameters for sparse matrix routines
`spy`	Visualize sparsity pattern

Reordering Algorithms

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

Linear Algebra

`cholinc`	Sparse incomplete Cholesky and Cholesky-Infinity factorizations
`condest`	1-norm condition number estimate
`eigs`	Largest eigenvalues and eigenvectors of 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

Utilities

`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

Utilities

`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`	Check if 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 "Strings" on page 1-61 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 if input is MATLAB object
`isreal`	Check if 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

`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. 1-59)	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 for functions like `xor`, `all`, `any`, etc.

&& Logical AND

|| Logical OR

& Logical AND for arrays

| Logical OR for arrays

~ Logical NOT

Special Characters

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

Strings

Description of Strings in MATLAB

`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 Operations

`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 Operations

`all`	Determine whether all array elements are nonzero
`and`	Find logical AND of array or scalar inputs
`any`	Determine whether any array elements are nonzero
`false`	Logical 0 (false)
`find`	Find indices and values of nonzero elements
`isa`	Determine whether input is object of given class
`iskeyword`	Determine whether input is MATLAB keyword
`isvarname`	Determine whether input is valid variable name
`logical`	Convert numeric values to logical
`not`	Find logical NOT of array or scalar input
`or`	Find logical OR of array or scalar inputs
`true`	Logical 1 (true)
`xor`	Logical exclusive-OR

See “Operators and Special Characters” on page 1-59 for logical operators.

Relational Operations

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

See “Operators and Special Characters” on page 1-59 for relational operators.

Set Operations

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

Date and Time Operations

`addtodate`	Modify date number by field
`calendar`	Calendar for specified month
`clock`	Current time as date vector
`cputime`	Elapsed CPU time
`date`	Current date string

`datenum`	Convert date and time to serial date number
`datestr`	Convert date and time to string format
`datevec`	Convert date and time to vector of components
`eomday`	Last day of month
`etime`	Time elapsed between date vectors
`now`	Current date and time
`weekday`	Day of week

Programming in MATLAB

M-Files and Scripts (p. 1-68)	Declare functions, handle arguments, identify dependencies, etc.
Evaluation (p. 1-69)	Evaluate expression in string, apply function to array, run script file, etc.
Timer (p. 1-70)	Schedule execution of MATLAB commands
Variables and Functions in Memory (p. 1-70)	List files in memory, clear M-files in memory, assign to variable in nondefault workspace, refresh caches
Control Flow (p. 1-71)	if-then-else, for loops, switch-case, try-catch
Error Handling (p. 1-72)	Generate warnings and errors, test for and catch errors, retrieve most recent error message
MEX Programming (p. 1-73)	Compile MEX function from C or Fortran code, list MEX-files in memory, debug MEX-files

M-Files and Scripts

`addOptional (inputParser)`	Add optional argument to `inputParser` schema
`addParamValue (inputParser)`	Add parameter-value argument to `inputParser` schema
`addRequired (inputParser)`	Add required argument to `inputParser` schema
`createCopy (inputParser)`	Create copy of `inputParser` object
`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

`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

`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
`mex.getCompilerConfigurations`	Get compiler configuration information for building MEX-files
`mexext`	Binary MEX-file name extension

Object-Oriented Programming

Classes and Objects

`class`	Create object or return class of object
`classdef`	Class definition key words
`fieldnames`	Field names of structure, or public fields of object
`inferiorto`	Specify inferior class relationship
`isa`	Determine whether input is object of given class
`isobject`	Determine if input is MATLAB object
`loadobj`	User-defined class method called by `load` function
`methods`	Information on class methods
`methodsview`	Information on class methods in separate window
`properties`	Display class property names
`saveobj`	Method called by `save` function for user-defined objects
`subsasgn`	Subscripted assignment for objects
`subsindex`	Subscripted indexing for objects
`subsref`	Subscripted reference for objects

`substruct`	Create structure argument for `subsasgn` or `subsref`
`superiorto`	Establish superior class relationship

Handle Classes

`addlistener (handle)`	Create event listener
`addprop (dynamicprops)`	Add dynamic property
`delete (handle)`	Handle object destructor function
`dynamicprops`	Abstract class used to derive handle class with dynamic properties
`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
`isvalid (handle)`	Is object valid handle object
`notify (handle)`	notify listeners that event is occurring
`relationaloperators (handle)`	Equality and sorting of handle objects

`set (hgsetget)`	Assign property values to handle objects derived from `hgsetget` class
`setdisp (hgsetget)`	Override to change command window display

Events and Listeners

`addlistener (handle)`	Create event listener
`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
`notify (handle)`	notify listeners that event is occurring

Meta-Classes

`meta.class`	`meta.class` class describes MATLAB classes
`meta.class.fromName`	Return `meta.class` object associated with named class
`meta.DynamicProperty`	`meta.DynamicProperty` class describes dynamic property of MATLAB object
`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

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

File Opening, Loading, and Saving

`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
`fileread`	Return contents of file as string vector
`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 (p. 1-82)	Read and write Microsoft Excel spreadsheet
Lotus 1-2-3 (p. 1-82)	Read and write Lotus WK1 spreadsheet

Microsoft Excel

`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

`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

`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

Network Common Data Form

File Operations

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

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

Dimensions

`netcdf.defDim`	Create netCDF dimension
`netcdf.inqDim`	Return netCDF dimension name and length
`netcdf.inqDimID`	Return dimension ID
`netcdf.renameDim`	Change name of netCDF dimension

Variables

`netcdf.defVar`	Create netCDF variable
`netcdf.getVar`	Return data from netCDF variable
`netcdf.inqVar`	Return information about variable
`netcdf.inqVarID`	Return ID associated with variable name

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

Attributes

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

Flexible Image Transport System

`fitsinfo`	Information about FITS file
`fitsread`	Read data from FITS file

Hierarchical Data Format

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

`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

Utilities

`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

`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

`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

`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. 1-89)	Send e-mail, read from given URL, extract from tar or zip file, compress and decompress files
FTP (p. 1-89)	Connect to FTP server, download from server, manage FTP files, close server connection

URL, Zip, Tar, E-Mail

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

FTP

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

Graphics

Basic Plots and Graphs

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

Plotting Tools

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

Annotating Plots

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

Specialized Plotting

Area, Bar, and Pie Plots

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

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

Bit-Mapped Images

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

Printing

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

Handle Graphics

Graphics Object Identification

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

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

Object Creation

`axes`	Create axes graphics object
`figure`	Create figure graphics object
`hggroup`	Create hggroup object
`hgtransform`	Create hgtransform graphics object
`image`	Display image object
`light`	Create light object
`line`	Create line object
`patch`	Create patch graphics object
`rectangle`	Create 2-D rectangle object
`root object`	Root 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

Object Property Operations

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

3-D Visualization

Surface and Mesh Plots

Surface and Mesh Creation

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

`tetramesh`	Tetrahedron mesh plot
`trimesh`	Triangular mesh plot
`triplot`	2-D triangular plot
`trisurf`	Triangular surface plot

Domain Generation

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

Color Operations

`brighten`	Brighten or darken colormap
`caxis`	Color axis scaling
`colorbar`	Colorbar showing color scale
`colordef`	Set default property values to display different color schemes
`colormap`	Set and get current colormap
`colormapeditor`	Start colormap editor
`ColorSpec (Color Specification)`	Color specification
`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

Camera Viewpoint

`camdolly`	Move camera position and target
`cameratoolbar`	Control camera toolbar programmatically
`camlookat`	Position camera to view object or group of objects
`camorbit`	Rotate camera position around camera target
`campan`	Rotate camera target around camera position

campos	Set or query camera position
camproj	Set or query projection type
camroll	Rotate camera about view axis
camtarget	Set or query location of camera target
camup	Set or query camera up vector
camva	Set or query camera view angle
camzoom	Zoom in and out on scene
makehgtform	Create 4-by-4 transform matrix
view	Viewpoint specification
viewmtx	View transformation matrices

Aspect Ratio and Axis Limits

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

Object Manipulation

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

Region of Interest

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

Lighting

`camlight`	Create or move light object in camera coordinates
`diffuse`	Calculate diffuse reflectance
`light`	Create light object
`lightangle`	Create or position `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

GUI Development

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

User Interface Deployment

`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

User Interface Development

`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
`uitable`	Create 2-D graphic table GUI component
`uitoggletool`	Create toggle button on toolbar
`uitoolbar`	Create toolbar on figure

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 Utilities

`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

Program Execution

`uiresume`	Resume execution of blocked M-file
`uiwait`	Block execution and wait for resume

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

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

Java

class	Create object or return class of object
fieldnames	Field names of structure, or public fields of object
import	Add package or class to current import list
inspect	Open Property Inspector
isa	Determine whether input is object of given class
isjava	Determine whether input is Sun Java object
javaaddpath	Add entries to dynamic Sun Java class path
javaArray	Construct Sun Java array
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 Automation server
`Feval (COM)`	Evaluate MATLAB function in Automation server

`fieldnames`	Field names of structure, or public fields of object
`get (COM)`	Get property value from interface, or display properties
`GetCharArray`	Get character array from 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 COM object or interface, or display methods
`isa`	Determine whether input is object of given class
`iscom`	Is input COM object
`isevent`	True if COM object event
`isinterface`	Is input COM interface
`ismethod`	Determine whether input is COM object method
`isprop`	Determine whether input is COM object property
`load (COM)`	Initialize control object from file
`MaximizeCommandWindow`	Open 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 COM interface
`save (COM)`	Serialize control object to file
`set (COM)`	Set object or interface property to specified value
`unregisterallevents`	Unregister all event handlers for COM object event at run-time
`unregisterevent`	Unregister event handler for COM object event at run-time

Web Services

`callSoapService`	Send SOAP message 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
`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

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Functions — Alphabetical List

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Purpose

Consolidate workspace memory

Syntax

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

Description

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

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

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

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

Remarks

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

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

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

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

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

The `pack` function frees space by

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

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

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

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

Examples

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

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

See Also

`clear`, `memory`

Purpose

Padé approximation of time delays

Syntax

```
[num,den] = padecoef(T,N)
```

Description

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

Class support for input T:

```
float: double, single
```

Class Support

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

References

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

See Also

`pade`

pagesetupdlg

Purpose

Page setup dialog box

Syntax

```
dlg = pagesetupdlg(fig)
```

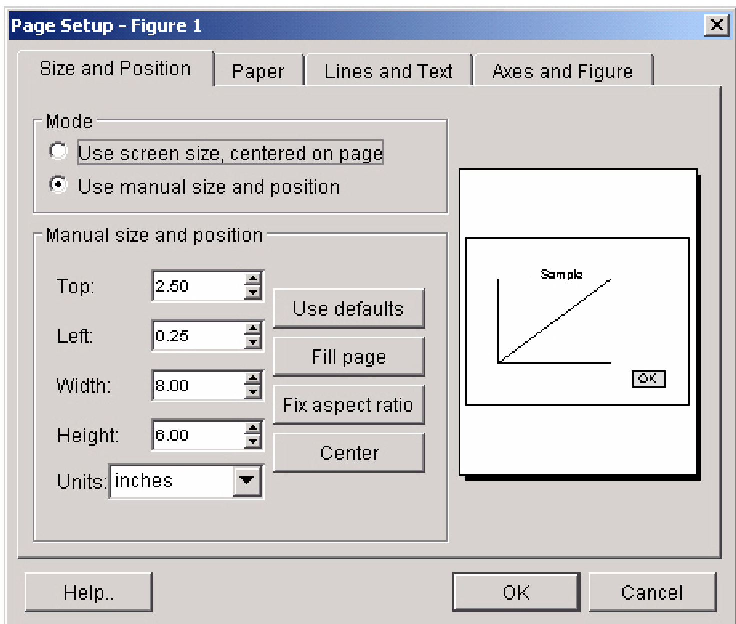
Note This function is obsolete. Use `printpreview` instead.

Description

`dlg = pagesetupdlg(fig)` creates a dialog box from which a set of pagelayout properties for the figure window, `fig`, can be set.

`pagesetupdlg` implements the "Page Setup..." option in the **Figure File Menu**.

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



See Also

`printdlg`, `printpreview`, `printopt`

pan

Purpose

Pan view of graph interactively

GUI Alternatives

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

Syntax

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

Description

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

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

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

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

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

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

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

Using Pan Mode Objects

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

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

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

Pan Mode Callbacks

You can program the following callbacks for pan mode operations.

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

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

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

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

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

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

  The event data struct has the following field:

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

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

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

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

Pan Mode Utility Functions

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

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

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

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

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

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

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

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

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

Examples

Example 1 — Entering Pan Mode

Plot a graph and turn on Pan mode:

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

Example 2 — Constrained Pan

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

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

Example 3 — Constrained Pan in Subplots

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

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

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

Example 4 — Coding a ButtonDown Callback

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

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

Example 5 — Coding Pre- and Post-Callback Behavior

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

```
function demo
% Listen to pan events
```

```
plot(1:10);
h = pan;
set(h,'ActionPreCallback',@myprecallback);
set(h,'ActionPostCallback',@mypostcallback);
set(h,'Enable','on');
%
function myprecallback(obj,evd)
disp('A pan is about to occur.');
%
function mypostcallback(obj,evd)
newLim = get(evd.Axes,'XLim');
msgbox(sprintf('The new X-Limits are [%.2f %.2f].',newLim));
```

Example 6 — Creating a Context Menu for Pan Mode

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

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

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

Remarks

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

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

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

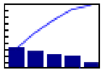
See Also

`zoom`, `linkaxes`, `rotate3d`

"Object Manipulation" on page 1-104 for related functions

Purpose

Pareto chart



GUI Alternatives

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

Syntax

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

Description

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

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

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

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

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

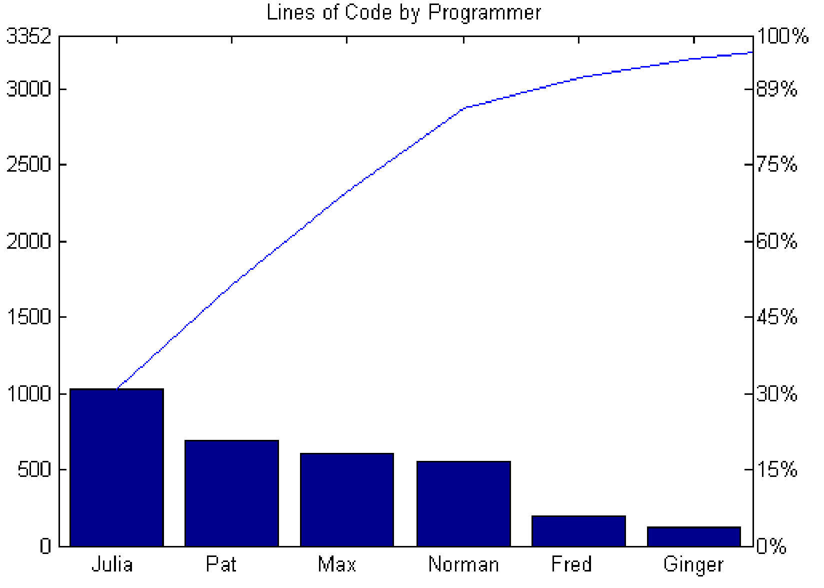
`H = pareto(...)` returns a combination of `patch` and `line` object handles.

Examples

Example 1:

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

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



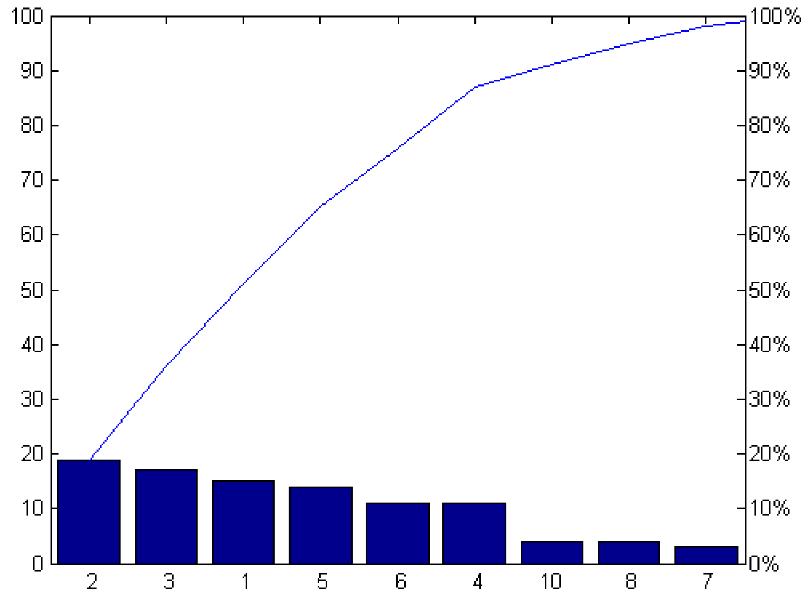
Example 2:

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

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

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

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



Remarks

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

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

See Also

`hist`, `bar`

parfor

Purpose

Parallel for-loop

Syntax

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

Description

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

The general format of a parfor statement is:

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

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

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

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

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

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

- You do not have Parallel Computing Toolbox

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

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

Examples

Perform three large eigenvalue computations using three computers or cores:

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

See Also

`for`

parse (inputParser)

Purpose Parse and validate named inputs

Syntax

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

Description `p.parse(arglist)` parses and validates the inputs named in `arglist`.

`parse(p, arglist)`is functionally the same as the syntax above.

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

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

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

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

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

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

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

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

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

```
p.Results.argname
```

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

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

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

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

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

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

The maximum height is 300.

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

See Also

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

parseSoapResponse

Purpose Convert response string from SOAP server into MATLAB types

Syntax `parseSoapResponse(response)`

Description `parseSoapResponse(response)` converts `response`, a string returned by a SOAP server, into a cell array of appropriate MATLAB types.

See Also `callSoapService`, `createClassFromWsdl`, `createSoapMessage`

Purpose

Partial pathname description

Description

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

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

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

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

Examples

The following example uses a partial pathname:

```
what graph2d/@figobj

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

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

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

```
what graph2d/figobj
```

See Also

`fileparts`, `matlabroot`, `path`

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

Purpose

Pascal matrix

Syntax

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

Description

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

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

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

Examples

`pascal(4)` returns

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

`A = pascal(3,2)` produces

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

See Also

`chol`

Purpose

Create patch graphics object

Syntax

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

Description

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

`patch(X,Y,C)` adds the filled two-dimensional patch to the current axes. The elements of `X` and `Y` specify the vertices of a polygon. If `X` and `Y` are matrices, MATLAB draws one polygon per column. `C` determines the color of the patch. It can be a single `ColorSpec`, one color per face, or one color per vertex (see "Remarks" on page 2-2609). If C is a 1-by-3 vector, it is assumed to be an RGB triplet, specifying a color directly.

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

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

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

`patch('`*`PropertyName`*`',propertyvalue,...)` specifies all properties using property name/property value pairs. This form enables you to omit the color specification because MATLAB uses the default face color and edge color unless you explicitly assign a value to the `FaceColor` and `EdgeColor` properties. This form also allows you to specify the patch using the `Faces` and `Vertices` properties instead of *x*-, *y*-, and *z*-coordinates. See the "Examples" on page 2-2611 section for more information.

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

Remarks

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

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

Specifying Patch Properties

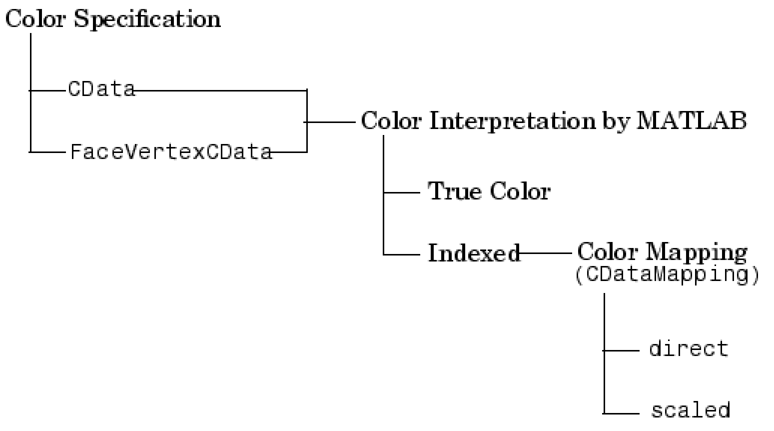
You can specify properties as property name/property value pairs, structure arrays, and cell arrays (see the `set` and `get` reference pages for examples of how to specify these data types).

There are two patch properties that specify color:

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

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

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



Color Data Interpretation

You can specify patch colors as

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

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

Interpretation of the CData Property

[X,Y,Z]Data	CData Required for		Results Obtained
Dimensions	Indexed	True Color	
m-by-n	scalar	1-by-1-by-3	Use the single color specified for all patch faces. Edges can be only a single color.

Interpretation of the CData Property (Continued)

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

Interpretation of the FaceVertexCData Property

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

Examples

This example creates a patch object using two different methods:

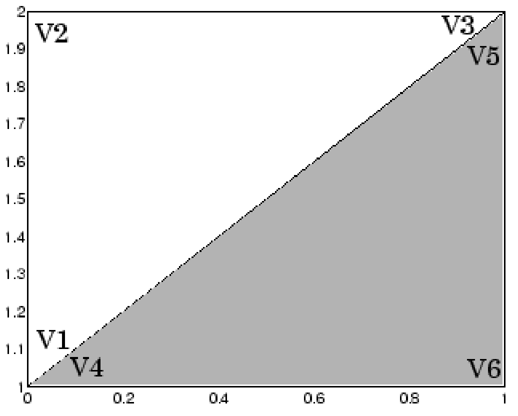
- Specifying *x*-, *y*-, and *z*-coordinates and color data (`XData`, `YData`, `ZData`, and `CData` properties)

- Specifying vertices, the connection matrix, and color data (`Vertices`, `Faces`, `FaceVertexCData`, and `FaceColor` properties)

Specifying X, Y, and Z Coordinates

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

```
x = [0 0;0 1;1 1];
y = [1 1;2 2;2 1];
z = [1 1;1 1;1 1];
tcolor(1,1,1:3) = [1 1 1];
tcolor(1,2,1:3) = [.7 .7 .7];
patch(x,y,z,tcolor)
```



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

Specifying Vertices and Faces

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

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

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

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

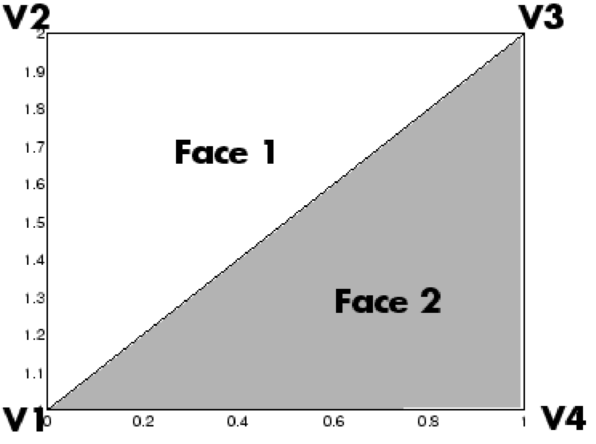
To specify the face colors, define a 2-by-3 matrix containing two RGB color definitions.

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

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

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

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



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

MATLAB does not require each face to have the same number of vertices. In cases where they do not, pad the `Faces` matrix with `NaNs`. To define a patch with faces that do not close, add one or more `NaNs` to the row in the `Vertices` matrix that defines the vertex you do not want connected.

Setting Default Properties

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

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

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

See Also

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

"Object Creation" on page 1-98 for related functions

`Patch Properties` for property descriptions

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

Patch Properties

Purpose

Patch properties

Modifying Properties

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

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

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

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

Patch Property Descriptions

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

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

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

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

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

`AmbientStrength`

scalar >= 0 and <= 1

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

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

`Annotation`

`hg.Annotation` object Read Only

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

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

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

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

Setting the IconDisplayStyle property

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

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

Using the IconDisplayStyle property

See “Controlling Legends” for more information and examples.

Selecting which objects to display in legend

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

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

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

`BackFaceLighting`

`unlit | lit | {reverselit}`

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

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

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

`BeingDeleted`

`on | {off}` Read Only

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

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

`BusyAction`

`cancel | {queue}`

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

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

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

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

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

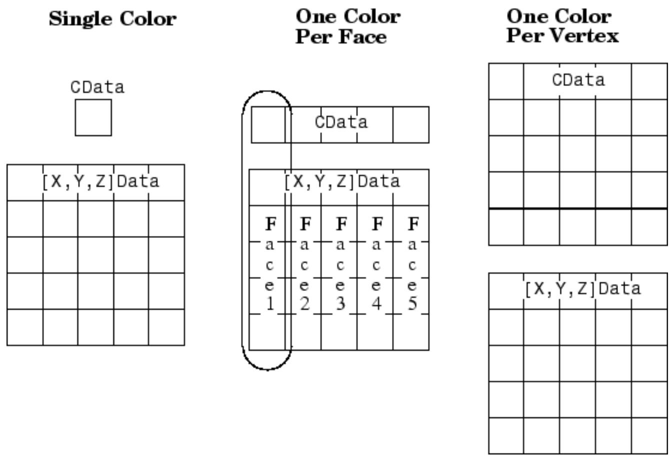
Set this property to a function handle that references the callback. You can also use a string that is a valid MATLAB expression or the name of an M-file. The expressions execute in the MATLAB workspace.

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

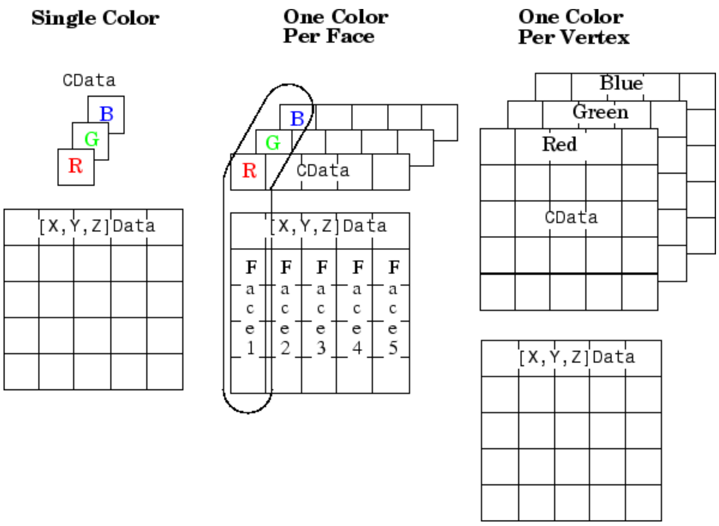
`CData`
scalar, vector, or matrix

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

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



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



Note that if `CData` contains `NaN`s, MATLAB does not color the faces.

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

`CDataMapping`
`{scaled} | direct`

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

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

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

`Children`
matrix of handles

Always the empty matrix; patch objects have no children.

`Clipping`
`{on} | off`

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

`CreateFcn`
string or function handle

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

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

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

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

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

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

`DeleteFcn`
string or function handle

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

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

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

`DiffuseStrength`
scalar >= 0 and <= 1

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

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

`DisplayName`
string (default is empty string)

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

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

See "Controlling Legends" for more examples.

`EdgeAlpha`

`{scalar = 1} | flat | interp`

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

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

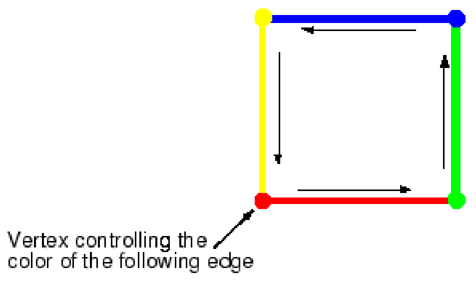
Note that you cannot specify `flat` or `interp` `EdgeAlpha` without first setting `FaceVertexAlphaData` to a matrix containing one alpha value per face (`flat`) or one alpha value per vertex (`interp`).

`EdgeColor`

`{ColorSpec} | none | flat | interp`

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

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



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

`EdgeLighting`

`{none} | flat | gouraud | phong`

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

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

`EraseMode`

`{normal} | none | xor | background`

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

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

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

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

Printing with Nonnormal Erase Modes

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

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

FaceAlpha
{scalar = 1} | flat | interp

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

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

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

FaceColor
{ColorSpec} | none | flat | interp

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

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

FaceLighting
{none} | flat | gouraud | phong

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

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

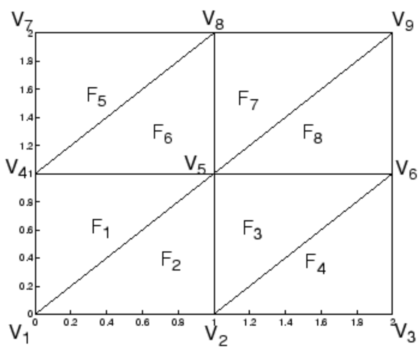
- `phong` — The effect of light objects is determined by interpolating the vertex normals across each face and calculating the reflectance at each pixel. Select this choice to view curved surfaces. Phong lighting generally produces better results than Gouraud lighting, but takes longer to render.

`Faces`

m-by-n matrix

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

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



`Faces` **property**

F1	V1	V4	V5
F2	V1	V5	V2
F3	V2	V5	V6
F4	V2	V6	V3
F5	V4	V7	V8
F6	V4	V8	V5
F7	V5	V8	V9
F8	V5	V9	V6

`Vertices` **property**

V1	X1	Y1	Z1
V2	X2	Y2	Z2
V3	X3	Y3	Z3
V4	X4	Y4	Z4
V5	X5	Y5	Z5
V6	X6	Y6	Z6
V7	X7	Y7	Z7
V8	X8	Y8	Z8
V9	X9	Y9	Z9

The corresponding `Faces` and `Vertices` properties are shown to the right of the patch. Note how some faces share vertices with other faces. For example, the fifth vertex (V5) is used six times, once each by faces one, two, and three and six, seven, and eight. Without sharing vertices, this same patch requires 24 vertex definitions.

`FaceVertexAlphaData`
m-by-1 matrix

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

`FaceVertexAlphaData` can be one of the following:

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

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

`FaceVertexCData`
matrix

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

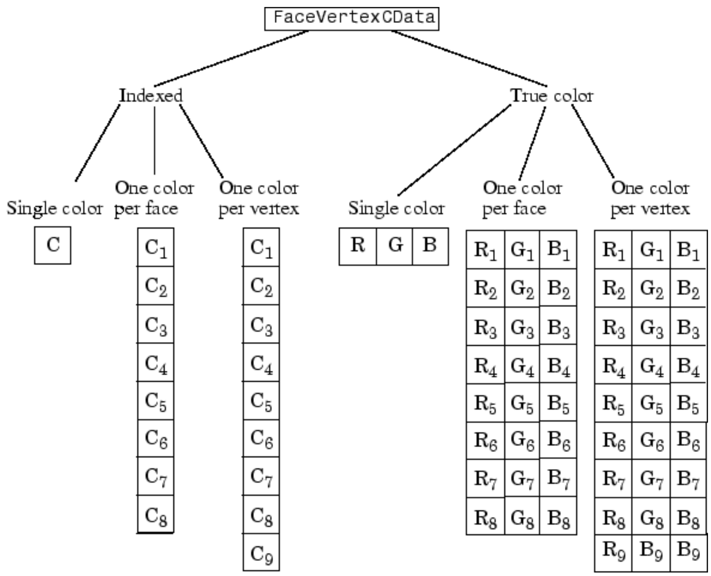
For indexed colors, FaceVertexCData can be

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

For true colors, FaceVertexCData can be

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

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



`HandleVisibility`
`{on} | callback | off`

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

Handles are always visible when `HandleVisibility` is `on`.

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

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

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

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

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

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

HitTest

{on} | off

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

Interruptible

{on} | off

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

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

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

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

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

`LineWidth`
scalar

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

`Marker`
character (see table)

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

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

`MarkerEdgeColor`

`ColorSpec | none | {auto} | flat`

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

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

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

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

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

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

`MarkerSize`
size in points

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

`NormalMode`
`{auto} | manual`

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

`Parent`
handle of axes, hggroup, or hgtransform

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

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

`Selected`
`on | {off}`

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

`SelectionHighlight`
`{on} | off`

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

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

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

`SpecularColorReflectance`
scalar in the range 0 to 1

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

`SpecularExponent`
scalar >= 1

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

`SpecularStrength`
scalar >= 0 and <= 1

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

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

`Tag`
string

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

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

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

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

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

`Type`
string (read only)

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

`UIContextMenu`
handle of a uicontextmenu object

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

`UserData`
matrix

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

`VertexNormals`
matrix

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

`Vertices`
matrix

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

`Visible`
`{on} | off`

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

`XData`
vector or matrix

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

`YData`
vector or matrix

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

`ZData`
vector or matrix

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

See Also

`patch`

path

Purpose

View or change search path

GUI Alternatives

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

Syntax

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

Description

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

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

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

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

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

Examples

To display the search path, run

```
path
```

MATLAB displays, for example

```
MATLABPATH

  H:\My Documents\MATLAB
  C:\Program Files\MATLAB\R2008b\toolbox\matlab\general
  C:\Program Files\MATLAB\R2008b\toolbox\matlab\ops
  C:\Program Files\MATLAB\R2008b\toolbox\matlab\lang
```

```
 C:\Program Files\MATLAB\R2008b\toolbox\matlab\elmat
 C:\Program Files\MATLAB\R2008b\toolbox\matlab\elfun
...
```

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

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

Add a new directory to the search path on UNIX[21] platforms.

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

See Also

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

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

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

Purpose Save current search path to `pathdef.m` file

Syntax `path2rc`

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

Purpose Path separator for current platform

Syntax

```
c = pathsep
```

Description `c = pathsep` returns the path separator character for this platform. The path separator is the character that separates directories in the `pathdef.m` file. The characters is a semicolon (`;`). For versions of MATLAB software prior to version 7.7 (R2008b), the character on UNIX[22] platforms was a colon (`:`). Use `pathsep` when you need to work with the path file content programmatically, as a string.

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

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

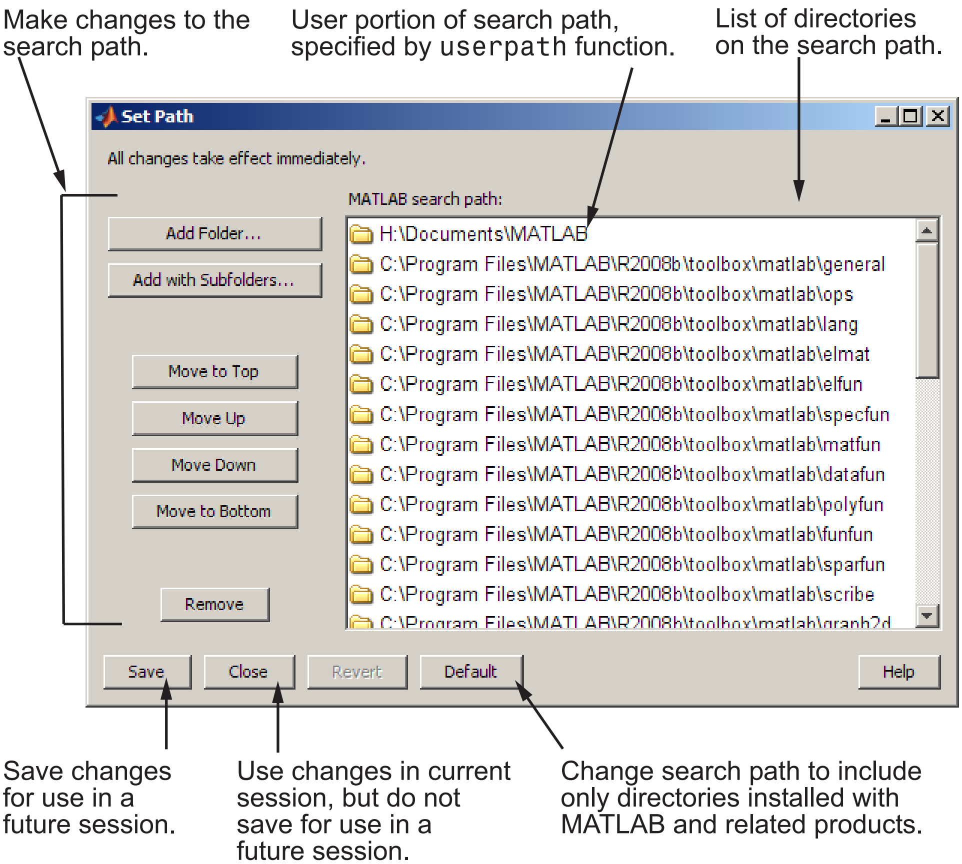
Purpose Open Set Path dialog box to view and change search path

GUI Alternatives As an alternative to the `pathtool` function, select **File > Set Path** in the MATLAB desktop.

Syntax

```
pathtool
```

Description `pathtool` opens the **Set Path** dialog box, a graphical user interface you use to view and modify the search path MATLAB uses.



See Also

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

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

Purpose

Halt execution temporarily

Syntax

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

Description

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

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

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

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

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

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

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

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

Remarks

While MATLAB is paused, the following continue to execute:

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

See Also

`keyboard`, `input`, `drawnow`

Purpose

Set or query plot box aspect ratio

Syntax

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

Description

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

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

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

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

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

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

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

Remarks

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

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

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

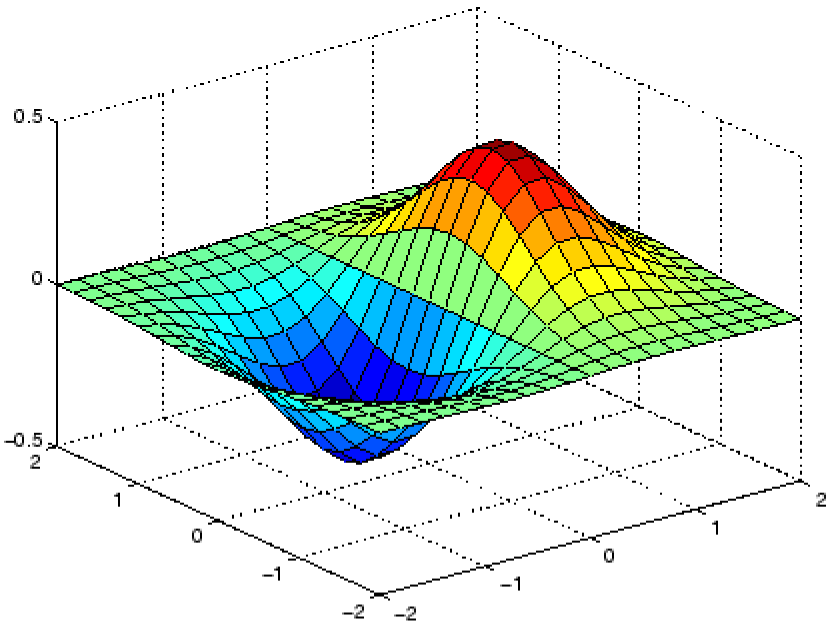
```
pbaspect(pbaspect)
```

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

Examples

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

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



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

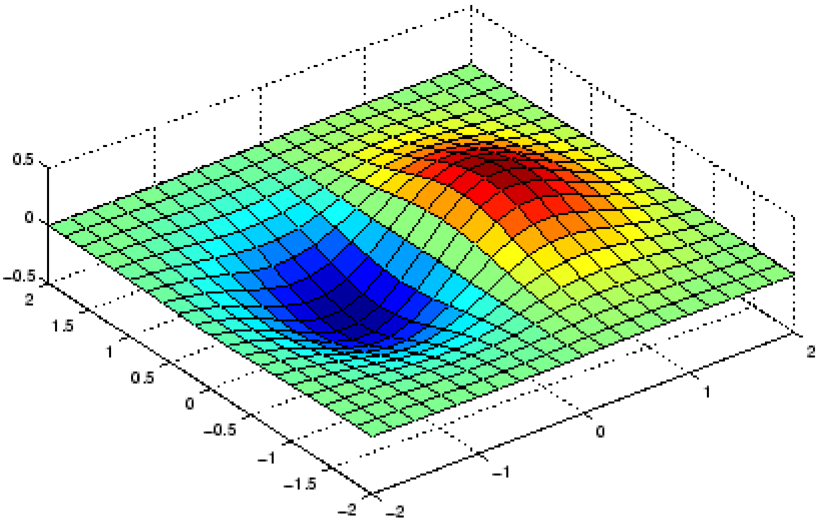
```
pbaspect
ans =
     1   1   1
```

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

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

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

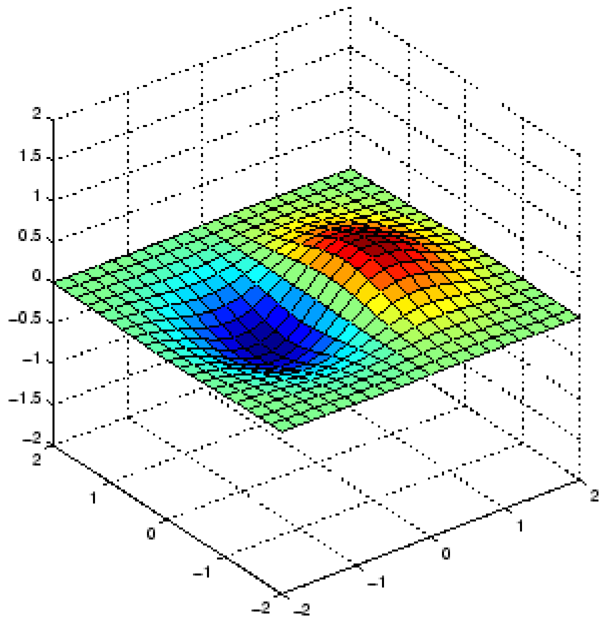
```
daspect([1 1 1])
```




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

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

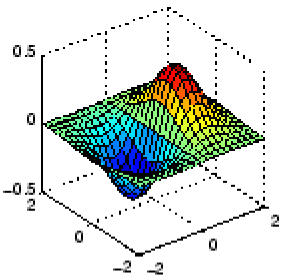
```
pbaspect([1 1 1])
```

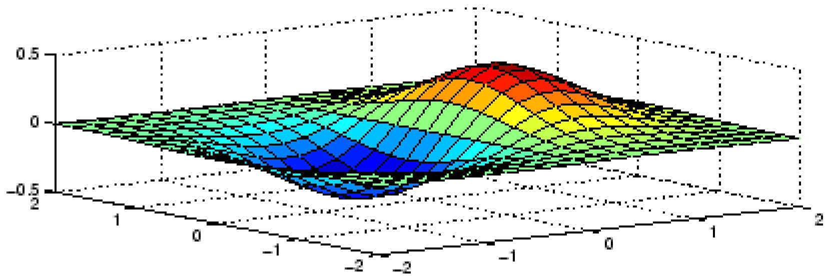


Notice how MATLAB changed the axes limits because of the constraints introduced by specifying both the plot box and data aspect ratios.

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

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





See Also

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

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

Setting Aspect Ratio in the MATLAB Graphics manual

Axes Aspect Ratio Properties in the 3-D Visualization manual

Purpose

Preconditioned conjugate gradients method

Syntax

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

Description

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

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

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

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

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

`pcg(A,b,tol,maxit,M)` and `pcg(A,b,tol,maxit,M1,M2)` use symmetric positive definite preconditioner `M` or `M = M1*M2` and effectively solve the system `inv(M)*A*x = inv(M)*b` for `x`. If `M` is `[]` then `pcg` applies no preconditioner. `M` can be a function handle `mfun` such that `mfun(x)` returns `M\x`.

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

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

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

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

`[x,flag,relres] = pcg(A,b,...)` also returns the relative residual `norm(b-A*x)/norm(b)`. If `flag` is `0`, `relres <= tol`.

`[x,flag,relres,iter] = pcg(A,b,...)` also returns the iteration number at which `x` was computed, where `0 <= iter <= maxit`.

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

Examples

Example 1

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

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

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

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

Example 2

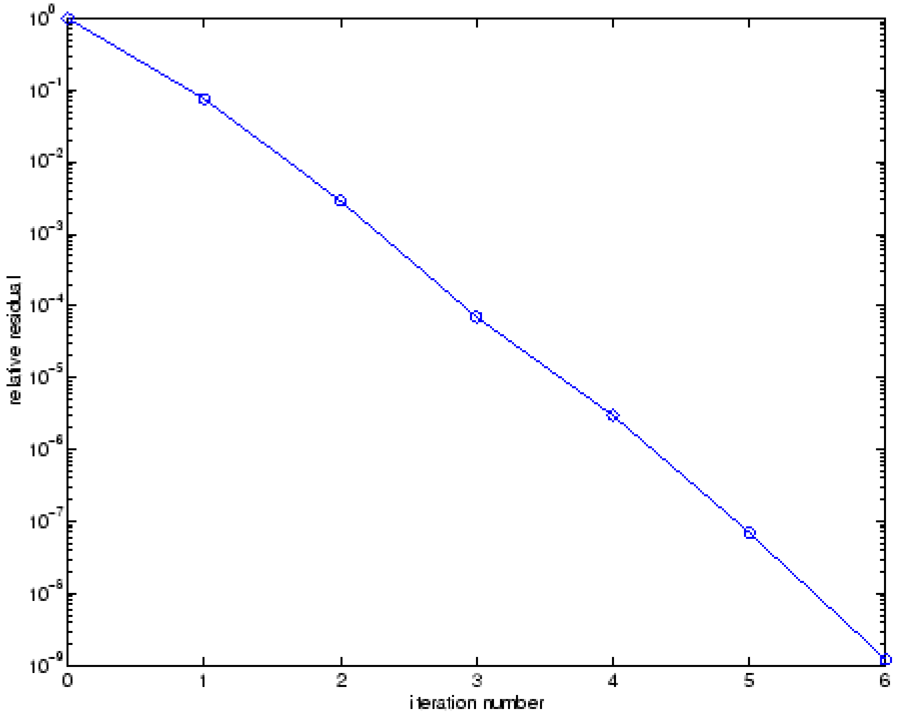
```
A = delsq(numgrid('C',25));
b = ones(length(A),1);
[x,flag] = pcg(A,b)
```

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

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

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

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



See Also

`bicg`, `bicgstab`, `cgs`, `cholinc`, `gmres`, `lsqr`, `minres`, `qmr`, `symmlq`

`function_handle` (`@`), `mldivide` (`\`)

References

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

Purpose

Piecewise Cubic Hermite Interpolating Polynomial (PCHIP)

Syntax

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

Description

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

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

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

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

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

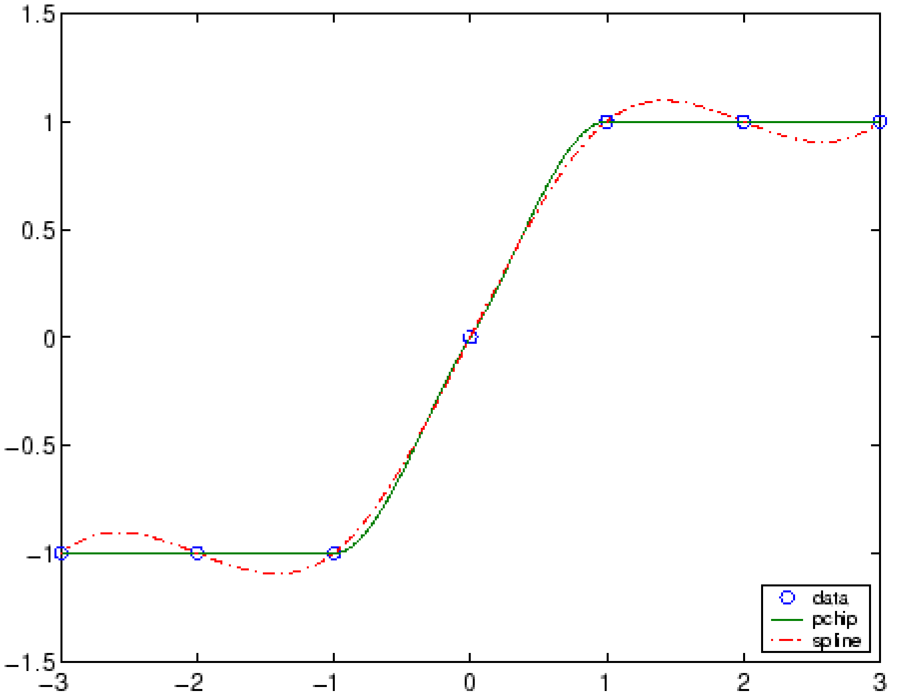
Remarks

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

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

Examples

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



See Also

`interp1`, `spline`, `ppval`

References

[1] Fritsch, F. N. and R. E. Carlson, "Monotone Piecewise Cubic Interpolation," *SIAM J. Numerical Analysis*, Vol. 17, 1980, pp.238-246.

[2] Kahaner, David, Cleve Moler, Stephen Nash, *Numerical Methods and Software*, Prentice Hall, 1988.

Purpose

Create preparsed pseudocode file (P-file)

Syntax

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

Description

`pcode` *`fun`* parses the M-file `fun.m` into the P-file `fun.p` and puts it into the current directory. The original M-file can be anywhere on the search path.

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

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

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

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

Examples

Example 1 – PCoding Multiple Files

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

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

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

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

dir C:\work\pcodetest

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

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

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

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

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

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

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

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

Example 3 – PCoding In Place

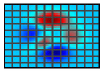
When you generate a pcode file `inplace`, MATLAB writes the output file to the same directory as the input file:

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

.        ..       test.m  test.p
```

pcolor

Purpose

Pseudocolor (checkerboard) plot



GUI Alternatives

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

Syntax

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

Description

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

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

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

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

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

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

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

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

Remarks

A pseudocolor plot is a flat surface plot viewed from above. `pcolor(X,Y,C)` is the same as viewing `surf(X,Y,zeros(size(X)),C)` using `view([0 90])`.

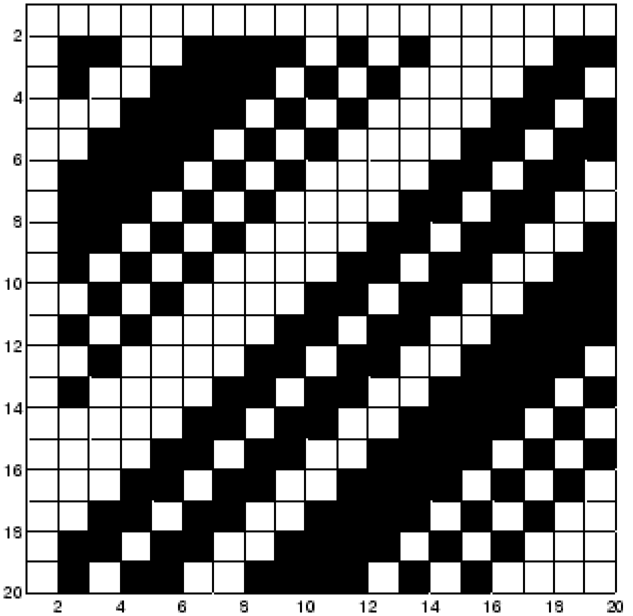
When you use `shading faceted` or `shading flat`, the constant color of each cell is the color associated with the corner having the smallest *x-y* coordinates. Therefore, `C(i,j)` determines the color of the cell in the *i*th row and *j*th column. The last row and column of C are not used.

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

Examples

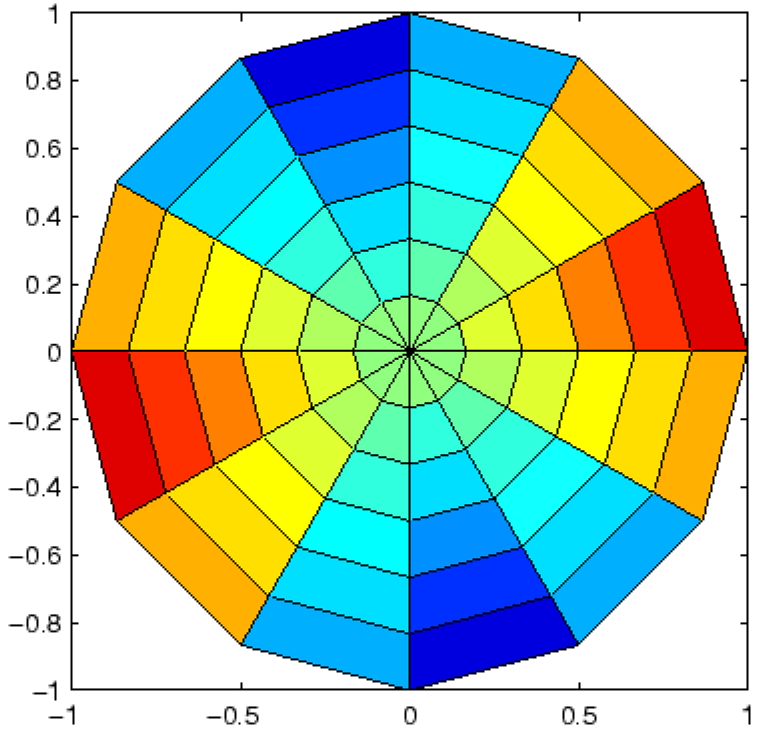
A Hadamard matrix has elements that are `+1` and `-1`. A colormap with only two entries is appropriate when displaying a pseudocolor plot of this matrix.

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



A simple color wheel illustrates a polar coordinate system.

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



Algorithm

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

See Also

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

pdepe

Purpose

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

Syntax

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

Arguments

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

Description

`sol = pdepe(m,pdefun,icfun,bcfun,xmesh,tspan)` solves initial-boundary value problems for systems of parabolic and elliptic PDEs in the one space variable x and time t. `pdefun`, `icfun`, and `bcfun` are function handles. See "Function Handles" in the MATLAB Programming documentation for more information. The ordinary differential equations (ODEs) resulting from discretization in space are integrated to obtain approximate solutions at times specified in `tspan`. The `pdepe` function returns values of the solution on a mesh provided in `xmesh`.

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

`pdepe` solves PDEs of the form:

$$c\left(x, t, u, \frac{\partial u}{\partial x}\right)\frac{\partial u}{\partial t} = x^{-m}\frac{\partial}{\partial x}\left(x^m f\left(x, t, u, \frac{\partial u}{\partial x}\right)\right) + s\left(x, t, u, \frac{\partial u}{\partial x}\right) \tag{2-2}$$

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

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

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

$$u(x, t_0) = u_0(x) \qquad (2\text{-}3)$$

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

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

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

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

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

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

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

  ```
  u = icfun(x)
  ```

  When called with an argument `x`, `icfun` evaluates and returns the initial values of the solution components at `x` in the column vector `u`.
- `bcfun` evaluates the terms p and q of the boundary conditions (Equation 2-4). It has the form

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

ul is the approximate solution at the left boundary xl = a and ur is the approximate solution at the right boundary xr = b. pl and ql are column vectors corresponding to p and q evaluated at xl, similarly pr and qr correspond to xr. When $m > 0$ and $a = 0$, boundedness of the solution near $x = 0$ requires that the flux f vanish at $a = 0$. pdepe imposes this boundary condition automatically and it ignores values returned in pl and ql.

pdepe returns the solution as a multidimensional array sol. u_i = ui = sol(:,:,i) is an approximation to the ith component of the solution vector u. The element ui(j,k) = sol(j,k,i) approximates u_i at (t, x) = (tspan(j),xmesh(k)).

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

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

Remarks

- The arrays xmesh and tspan play different roles in pdepe.

  tspan – The pdepe function performs the time integration with an ODE solver that selects both the time step and formula dynamically. The elements of tspan merely specify where you want answers and the cost depends weakly on the length of tspan.

  xmesh – Second order approximations to the solution are made on the mesh specified in xmesh. Generally, it is best to use closely spaced mesh points where the solution changes rapidly. pdepe does *not* select the mesh in x automatically. You must provide an appropriate fixed mesh in `xmesh`. The cost depends strongly on the length of `xmesh`. When $m > 0$, it is not necessary to use a fine mesh near $x = 0$ to account for the coordinate singularity.

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

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

Examples

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

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

This equation holds on an interval $0 \le x \le 1$ for times $t \ge 0$.

The PDE satisfies the initial condition

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

and boundary conditions

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

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

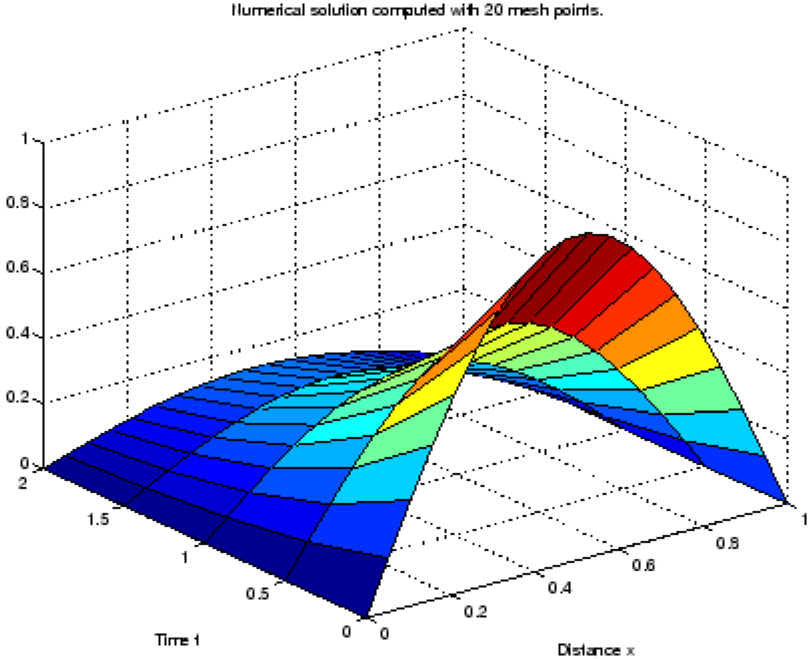
It is convenient to use subfunctions to place all the functions required by pdepe in a single M-file.

```
function pdex1

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

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

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

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

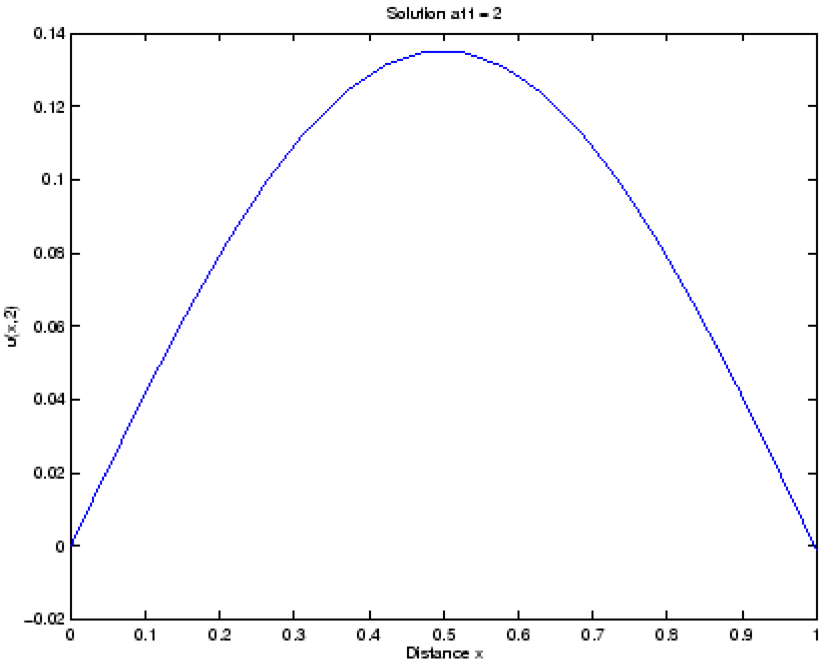
```
% --------------------------------------------------------------
function [pl,ql,pr,qr] = pdex1bc(xl,ul,xr,ur,t)
pl = ul;
ql = 0;
pr = pi * exp(-t);
qr = 1;
```

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

The surface plot shows the behavior of the solution.



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



Example 2. This example illustrates the solution of a system of PDEs. The problem has boundary layers at both ends of the interval. The solution changes rapidly for small t.

The PDEs are

$$\frac{\partial u_1}{\partial t} = 0.024\,\frac{\partial^2 u_1}{\partial x^2} - F(u_1 - u_2)$$

$$\frac{\partial u_2}{\partial t} = 0.170\,\frac{\partial^2 u_2}{\partial x^2} + F(u_1 - u_2)$$

where $F(y) = \exp(5.73y) - \exp(-11.46y)$.

This equation holds on an interval $0 \le x \le 1$ for times $t \ge 0$.

The PDE satisfies the initial conditions

$$u_1(x, 0) \equiv 1$$

$$u_2(x, 0) \equiv 0$$

and boundary conditions

$$\frac{\partial u_1}{\partial x}(0, t) \equiv 0$$

$$u_2(0, t) \equiv 0$$

$$u_1(1, t) \equiv 1$$

$$\frac{\partial u_2}{\partial x}(1, t) \equiv 0$$

In the form expected by `pdepe`, the equations are

$$\begin{bmatrix} 1 \\ 1 \end{bmatrix} .* \frac{\partial}{\partial t}\begin{bmatrix} u_1 \\ u_2 \end{bmatrix} = \frac{\partial}{\partial x}\begin{bmatrix} 0.024(\partial u_1/\partial x) \\ 0.170(\partial u_2/\partial x) \end{bmatrix} + \begin{bmatrix} -F(u_1 - u_2) \\ F(u_1 - u_2) \end{bmatrix}$$

The boundary conditions on the partial derivatives of u have to be written in terms of the flux. In the form expected by `pdepe`, the left boundary condition is

$$\begin{bmatrix} 0 \\ u_2 \end{bmatrix} + \begin{bmatrix} 1 \\ 0 \end{bmatrix} .* \begin{bmatrix} 0.024(\partial u_1/\partial x) \\ 0.170(\partial u_2/\partial x) \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$$

and the right boundary condition is

$$\begin{bmatrix} u_1 - 1 \\ 0 \end{bmatrix} + \begin{bmatrix} 0 \\ 1 \end{bmatrix} .* \begin{bmatrix} 0.024(\partial u_1/\partial x) \\ 0.170(\partial u_2/\partial x) \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$$

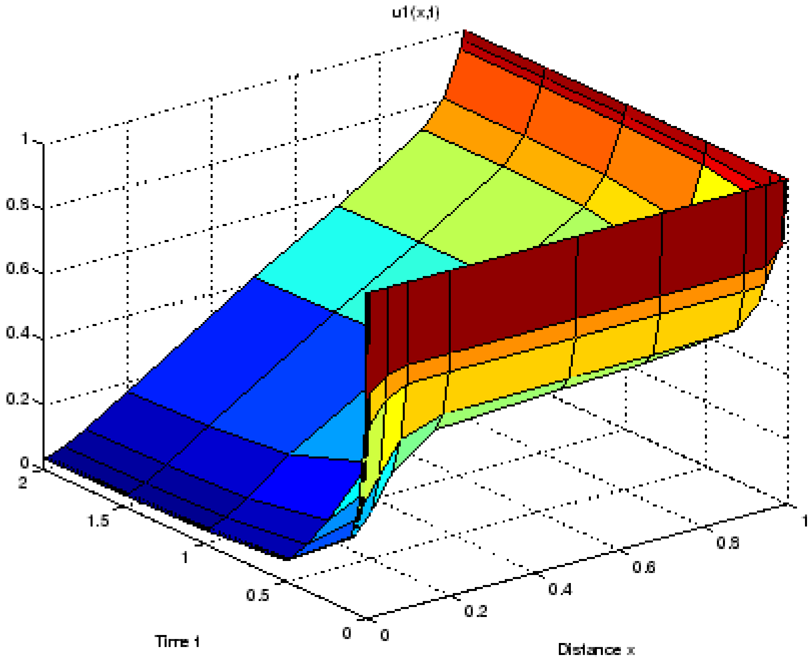
The solution changes rapidly for small t. The program selects the step size in time to resolve this sharp change, but to see this behavior in the plots, the example must select the output times accordingly. There are boundary layers in the solution at both ends of [0,1], so the example places mesh points near 0 and 1 to resolve these sharp changes. Often some experimentation is needed to select a mesh that reveals the behavior of the solution.

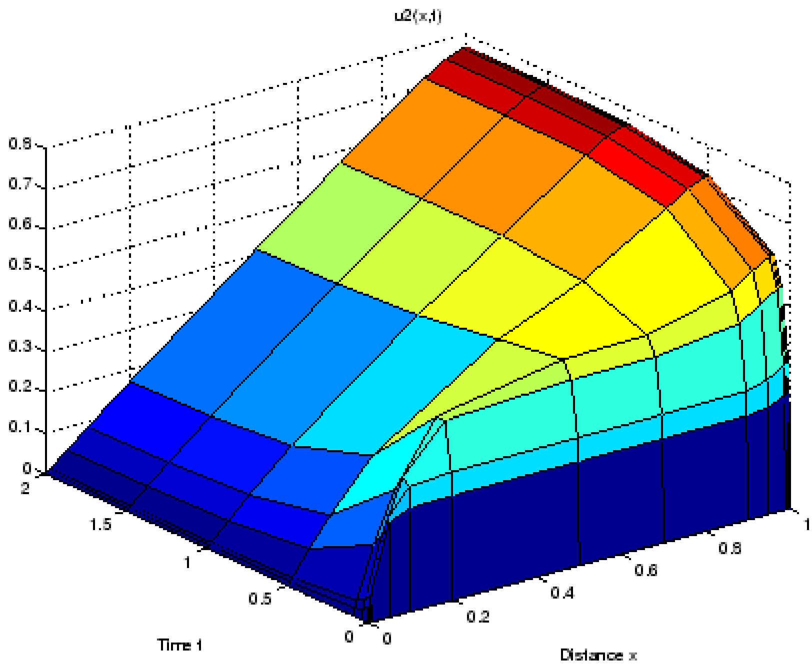
```
function pdex4
m = 0;
x = [0 0.005 0.01 0.05 0.1 0.2 0.5 0.7 0.9 0.95 0.99 0.995 1];
t = [0 0.005 0.01 0.05 0.1 0.5 1 1.5 2];

sol = pdepe(m,@pdex4pde,@pdex4ic,@pdex4bc,x,t);
u1 = sol(:,:,1);
u2 = sol(:,:,2);

figure
surf(x,t,u1)
title('u1(x,t)')
xlabel('Distance x')
ylabel('Time t')

figure
surf(x,t,u2)
title('u2(x,t)')
xlabel('Distance x')
ylabel('Time t')
% --------------------------------------------------------------
function [c,f,s] = pdex4pde(x,t,u,DuDx)
c = [1; 1];
f = [0.024; 0.17] .* DuDx;
y = u(1) - u(2);
```

```
F = exp(5.73*y)-exp(-11.47*y);
s = [-F; F];
% --------------------------------------------------------------
function u0 = pdex4ic(x);
u0 = [1; 0];
% --------------------------------------------------------------
function [pl,ql,pr,qr] = pdex4bc(xl,ul,xr,ur,t)
pl = [0; ul(2)];
ql = [1; 0];
pr = [ur(1)-1; 0];
qr = [0; 1];
```

In this example, the PDEs, initial conditions, and boundary conditions are coded in subfunctions `pdex4pde`, `pdex4ic`, and `pdex4bc`.

The surface plots show the behavior of the solution components.





See Also

`function_handle (@)`, `pdeval`, `ode15s`, `odeset`, `odeget`

References

[1] Skeel, R. D. and M. Berzins, "A Method for the Spatial Discretization of Parabolic Equations in One Space Variable," *SIAM Journal on Scientific and Statistical Computing*, Vol. 11, 1990, pp.1-32.

pdeval

Purpose

Evaluate numerical solution of PDE using output of `pdepe`

Syntax

```
[uout,duoutdx] = pdeval(m,x,ui,xout)
```

Arguments

`m`	Symmetry of the problem: slab = `0`, cylindrical = `1`, spherical = `2`. This is the first input argument used in the call to `pdepe`.
`xmesh`	A vector [`x0`, `x1`, ..., `xn`] specifying the points at which the elements of `ui` were computed. This is the same vector with which `pdepe` was called.
`ui`	A vector `sol`(j,:,`i`) that approximates component `i` of the solution at time t_f and mesh points `xmesh`, where `sol` is the solution returned by `pdepe`.
`xout`	A vector of points from the interval [`x0`,`xn`] at which the interpolated solution is requested.

Description

`[uout,duoutdx] = pdeval(m,x,ui,xout)` approximates the solution u_i and its partial derivative $\partial u_i / \partial x$ at points from the interval [`x0`,`xn`]. The `pdeval` function returns the computed values in `uout` and `duoutdx`, respectively.

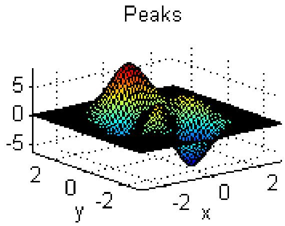
Note `pdeval` evaluates the partial derivative $\partial u_i / \partial x$ rather than the flux f. Although the flux is continuous, the partial derivative may have a jump at a material interface.

See Also

`pdepe`

Purpose

Example function of two variables



Syntax

```
Z = peaks;
Z = peaks(n);
Z = peaks(V);
Z = peaks(X,Y);

peaks;
peaks(N);
peaks(V);
peaks(X,Y);

X,Y,Z] = peaks;
[X,Y,Z] = peaks(n);
[X,Y,Z] = peaks(V);
```

Description

`peaks` is a function of two variables, obtained by translating and scaling Gaussian distributions, which is useful for demonstrating `mesh`, `surf`, `pcolor`, `contour`, and so on.

`Z = peaks;` returns a 49-by-49 matrix.

`Z = peaks(n);` returns an `n`-by-`n` matrix.

`Z = peaks(V);` returns an `n`-by-`n` matrix, where `n = length(V)`.

`Z = peaks(X,Y);` evaluates `peaks` at the given `X` and `Y` (which must be the same size) and returns a matrix the same size.

`peaks(...)` (with no output argument) plots the peaks function with `surf`.

`[X,Y,Z] = peaks(...);` returns two additional matrices, `X` and `Y`, for parametric plots, for example, `surf(X,Y,Z,del2(Z))`. If not given as input, the underlying matrices `X` and `Y` are

```
[X,Y] = meshgrid(V,V)
```

where `V` is a given vector, or `V` is a vector of length `n` with elements equally spaced from -3 to 3. If no input argument is given, the default `n` is 49.

See Also

`meshgrid`, `surf`

Purpose Call Perl script using appropriate operating system executable

Syntax

```
perl('perlfile')
perl('perlfile',arg1,arg2,...)
result = perl(...)
[result, status] = perl(...)
```

Description `perl('perlfile')` calls the Perl script `perlfile`, using the appropriate operating system Perl executable. Perl is included with the MATLAB software on Microsoft Windows systems, and thus MATLAB users can run M-files containing the `perl` function. On UNIX [23] systems, MATLAB calls the Perl interpreter available with the operating system.

`perl('perlfile',arg1,arg2,...)` calls the Perl script `perlfile`, using the appropriate operating system Perl executable, and passes the arguments `arg1`, `arg2`, and so on, to `perlfile`.

`result = perl(...)` returns the results of attempted Perl call to `result`.

`[result, status] = perl(...)` returns the results of attempted Perl call to `result` and its exit status to `status`.

It is sometimes beneficial to use Perl scripts instead of MATLAB code. The `perl` function allows you to run those scripts from MATLAB. Specific examples where you might choose to use a Perl script include:

- Perl script already exists
- Perl script preprocesses data quickly, formatting it in a way more easily read by MATLAB
- Perl has features not supported by MATLAB

Examples

Given the Perl script, `hello.pl`:

```
$input = $ARGV[0];
print "Hello $input.";
```

At the MATLAB command line, type:

```
perl('hello.pl','World')
```

MATLAB displays:

```
ans =
Hello World.
```

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

See Also

`!` (exclamation point), `dos`, `regexp`, `system`, `unix`

perms

Purpose

All possible permutations

Syntax

```
P = perms(v)
```

Description

`P = perms(v)`, where `v` is a row vector of length `n`, creates a matrix whose rows consist of all possible permutations of the `n` elements of `v`. Matrix `P` contains `n!` rows and `n` columns.

Examples

The command `perms(2:2:6)` returns *all* the permutations of the numbers 2, 4, and 6:

```
6    4    2
6    2    4
4    6    2
4    2    6
2    4    6
2    6    4
```

Limitations

This function is only practical for situations where `n` is less than about 15.

See Also

`nchoosek`, `permute`, `randperm`

Purpose

Rearrange dimensions of N-D array

Syntax

```
B = permute(A,order)
```

Description

`B = permute(A,order)` rearranges the dimensions of `A` so that they are in the order specified by the vector `order`. `B` has the same values of `A` but the order of the subscripts needed to access any particular element is rearranged as specified by `order`. All the elements of `order` must be unique.

Remarks

`permute` and `ipermute` are a generalization of transpose (`.'`) for multidimensional arrays.

Examples

Given any matrix `A`, the statement

```
permute(A,[2 1])
```

is the same as `A.'`.

For example:

```
A = [1 2; 3 4]; permute(A,[2 1])
ans =
     1     3
     2     4
```

The following code permutes a three-dimensional array:

```
X = rand(12,13,14);
Y = permute(X,[2 3 1]);
size(Y)
ans =
    13    14    12
```

See Also

`ipermute`, `circshift`, `shiftdim`

persistent

Purpose Define persistent variable

Syntax

```
persistent X Y Z
```

Description

`persistent X Y Z` defines `X`, `Y`, and `Z` as variables that are local to the function in which they are declared; yet their values are retained in memory between calls to the function. Persistent variables are similar to global variables because the MATLAB software creates permanent storage for both. They differ from global variables in that persistent variables are known only to the function in which they are declared. This prevents persistent variables from being changed by other functions or from the MATLAB command line.

Persistent variables are cleared when the M-file is cleared from memory or when the M-file is changed. To keep an M-file in memory until MATLAB quits, use `mlock`.

If the persistent variable does not exist the first time you issue the `persistent` statement, it is initialized to the empty matrix.

It is an error to declare a variable persistent if a variable with the same name exists in the current workspace. MATLAB also errors if you declare any of a function's input or output arguments as persistent within that same function. For example, the following persistent declaration is invalid:

```
function myfun(argA, argB, argC)
persistent argB
```

Remarks

There is no function form of the `persistent` command (i.e., you cannot use parentheses and quote the variable names).

Example

This function prompts a user to enter a directory name to use in locating one or more files. If the user has already entered this information, and it requires no modification, they do not need to enter it again. This is because the function stores it in a persistent variable (`lastDir`), and offers it as the default selection. Here is the function definition:

```
function find_file(file)
persistent lastDir

if isempty(lastDir)
    prompt = 'Enter directory:  ';
else
    prompt = ['Enter directory[' lastDir ']:  '];
end
response = input(prompt, 's');

if ~isempty(response)
    dirName = response;
else
    dirName = lastDir;
end

dir(strcat(dirName, file))
lastDir = dirName;
```

Execute the function twice. The first time, it prompts you to enter the information and does not offer a default:

```
cd(matlabroot)

find_file('is*.m')
Enter directory:  toolbox/matlab/strfun/

iscellstr.m   ischar.m   isletter.m   isspace.m   isstr.m
isstrprop.m
```

The second time, it does offer a default taken from the persistent variable `dirName`:

```
find_file('is*.m')
Enter directory[toolbox/matlab/strfun/]:
toolbox/matlab/elmat/
```

```
isempty.m              isfinite.m            isscalar.m
isequal.m              isinf.m               isvector.m
isequalwithequalnans.m  isnan.m
```

See Also `global`, `clear`, `mislocked`, `mlock`, `munlock`, `isempty`

Purpose

Ratio of circle's circumference to its diameter, π

Syntax

```
pi
```

Description

`pi` returns the floating-point number nearest the value of π. The expressions `4*atan(1)` and `imag(log(-1))` provide the same value.

Examples

The expression `sin(pi)` is not exactly zero because `pi` is not exactly π.

```
sin(pi)

ans =

    1.2246e-16
```

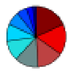
See Also

`ans`, `eps`, `i`, `Inf`, `j`, `NaN`

pie

Purpose

Pie chart



GUI Alternatives

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

Syntax

```
pie(X)
pie(X,explode)
pie(...,labels)
pie(axes_handle,...)
h = pie(...)
```

Description

`pie(X)` draws a pie chart using the data in `X`. Each element in `X` is represented as a slice in the pie chart.

`pie(X,explode)` offsets a slice from the pie. `explode` is a vector or matrix of zeros and nonzeros that correspond to `X`. A nonzero value offsets the corresponding slice from the center of the pie chart, so that `X(i,j)` is offset from the center if `explode(i,j)` is nonzero. `explode` must be the same size as `X`.

`pie(...,labels)` specifies text labels for the slices. The number of labels must equal the number of elements in `X`. For example,

```
pie(1:3,{'Taxes','Expenses','Profit'})
```

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

`h = pie(...)` returns a vector of handles to patch and text graphics objects.

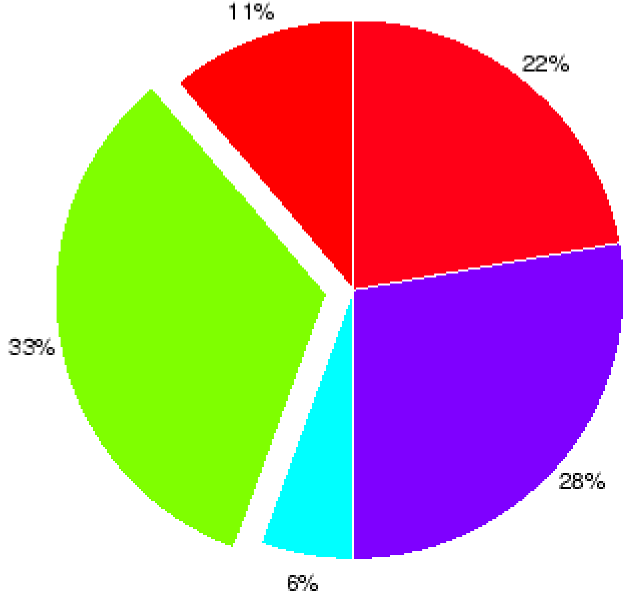
Remarks

The values in X are normalized via X/sum(X) to determine the area of each slice of the pie. If sum(X) ≤ 1, the values in X directly specify the area of the pie slices. MATLAB draws only a partial pie if sum(X) < 1.

Examples

Emphasize the second slice in the chart by setting its corresponding explode element to 1.

```
x = [1 3 0.5 2.5 2];
explode = [0 1 0 0 0];
pie(x,explode)
colormap jet
```

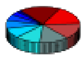


See Also

pie3

Purpose

3-D pie chart



GUI Alternatives

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

Syntax

```
pie3(X)
pie3(X,explode)
pie3(...,labels)
pie3(axes_handle,...)
h = pie3(...)
```

Description

`pie3(X)` draws a three-dimensional pie chart using the data in `X`. Each element in `X` is represented as a slice in the pie chart.

`pie3(X,explode)` specifies whether to offset a slice from the center of the pie chart. `X(i,j)` is offset from the center of the pie chart if `explode(i,j)` is nonzero. `explode` must be the same size as `X`.

`pie3(...,labels)` specifies text labels for the slices. The number of labels must equal the number of elements in `X`. For example,

```
pie3(1:3,{'Taxes','Expenses','Profit'})
```

`pie3(axes_handle,...)` plots into the axes with the handle `axes_handle` instead of into the current axes (`gca`).

`h = pie3(...)` returns a vector of handles to patch, surface, and text graphics objects.

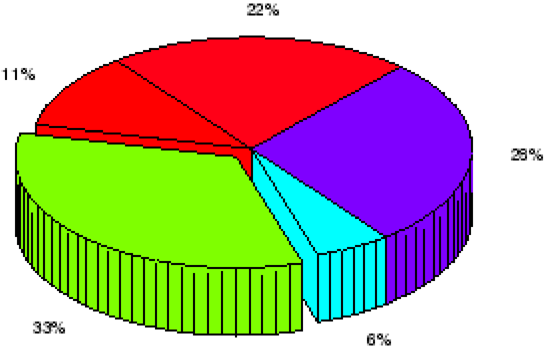
Remarks

The values in X are normalized via X/sum(X) to determine the area of each slice of the pie. If sum(X) ≤ 1, the values in X directly specify the area of the pie slices. MATLAB draws only a partial pie if sum(X) < 1.

Examples

Offset a slice in the pie chart by setting the corresponding explode element to 1:

```
x = [1 3 0.5 2.5 2];
explode = [0 1 0 0 0];
pie3(x,explode)
colormap hsv
```



See Also

pie

Purpose

Moore-Penrose pseudoinverse of matrix

Syntax

```
B = pinv(A)
B = pinv(A,tol)
```

Definition

The Moore-Penrose pseudoinverse is a matrix B of the same dimensions as A' satisfying four conditions:

```
A*B*A = A
B*A*B = B
A*B is Hermitian
B*A is Hermitian
```

The computation is based on svd(A) and any singular values less than tol are treated as zero.

Description

B = pinv(A) returns the Moore-Penrose pseudoinverse of A.

B = pinv(A,tol) returns the Moore-Penrose pseudoinverse and overrides the default tolerance, max(size(A))*norm(A)*eps.

Examples

If A is square and not singular, then pinv(A) is an expensive way to compute inv(A). If A is not square, or is square and singular, then inv(A) does not exist. In these cases, pinv(A) has some of, but not all, the properties of inv(A).

If A has more rows than columns and is not of full rank, then the overdetermined least squares problem

```
minimize norm(A*x-b)
```

does not have a unique solution. Two of the infinitely many solutions are

```
x = pinv(A)*b
```

and

```
y = A\b
```

These two are distinguished by the facts that norm(x) is smaller than the norm of any other solution and that y has the fewest possible nonzero components.

For example, the matrix generated by

```
A = magic(8); A = A(:,1:6)
```

is an 8-by-6 matrix that happens to have rank(A) = 3.

```
A =
    64     2     3    61    60     6
     9    55    54    12    13    51
    17    47    46    20    21    43
    40    26    27    37    36    30
    32    34    35    29    28    38
    41    23    22    44    45    19
    49    15    14    52    53    11
     8    58    59     5     4    62
```

The right-hand side is b = 260*ones(8,1),

```
b =
     260
     260
     260
     260
     260
     260
     260
     260
```

The scale factor 260 is the 8-by-8 magic sum. With all eight columns, one solution to A*x = b would be a vector of all 1's. With only six columns, the equations are still consistent, so a solution exists, but it is not all 1's. Since the matrix is rank deficient, there are infinitely many solutions. Two of them are

```
x = pinv(A)*b
```

which is

```
x =
    1.1538
    1.4615
    1.3846
    1.3846
    1.4615
    1.1538
```

and

```
y = A\b
```

which produces this result.

```
Warning: Rank deficient, rank = 3  tol =   1.8829e-013.
y =
    4.0000
    5.0000
         0
         0
         0
   -1.0000
```

Both of these are exact solutions in the sense that `norm(A*x-b)` and `norm(A*y-b)` are on the order of roundoff error. The solution `x` is special because

```
norm(x) = 3.2817
```

is smaller than the norm of any other solution, including

```
norm(y) = 6.4807
```

On the other hand, the solution `y` is special because it has only three nonzero components.

See Also

`inv`, `qr`, `rank`, `svd`

Purpose Givens plane rotation

Syntax `[G,y] = planerot(x)`

Description `[G,y] = planerot(x)` where `x` is a 2-component column vector, returns a 2-by-2 orthogonal matrix G so that `y = G*x` has `y(2) = 0`.

Examples

```
x = [3 4];
[G,y] = planerot(x')

G  =
    0.6000    0.8000
   -0.8000    0.6000

y =
     5
     0
```

See Also `qrdelete`, `qrinsert`

playshow

Purpose Run M-file demo (deprecated; use `echodemo` instead)

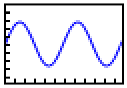
Syntax `playshow filename`

Description `playshow filename` runs `filename`, which is a demo. Replace `playshow` filename with `echodemo` filename. Note that other arguments supported by `playshow` are not supported by `echodemo`.

See Also `demo`, `echodemo`, `helpbrowser`

Purpose

2-D line plot



Contents

GUI Alternatives

Use the Plot Selector  to graph selected variables in the Workspace Browser and the Plot Catalog, accessed from the Figure Palette. Directly manipulate graphs in *plot edit* mode, and modify them using the Property Editor. For details, see Using Plot Edit Mode, and The Figure Palette in the MATLAB Graphics documentation, and also Creating Graphics from the Workspace Browser in the MATLAB Desktop documentation.

Syntax

```
plot(Y)
plot(X1,Y1,...)
plot(X1,Y1,LineSpec,...)
plot(...,'PropertyName',PropertyValue,...)
plot(axes_handle,...)
h = plot(...)
```

```
hlines = plot('v6',...)
```

Description

`plot(Y)` plots the columns of `Y` versus their index if `Y` is a real number. If `Y` is complex, `plot(Y)` is equivalent to `plot(real(Y),imag(Y))`. In all other uses of `plot`, the imaginary component is ignored.

`plot(X1,Y1,...)` plots all lines defined by `Xn` versus `Yn` pairs. If only one of `Xn` or `Yn` is a matrix, the vector is plotted versus the rows or columns of the matrix, depending on whether the vector's row or column dimension matches the matrix. If `Xn` is a scalar and `Yn` is a vector, disconnected line objects are created and plotted as discrete points vertically at `Xn`.

`plot(X1,Y1,LineSpec,...)` plots all lines defined by the `Xn,Yn,LineSpec` triples, where `LineSpec` is a line specification that determines line type, marker symbol, and color of the plotted lines. You can mix `Xn,Yn,LineSpec` triples with `Xn,Yn` pairs: `plot(X1,Y1,X2,Y2,LineSpec,X3,Y3)`.

Note See `LineSpec` for a list of line style, marker, and color specifiers.

`plot(...,'`*`PropertyName`*`',PropertyValue,...)` sets properties to the specified property values for all lineseries graphics objects created by `plot`. (See the "Examples" on page 2-2706 section for examples.)

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

`h = plot(...)` returns a column vector of handles to lineseries graphics objects, one handle per line.

Backward-Compatible Version

`hlines = plot('v6',...)` returns the handles to line objects instead of lineseries objects.

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

See Plot Objects and Backward Compatibility for more information.

Remarks

Cycling Through Line Colors and Styles

If you do not specify a color when plotting more than one line, `plot` automatically cycles through the colors in the order specified by the current axes `ColorOrder` property. After cycling through all the colors defined by `ColorOrder`, `plot` then cycles through the line styles defined in the axes `LineStyleOrder` property.

The default `LineStyleOrder` property has a single entry (a solid line with no marker).

By default, MATLAB resets the `ColorOrder` and `LineStyleOrder` properties each time you call `plot`. If you want the changes you make to these properties to persist, you must define these changes as default values. For example,

```
set(0,'DefaultAxesColorOrder',[0 0 0],...
      'DefaultAxesLineStyleOrder','-|-.|--|:')
```

sets the default `ColorOrder` to use only the color black and sets the `LineStyleOrder` to use solid, dash-dot, dash-dash, and dotted line styles.

Prevent Resetting of Color and Styles with hold all

The `all` option to the `hold` command prevents the `ColorOrder` and `LineStyleOrder` from being reset in subsequent `plot` commands. In the following sequence of commands, MATLAB continues to cycle through the colors defined by the axes `ColorOrder` property (see above).

```
plot(rand(12,2))
hold all
```

```
plot(randn(12,2))
```

Additional Information

- See Creating Line Plots and Annotating Graphs for more information on plotting.
- See `LineSpec` for more information on specifying line styles and colors.

Examples

Specifying the Color and Size of Markers

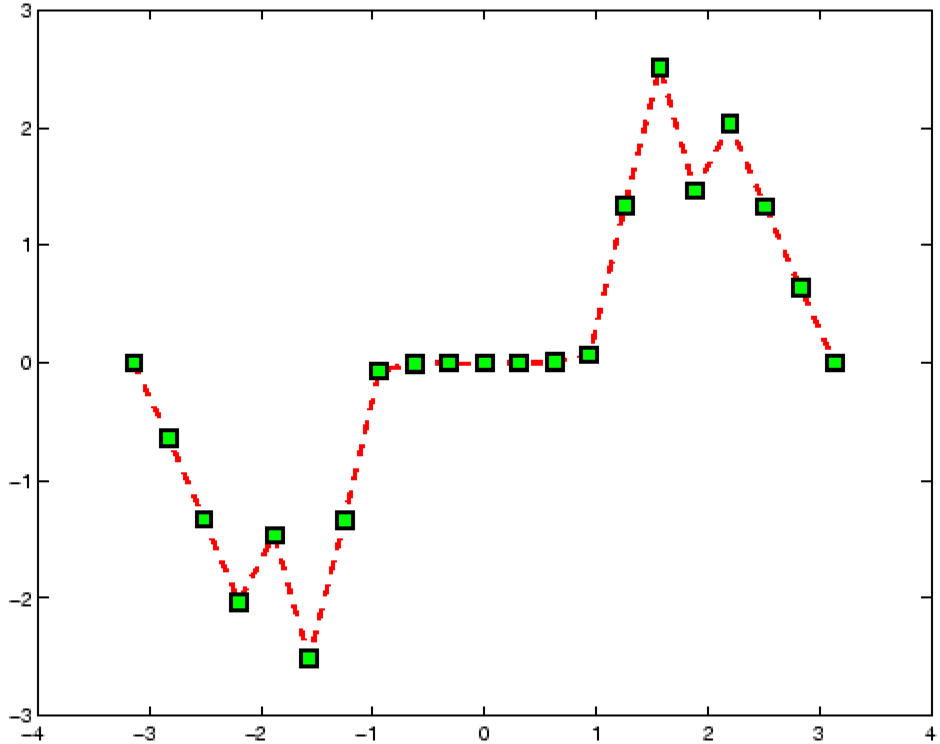
You can also specify other line characteristics using graphics properties (see `line` for a description of these properties):

- `LineWidth` — Specifies the width (in points) of the line.
- `MarkerEdgeColor` — Specifies the color of the marker or the edge color for filled markers (circle, square, diamond, pentagram, hexagram, and the four triangles).
- `MarkerFaceColor` — Specifies the color of the face of filled markers.
- `MarkerSize` — Specifies the size of the marker in units of points.

For example, these statements,

```
x = -pi:pi/10:pi;
y = tan(sin(x)) - sin(tan(x));
plot(x,y,'--rs','LineWidth',2,...
                'MarkerEdgeColor','k',...
                'MarkerFaceColor','g',...
                'MarkerSize',10)
```

produce this graph.

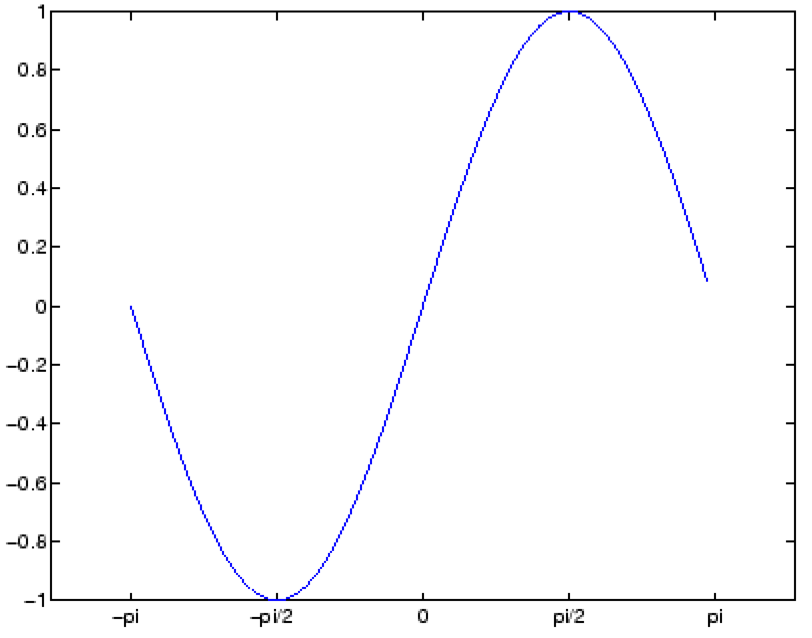


Specifying Tick-Mark Location and Labeling

You can adjust the axis tick-mark locations and the labels appearing at each tick. For example, this plot of the sine function relabels the *x*-axis with more meaningful values:

```
x = -pi:.1:pi;
y = sin(x);
plot(x,y)
set(gca,'XTick',-pi:pi/2:pi)
set(gca,'XTickLabel',{'-pi','-pi/2','0','pi/2','pi'})
```

Now add axis labels and annotate the point -pi/4, sin(-pi/4).



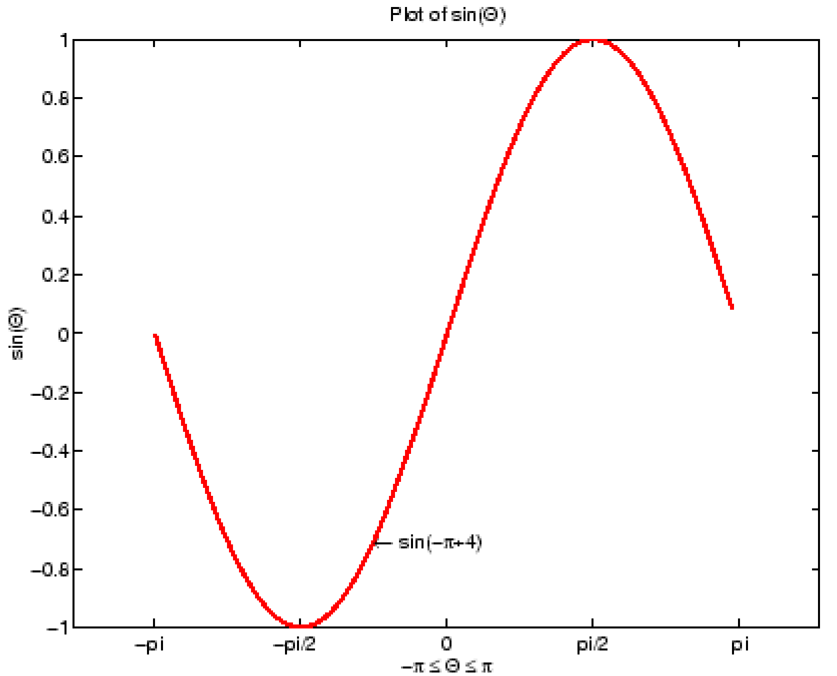
Adding Titles, Axis Labels, and Annotations

MATLAB enables you to add axis labels and titles. For example, using the graph from the previous example, add an *x*- and *y*-axis label:

```
xlabel('-\pi \leq \Theta \leq \pi')
ylabel('sin(\Theta)')
title('Plot of sin(\Theta)')
text(-pi/4,sin(-pi/4),'\leftarrow sin(-\pi\div4)',...
     'HorizontalAlignment','left')
```

Now change the line color to red by first finding the handle of the line object created by `plot` and then setting its `Color` property. In the same statement, set the `LineWidth` property to 2 points.

```
set(findobj(gca,'Type','line','Color',[0 0 1]),...
    'Color','red',...
    'LineWidth',2)
```



See Also

`axis`, `bar`, `grid`, `hold`, `legend`, `line`, `LineSpec`, `loglog`, `plot3`, `plotyy`, `semilogx`, `semilogy`, `subplot`, `title`, `xlabel`, `xlim`, `ylabel`, `ylim`, `zlabel`, `zlim`, `stem`

See the `text String` property for a list of symbols and how to display them.

See the Plot Editor for information on plot annotation tools in the figure window toolbar.

See "Basic Plots and Graphs" on page 1-90 for related functions.

plot (timeseries)

Purpose

Plot time series

Syntax

```
plot(ts)
plot(tsc.tsname)
plot(function)
```

Description

`plot(ts)` plots the time-series data `ts` against time and interpolates values between samples by using either zero-order-hold (`'zoh'`) or linear interpolation.

`plot(tsc.tsname)` plots the `timeseries` object `tsname` that is part of the `tscollection` `tsc`.

`plot(function)` accepts the modifiers used by the MATLAB plotting utility for numerical arrays. These modifiers can be specified as auxiliary inputs for modifying the appearance of the plot. See Examples below.

Remarks

Time-series events, when defined, are marked in the plot by a red circular marker.

When you resize a timeseries plot to be narrower, the *x*-axis ticks and labels are readjusted so that they do not overlap one another. Unlike plots of regular variables, this behavior cannot be overridden (for example, by setting the axes `XTickMode` to `'Auto'`).

Examples

`plot(ts,'-r*')` uses a regular line with the color red and marker `'*'` to render the plot.

`plot(ts,'ko','MarkerSize',3)` uses black circular markers of size `3` to render the plot.

Purpose

3-D line plot

GUI Alternatives

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

Syntax

```
plot3(X1,Y1,Z1,...)
plot3(X1,Y1,Z1,LineSpec,...)
plot3(...,'PropertyName',PropertyValue,...)
h = plot3(...)
```

Description

The `plot3` function displays a three-dimensional plot of a set of data points.

`plot3(X1,Y1,Z1,...)`, where `X1`, `Y1`, `Z1` are vectors or matrices, plots one or more lines in three-dimensional space through the points whose coordinates are the elements of `X1`, `Y1`, and `Z1`.

`plot3(X1,Y1,Z1,LineSpec,...)` creates and displays all lines defined by the `Xn,Yn,Zn,LineSpec` quads, where `LineSpec` is a line specification that determines line style, marker symbol, and color of the plotted lines.

`plot3(...,'`*`PropertyName`*`',PropertyValue,...)` sets properties to the specified property values for all line graphics objects created by `plot3`.

`h = plot3(...)` returns a column vector of handles to lineseries graphics objects, with one handle per object.

Remarks

If one or more of `X1`, `Y1`, `Z1` is a vector, the vectors are plotted versus the rows or columns of the matrix, depending whether the vectors' lengths equal the number of rows or the number of columns.

You can mix `Xn,Yn,Zn` triples with `Xn,Yn,Zn,`*`LineSpec`* quads, for example,

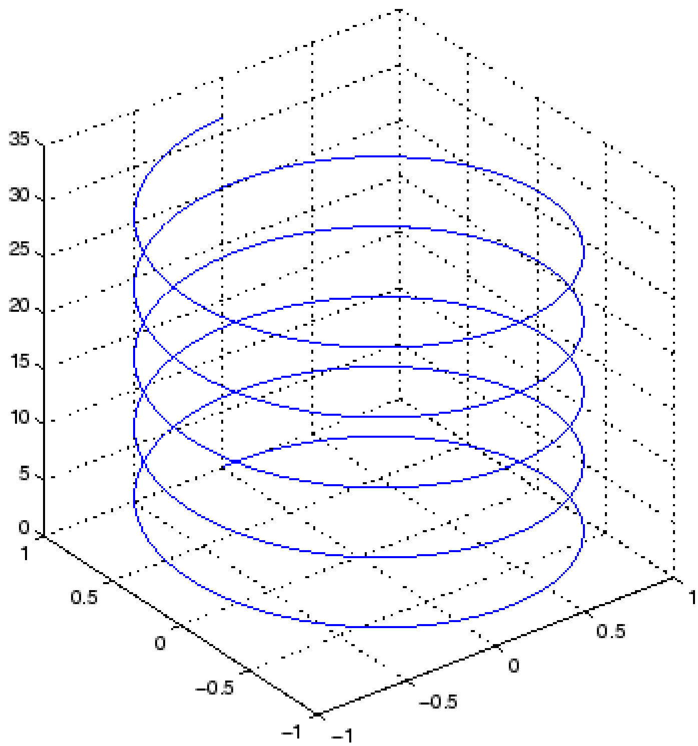
```
plot3(X1,Y1,Z1,X2,Y2,Z2,LineSpec,X3,Y3,Z3)
```

See `LineSpec` and `plot` for information on line types and markers.

Examples

Plot a three-dimensional helix.

```
t = 0:pi/50:10*pi;
plot3(sin(t),cos(t),t)
grid on
axis square
```



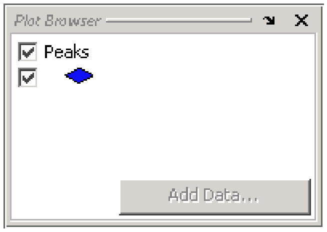
See Also

`axis`, `bar3`, `grid`, `line`, `LineSpec`, `loglog`, `plot`, `semilogx`, `semilogy`, `subplot`

plotbrowser

Purpose

Show or hide figure plot browser



GUI Alternatives

Click the larger **Plotting Tools** icon  on the figure toolbar to collectively enable plotting tools, and the smaller icon  to collectively disable them. Open or close the **Plot Browser** tool from the figure's **View** menu. For details, see "The Plot Browser" in the MATLAB Graphics documentation.

Syntax

```
plotbrowser('on')
plotbrowser('off')
plotbrowser('toggle')
plotbrowser
plotbrowser(figure_handle,...)
```

Description

`plotbrowser('on')` displays the Plot Browser on the current figure.

`plotbrowser('off')` hides the Plot Browser on the current figure.

`plotbrowser('toggle')` or `plotbrowser` toggles the visibility of the Plot Browser on the current figure.

`plotbrowser(figure_handle,...)` shows or hides the Plot Browser on the figure specified by `figure_handle`.

See Also

`plottools`, `figurepalette`, `propertyeditor`

Purpose

Interactively edit and annotate plots

Syntax

```
plotedit on
plotedit off
plotedit
plotedit(h)
plotedit('state')
plotedit(h,'state')
```

Description

`plotedit on` starts plot edit mode for the current figure, allowing you to use a graphical interface to annotate and edit plots easily. In plot edit mode, you can label axes, change line styles, and add text, line, and arrow annotations.

`plotedit off` ends plot mode for the current figure.

`plotedit` toggles the plot edit mode for the current figure.

`plotedit(h)` toggles the plot edit mode for the figure specified by figure handle `h`.

`plotedit('state')` specifies the `plotedit` state for the current figure. Values for `state` can be as shown.

Value for state	Description
`on`	Starts plot edit mode
`off`	Ends plot edit mode
`showtoolsmenu`	Displays the **Tools** menu in the menu bar
`hidetoolsmenu`	Removes the **Tools** menu from the menu bar

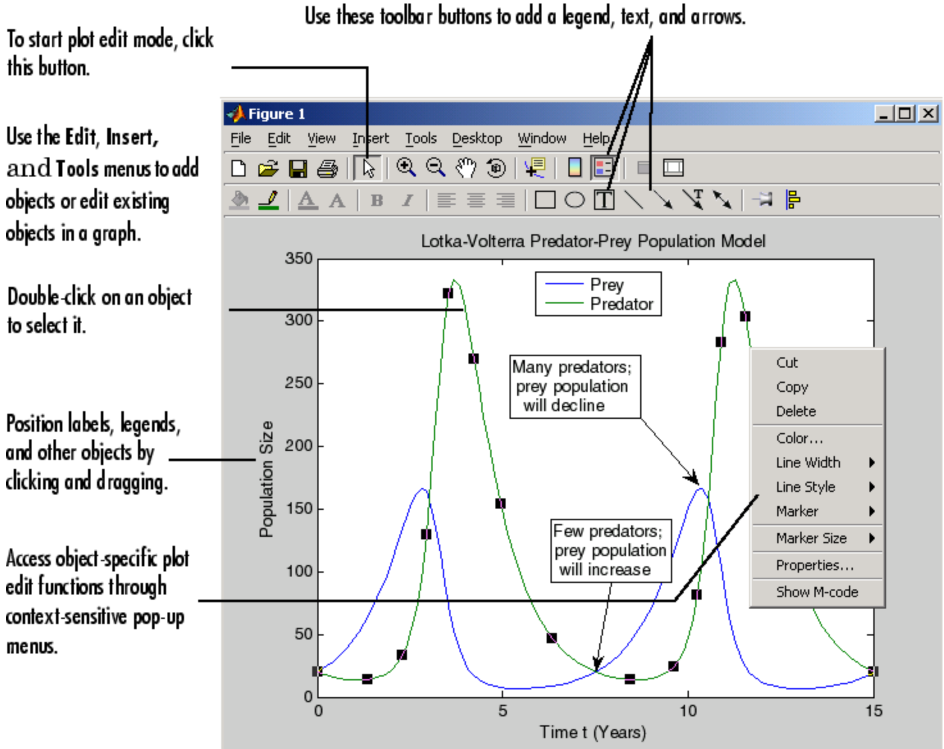
Note `hidetoolsmenu` is intended for GUI developers who do not want the **Tools** menu to appear in applications that use the figure window.

plotedit

`plotedit(h,'state')` specifies the `plotedit` `state` for figure handle `h`.

Remarks

Plot Editing Mode Graphical Interface Components



Examples

Start plot edit mode for figure 2.

```
plotedit(2)
```

End plot edit mode for figure 2.

```
plotedit(2, 'off')
```

Hide the **Tools** menu for the current figure:

```
plotedit('hidetoolsmenu')
```

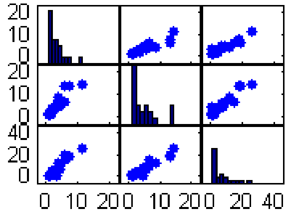
See Also

axes, line, open, plot, print, saveas, text, propedit

plotmatrix

Purpose

Scatter plot matrix



Syntax

```
plotmatrix(X,Y)
plotmatrix(X)
plotmatrix(...,'LineSpec')
[H,AX,BigAx,P] = plotmatrix(...)
```

Description

`plotmatrix(X,Y)` scatter plots the columns of `X` against the columns of `Y`. If `X` is *p*-by-*m* and `Y` is *p*-by-*n*, `plotmatrix` produces an *n*-by-*m* matrix of axes.

`plotmatrix(X)` is the same as `plotmatrix(X,X)`, except that the diagonal is replaced by `hist(X(:,i))`.

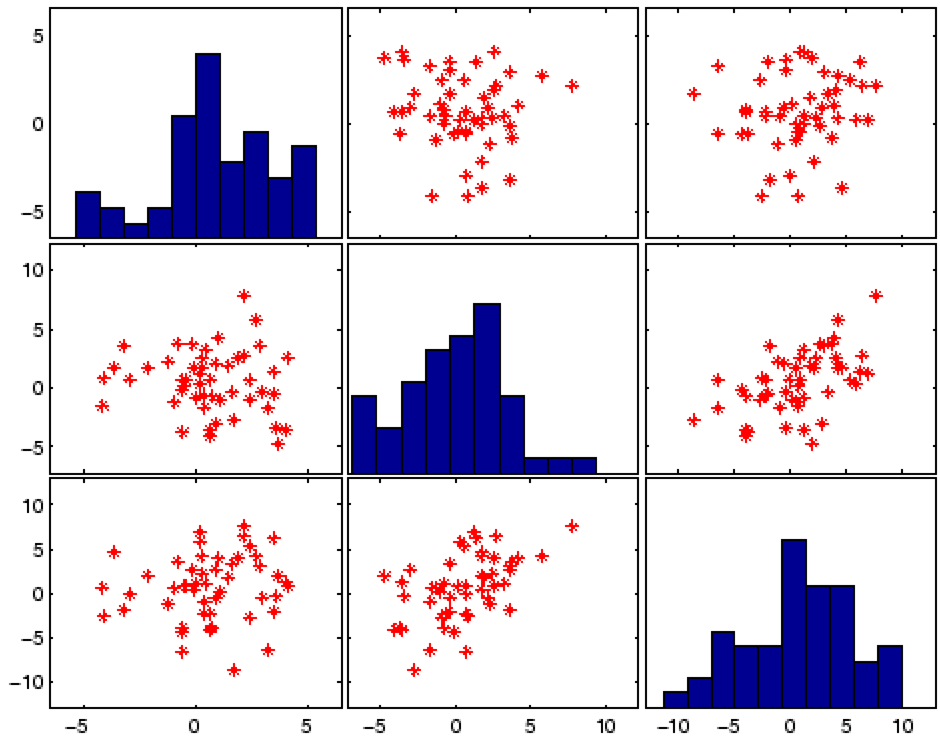
`plotmatrix(...,'LineSpec')` uses a `LineSpec` to create the scatter plot. The default is `'.'`.

`[H,AX,BigAx,P] = plotmatrix(...)` returns a matrix of handles to the objects created in `H`, a matrix of handles to the individual subaxes in `AX`, a handle to a big (invisible) axes that frames the subaxes in `BigAx`, and a matrix of handles for the histogram plots in `P`. `BigAx` is left as the current axes so that a subsequent `title`, `xlabel`, or `ylabel` command is centered with respect to the matrix of axes.

Examples

Generate plots of random data.

```
x = randn(50,3); y = x*[-1 2 1;2 0 1;1 -2 3;]';
plotmatrix(y,'*r')
```



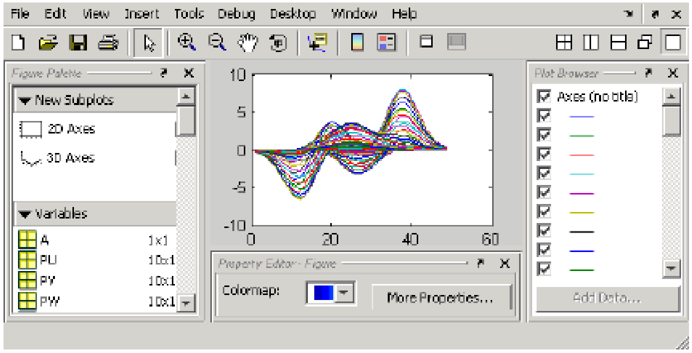
See Also

`scatter`, `scatter3`

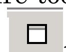
plottools

Purpose

Show or hide plot tools



GUI Alternatives

Click the larger **Plotting Tools** icon  on the figure toolbar to collectively enable plotting tools, and the smaller icon  to collectively disable them. Individually select the **Figure Palette**, **Plot Browser**, and **Property Editor** tools from the figure's **View** menu. For details, see "Plotting Tools — Interactive Plotting" in the MATLAB Graphics documentation.

Syntax

```
plottools('on')
plottools('off')
plottools
plottools(figure_handle,...)
plottools(...,'tool')
```

Description

`plottools('on')` displays the Figure Palette, Plot Browser, and Property Editor on the current figure, configured as you last used them.

`plottools('off')` hides the Figure Palette, Plot Browser, and Property Editor on the current figure.

`plottools` with no arguments, is the same as `plottools('on')`

`plottools(figure_handle,...)` displays or hides the plot tools on the specified figure instead of on the current figure.

`plottools(...,'tool')` operates on the specified tool only. `tool` can be one of the following strings:

- `figurepalette`
- `plotbrowser`
- `propertyeditor`

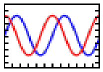
Note The first time you open the plotting tools, all three of them appear, grouped around the current figure as shown above. If you close, move, or undock any of the tools, MATLAB remembers the configuration you left them in and restores it when you invoke the tools for subsequent figures, both within and across MATLAB sessions.

See Also

`figurepalette`, `plotbrowser`, `propertyeditor`

Purpose

2-D line plots with y-axes on both left and right side



GUI Alternatives

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

Syntax

```
plotyy(X1,Y1,X2,Y2)
plotyy(X1,Y1,X2,Y2,function)
plotyy(X1,Y1,X2,Y2,'function1','function2')
[AX,H1,H2] = plotyy(...)
```

Description

`plotyy(X1,Y1,X2,Y2)` plots `X1` versus `Y1` with *y*-axis labeling on the left and plots `X2` versus `Y2` with *y*-axis labeling on the right.

`plotyy(X1,Y1,X2,Y2,function)` uses the specified plotting function to produce the graph.

`function` can be either a function handle or a string specifying `plot`, `semilogx`, `semilogy`, `loglog`, `stem`, or any MATLAB function that accepts the syntax

```
h = function(x,y)
```

For example,

```
plotyy(x1,y1,x2,y2,@loglog) % function handle
plotyy(x1,y1,x2,y2,'loglog') % string
```

Function handles enable you to access user-defined subfunctions and can provide other advantages. See @ for more information on using function handles.

`plotyy(X1,Y1,X2,Y2,'function1','function2')` uses `function1(X1,Y1)` to plot the data for the left axis and `function2(X2,Y2)` to plot the data for the right axis.

`[AX,H1,H2] = plotyy(...)` returns the handles of the two axes created in `AX` and the handles of the graphics objects from each plot in `H1` and `H2`. `AX(1)` is the left axes and `AX(2)` is the right axes.

Examples

This example graphs two mathematical functions using `plot` as the plotting function. The two *y*-axes enable you to display both sets of data on one graph even though relative values of the data are quite different.

```
x = 0:0.01:20;
y1 = 200*exp(-0.05*x).*sin(x);
y2 = 0.8*exp(-0.5*x).*sin(10*x);
[AX,H1,H2] = plotyy(x,y1,x,y2,'plot');
```

You can use the handles returned by `plotyy` to label the axes and set the line styles used for plotting. With the axes handles you can specify the `YLabel` properties of the left- and right-side *y*-axis:

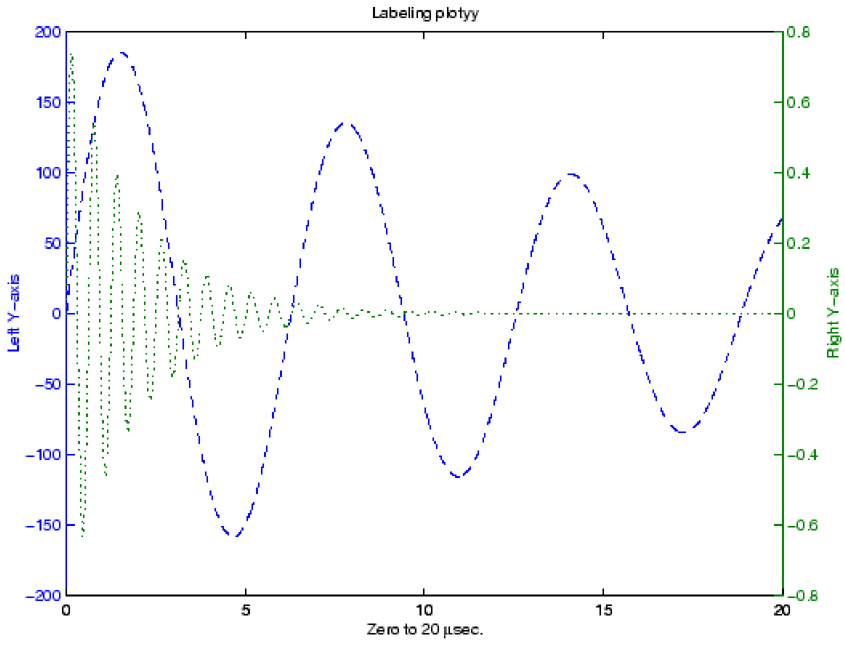
```
set(get(AX(1),'Ylabel'),'String','Slow Decay')
set(get(AX(2),'Ylabel'),'String','Fast Decay')
```

Use the `xlabel` and `title` commands to label the *x*-axis and add a title:

```
xlabel('Time (\musec)')
title('Multiple Decay Rates')
```

Use the line handles to set the `LineStyle` properties of the left- and right-side plots:

```
set(H1,'LineStyle','--')
set(H2,'LineStyle',':')
```



See Also

`plot`, `loglog`, `semilogx`, `semilogy`, axes properties `XAxisLocation`, `YAxisLocation`

See "Using Multiple X- and Y-Axes" for more information.

Purpose

Transform polar or cylindrical coordinates to Cartesian

Syntax

```
[X,Y] = pol2cart(THETA,RHO)
[X,Y,Z] = pol2cart(THETA,RHO,Z)
```

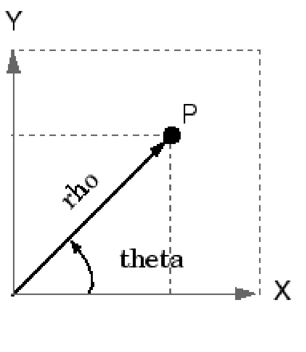
Description

`[X,Y] = pol2cart(THETA,RHO)` transforms the polar coordinate data stored in corresponding elements of `THETA` and `RHO` to two-dimensional Cartesian, or *xy*, coordinates. The arrays `THETA` and `RHO` must be the same size (or either can be scalar). The values in `THETA` must be in radians.

xyz, `[X,Y,Z] = pol2cart(THETA,RHO,Z)` transforms the cylindrical coordinate data stored in corresponding elements of `THETA`, `RHO`, and `Z` to three-dimensional Cartesian, or coordinates. The arrays `THETA`, `RHO`, and `Z` must be the same size (or any can be scalar). The values in `THETA` must be in radians.

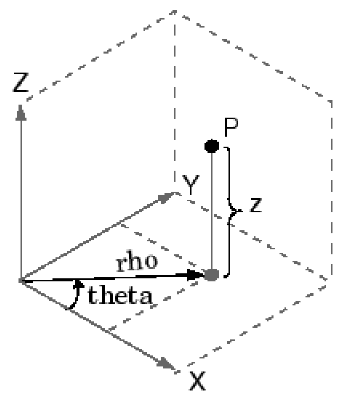
Algorithm

The mapping from polar and cylindrical coordinates to Cartesian coordinates is:



Polar to Cartesian Mapping

```
theta = atan2(y,x)
rho = sqrt(x.^2 + y.^2)
```



Cylindrical to Cartesian Mapping

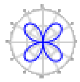
```
theta = atan2(y,x)
rho = sqrt(x.^2 + y.^2)
z = z
```

See Also

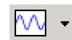
cart2pol, cart2sph, sph2cart

Purpose

Polar coordinate plot



GUI Alternatives

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

Syntax

```
polar(theta,rho)
polar(theta,rho,LineSpec)
polar(axes_handle,...)
h = polar(...)
```

Description

The `polar` function accepts polar coordinates, plots them in a Cartesian plane, and draws the polar grid on the plane.

`polar(theta,rho)` creates a polar coordinate plot of the angle `theta` versus the radius `rho`. `theta` is the angle from the *x*-axis to the radius vector specified in radians; `rho` is the length of the radius vector specified in dataspace units.

`polar(theta,rho,LineSpec)` `LineSpec` specifies the line type, plot symbol, and color for the lines drawn in the polar plot.

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

`h = polar(...)` returns the handle of a line object in `h`.

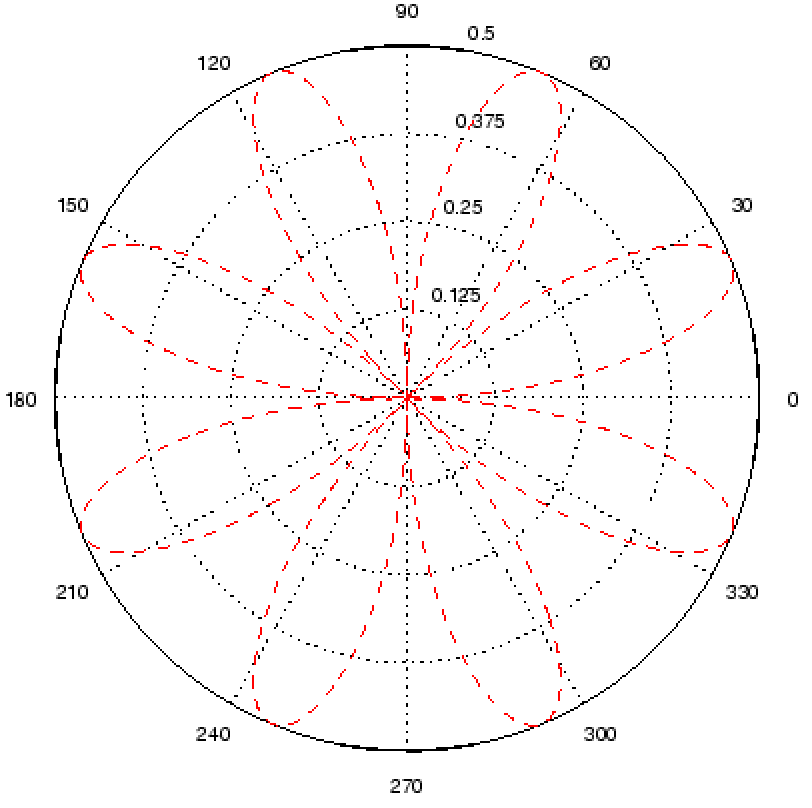
Remarks

Negative `r` values reflect through the origin, rotating by `pi` (since `(theta,r)` transforms to `(r*cos(theta), r*sin(theta))`). If you want different behavior, you can manipulate `r` prior to plotting. For example, you can make `r` equal to `max(0,r)` or `abs(r)`.

Examples

Create a simple polar plot using a dashed red line:

```
t = 0:.01:2*pi;
polar(t,sin(2*t).*cos(2*t),'--r')
```



See Also

`cart2pol`, `compass`, `LineSpec`, `plot`, `pol2cart`, `rose`

Purpose

Polynomial with specified roots

Syntax

```
p = poly(A)
p = poly(r)
```

Description

`p = poly(A)` where `A` is an `n`-by-`n` matrix returns an `n+1` element row vector whose elements are the coefficients of the characteristic polynomial, $\det(sI - A)$. The coefficients are ordered in descending powers: if a vector `c` has `n+1` components, the polynomial it represents is $c_1 s^n + \ldots + c_n s + c_{n+1}$

`p = poly(r)` where `r` is a vector returns a row vector whose elements are the coefficients of the polynomial whose roots are the elements of `r`.

Remarks

Note the relationship of this command to

```
r = roots(p)
```

which returns a column vector whose elements are the roots of the polynomial specified by the coefficients row vector `p`. For vectors, `roots` and `poly` are inverse functions of each other, up to ordering, scaling, and roundoff error.

Examples

MATLAB displays polynomials as row vectors containing the coefficients ordered by descending powers. The characteristic equation of the matrix

```
A =

     1     2     3
     4     5     6
     7     8     0
```

is returned in a row vector by `poly`:

```
p = poly(A)

p =
```

```
     1     -6     -72     -27
```

The roots of this polynomial (eigenvalues of matrix `A`) are returned in a column vector by `roots`:

```
r = roots(p)

r =

    12.1229
    -5.7345
    -0.3884
```

Algorithm

The algorithms employed for `poly` and `roots` illustrate an interesting aspect of the modern approach to eigenvalue computation. `poly(A)` generates the characteristic polynomial of `A`, and `roots(poly(A))` finds the roots of that polynomial, which are the eigenvalues of `A`. But both `poly` and `roots` use `eig`, which is based on similarity transformations. The classical approach, which characterizes eigenvalues as roots of the characteristic polynomial, is actually reversed.

If `A` is an `n`-by-`n` matrix, `poly(A)` produces the coefficients `c(1)` through `c(n+1)`, with `c(1) = 1`, in

$$det(\lambda I - A) = c_1\lambda^n + \ldots + c_n\lambda + c_{n+1}$$

The algorithm is

```
z = eig(A);
c = zeros(n+1,1); c(1) = 1;
for j = 1:n
    c(2:j+1) = c(2:j+1)-z(j)*c(1:j);
end
```

This recursion is easily derived by expanding the product.

$$(\lambda - \lambda_1)(\lambda - \lambda_2)\ldots(\lambda - \lambda_n)$$

It is possible to prove that poly(A) produces the coefficients in the characteristic polynomial of a matrix within roundoff error of A. This is true even if the eigenvalues of A are badly conditioned. The traditional algorithms for obtaining the characteristic polynomial, which do not use the eigenvalues, do not have such satisfactory numerical properties.

See Also

conv, polyval, residue, roots

polyarea

Purpose

Area of polygon

Syntax

```
A = polyarea(X,Y)
A = polyarea(X,Y,dim)
```

Description

`A = polyarea(X,Y)` returns the area of the polygon specified by the vertices in the vectors `X` and `Y`.

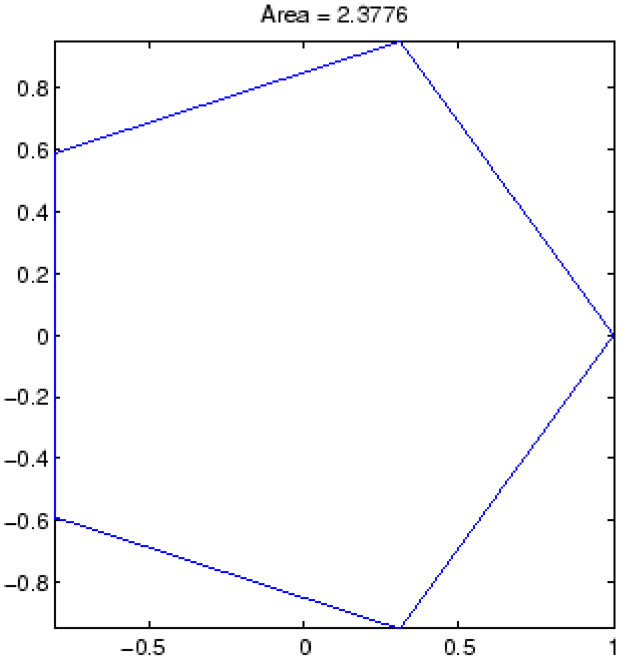
If `X` and `Y` are matrices of the same size, then `polyarea` returns the area of polygons defined by the columns `X` and `Y`.

If `X` and `Y` are multidimensional arrays, `polyarea` returns the area of the polygons in the first nonsingleton dimension of `X` and `Y`.

`A = polyarea(X,Y,dim)` operates along the dimension specified by scalar `dim`.

Examples

```
L = linspace(0,2.*pi,6); xv = cos(L)';yv = sin(L)';
xv = [xv ; xv(1)]; yv = [yv ; yv(1)];
A = polyarea(xv,yv);
plot(xv,yv); title(['Area = ' num2str(A)]); axis image
```



See Also

`convhull`, `inpolygon`, `rectint`

polyder

Purpose

Polynomial derivative

Syntax

```
k = polyder(p)
k = polyder(a,b)
[q,d] = polyder(b,a)
```

Description

The `polyder` function calculates the derivative of polynomials, polynomial products, and polynomial quotients. The operands `a`, `b`, and `p` are vectors whose elements are the coefficients of a polynomial in descending powers.

`k = polyder(p)` returns the derivative of the polynomial `p`.

`k = polyder(a,b)` returns the derivative of the product of the polynomials `a` and `b`.

`[q,d] = polyder(b,a)` returns the numerator `q` and denominator `d` of the derivative of the polynomial quotient `b/a`.

Examples

The derivative of the product

$$(3x^2 + 6x + 9)(x^2 + 2x)$$

is obtained with

```
a = [3 6 9];
b = [1 2 0];
k = polyder(a,b)
k =
    12    36    42    18
```

This result represents the polynomial

$$12x^3 + 36x^2 + 42x + 18$$

See Also

`conv`, `deconv`

Purpose Polynomial eigenvalue problem

Syntax

```
[X,e] = polyeig(A0,A1,...Ap)
e = polyeig(A0,A1,..,Ap)
[X, e, s] = polyeig(A0,A1,..,AP)
```

Description

`[X,e] = polyeig(A0,A1,...Ap)` solves the polynomial eigenvalue problem of degree `p`

$$(A_0 + \lambda A_1 + \ldots + \lambda^P A_p)x = 0$$

where polynomial degree `p` is a non-negative integer, and `A0,A1,...Ap` are input matrices of order `n`. The output consists of a matrix `X` of size `n`-by-`n*p` whose columns are the eigenvectors, and a vector `e` of length `n*p` containing the eigenvalues.

If `lambda` is the `j`th eigenvalue in `e`, and `x` is the `j`th column of eigenvectors in `X`, then `(A0 + lambda*A1 + ... + lambda^p*Ap)*x` is approximately `0`.

`e = polyeig(A0,A1,..,Ap)` is a vector of length `n*p` whose elements are the eigenvalues of the polynomial eigenvalue problem.

`[X, e, s] = polyeig(A0,A1,..,AP)` also returns a vector `s` of length `p*n` containing condition numbers for the eigenvalues. At least one of `A0` and `AP` must be nonsingular. Large condition numbers imply that the problem is close to a problem with multiple eigenvalues.

Remarks

Based on the values of `p` and `n`, `polyeig` handles several special cases:

- `p = 0`, or `polyeig(A)` is the standard eigenvalue problem: `eig(A)`.
- `p = 1`, or `polyeig(A,B)` is the generalized eigenvalue problem: `eig(A,-B)`.
- `n = 1`, or `polyeig(a0,a1,...ap)` for scalars `a0`, `a1` ..., `ap` is the standard polynomial problem: `roots([ap ... a1 a0])`.

If both `A0` and `Ap` are singular the problem is potentially ill-posed. Theoretically, the solutions might not exist or might not be unique. Computationally, the computed solutions might be inaccurate. If one, but not both, of `A0` and `Ap` is singular, the problem is well posed, but some of the eigenvalues might be zero or infinite.

Note that scaling `A0,A1,..,Ap` to have `norm(Ai)` roughly equal 1 may increase the accuracy of `polyeig`. In general, however, this cannot be achieved. (See Tisseur [3] for more detail.)

Algorithm

The `polyeig` function uses the QZ factorization to find intermediate results in the computation of generalized eigenvalues. It uses these intermediate results to determine if the eigenvalues are well-determined. See the descriptions of `eig` and `qz` for more on this.

See Also

`condeig`, `eig`, `qz`

References

[1] Dedieu, Jean-Pierre Dedieu and Francoise Tisseur, "Perturbation theory for homogeneous polynomial eigenvalue problems," *Linear Algebra Appl.*, Vol. 358, pp. 71-94, 2003.

[2] Tisseur, Francoise and Karl Meerbergen, "The quadratic eigenvalue problem," *SIAM Rev.*, Vol. 43, Number 2, pp. 235-286, 2001.

[3] Francoise Tisseur, "Backward error and condition of polynomial eigenvalue problems" *Linear Algebra Appl.*, Vol. 309, pp. 339-361, 2000.

Purpose Polynomial curve fitting

Syntax

```
p = polyfit(x,y,n)
[p,S] = polyfit(x,y,n)
[p,S,mu] = polyfit(x,y,n)
```

Description

`p = polyfit(x,y,n)` finds the coefficients of a polynomial `p(x)` of degree `n` that fits the data, `p(x(i))` to `y(i)`, in a least squares sense. The result `p` is a row vector of length `n+1` containing the polynomial coefficients in descending powers

$$p(x) = p_1x^n + p_2x^{n-1} + \ldots + p_nx + p_{n+1}$$

`[p,S] = polyfit(x,y,n)` returns the polynomial coefficients `p` and a structure `S` for use with `polyval` to obtain error estimates or predictions. Structure `S` contains fields `R`, `df`, and `normr`, for the triangular factor from a QR decomposition of the Vandermonde matrix of `X`, the degrees of freedom, and the norm of the residuals, respectively. If the data `Y` are random, an estimate of the covariance matrix of `P` is `(Rinv*Rinv')*normr^2/df`, where `Rinv` is the inverse of `R`. If the errors in the data `y` are independent normal with constant variance, `polyval` produces error bounds that contain at least 50% of the predictions.

`[p,S,mu] = polyfit(x,y,n)` finds the coefficients of a polynomial in

$$\hat{x} = \frac{x - \mu_1}{\mu_2}$$

where $\mu_1 = \mathrm{mean}(x)$ and $\mu_2 = \mathrm{std}(x)$. `mu` is the two-element vector $[\mu_1, \mu_2]$. This centering and scaling transformation improves the numerical properties of both the polynomial and the fitting algorithm.

Examples

This example involves fitting the error function, `erf(x)`, by a polynomial in `x`. This is a risky project because `erf(x)` is a bounded function, while polynomials are unbounded, so the fit might not be very good.

First generate a vector of x points, equally spaced in the interval $[0, 2.5]$; then evaluate erf(x) at those points.

```
x = (0: 0.1: 2.5)';
y = erf(x);
```

The coefficients in the approximating polynomial of degree 6 are

```
p = polyfit(x,y,6)

p =

 0.0084  -0.0983   0.4217   -0.7435  0.1471   1.1064  0.0004
```

There are seven coefficients and the polynomial is

$$0.0084x^6 - 0.0983x^5 + 0.4217x^4 - 0.7435x^3 + 0.1471x^2 + 1.1064x + 0.0004$$

To see how good the fit is, evaluate the polynomial at the data points with

```
f = polyval(p,x);
```

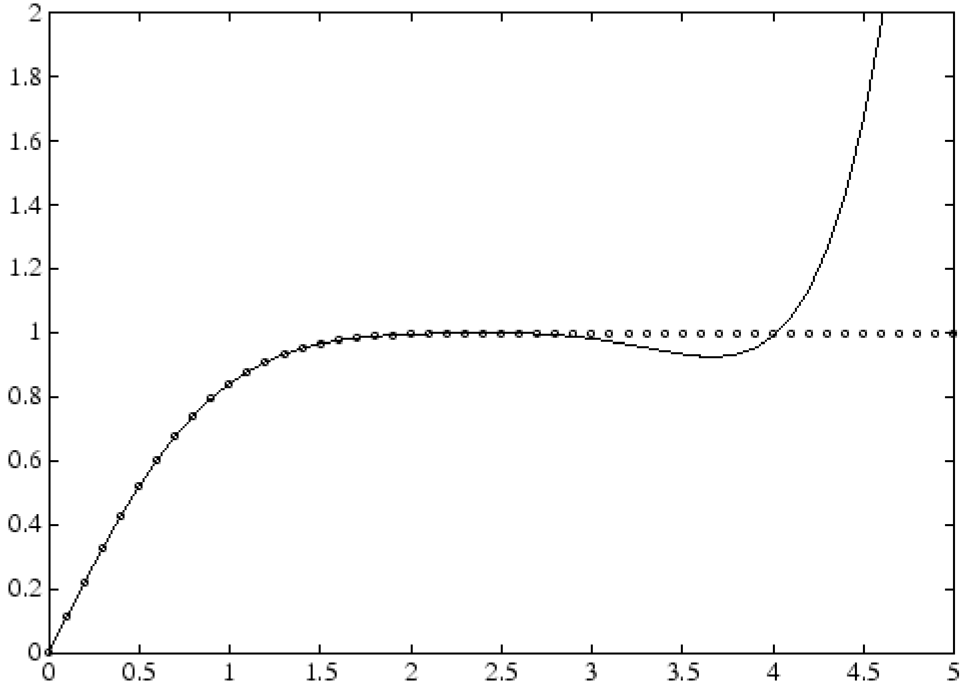
A table showing the data, fit, and error is

```
table = [x y f y-f]

table =

   0         0         0.0004    -0.0004
   0.1000    0.1125    0.1119     0.0006
   0.2000    0.2227    0.2223     0.0004
   0.3000    0.3286    0.3287    -0.0001
   0.4000    0.4284    0.4288    -0.0004
   ...
   2.1000    0.9970    0.9969     0.0001
   2.2000    0.9981    0.9982    -0.0001
   2.3000    0.9989    0.9991    -0.0003
   2.4000    0.9993    0.9995    -0.0002
```

```
    2.5000      0.9996      0.9994      0.0002
```

So, on this interval, the fit is good to between three and four digits. Beyond this interval the graph shows that the polynomial behavior takes over and the approximation quickly deteriorates.

```
x = (0: 0.1: 5)';
y = erf(x);
f = polyval(p,x);
plot(x,y,'o',x,f,'-')
axis([0  5  0  2])
```



Algorithm

The `polyfit` M-file forms the Vandermonde matrix, V, whose elements are powers of x.

$$v_{i,j} = x_i^{n-j}$$

It then uses the backslash operator, `\`, to solve the least squares problem

$$Vp \cong y$$

You can modify the M-file to use other functions of x as the basis functions.

See Also

`poly`, `polyval`, `roots`, `lscov`

Purpose

Integrate polynomial analytically

Syntax

```
polyint(p,k)
polyint(p)
```

Description

`polyint(p,k)` returns a polynomial representing the integral of polynomial `p`, using a scalar constant of integration `k`.

`polyint(p)` assumes a constant of integration `k=0`.

See Also

`polyder`, `polyval`, `polyvalm`, `polyfit`

polyval

Purpose

Polynomial evaluation

Syntax

```
y = polyval(p,x)
y = polyval(p,x,[],mu)
[y,delta] = polyval(p,x,S)
[y,delta] = polyval(p,x,S,mu)
```

Description

`y = polyval(p,x)` returns the value of a polynomial of degree `n` evaluated at `x`. The input argument `p` is a vector of length `n+1` whose elements are the coefficients in descending powers of the polynomial to be evaluated.

$$y = p_1 x^n + p_2 x^{n-1} + \ldots + p_n x + p_{n+1}$$

`x` can be a matrix or a vector. In either case, `polyval` evaluates `p` at each element of `x`.

`y = polyval(p,x,[],mu)` uses $\hat{x} = (x-\mu_1)/\mu_2$ in place of x. In this equation, $\mu_1 = \mathrm{mean}(x)$ and $\mu_2 = \mathrm{std}(x)$. The centering and scaling parameters `mu =` $[\mu_1, \mu_2]$ are optional output computed by `polyfit`.

`[y,delta] = polyval(p,x,S)` and `[y,delta] = polyval(p,x,S,mu)` use the optional output structure `S` generated by `polyfit` to generate error estimates, `y±delta`. If the errors in the data input to `polyfit` are independent normal with constant variance, `y±delta` contains at least 50% of the predictions.

Remarks

The `polyvalm(p,x)` function, with `x` a matrix, evaluates the polynomial in a matrix sense. See `polyvalm` for more information.

Examples

The polynomial $p(x) = 3x^2 + 2x + 1$ is evaluated at x = 5, 7, and 9 with

```
p = [3 2 1];
polyval(p,[5 7 9])
```

which results in

```
ans =

    86   162   262
```

For another example, see `polyfit`.

See Also

`polyfit`, `polyvalm`

polyvalm

Purpose Matrix polynomial evaluation

Syntax

```
Y = polyvalm(p,X)
```

Description

`Y = polyvalm(p,X)` evaluates a polynomial in a matrix sense. This is the same as substituting matrix `X` in the polynomial `p`.

Polynomial `p` is a vector whose elements are the coefficients of a polynomial in descending powers, and `X` must be a square matrix.

Examples

The Pascal matrices are formed from Pascal's triangle of binomial coefficients. Here is the Pascal matrix of order 4.

```
X = pascal(4)
X =
     1     1     1     1
     1     2     3     4
     1     3     6    10
     1     4    10    20
```

Its characteristic polynomial can be generated with the `poly` function.

```
p = poly(X)
p =
     1     -29     72     -29     1
```

This represents the polynomial $x^4 - 29x^3 + 72x^2 - 29x + 1$.

Pascal matrices have the curious property that the vector of coefficients of the characteristic polynomial is palindromic; it is the same forward and backward.

Evaluating this polynomial at each element is not very interesting.

```
polyval(p,X)
ans =
     16        16         16         16
     16        15       -140       -563
     16      -140      -2549     -12089
```

```
     16     -563   -12089   -43779
```

But evaluating it in a matrix sense is interesting.

```
polyvalm(p,X)
ans =
     0     0     0     0
     0     0     0     0
     0     0     0     0
     0     0     0     0
```

The result is the zero matrix. This is an instance of the Cayley-Hamilton theorem: a matrix satisfies its own characteristic equation.

See Also

`polyfit`, `polyval`

Purpose

Base 2 power and scale floating-point numbers

Syntax

```
X = pow2(Y)
X = pow2(F,E)
```

Description

`X = pow2(Y)` returns an array `X` whose elements are 2 raised to the power `Y`.

`X = pow2(F,E)` computes $x = f * 2^e$ for corresponding elements of `F` and `E`. The result is computed quickly by simply adding `E` to the floating-point exponent of `F`. Arguments `F` and `E` are real and integer arrays, respectively.

Remarks

This function corresponds to the ANSI C function `ldexp()` and the IEEE floating-point standard function `scalbn()`.

Examples

For IEEE arithmetic, the statement `X = pow2(F,E)` yields the values:

```
F          E        X
1/2        1        1
pi/4       2        pi
-3/4       2        -3
1/2        -51      eps
1-eps/2    1024     realmax
1/2        -1021    realmin
```

See Also

`log2`, `exp`, `hex2num`, `realmax`, `realmin`

The arithmetic operators `^` and `.^`

Purpose

Array power

Syntax

```
Z = X.^Y
```

Description

`Z = X.^Y` denotes element-by-element powers. `X` and `Y` must have the same dimensions unless one is a scalar. A scalar is expanded to an array of the same size as the other input.

`C = power(A,B)` is called for the syntax `'A .^ B'` when `A` or `B` is an object.

Note that for a negative value `X` and a non-integer value `Y`, if the `abs(Y)` is less than one, the `power` function returns the complex roots. To obtain the remaining real roots, use the `nthroot` function.

See Also

`nthroot`, `realpow`

Purpose

Evaluate piecewise polynomial

Syntax

`v = ppval(pp,xx)`

Description

`v = ppval(pp,xx)` returns the value of the piecewise polynomial *f*, contained in `pp`, at the entries of `xx`. You can construct `pp` using the functions `interp1`, `pchip`, `spline`, or the spline utility `mkpp`.

`v` is obtained by replacing each entry of `xx` by the value of *f* there. If *f* is scalar-valued, `v` is of the same size as `xx`. `xx` may be N-dimensional.

If `pp` was constructed by `pchip`, `spline`, or `mkpp` using the orientation of non-scalar function values specified for those functions, then:

If `f` is `[D1,..,Dr]`-valued, and `xx` is a vector of length `N`, then `V` has size `[D1,...,Dr, N]`, with `V(:,...,:,J)` the value of `f` at `xx(J)`.

If `f` is `[D1,..,Dr]`-valued, and `xx` has size `[N1,...,Ns]`, then `V` has size `[D1,...,Dr, N1,...,Ns]`, with `V(:,...,:, J1,...,Js)` the value of `f` at `xx(J1,...,Js)`.

If `pp` was constructed by `interp1` using the orienatation of non-scalar function values specified for that function, then:

If `f` is `[D1,..,Dr]`-valued, and `xx` is a vector of length `N`, then `V` has size `[N,D1,...,Dr]`, with `V(J,:,...,:)` the value of `f` at `xx(J)`.

If `f` is `[D1,..,Dr]`-valued, and `xx` has size `[N1,...,Ns]`, then `V` has size `[N1,...,Ns,D1,...,Dr]`, with `V(J1,...,Js,:,...,:)` the value of `f` at `xx(J1,...,Js)`.

Examples

Compare the results of integrating the function `cos`

```
a = 0; b = 10;
int1 = quad(@cos,a,b)

int1 =
   -0.5440
```

with the results of integrating the piecewise polynomial pp that approximates the cosine function by interpolating the computed values x and y.

```
x = a:b;
y = cos(x);
pp = spline(x,y);
int2 = quad(@(x)ppval(pp,x),a,b)

int2 =
   -0.5485
```

int1 provides the integral of the cosine function over the interval [a,b], while int2 provides the integral over the same interval of the piecewise polynomial pp.

See Also

mkpp, spline, unmkpp

Purpose Directory containing preferences, history, and layout files

Syntax

```
prefdir
d = prefdir
d = prefdir(1)
```

Description `prefdir` returns the directory that contains

- Preferences for MATLAB and related products (`matlab.prf`)
- Command history file (`history.m`)
- MATLAB shortcuts (`shortcuts.xml`)
- MATLAB desktop layout files (`MATLABDesktop.xml` and `Your_Saved_LayoutMATLABLayout.xml`)
- Other related files

`d = prefdir` assigns to `d` the name of the directory containing preferences and related files.

`d = prefdir(1)` creates a directory for preferences and related files if one does not exist. If the directory does exist, the name is assigned to `d`.

Remarks You must have write access to the preferences directory, or MATLAB generates an error in the Command Window when you try to change preferences.

The directory might be in a hidden folder, for example, `myname/.matlab/R2008b`. How to access hidden folders depends on your platform:

- On Microsoft Windows platforms, in any folder window, select **Tools > Folder Options**. Click the **View** tab, and under **Advanced** settings, select **Show hidden files and folders**. Then you should be able to see the folder returned by `prefdir`.

- On Apple Macintosh platforms, in the Finder, select **Go -> Go to Folder**. In the resulting dialog box, type the path returned by `prefdir` and press **Enter**.

The preferences directory MATLAB uses depends on the release. The preference directory naming and preference migration practice used from R13 through R14SP2 was changed starting in R14SP3 to address backwards compatibility problems. The differences are relevant primarily if you run multiple versions of MATLAB, and especially if one version is prior to R14SP3:

- For R2008b back through and including R2006a, and R14SP3, MATLAB uses the name of the release for the preference directory. For example, it uses `R2008b`, `R2007b`, ... through `R14SP3`. When you install R2008b, MATLAB migrates the files in the `R2008a` preferences directory to the `R2008b` preferences directory. While running R2008b through R14SP3, any changes made to files in those preferences directories (`R2008b` through `R14SP3`) are used only in their respective versions. As an example, commands you run in R2008b will *not* appear in the Command History when you run R2007b, and so on. The converse is also true.

  Upon startup, MATLAB 7.7 (R2008b) looks for, and if found uses, the `R2008b` preferences directory. If not found, MATLAB creates an `R2008b` preferences directory. This happens when the R2008b preferences directory is deleted or does not exist for some other reason. MATLAB then looks for the `R2008a` preferences directory, and if found, migrates the R2008a preferences to the R2008b preferences. If it does not find the `R2008a` preferences directory, it uses the default preferences for R2008b. This process also applies when starting MATLAB 7.6 through 7.1.

  If you want to use default preferences for R2008b, and do not want MATLAB to migrate preferences from R2008a, the `R2008b` preferences directory *must exist but be empty* when you start MATLAB. If you want to maintain some of your R2008b preferences, but restore the defaults for others, in the `R2008b` preferences directory, delete the files for which you want the defaults to be restored. One file you might want to maintain is `history.m`—for more information about the file, see "Viewing Statements in the Command History Window" in the MATLAB Desktop Tools and Development Environment documentation.

- The R14 through R14SP2 releases all share the `R14` preferences directory. While running R14SP1, for example, any changes made to files in the preferences directory, `R14`, are used when you run R14SP2 and R14. As another example, commands you run in R14 appear in the Command History when you run R14SP2, and the converse is also true. The preferences are not used when you run R14SP3 or later versions because those versions each use their own preferences directories.
- All R13 releases use the `R13` preferences directory. While running R13SP1, for example, any changes made to files in the preferences directory, `R13`, are used when you run R13. As an example, commands you run in R13 will appear in the Command History when you run R13SP1, and the converse is true. The preferences are not used when you run any R14 or later releases because R14 and later releases use different preferences directories, and the converse is true.

Examples

Run

```
prefdir
```

MATLAB returns

```
ans =

C:\WINNT\Profiles\my_user_name\MATHWORKS\Application Data\MathWorks\MATLAB\R2008b
```

Running `dir` for the directory shows these files and others for MathWorks products:

```
.                   history.m
..                  matlab.prf
cwdhistory.m        MATLABDesktop.xml
shortcuts.xml       MATLAB EditorDesktop.xml
```

In MATLAB, run `cd(prefdir)` to change to that directory.

On Windows platforms, go directly to the preferences directory in Microsoft Windows Explorer by running `winopen(prefdir)`.

See Also

`preferences`, `winopen`

"Preferences" in the MATLAB Desktop Tools and Development Environment documentation

preferences

Purpose Open Preferences dialog box

GUI Alternatives As an alternative to the `preferences` function, select **File > Preferences** in the MATLAB desktop or any desktop tool.

Syntax

```
preferences
```

Description `preferences` displays the Preferences dialog box, from which you can make changes to options for MATLAB and related products.

See Also `prefdir`

"Preferences" in the MATLAB Desktop Tools and Development Environment documentation

Purpose

Generate list of prime numbers

Syntax

```
p = primes(n)
```

Description

`p = primes(n)` returns a row vector of the prime numbers less than or equal to `n`. A prime number is one that has no factors other than `1` and itself.

Examples

```
p = primes(37)

p = 2   3   5   7   11   13   17   19   23   29   31   37
```

See Also

`factor`

Purpose

Print figure or save to file and configure printer defaults

Contents

GUI Alternative

Select **File > Print** from the figure window to open the Print dialog box and **File > Print Preview** to open the Print Preview GUI. For details, see "How to Print or Export" in the MATLAB Graphics documentation.

Syntax

```
print
print file name
print -ddriver
print -dformat
print -dformat file name
print -smodelname
print -options
print(...)
[pcmd,dev] = printopt
```

Description

`print` and `printopt` produce hard-copy output. All arguments to the `print` command are optional. You can use them in any combination or order.

`print` sends the contents of the current figure, including bitmap representations of any user interface controls, to the printer using the device and system printing command defined by `printopt`.

`print file name` directs the output to the PostScript file designated by `file name`. If `file name` does not include an extension, `print` appends an appropriate extension.

`print -ddriver` prints the figure using the specified printer *driver*, (such as color PostScript). If you omit `-ddriver`, `print` uses the default value stored in `printopt.m`. The table in "Printer Drivers" on page 2-2758 lists all supported device types.

`print -dformat` copies the figure to the system Clipboard (Microsoft Windows platforms only). To be valid, the *format* for this operation must be either `-dmeta` (Windows Enhanced Metafile) or `-dbitmap` (Windows Bitmap).

`print -dformat file name` exports the figure to the specified file using the specified graphics *format* (such as TIFF). The table of "Graphics Format Files" on page 2-2762 lists all supported graphics file formats.

`print -smodelname` prints the current Simulink model *modelname*.

`print -options` specifies print options that modify the action of the `print` command. (For example, the `-noui` option suppresses printing of user interface controls.) "Printing Options" on page 2-2766 lists available options.

`print(...)` is the function form of `print`. It enables you to pass variables for any input arguments. This form is useful for passing file names and handles. See Batch Processing for an example.

`[pcmd,dev] = printopt` returns strings containing the current system-dependent printing command and output device. `printopt` is an M-file used by `print` to produce the hard-copy output. You can edit the M-file `printopt.m` to set your default printer type and destination.

`pcmd` and `dev` are platform-dependent strings. `pcmd` contains the command that `print` uses to send a file to the printer. `dev` contains the printer driver or graphics format option for the `print` command. Their defaults are platform dependent.

Platform	Print Command	Driver or Format
Mac and UNIX	`lpr -r`	`-dps2`
Windows	COPY /B %s LPT1:	`-dwin`

Printer Drivers

The following table shows the more widely used printer drivers supported by MATLAB software. If you do not specify a driver, the default setting shown in the previous table is used. For a list of all supported printer drivers, type `print -d` at the MATLAB prompt. Some things to remember:

- As indicated in "Description" on page 2-2756 the `-d` switch specifies a printer driver or a graphics file format:
  - Specifying a printer driver without a file name or printer name (the `-P` option) sends the output formatted by the specified driver to your default printer, which may not be what you want to do.

    Note On Windows systems, when you use the `-P` option to identify a printer to use, if you specify any driver other than `-dwin` or `-dwinc`, MATLAB writes the output to a file with an appropriate extension but does not send it to the printer. You can then copy that file to a printer.

  - Specifying a `-dmeta` or a `-dbitmap` graphics format without a file name places the graphic on the system Clipboard, if possible (Windows platforms only).
  - Specifying any other graphics format without a file name creates a file in the current directory with a name such as `figureN.`*`fmt`*,

where `N` is 1, 2, 3, ... and *`fmt`* indicates the format type, for example, `eps` or `png`.

- Several drivers come from a product called Ghostscript, which is shipped with MATLAB software. The last column indicates when Ghostscript is used.
- Not all drivers are supported on all platforms. Non support is noted in the first column of the table.
- If you specify a particular printer with the `-P` option and do not specify a driver, a default driver for that printer is selected, either by the operating system or by MATLAB , depending on the platform:
  - On MATLAB, the driver associated with this particular printing device is used.
  - On Macintosh and UNIX platforms, the driver specified in `printop.m` is used

See Selecting the Printer in the Graphics documentation for more information.

Note The MathWorks™ is planning to leverage existing operating system (OS) support for printer drivers and devices. As a result, the ability to specify certain print devices using the `print -d` command, and certain graphics formats using the `print -d` command and/or the `saveas` command, will be removed in a future release. In the following table, the affected formats have an asterisk (*) next to the `print` command option string. The asterisks provide a link to the Web site which supplies a form for users to give feedback about these changes.

Printer Driver	Print Command Option String	Ghostscript
Canon BubbleJet BJ10e	`-dbj10e` *	Yes

Printer Driver	Print Command Option String	Ghostscript
Canon BubbleJet BJ200 color	-dbj200 *	Yes
Canon Color BubbleJet BJC-70/BJC-600/BJC-4000	-dbjc600 *	Yes
Canon Color BubbleJet BJC-800	-dbjc800 *	Yes
Epson and compatible 9- or 24-pin dot matrix print drivers	-depson *	Yes
Epson and compatible 9-pin with interleaved lines (triple resolution)	-deps9high *	Yes
Epson LQ-2550 and compatible; color (not supported on HP-700)	-depsonc *	Yes
Fujitsu 3400/2400/1200	-depsonc *	Yes
HP DesignJet 650C color (not supported on Windows)	-ddnj650c *	Yes
HP DeskJet 500	-ddjet500 *	Yes
HP DeskJet 500C (creates black and white output)	-dcdjmono *	Yes
HP DeskJet 500C (with 24 bit/pixel color and high-quality Floyd-Steinberg color dithering) (not supported on Windows)	-dcdjcolor *	Yes

Printer Driver	Print Command Option String	Ghostscript
HP DeskJet 500C/540C color (not supported on Windows)	`-dcdj500` *	Yes
HP Deskjet 550C color (not supported on Windows)	`-dcdj550` *	Yes
HP DeskJet and **DeskJet Plus**	`-ddeskjet` *	Yes
HP LaserJet	`-dlaserjet` *	Yes
HP LaserJet+	`-dljetplus` *	Yes
HP LaserJet IIP	`-dljet2p` *	Yes
HP LaserJet III	`-dljet3` *	Yes
HP LaserJet 4.5L and 5P	`-dljet4` *	Yes
HP LaserJet 5 and 6	`-dpxlmono` *	Yes
HP PaintJet color	`-dpaintjet` *	Yes
HP PaintJet XL color	`-dpjxl` *	Yes
HP PaintJet XL color	`-dpjetxl` *	Yes
HP PaintJet XL300 color (not supported on Windows)	`-dpjxl300` *	Yes
HPGL for HP 7475A and other compatible plotters. (Renderer cannot be set to Z-buffer.)	`-dhpgl` *	No
IBM® 9-pin Proprinter	`-dibmpro` *	Yes

Printer Driver	Print Command Option String	Ghostscript
PostScript black and white	`-dps`	No
PostScript color	`-dpsc`	No
PostScript Level 2 black and white	`-dps2`	No
PostScript Level 2 color	`-dpsc2`	No
Windows color (Windows only)	`-dwinc`	No
Windows monochrome (Windows only)	`-dwin`	No

Tip Generally, Level 2 PostScript files are smaller and are rendered more quickly when printing than Level 1 PostScript files. However, not all PostScript printers support Level 2, so determine the capabilities of your printer before using those drivers. Level 2 PostScript printing is the default for UNIX platforms. You can change this default by editing the `printopt.m` file. Likewise, if you want color PostScript printing to be the default instead of black-and-white PostScript printing, edit the line in the `printopt.m` file that reads `dev = '-dps2';` to be `dev = '-dpsc2';`.

Graphics Format Files

To save your figure as a graphics format file, specify a format switch and file name. To set the resolution of the output file for a built-in MATLAB format, use the `-r` switch. (For example, `-r300` sets the output resolution to 300 dots per inch.) The `-r` switch is also supported for Windows Enhanced Metafiles, JPEG, TIFF and PNG files, but is not supported for Ghostscript raster formats. For more information, see “Printing and Exporting without a Display” on page 2-2765 and “Resolution Considerations” on page 2-2768.

The following table shows the supported output formats for exporting from MATLAB figures and the switch settings to use. In some cases, a format is available both as a MATLAB output filter and as a Ghostscript output filter. All formats except for EMF are supported on both PC and UNIX platforms.

Graphics Format	Bitmap or Vector	Print Command Option String	MATLAB or Ghostscript
BMP monochrome BMP	Bitmap	`-dbmpmono`	Ghostscript
BMP 24-bit BMP	Bitmap	`-dbmp16m`	Ghostscript
BMP 8-bit (256-color) BMP (this format uses a fixed colormap)	Bitmap	`-dbmp256`	Ghostscript
BMP 24-bit	Bitmap	`-dbmp`	MATLAB
EMF	Vector	`-dmeta`	MATLAB
EPS black and white	Vector	`-deps`	MATLAB
EPS color	Vector	`-depsc`	MATLAB
EPS Level 2 black and white	Vector	`-deps2`	MATLAB
EPS Level 2 color	Vector	`-depsc2`	MATLAB
HDF 24-bit	Bitmap	`-dhdf`	MATLAB
ILL (Adobe Illustrator)	Vector	`-dill`	MATLAB
JPEG 24-bit	Bitmap	`-djpeg`	MATLAB
PBM (plain format) 1-bit	Bitmap	`-dpbm`	Ghostscript

Graphics Format	Bitmap or Vector	Print Command Option String	MATLAB or Ghostscript
PBM (raw format) 1-bit	Bitmap	`-dpbmraw`	Ghostscript
PCX 1-bit	Bitmap	`-dpcxmono`	Ghostscript
PCX 24-bit color PCX file format, three 8-bit planes	Bitmap	`-dpcx24b`	Ghostscript
PCX 8-bit newer color PCX file format (256-color)	Bitmap	`-dpcx256`	Ghostscript
PCX Older color PCX file format (EGA/VGA, 16-color)	Bitmap	`-dpcx16`	Ghostscript
PDF Color PDF file format	Vector	`-dpdf`	Ghostscript
PGM Portable Graymap (plain format)	Bitmap	`-dpgm`	Ghostscript
PGM Portable Graymap (raw format)	Bitmap	`-dpgmraw`	Ghostscript
PNG 24-bit	Bitmap	`-dpng`	MATLAB
PPM Portable Pixmap (plain format)	Bitmap	`-dppm`	Ghostscript
PPM Portable Pixmap (raw format)	Bitmap	`-dppmraw`	Ghostscript

Graphics Format	Bitmap or Vector	Print Command Option String	MATLAB or Ghostscript
TIFF 24-bit	Bitmap	`-dtiff` or `-dtiffn`	MATLAB
TIFF preview for EPS files	Bitmap	`-tiff`	

The TIFF image format is supported on all platforms by almost all word processors for importing images. The `-dtiffn` variant writes an uncompressed TIFF. JPEG is a lossy, highly compressed format that is supported on all platforms for image processing and for inclusion into HTML documents on the Web. To create these formats, MATLAB renders the figure using the Z-buffer rendering method and the resulting bitmap is then saved to the specified file.

Printing and Exporting without a Display

On a UNIX platform (including Macintosh), where you can start in MATLAB `nodisplay` mode (`matlab -nodisplay`), you can print using most of the drivers you can use with a display and export to most of the same file formats. The PostScript and Ghostscript devices all function in `nodisplay` mode on UNIX platforms. The graphic devices `-djpeg`, `-dpng`, `-dtiff` (compressed TIFF bitmaps), and `-tiff` (EPS with TIFF preview) work as well, but under `nodisplay` they use Ghostscript to generate output instead of using the drivers built into MATLAB. However, Ghostscript ignores the `-r` option when generating `-djpeg`, `-dpng`, `-dtiff`, and `-tiff` image files. This means that you cannot vary the resolution of image files when running in `nodisplay` mode.

Naturally, the Windows only `-dwin` and `-dwinc` output formats cannot be used on UNIX or Mac platforms with or without a display.

The same holds true on Windows platforms with the `-noFigureWindows` startup option. The `-dwin`, `-dwinc`, and `-dsetup` options operate as usual under `-noFigureWindows`. However, the `printpreview` GUI does not function in this mode.

The formats which you cannot generate in `nodisplay` mode on UNIX and Mac platforms are:

- bitmap (`-dbitmap`) — Windows bitmap file (except for Simulink models)
- bmp (`-dbmp...`) — Monochrome and color bitmaps
- hdf (`-dhdf`) — Hierarchical Data Format
- svg (`-dsvg`) — Scalable Vector Graphics file (except for Simulink models)
- tiffn (`-dtiffn`) — TIFF image file, no compression

In addition, uicontrols do not print or export in `nodisplay` mode.

Printing Options

This table summarizes options that you can specify for `print`. The second column links to tutorials in "Printing and Exporting" in the MATLAB Graphics documentation that provide operational details. Also see "Resolution Considerations" on page 2-2768 for information on controlling output resolution.

Option	Description
`-adobecset`	PostScript devices only. Use PostScript default character set encoding. See "Early PostScript 1 Printers".
`-append`	PostScript devices only. Append figure to existing PostScript file. See "Settings That Are Driver Specific".
`-cmyk`	PostScript devices only. Print with CMYK colors instead of RGB. See "Setting CMYK Color".
`-ddriver`	Printing only. Printer driver to use. See "Printer Drivers" on page 2-2758 table.
`-dformat`	Exporting only. Graphics format to use. See "Graphics Format Files" table.

Option	Description
`-dsetup`	Windows printing only. Display the (platform-specific) Print Setup dialog. Settings you make in it are saved, but nothing is printed.
`-fhandle`	Handle of figure to print. Note that you cannot specify both this option and the `-s`*`windowtitle`* option. See "Which Figure Is Printed".
`-loose`	PostScript and Ghostscript printing only. Use loose bounding box for PostScript output. See "Producing Uncropped Figures".
`-noui`	Suppress printing of user interface controls. See "Excluding User Interface Controls".
`-opengl`	Render using the OpenGL algorithm. Note that you cannot specify this method in conjunction with `-zbuffer` or `-painters`. See "Selecting a Renderer".
`-painters`	Render using the Painter's algorithm. Note that you cannot specify this method in conjunction with `-zbuffer` or `-opengl`. See "Selecting a Renderer".
`-P`*`printer`*	Specify name of printer to use. See "Selecting the Printer".
`-r`*`number`*	PostScript and built-in raster formats, and Ghostscript vector format only. Specify resolution in dots per inch. Defaults to `90` for Simulink, `150` for figures in image formats and when printing in Z-buffer or OpenGL mode, screen resolution for metafiles, and `864` otherwise. Use `-r0` to specify screen resolution. For details, see "Resolution Considerations" on page 2-2768 and "Setting the Resolution".

Option	Description
`-swindowtitle`	Specify name of Simulink system window to print. Note that you cannot specify both this option and the `-fhandle` option. See "Which Figure Is Printed".
`-v`	Windows printing only. Display the Windows Print dialog box. The `v` stands for "verbose mode."
`-zbuffer`	Render using the Z-buffer algorithm. Note that you cannot specify this method in conjunction with `-opengl` or `-painters`. See "Selecting a Renderer".

Resolution Considerations

Use `-rnumber` to specify the resolution of the generated output. In general, using a higher value will yield higher quality output but at the cost of larger output files. It affects the resolution and output size of all MATLAB built-in *raster* formats (which are identified in column four of the table in "Graphics Format Files" on page 2-2762).

Note Built-in graphics formats are generated directly from MATLAB without conversion through the Ghostscript library. Also, in headless (`nodisplay`) mode, writing to certain image formats is not done by built-in drivers, as it is when a display is being used. These formats are `-djpeg`, `-dtiff`, and `-dpng`. Furthermore, the `-dhdf` and `-dbmp` formats cannot be generated in headless mode (but you can substitute `-dbmp16m` for `-dbmp`). See "Printing and Exporting without a Display" on page 2-2765 for details on printing when not using a display.

Unlike the built-in MATLAB formats, graphic output generated via Ghostscript does not directly obey `-r` option settings. However, the intermediate PostScript file generated by MATLAB as input for the Ghostscript processor is affected by the `-r` setting and thus can indirectly influence the quality of the final Ghostscript generated output.

The effect of the `-r` option on output quality can be subtle at ordinary magnification when using the OpenGL or ZBuffer renderers and writing to one of the MATLAB built-in raster formats, or when generating vector output that contains an embedded raster image (for example, PostScript or PDF). The effect of specifying higher resolution is more apparent when viewing the output at higher magnification or when printed, since a larger `-r` setting provides more data to use when scaling the image.

When generating fully vectorized output (as when using the Painters renderer to output a vector format such as PostScript or PDF), the resolution setting affects the degree of detail of the output; setting resolution higher generates crisper output (but small changes in the resolution may have no observable effect). For example, the gap widths of lines that do not use a solid (`'-'`) linestyle can be affected.

Paper Sizes

MATLAB printing supports a number of standard paper sizes. You can select from the following list by setting the `PaperType` property of the figure or selecting a supported paper size from the Print dialog box.

Property Value	Size (Width by Height)
`usletter`	8.5 by 11 inches
`uslegal`	11 by 14 inches
`tabloid`	11 by 17 inches
`A0`	841 by 1189 mm
`A1`	594 by 841 mm
`A2`	420 by 594 mm
`A3`	297 by 420 mm
`A4`	210 by 297 mm
`A5`	148 by 210 mm
`B0`	1029 by 1456 mm

Property Value	Size (Width by Height)
B1	728 by 1028 mm
B2	514 by 728 mm
B3	364 by 514 mm
B4	257 by 364 mm
B5	182 by 257 mm
arch-A	9 by 12 inches
arch-B	12 by 18 inches
arch-C	18 by 24 inches
arch-D	24 by 36 inches
arch-E	36 by 48 inches
A	8.5 by 11 inches
B	11 by 17 inches
C	17 by 22 inches
D	22 by 34 inches
E	34 by 43 inches

Printing Tips

Figures with Resize Functions

The `print` command produces a warning when you print a figure having a callback routine defined for the figure `ResizeFcn`. To avoid the warning, set the figure `PaperPositionMode` property to `auto` or select **Match Figure Screen Size** in the **File > Page Setup** dialog box.

Troubleshooting Microsoft Windows Printing

If you encounter problems such as segmentation violations, general protection faults, or application errors, or the output does not appear as you expect when using Microsoft printer drivers, try the following:

- If your printer is PostScript compatible, print with one of the MATLAB built-in PostScript drivers. There are various PostScript device options that you can use with `print` , which all start with `-dps`.
- The behavior you are experiencing might occur only with certain versions of the print driver. Contact the print driver vendor for information on how to obtain and install a different driver.
- Try printing with one of the MATLAB built-in Ghostscript devices. These devices use Ghostscript to convert PostScript files into other formats, such as HP LaserJet, PCX, Canon BubbleJet, and so on.
- Copy the figure as a Windows Enhanced Metafile using the **Edit > Copy Figure** menu item on the figure window menu or the `print -dmeta` option at the command line. You can then import the file into another application for printing.

  You can set copy options in the figure's **File > Preferences > Copying Options** dialog box. The Windows Enhanced Metafile Clipboard format produces a better quality image than Windows Bitmap.

Printing MATLAB GUIs

You can generally obtain better results when printing a figure window that contains MATLAB `uicontrols` by setting these key properties:

- Set the figure `PaperPositionMode` property to `auto`. This ensures that the printed version is the same size as the on-screen version. With `PaperPositionMode` set to `auto` MATLAB, does not resize the figure to fit the current value of the `PaperPosition`. This is particularly important if you have specified a figure `ResizeFcn`, because if MATLAB resizes the figure during the print operation, `ResizeFcn` is automatically called.

  To set `PaperPositionMode` on the current figure, use the command:

  ```
  set(gcf,'PaperPositionMode','auto')
  ```

- Set the figure `InvertHardcopy` property to `off`. By default, MATLAB changes the figure background color of printed output to white, but does not change the color of `uicontrols`. If you have set the background color, for example, to match the gray of the GUI devices, you must set `InvertHardcopy` to `off` to preserve the color scheme.

To set `InvertHardcopy` on the current figure, use the command:

```
set(gcf,'InvertHardcopy','off')
```

- Use a color device if you want lines and text that are in color on the screen to be written to the output file as colored objects. Black and white devices convert colored lines and text to black or white to provide the best contrast with the background and to avoid dithering.
- Use the `print` command's `-loose` option to keep a bounding box from being too tightly wrapped around objects contained in the figure. This is important if you have intentionally used space between `uicontrols` or axes and the edge of the figure and you want to maintain this appearance in the printed output.

If you print or export in `nodisplay` mode, none of the `uicontrols` the figure has will be visible. If you run code that adds `uicontrols` to a figure when the figure is invisible, the controls will not print until the figure is made visible.

Printing Interpolated Shading with PostScript Drivers

You can print MATLAB surface objects (such as graphs created with `surf` or `mesh`) using interpolated colors. However, only patch objects that are composed of triangular faces can be printed using interpolated shading.

Printed output is always interpolated in RGB space, not in the colormap colors. This means that if you are using indexed color and interpolated face coloring, the printed output can look different from what is displayed on screen.

PostScript files generated for interpolated shading contain the color information of the graphics object's vertices and require the printer to perform the interpolation calculations. This can take an excessive amount of time and in some cases, printers might time out before finishing the print job. One solution to this problem is to interpolate the data and generate a greater number of faces, which can then be flat shaded.

To ensure that the printed output matches what you see on the screen, print using the `-zbuffer` option. To obtain higher resolution (for example, to make text look better), use the `-r` option to increase the resolution. There is, however, a tradeoff between the resolution and the size of the created PostScript file, which can be quite large at higher resolutions. The default resolution of 150 dpi generally produces good results. You can reduce the size of the output file by making the figure smaller before printing it and setting the figure `PaperPositionMode` to `auto`, or by just setting the `PaperPosition` property to a smaller size.

Examples

Specifying the Figure to Print

You can print a noncurrent figure by specifying the figure's handle. If a figure has the title "Figure 2", its handle is 2. The syntax is:

```
print -fhandle
```

This example prints the figure whose handle is 2, regardless of which figure is the current figure:

```
print -f2
```

Note You must use the `-f` option if the figure's handle is hidden (i.e., its `HandleVisibility` property is set to `off`).

This example saves the figure with the handle `-f2` to a PostScript file named `Figure2`, which can be printed later:

```
print -f2 -dps 'Figure2.ps'
```

If the figure uses noninteger handles, use the `figure` command to get its value, and then pass it in as the first argument. For example:

```
h = figure('IntegerHandle','off')
print h -depson
```

You can also pass a figure handle as a variable to the function form of `print`. For example:

```
h = figure; plot(1:4,5:8)
print(h)
```

This example uses the function form of `print` to enable a file name to be passed in as a variable:

```
file name = 'mydata';
print('-f3', '-dpsc', file name);
```

(Because a file name is specified, the figure will be printed to a file.)

Specifying the Model to Print

To print a noncurrent Simulink model, use the `-s` option with the title of the window. For example, this command prints the Simulink window titled `f14`:

```
print -sf14
```

If the window title includes any spaces, you must call the function form rather than the command form of `print`. For example, this command saves the Simulink window title `Thruster Control`:

```
print('-sThruster Control')
```

To print the current system, use:

```
print -s
```

For information about issues specific to printing Simulink windows, see the Simulink documentation.

Printing Figures at Screen Size

This example prints a surface plot with interpolated shading. Setting the current figure's (gcf) PaperPositionMode to auto enables you to resize the figure window and print it at the size you see on the screen. See "Printing Options" on page 2-2766 and "Printing Interpolated Shading with PostScript Drivers" on page 2-2772 for information on the -zbuffer and -r200 options.

```
surf(peaks)
shading interp
set(gcf,'PaperPositionMode','auto')
print -dpsc2 -zbuffer -r200
```

For additional details, see "Printing Images" in the MATLAB Graphics documentation.

Batch Processing

You can use the function form of print to pass variables containing file names. For example, this for loop uses file names stored in a cell array to create a series of graphs and prints each one with a different file name:

```
fnames = {'file1', 'file2', 'file3'};
for k=1:length(fnames)
    surf(peaks)
    print('-dtiff','-r200',fnames{k})
end
```

Tiff Preview

The command

```
print -depsc -tiff -r300 picture1
```

saves the current figure at 300 dpi, in a color Encapsulated PostScript file named picture1.eps. The -tiff option creates a 72 dpi TIFF preview, which many word processor applications can display on screen after you import the EPS file. This enables you to view the picture on screen within your word processor and print the document to a PostScript printer using a resolution of 300 dpi.

See Also `figure`, `hgsave`, `imwrite`, `orient`, `printdlg`, `printopt`, `saveas`

Purpose

Print dialog box

Syntax

```
printdlg
printdlg(fig)
printdlg('-crossplatform',fig)
printdlg('-setup',fig)
```

Description

`printdlg` prints the current figure.

`printdlg(fig)` creates a modal dialog box from which you can print the figure window identified by the handle `fig`. Note that uimenus do not print.

`printdlg('-crossplatform',fig)` displays the standard cross-platform MATLAB printing dialog rather than the built-in printing dialog box for Microsoft Windows computers. Insert this option before the `fig` argument.

`printdlg('-setup',fig)` forces the printing dialog to appear in a setup mode. Here one can set the default printing options without actually printing.

Note A modal dialog box prevents the user from interacting with other windows before responding. For more information, see `WindowStyle` in the MATLAB Figure Properties.

See Also

`pagesetupdlg`, `printpreview`

Purpose

Preview figure to print

Contents

GUI Alternative

Use **File > Print Preview** on the figure window menu to access the Print Preview dialog box, described below. For details, see "Using Print Preview" in the MATLAB Graphics documentation.

Syntax

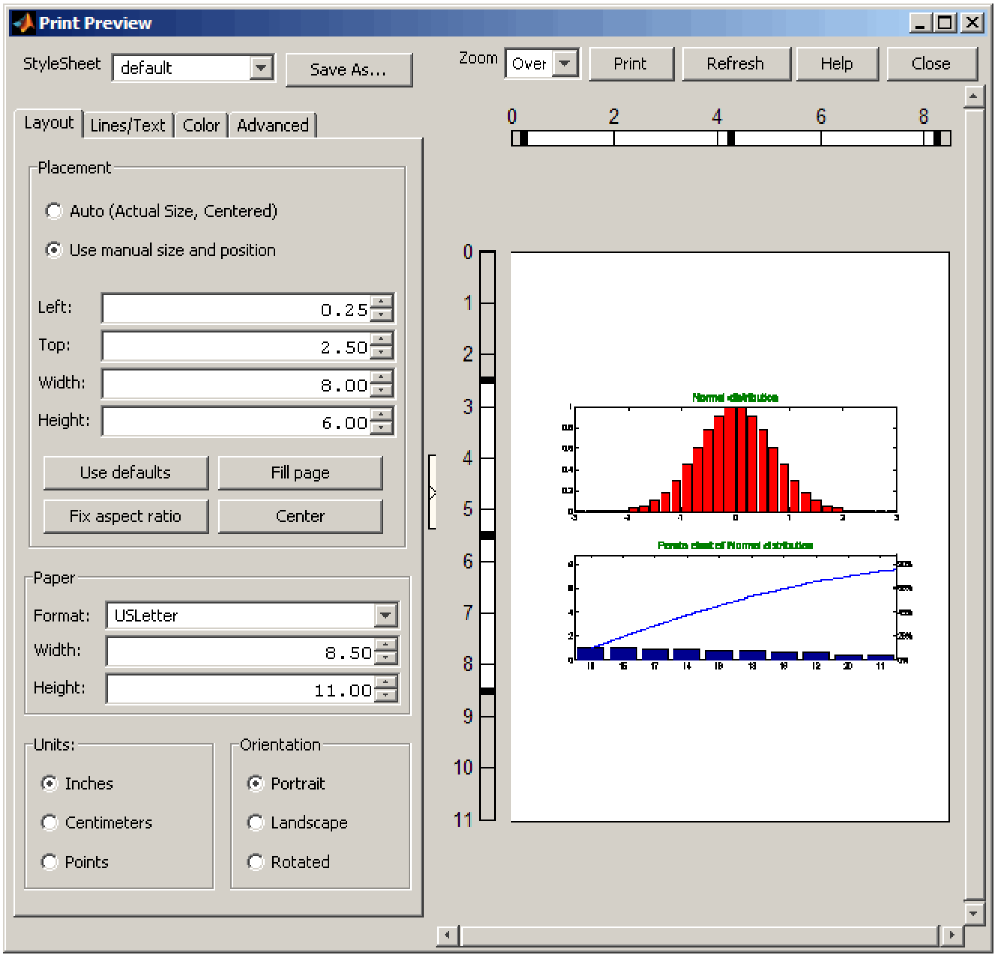
```
printpreview
printpreview(f)
```

Description

`printpreview` displays a dialog box showing the figure in the currently active figure window as it will print. A scaled version of the figure displays in the right-hand pane of the GUI.

`printpreview(f)` displays a dialog box showing the figure having the handle `f` as it will print.

Use the Print Preview dialog box, shown below, to control the layout and appearance of figures before sending them to a printer or print file. Controls are grouped into four tabbed panes: **Layout**, **Lines/Text**, **Color**, and **Advanced**.



Right Pane Controls

You can position and scale plots on the printed page using the rulers in the right-hand pane of the Print Preview dialog. Use the outer ruler handlebars to change margins. Moving them changes plot proportions. Use the center ruler handlebars to change the position of the plot on the page. Plot proportions do not change, but you can move portions of the plot off the paper. The buttons on that pane let you refresh the plot, close the dialog (preserving all current settings), print the page immediately, or obtain context-sensitive help. Use the **Zoom** box and scroll bars to view and position page elements more precisely.

The Layout Tab

Use the **Layout** tab, shown above, to control the paper format and placement of the plot on printed pages. The following table summarizes the **Layout** options:

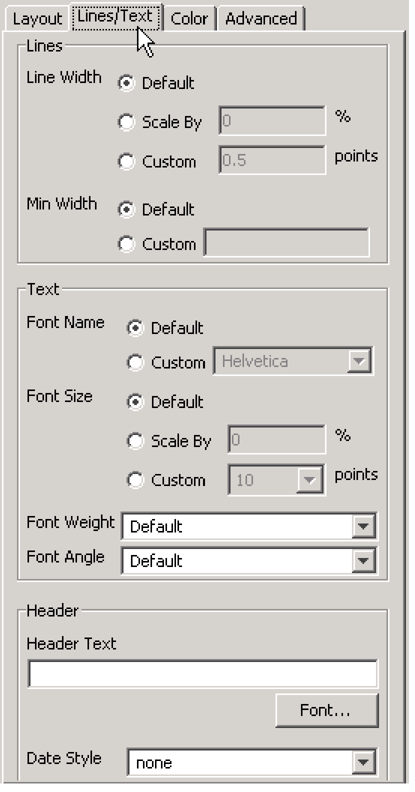
Group	Option	Description
Placement	**Auto**	Let MATLAB decide placement of plot on page
	Use manual...	Specify position parameters for plot on page
	Top, Left, Width, Height	Standard position parameters in current units
	Use defaults	Revert to default position
	Fill page	Expand figure to fill printable area (see note below)
	Fix aspect ratio	Correct height/width ratio
	Center	Center plot on printed page
Paper	**Format**	U.S. and ISO® sheet size selector
	Width, Height	Sheet size in current units
Units	**Inches**	Use inches as units for dimensions and positions
	Centimeters	Use centimeters as units for dimensions and positions
	Points	Use points as units for dimensions and positions
Orientation	**Portrait**	Upright paper orientation

Group	Option	Description
	Landscape	Sideways paper orientation
	Rotated	Currently the same as **Landscape**

Note Selecting the **Fill page** option changes the `PaperPosition` property to fill the page, allowing objects in normalized units to expand to fill the space. If an object within the figure has an absolute size, for example a table, it can overflow the page when objects with normalized units expand. To avoid having objects fall off the page, do not use **Fill page** under such circumstances.

The Lines/Text Tab

Use the **Lines/Text** tab, shown below, to control the line weights, font characteristics, and headers for printed pages. The following table summarizes the **Lines/Text** options:

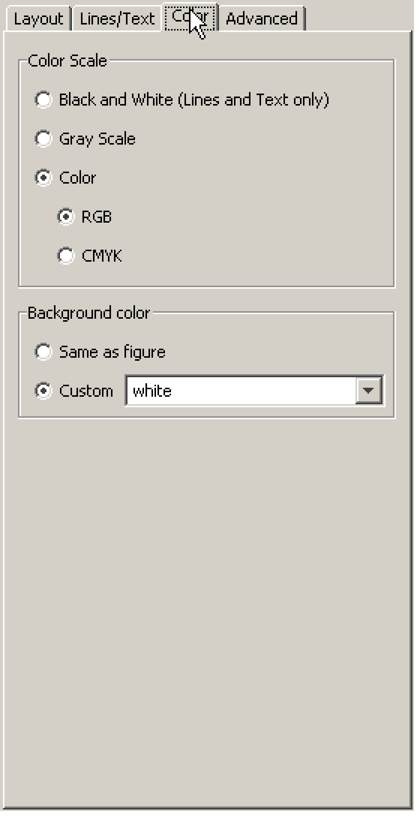


Group	Option	Description
Lines	**Line Width**	Scale all lines by a percentage from 0 upward (100 being no change), print lines at a specified point size, or default line widths used on the plot
	Min Width	Smallest line width (in points) to use when printing; defaults to 0.5 point
Text	**Font Name**	Select a system font for all text on plot, or default to fonts currently used on the plot

Group	Option	Description
	Font Size	Scale all text by a percentage from 0 upward (100 being no change), print text at a specified point size, or default to this
	Font Weight	Select `Normal` ... `Bold` font styling for all text from drop-down menu or default to the font weights used on the plot
	Font Angle	Select `Normal`, `Italic` or `Oblique` font styling for all text from drop-down menu or default to the font angles used on the plot
Header	**Header Tex**t	Type the text to appear on the header at the upper left of printed pages, or leave blank for no header
	Date Style	Select a date format to have today's date appear at the upper left of printed pages, or `none` for no date

The Color Tab

Use the **Color** tab, shown below, to control how colors are printed for lines and backgrounds. The following table summarizes the **Color** options:

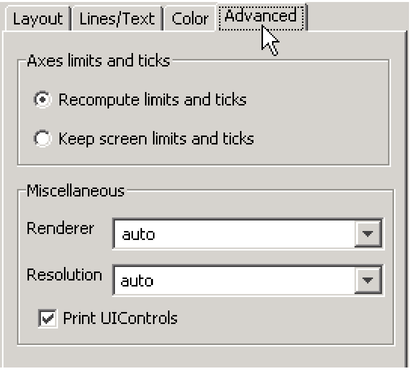


Group	Option	Description
Color Scale	**Black and White**	Select to print lines and text in black and white, but use color for patches and other objects
	Gray Scale	Convert colors to shades of gray on printed pages

Group	Option	Description
	Color	Print everything in color, matching colors on plot; select RGB (default) or CMYK color model for printing
Background Color	**Same as figure**	Print the figure's background color as it is
	Custom	Select a color name, or type a colorspec for the background; white (default) implies no background color, even on colored paper.

The Advanced Tab

Use the **Advanced** tab, shown below, to control finer details of printing, such as limits and ticks, renderer, resolution, and the printing of UIControls. The following table summarizes the **Advanced** options:



Group	Option	Description
Axes limits and ticks	**Recompute limits and ticks**	Redraw *x*- and *y*-axes ticks and limits based on printed plot size (default)

Group	Option	Description
	Keep limits and ticks	Use the *x*- and *y*-axes ticks and limits shown on the plot when printing the previewed figure
Miscellaneous	**Renderer**	Select a rendering algorithm for printing: `painters`, `zbuffer`, `opengl`, or `auto` (default)
	Resolution	Select resolution to print at in dots per inch: `150`, `300`, `600`, or `auto` (default), or type in any other positive value
	Print UIControls	Print all visible UIControls in the figure (default), or uncheck to exclude them from being printed

See Also

`printdlg`, `pagesetupdlg`

For more information, see How to Print or Export in the MATLAB Graphics documentation.

Purpose

Product of array elements

Syntax

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

Description

`B = prod(A)` returns the products along different dimensions of an array.

If `A` is a vector, `prod(A)` returns the product of the elements.

If `A` is a matrix, `prod(A)` treats the columns of `A` as vectors, returning a row vector of the products of each column.

If `A` is a multidimensional array, `prod(A)` treats the values along the first non-singleton dimension as vectors, returning an array of row vectors.

`B = prod(A,dim)` takes the products along the dimension of `A` specified by scalar `dim`.

Examples

The magic square of order 3 is

```
M = magic(3)

M =
     8     1     6
     3     5     7
     4     9     2
```

The product of the elements in each column is

```
prod(M) =

     96    45    84
```

The product of the elements in each row can be obtained by:

```
prod(M,2) =

      48
```

```
   105
    72
```

See Also `cumprod`, `diff`, `sum`

Purpose

Profile execution time for function

GUI Alternatives

As an alternative to the profile function, select **Desktop > Profiler** to open the Profiler.

Syntax

```
profile on
profile -history
profile -nohistory
profile -history -historysize integer
profile -timer clock
profile -history -historysize integer -timer clock
profile off
profile resume
profile clear
profile viewer
S = profile( status')
stats = profile('info')
```

Description

The profile function helps you debug and optimize M-files by tracking their execution time. For each M-function, M-subfunction, or MEX-function in the file, profile records information about execution time, number of calls, parent functions, child functions, code line hit count, and code line execution time. Some people use profile simply to see the child functions; see also depfun for that purpose. To open the Profiler graphical user interface, use the profile viewer syntax. By default, Profiler time is CPU time. The total time reported by the Profiler is not the same as the time reported using the tic and toc functions or the time you would observe using a stopwatch.

Note If your system uses Intel multi-core chips, you may want to restrict the active number of CPUs to 1 for the most accurate and efficient profiling. See "Intel Multi-Core Processors — Setting for Most Accurate Profiling" for details on how to do this.

`profile on` starts the Profiler, clearing previously recorded profile statistics. Note the following:

- You can specify all, none, or a subset, of the `history`, `historysize` and `timer` options with the `profile on` syntax.
- You can specify options in any order, including before or after `on`.
- If the Profiler is currently on and you specify `profile` with one of the options, MATLAB software returns an error message and the option has no effect. For example, if you specify `profile timer real`, MATLAB returns the following error: `The profiler has already been started. TIMER cannot be changed.`
- To change options, first specify `profile off`, and then specify `profile on` or `profile resume` with new options.

`profile -history` records the exact sequence of function calls. The `profile` function records, by default, up to 1,000,000 function entry and exit events. For more than 1,000,000 events, `profile` continues to record other profile statistics, but not the sequence of calls. To change the number of function entry and exit events that the `profile` function records, use the **`historysize`** option. By default, the `history` option is not enabled.

`profile -nohistory` disables further recording of the history (exact sequence of function calls). Use the `-nohistory` option after having previously set the `-history` option. All other profiling statistics continue to be collected.

`profile -history -historysize` *`integer`* specifies the number of function entry and exit events to record. By default, `historysize` is set to 1,000,000.

`profile -timer` *`clock`* specifies the type of time to use. Valid values for *`clock`* are:

- `'cpu'` — The Profiler uses computer time (the default).
- `'real'` — The Profiler uses wall-clock time.

For example, `cpu` time for the `pause` function is typically small, but `real` time accounts for the actual time paused, and therefore would be larger.

`profile` **`-history -historysize`** *`integer`* **`-timer`** *`clock`* specifies all of the options. Any order is acceptable, as is a subset.

`profile` **`off`** stops the Profiler.

`profile` **`resume`** restarts the Profiler without clearing previously recorded statistics.

`profile` **`clear`** clears the statistics recorded by `profile`.

`profile` **`viewer`** stops the Profiler and displays the results in the Profiler window. For more information, see Profiling for Improving Performance in the Desktop Tools and Development Environment documentation.

`S = profile(` **`status`**`')` returns a structure containing information about the current status of the Profiler. The table lists the fields in the order that they appear in the structure.

Field	Values	Default Value
`ProfilerStatus`	`'on'` or `'off'`	off
`DetailLevel`	`'mmex'`	'mmex'
`Timer`	`'cpu'` or `'real'`	'cpu'
`HistoryTracking`	`'on'` or `'off'`	'off'
`HistorySize`	integer	1000000

`stats = profile('`**`info`**`')`stops the Profiler and displays a structure containing the results. Use this function to access the data generated by `profile`. The table lists the fields in the order that they appear in the structure.

Field	Description
FunctionTable	Structure array containing statistics about each function called
FunctionHistory	Array containing function call history
ClockPrecision	Precision of the profile function's time measurement
ClockSpeed	Estimated clock speed of the CPU
Name	Name of the profiler

The FunctionTable field is an array of structures, where each structure contains information about one of the functions or subfunctions called during execution. The following table lists these fields in the order that they appear in the structure.

Field	Description
CompleteName	Full path to FunctionName, including subfunctions
FunctionName	Function name; includes subfunctions
FileName	Full path to FunctionName, with file extension, excluding subfunctions
Type	M-functions, MEX-functions, and many other types of functions including M-subfunctions, nested functions, and anonymous functions
NumCalls	Number of times the function was called
TotalTime	Total time spent in the function and its child functions
TotalRecursiveTime	No longer used.
Children	FunctionTable indices to child functions
Parents	FunctionTable indices to parent functions

Field	Description
ExecutedLines	Array containing line-by-line details for the function being profiled. Column 1: Number of the line that executed. If a line was not executed, it does not appear in this matrix. Column 2: Number of times the line was executed Column 3: Total time spent on that line. Note: The sum of Column 3 entries does not necessarily add up to the function's `TotalTime`.
IsRecursive	`BOOLEAN` value: Logical `1` (true) if recursive, otherwise logical `0` (false)
PartialData	`BOOLEAN` value: Logical `1` (true) if function was modified during profiling, for example by being edited or cleared. In that event, data was collected only up until the point when the function was modified.

Examples

Profile and Display Results

This example profiles the MATLAB `magic` command and then displays the results in the Profiler window. The example then retrieves the profile data on which the HTML display is based and uses the `profsave` command to save the profile data in HTML form.

```
profile on
plot(magic(35))
profile viewer
p = profile('info');
profsave(p,'profile_results')
```

Profile and Save Results

Another way to save profile data is to store it in a MAT-file. This example stores the profile data in a MAT-file, clears the profile data from memory, and then loads the profile data from the MAT-file. This example also shows a way to bring the reloaded profile data into the Profiler graphical interface as live profile data, not as a static HTML page.

```
p = profile('info');
save myprofiledata p
clear p
load myprofiledata
profview(0,p)
```

Profile and Show Results Including History

This example illustrates an effective way to view the results of profiling when the `history` option is enabled. The history data describes the sequence of functions entered and exited during execution. The `profile` command returns history data in the `FunctionHistory` field of the structure it returns. The history data is a 2-by-n array. The first row contains Boolean values, where `0` means entrance into a function and `1` means exit from a function. The second row identifies the function being entered or exited by its index in the `FunctionTable` field. This example reads the history data and displays it in the MATLAB Command Window.

```
profile on -history
plot(magic(4));
p = profile('info');

for n = 1:size(p.FunctionHistory,2)
 if p.FunctionHistory(1,n)==0
        str = 'entering function: ';
 else
        str = 'exiting function: ';
 end
```

```
  disp([str p.FunctionTable(p.FunctionHistory(2,n)).FunctionName])
end
```

See Also

depdir, depfun, mlint, profsave

Profiling for Improving Performance in the MATLAB Desktop Tools and Development Environment documentation

Purpose Save profile report in HTML format

Syntax

```
profsave
profsave(profinfo)
profsave(profinfo,dirname)
```

Description

`profsave` executes the `profile('info')` function and saves the results in HTML format. `profsave` creates a separate HTML file for each function listed in the `FunctionTable` field of the structure returned by `profile`. By default, `profsave` stores the HTML files in a subdirectory of the current directory named `profile_results`.

`profsave(profinfo)` saves the profiling results, `profinfo`, in HTML format. `profinfo` is a structure of profiling information returned by the `profile('info')` function.

`profsave(profinfo,dirname)` saves the profiling results, `profinfo`, in HTML format. `profsave` creates a separate HTML file for each function listed in the `FunctionTable` field of `profinfo` and stores them in the directory specified by `dirname`.

Examples

Run `profile` and save the results.

```
profile on
plot(magic(5))
profile off
profsave(profile('info'),'myprofile_results')
```

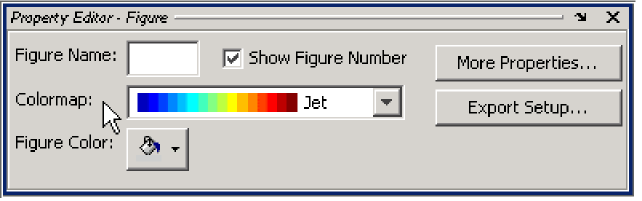
See Also

`profile`

Profiling for Improving Performance in the MATLAB Desktop Tools and Development Environment documentation

Purpose

Open Property Editor



Syntax

```
propedit
propedit(handle_list)
```

Description

`propedit` starts the Property Editor, a graphical user interface to the properties of graphics objects. If no current figure exists, `propedit` will create one.

`propedit(handle_list)` edits the properties for the object (or objects) in `handle_list`.

Starting the Property Editor enables plot editing mode for the figure.

See Also

`inspect`, `plotedit`, `propertyeditor`

propedit (COM)

Purpose Open built-in property page for control

Syntax

```
h.propedit
propedit(h)
```

Description `h.propedit` requests the control to display its built-in property page. Note that some controls do not have a built-in property page. For those controls, this command fails.

`propedit(h)` is an alternate syntax for the same operation.

Remarks COM functions are available on Microsoft Windows systems only.

Examples Create a Microsoft Calendar control and display its property page:

```
cal = actxcontrol('mscal.calendar', [0 0 500 500]);
cal.propedit
```

See Also `inspect`, `get (COM)`

Purpose

Display class property names

Syntax

```
properties('classname')
properties(obj)
p = properties(...)
```

Description

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

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

See "Dynamic Properties — Adding Properties to an Instance" for information on using dynamic properties.

`p = properties(...)` returns the property names in a cell array of strings. Note that you can use the Workspace browser to browse current property values. See "MATLAB Workspace" for more information on using the Workspace browser.

A property is public when its `GetAccess` attributes are set to `public` and its `Hidden` attribute is set to `false` (default values for these attributes). See "Property Attributes" for a complete list of attributes.

You can also use the `fieldnames` function to list property names of MATLAB classes.

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

See "Properties — Storing Class Data" for more information on class properties.

Examples

Retrieve the names of the public properties of class `memmapfile` and store the result in a cell array of strings:

```
p = properties('memmapfile');
p
ans =

    'writable'
    'offset'
    'format'
    'repeat'
    'filename'
```

Construct an instance of the `MException` class and get its properties names:

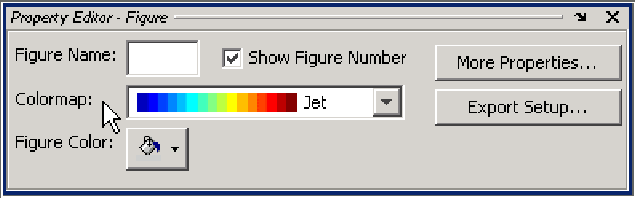
```
me = MException('Msg:ID','MsgText');
properties(me)
Properties for class MException:

    identifier
    message
    cause
    stack
```

See Also

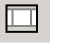
`events`, `fieldnames`, `methods`

Purpose

Show or hide property editor



GUI Alternatives

Click the larger **Plotting Tools** icon  on the figure toolbar to collectively enable plotting tools, and the smaller icon  to collectively disable them. Open or close the **Property Editor** tool from the figure's **View** menu. For details, see "The Property Editor" in the MATLAB Graphics documentation.

Syntax

```
propertyeditor('on')
propertyeditor('off')
propertyeditor('toggle')
propertyeditor
propertyeditor(figure_handle,...)
```

Description

`propertyeditor('on')` displays the Property Editor on the current figure.

`propertyeditor('off')` hides the Property Editor on the current figure.

`propertyeditor('toggle')` or `propertyeditor` toggles the visibility of the property editor on the current figure.

`propertyeditor(figure_handle,...)` displays or hides the Property Editor on the figure specified by `figure_handle`.

See Also

`plottools`, `plotbrowser`, `figurepalette`, `inspect`

Purpose

Psi (polygamma) function

Syntax

```
Y = psi(X)
Y = psi(k,X)
Y = psi(k0:k1,X)
```

Description

`Y = psi(X)` evaluates the Ψ function for each element of array `X`. `X` must be real and nonnegative. The Ψ function, also known as the digamma function, is the logarithmic derivative of the gamma function

$$\begin{aligned}\psi(x) &= \mathbf{digamma}(x)\\ &= \frac{d(\log(\Gamma(x)))}{dx}\\ &= \frac{d(\Gamma(x))/dx}{\Gamma(x)}\end{aligned}$$

`Y = psi(k,X)` evaluates the `k`th derivative of Ψ at the elements of `X`. `psi(0,X)` is the digamma function, `psi(1,X)` is the trigamma function, `psi(2,X)` is the tetragamma function, etc.

`Y = psi(k0:k1,X)` evaluates derivatives of order `k0` through `k1` at `X`. `Y(k,j)` is the `(k-1+k0)`th derivative of Ψ, evaluated at `X(j)`.

Examples

Example 1

Use the `psi` function to calculate Euler's constant, γ.

```
format long
-psi(1)
ans =
   0.57721566490153

-psi(0,1)
ans =
   0.57721566490153
```

Example 2

The trigamma function of 2, `psi(1,2)`, is the same as $(\pi^2/6) - 1$.

```
format long
psi(1,2)
ans =
   0.64493406684823

pi^2/6 - 1
ans =
   0.64493406684823
```

Example 3

This code produces the first page of Table 6.1 in Abramowitz and Stegun [1].

```
x = (1:.005:1.250)';
[x gamma(x) gammaln(x) psi(0:1,x)' x-1]
```

Example 4

This code produces a portion of Table 6.2 in [1].

```
psi(2:3,1:.01:2)'
```

See Also

`gamma`, `gammainc`, `gammaln`

References

[1] Abramowitz, M. and I. A. Stegun, *Handbook of Mathematical Functions*, Dover Publications, 1965, Sections 6.3 and 6.4.

Purpose

Publish M-file containing cells, saving output to a file of specified type

GUI Alternatives

As an alternative to the `publish` function, use the **File > Publish *filename*** menu or **File > Publish Configuration for *filename*** items in the Editor.

Syntax

```
publish('script')
publish('script','format')
publish('script', options)
publish('function', options)
```

Description

`publish('script')` runs the M-file script named `script` in the base workspace one cell at a time, and saves the code, comments, and results to an HTML output file. The output file is named `script.html` and is stored, along with other supporting output files, in an `html` subdirectory in `script`'s directory.

`publish('script','format')` runs the M-file script named `script`, one cell at a time in the base workspace, and publishes the code, comments, and results to an output file using the specified *`format`*. Allowable values for *`format`* are `html` (the default), `xml`, `latex` for LaTeX, `doc` for Microsoft Word documents, and `ppt` for Microsoft PowerPoint documents. The output file is named `script.format` and is stored, along with other supporting output files, in an `html` subdirectory in `script`'s directory. The `doc` format requires the Word application, and the `ppt` format requires PowerPoint application. When publishing to HTML, the M-file code is included at the end of published HTML file as comments, even when the `showCode` option is set to `false`. Because it is included as comments, it does not display in a Web browser. Use the `grabcode` function to extract the code from the HTML file.

`publish('script', options)` publishes using the structure *`options`*, which can contain any of the fields and corresponding value for each field as shown in Options for publish on page 2-2805. Create and save structures for the options you use regularly. For details, see "Specify Values for the Publish Settings Property Table" in the online documentation for MATLAB software.

`publish('function', options)` publishes an M-file function using the structure *options*. The `codeToEvaluate` field must specify the function input and the file to publish if you set the `evalCode` field to `true`. If you set the `evalCode` field to `false`, it essentially saves the M-file to another format, such as HTML, which allows display with formatting in a Web browser.

Options for publish

Field	Allowable Values
`format`	`'doc'`,`'html'` (default), `'latex'`, `'ppt'`, `'xml'`
`stylesheet`	`''` (default), XSL file name (used only when `format` is `html`, `latex`, or `xml`)
`outputDir`	`''` (default, a subfolder named `html`), full path
`imageFormat`	`'png'` (default unless `format` is `latex`), `'epsc2'` (default when `format` is `latex`), any format supported by `print` when `figureSnapMethod` is `print`, any format supported by `imwrite` functions when `figureSnapMethod` is `getframe`, `entireFigureWindow`, or `entireGUIWindow`.

Options for publish (Continued)

Field	Allowable Values
`figureSnapMethod`	`'print'` (default),`'getframe'`,`'entireGUIWindow'`,`'entireFigureWindow'` • `print` uses the `print` function to capture figures. MATLAB captures figures without Window decorations. *Window decorations* are details such as the title bar, x- and y-axis labels, and so on. • `getframe` uses the `getframe` function to capture a movie frame. MATLAB captures the movie frame without Window decorations. • `entireFigureWindow` uses the `getframe` function to capture figures. MATLAB captures all Figures with Window decorations. • `entireGUIWindow` uses the `getframe` function to capture figures. MATLAB captures Window decorations for a Figure only if the Figure's `HandleVisibility` property is set to `off`. MATLAB captures all other Figures without Window decorations.
`useNewFigure`	`true` (default), `false`
`maxHeight`	`[]` (default), any positive integer specifying the maximum height, in pixels, for an image that `publish.m` generates
`maxWidth`	`[]` (default), any positive integer specifying the maximum width, in pixels, for an image that `publish.m` generates
`showCode`	`true` (default), `false`
`evalCode`	`true` (default), `false`
`catchError`	`true` (default, continues publishing and includes the error in the published file), `false` (displays the error and publishing ends)
`codeToEvaluate`	M-file you are publishing (default), any valid code

Options for publish (Continued)

Field	Allowable Values
createThumbnail	true (default), false
maxOutputLines	Inf (default), nonnegative integer specifying the maximum number of output lines to publish per M-file cell before truncating the output

Remarks

Be aware that publish opens a Figure window and sets the background color to white when publishing begins. It closes this Figure window when publishing ends. If your M-code explicitly creates one or more additional Figure windows, publish uses the default background color (gray) unless you specify otherwise. For example, if you publish the following code (using default option settings), the first and second plots publish with a white background and the third plot publishes with a gray background.

```
%% Plot 1
plot(1:10)

%% Plot 2
plot(5:5:25)

%% Plot 3
f = figure;
plot(1:10)
```

Examples

To use the M-Files referenced in the following examples, open the files using the following commands and save each file to a directory to which you have write access. In each example, it is assumed that the directory to which you save the files is I:/my_matlab_files/my_mfiles, so you may need to adjust accordingly.

```
edit(fullfile(matlabroot,'help','techdoc','matlab_env','examples','
edit(fullfile(matlabroot,'help','techdoc','matlab_env','examples','
```

Publish to HTML Format

To publish the M-file script I:/mymfiles/sine_wave.m to HTML, run the following command:

```
publish('I:/my_matlab_files/my_mfiles/sine_wave.m', 'html')
web('I:/my_matlab_files/my_mfiles/html/sine_wave.html')
```

MATLAB runs the file and saves the code, comments, and results to I:/mymfiles/html/sine_wave.html. Open that file in the Web browser to view the published output.

Publish to Microsoft Word Format

This example defines the structure options_doc_nocode, publishes sine_wave.m using the defined options, and displays the resulting document. The resulting report is a Microsoft Word document, I:/my_doc_files/sine_wave.doc and includes results, but not theMATLAB code.

```
options_doc_nocode.format='doc'
options_doc_nocode.outputDir='I:/my_doc_files'
options_doc_nocode.showCode=false
publish('I:/my_matlab_files/my_mfiles/sine_wave.m',options_doc_nocode)
winopen('I:/my_doc_files/sine_wave.doc')
```

Publish Function M-File and Evaluate Code

This examples defines the structure function_options, which specifies the value of the input argument to the function, publishes the function I:/my_matlab_files/my_mfiles/collatz.m, and displays the resulting HTML document, I:/my_matlab_files/my_mfiles/html/collatz.html:

```
function_options.format='html';
function_options.evalCode=true;
function_options.codeToEvaluate=[ ...
'n=3' char(10) ...
'collatz(3)' char(10) ...
```

```
]
function_options.showCode=true;
publish('I:/my_matlab_files/my_mfiles/collatz.m',function_options);
web('I:/my_matlab_files/my_mfiles/html/collatz.html')
```

Publish M-File Script and Capture Window Decorations

This example defines the structure `function_options`, publishes the function `I:/my_matlab_files/my_mfiles/sine_wave.m`, and displays the resulting HTML document, `I:/my_matlab_files/my_mfiles/html/sine_wave.html`:

```
function_options.format='html';
function_options.figureSnapMethod='entireFigureWindow';
publish('I:/my_matlab_files/my_mfiles/sine_wave.m',function_options
web('I:/my_matlab_files/my_mfiles/html/sine_wave.html')
```

See Also

`grabcode`, `notebook`, `web`, `winopen`

MATLAB Desktop Tools and Development Environment documentation, specifically:

- "Overview of Publishing M-Files"
- "Defining Cells"

PutCharArray

Purpose

Store character array in server

Syntax

MATLAB Client

```
h.PutCharArray('varname', 'workspace', 'string')
PutCharArray(h, 'varname', 'workspace', 'string')
invoke(h, 'PutCharArray', 'varname', 'workspace', 'string')
```

Method Signature

```
PutCharArray([in] BSTR varname, [in] BSTR workspace,
[in] BSTR string)
```

Microsoft Visual Basic Client

```
PutCharArray(varname As String, workspace As String,
string As String)
```

Description

`PutCharArray` stores the character array in `string` in the specified `workspace` of the server attached to handle `h`, assigning to it the variable `varname`. The `workspace` argument can be either `base` or `global`.

Remarks

The character array specified in the `string` argument can have any dimensions. However, `PutCharArray` changes the dimensions to a 1–by-n column-wise representation, where n is the number of characters in the array. Executing the following commands in MATLAB illustrates this behavior:

```
h = actxserver('matlab.application');
chArr = ['abc'; 'def'; 'ghk']
chArr =
abc
def
ghk

h.PutCharArray('Foo', 'base', chArr)
tstArr = h.GetCharArray('Foo', 'base')
tstArr =
adgbehcfk
```

Server function names, like PutCharArray, are case sensitive when using the dot notation syntax shown in the Syntax section.

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

Examples

Store string str in the base workspace of the server using PutCharArray.

MATLAB Client

```
h = actxserver('matlab.application');
h.PutCharArray('str', 'base', ...
   'He jests at scars that never felt a wound.')

S = h.GetCharArray('str', 'base')
S =
    He jests at scars that never felt a wound.
```

Visual Basic .NET Client

This example uses the Visual Basic MsgBox command to control flow between MATLAB and the Visual Basic Client.

```
Dim Matlab As Object
Try
    Matlab = GetObject(, "matlab.application")
Catch e As Exception
    Matlab = CreateObject("matlab.application")
End Try
MsgBox("MATLAB window created; now open it...")
```

Open the MATLAB window, then click **Ok**.

```
Matlab.PutCharArray("str", "base", _
       "He jests at scars that never felt a wound.")
MsgBox("In MATLAB, type" & vbCrLf _
  & "str")
```

In the MATLAB window type `str`; MATLAB displays:

```
str =
He jests at scars that never felt a wound.
```

Click **Ok**.

```
MsgBox("closing MATLAB window...")
```

Click **Ok** to close and terminate MATLAB.

```
Matlab.Quit()
```

See Also

`GetCharArray`, `PutWorkspaceData`, `GetWorkspaceData`, `Execute`

Purpose

Store matrix in server

Syntax

MATLAB Client

```
h.PutFullMatrix('varname', 'workspace', xreal, ximag)
PutFullMatrix(h, 'varname', 'workspace', xreal, ximag)
invoke(h, 'PutFullMatrix', 'varname', 'workspace',
xreal, ximag)
```

Method Signature

```
PutFullMatrix([in] BSTR varname, [in] BSTR workspace,
   [in] SAFEARRAY(double) xreal, [in] SAFEARRAY(double) ximag)
```

Microsoft Visual Basic Client

```
PutFullMatrix([in] varname As String, [in] workspace As String,
   [in] xreal As Double, [in] ximag As Double)
```

Description

`PutFullMatrix` stores a matrix in the specified `workspace` of the server attached to handle `h`, assigning to it the variable `varname`. Enter the real and imaginary parts of the matrix in the `xreal` and `ximag` input arguments. The `workspace` argument can be either `base` or `global`.

Remarks

The matrix specified in the `xreal` and `ximag` arguments cannot be scalar, an empty array, or have more than two dimensions.

Server function names, like `PutFullMatrix`, are case sensitive when using the first syntax shown.

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

For VBScript clients, use the `GetWorkspaceData` and `PutWorkspaceData` functions to pass numeric data to and from the MATLAB workspace. These functions use the `variant` data type instead of `safearray` which is not supported by VBScript.

Examples

Writing to the Base Workspace Example

Assign a 5-by-5 real matrix to the variable `M` in the base workspace of the server, and then read it back with `GetFullMatrix`. The real and imaginary parts are passed in through separate arrays of doubles.

MATLAB Client

```
h = actxserver('matlab.application');
h.PutFullMatrix('M', 'base', rand(5), zeros(5))
% One output returns real, use two for real and imag
xreal = h.GetFullMatrix('M', 'base', zeros(5), zeros(5))
xreal =
    0.9501    0.7621    0.6154    0.4057    0.0579
    0.2311    0.4565    0.7919    0.9355    0.3529
    0.6068    0.0185    0.9218    0.9169    0.8132
    0.4860    0.8214    0.7382    0.4103    0.0099
    0.8913    0.4447    0.1763    0.8936    0.1389
```

Visual Basic .NET Client

```
Dim MatLab As Object
Dim XReal(4, 4) As Double
Dim XImag(4, 4) As Double
Dim ZReal(4, 4) As Double
Dim ZImag(4, 4) As Double
Dim i, j As Integer

For i = 0 To 4
   For j = 0 To 4
   XReal(i, j)  = Rnd() * 6
   XImag(i, j) = 0
   Next j
Next i

Matlab = CreateObject("matlab.application")
MatLab.PutFullMatrix("M", "base", XReal, XImag)
MatLab.GetFullMatrix("M", "base", ZReal, ZImag)
```

Writing to the Global Workspace Example

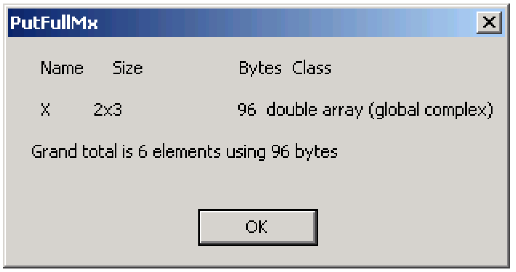
Write a matrix to the global workspace of the server and then examine the server's global workspace from the client.

MATLAB Client

```
h = actxserver('matlab.application');
h.PutFullMatrix('X', 'global', [1 3 5; 2 4 6], ...
                [1 1 1; 1 1 1])
h.invoke('Execute', 'whos global')
ans =
  Name    Size         Bytes  Class
  X       2x3          96  double array (global complex)
Grand total is 6 elements using 96 bytes
```

Visual Basic .NET Client

```
Dim MatLab As Object
Dim XReal(1, 2) As Double
Dim XImag(1, 2) As Double
Dim result As String
Dim i, j As Integer

For i = 0 To 1
 For j = 0 To 2
  XReal(i, j) = (j * 2 + 1) + i
  XImag(i, j) = 1
 Next j
Next i

Matlab = CreateObject("matlab.application")
MatLab.PutFullMatrix("X", "global", XReal, XImag)
result = Matlab.Execute("whos global")
MsgBox(result)
```



See Also

`GetFullMatrix`, `PutWorkspaceData`, `GetWorkspaceDataExecute`

Purpose

Store data in server workspace

Syntax

MATLAB Client

```
h.PutWorkspaceData('varname', 'workspace', data)
PutWorkspaceData(h, 'varname', 'workspace', data)
invoke(h, 'PutWorkspaceData', 'varname', 'workspace', data)
```

Method Signature

```
PutWorkspaceData([in] BSTR varname, [in] BSTR workspace,
[in] VARIANT data)
```

Microsoft Visual Basic Client

```
PutWorkspaceData(varname As String, workspace As String,
data As Object)
```

Description

`PutWorkspaceData` stores `data` in the specified `workspace` of the server attached to handle `h`, assigning to it the variable `varname`. The `workspace` argument can be either `base` or `global`.

Note `PutWorkspaceData` works on all MATLAB types except sparse arrays, structure arrays, and function handles. Use the `Execute` method for these data types.

Passing Character Arrays

MATLAB enables you to define 2-D character arrays such as the following:

```
chArr = ['abc';'def';'ghk']
chArr =
abc
def
ghk

size(chArr)
ans =
     3     3
```

However, PutWorkspaceData does not preserve the dimensions of character arrays when passing them to a COM server. 2-D arrays are converted to 1-by-n arrays of characters, where n equals the number of characters in the original array plus one newline character for each row in the original array. This means that chArr above is converted to a 1-by-12 array, but the newline characters make it display with three rows in the MATLAB command window. For example:

```
h = actxserver('matlab.application');
h.PutWorkspaceData('Foo','base',chArr);
tstArr = h.GetWorkspaceData('Foo','base')
tstArr =
abc
def
ghk

size(tstArr)
ans =
     1    12
```

Remarks

You can use PutWorkspaceData in place of PutFullMatrix and PutCharArray to pass numeric and character array data respectively to the server.

Server function names, like PutWorkspaceData, are case sensitive when using the first syntax shown.

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

The GetWorkspaceData and PutWorkspaceData functions pass numeric data as a variant data type. These functions are especially useful for VBScript clients as VBScript does not support the safearray data type used by GetFullMatrix and PutFullMatrix.

Examples

Create an array in the client and assign it to variable A in the base workspace of the server:

MATLAB Client

```
h = actxserver('matlab.application');
for i = 0:6
   data(i+1)  = i * 15;
end
h.PutWorkspaceData('A', 'base', data)
```

Visual Basic .NET Client

This example uses the Visual Basic `MsgBox` command to control flow between MATLAB and the Visual Basic Client.

```
Dim Matlab As Object
Dim data(6) As Double
Dim i As Integer
MatLab = CreateObject("matlab.application")
For i = 0 To 6
   data(i)  = i * 15
Next i
MatLab.PutWorkspaceData("A", "base", data)
MsgBox("In MATLAB, type" & vbCrLf & "A")
```

Open the MATLAB window and type `A`. MATLAB displays:

```
A =
     0    15    30    45    60    75    90
```

Click **Ok** to close and terminate MATLAB.

See Also

`GetWorkspaceData`, `PutFullMatrix`, `GetFullMatrix`, `PutCharArray`, `GetCharArrayExecute`

See “Introduction” for more examples.

Purpose

Identify current directory

Graphical Interface

As an alternative to the pwd function, you can use the current directory field on the desktop toolbar or the Current Directory browser.

Syntax

```
pwd
s = pwd
```

Description

pwd displays the current working directory.

s = pwd returns the current directory to the variable s.

On Microsoft Windows platforms, to go directly to the current working directory, use

```
winopen(pwd)
```

See Also

cd, dir, fileparts, mfilename, path, what, winopen

"Managing Files and Working with the Current Directory"

Purpose Quasi-minimal residual method

Syntax

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

Description

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

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

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

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

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

`qmr(A,b,tol,maxit,M)` and `qmr(A,b,tol,maxit,M1,M2)` use preconditioners `M` or `M = M1*M2` and effectively solve the system inv(M)*A*x = inv(M)*b for x. If M is [] then qmr applies no preconditioner. M can be a function handle mfun such that mfun(x,'notransp') returns M\x and mfun(x,'transp') returns M'\x.

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

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

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

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

[x,flag,relres] = qmr(A,b,...) also returns the relative residual norm(b-A*x)/norm(b). If flag is 0, relres <= tol.

[x,flag,relres,iter] = qmr(A,b,...) also returns the iteration number at which x was computed, where 0 <= iter <= maxit.

[x,flag,relres,iter,resvec] = qmr(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 = qmr(A,b,tol,maxit,M1,M2);
```

displays the message

```
qmr converged at iteration 9 to a solution...
with relative residual
5.6e-009
```

Example 2

This example replaces the matrix `A` in Example 1 with a handle to a matrix-vector product function `afun`. The example is contained in an M-file `run_qmr` that

- Calls `qmr` with the function handle `@afun` as its first argument.
- Contains `afun` as a nested function, so that all variables in `run_qmr` are available to `afun`.

The following shows the code for `run_qmr`:

```
function x1 = run_qmr
n = 100;
on = ones(n,1);
A = spdiags([-2*on 4*on -on],-1:1,n,n);
b = sum(A,2);
tol = 1e-8;
maxit = 15;
M1 = spdiags([on/(-2) on],-1:0,n,n);
M2 = spdiags([4*on -on],0:1,n,n);
x1 = qmr(@afun,b,tol,maxit,M1,M2);

    function y = afun(x,transp_flag)
       if strcmp(transp_flag,'transp')      % y = A'*x
```

```
            y = 4 * x;
            y(1:n-1) = y(1:n-1) - 2 * x(2:n);
            y(2:n) = y(2:n) - x(1:n-1);
         elseif strcmp(transp_flag,'notransp') % y = A*x
            y = 4 * x;
            y(2:n) = y(2:n) - 2 * x(1:n-1);
            y(1:n-1) = y(1:n-1) - x(2:n);
         end
      end
   end
```

When you enter

```
x1=run_qmr;
```

MATLAB software displays the message

```
qmr converged at iteration 9 to a solution with relative residual
5.6e-009
```

Example 3

```
load west0479;
A = west0479;
b = sum(A,2);
[x,flag] = qmr(A,b)
```

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

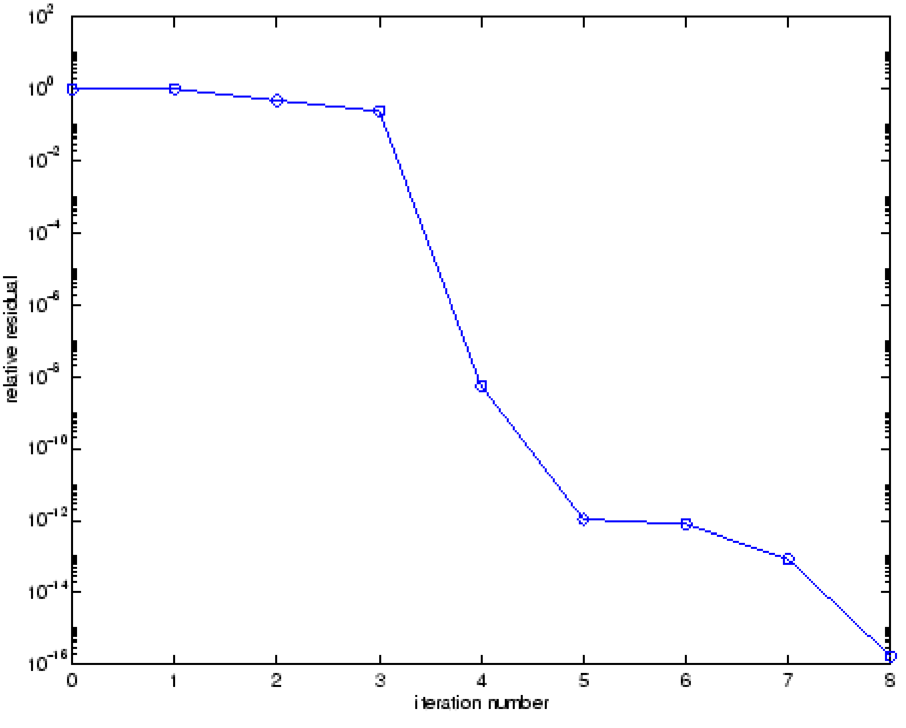
```
[L1,U1] = luinc(A,1e-5);
[x1,flag1] = qmr(A,b,1e-6,20,L1,U1)
```

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

```
[L2,U2] = luinc(A,1e-6);
[x2,flag2,relres2,iter2,resvec2] = qmr(A,b,1e-15,10,L2,U2)
```

`flag2` is `0` because `qmr` converges to the tolerance of `1.6571e-016` (the value of `relres2`) at the eighth iteration (the value of `iter2`) when preconditioned by the incomplete LU factorization with a drop tolerance of `1e-6`. `resvec2(1) = norm(b)` and `resvec2(9) = norm(b-A*x2)`. You can follow the progress of `qmr` by plotting the relative residuals at each iteration starting from the initial estimate (iterate number `0`).

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



See Also

`bicg`, `bicgstab`, `cgs`, `gmres`, `lsqr`, `luinc`, `minres`, `pcg`, `symmlq`, `function_handle` (`@`), `mldivide` (`\`)

References

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

[2] Freund, Roland W. and Nöel M. Nachtigal, “QMR: A quasi-minimal residual method for non-Hermitian linear systems,” *SIAM Journal: Numer. Math.* 60, 1991, pp. 315-339.

Purpose

Orthogonal-triangular decomposition

Syntax

```
[Q,R] = qr(A)        (full and sparse matrices)
[Q,R] = qr(A,0)      (full and sparse matrices)
[Q,R,E] = qr(A)      (full matrices)
[Q,R,E] = qr(A,0)    (full matrices)
X = qr(A)            (full matrices)
R = qr(A)            (sparse matrices)
[C,R] = qr(A,B)      (sparse matrices)
R = qr(A,0)          (sparse matrices)
[C,R] = qr(A,B,0)    (sparse matrices)
```

Description

The `qr` function performs the orthogonal-triangular decomposition of a matrix. This factorization is useful for both square and rectangular matrices. It expresses the matrix as the product of a real complex unitary matrix and an upper triangular matrix.

`[Q,R] = qr(A)` produces an upper triangular matrix `R` of the same dimension as `A` and a unitary matrix `Q` so that `A = Q*R`. For sparse matrices, `Q` is often nearly full. If `[m n] = size(A)`, then `Q` is `m`-by-`m` and `R` is `m`-by-`n`.

`[Q,R] = qr(A,0)` produces an "economy-size" decomposition. If `[m n] = size(A)`, and `m > n`, then `qr` computes only the first `n` columns of `Q` and `R` is `n`-by-`n`. If `m <= n`, it is the same as `[Q,R] = qr(A)`.

`[Q,R,E] = qr(A)` for full matrix `A`, produces a permutation matrix `E`, an upper triangular matrix `R` with decreasing diagonal elements, and a unitary matrix `Q` so that `A*E = Q*R`. The column permutation `E` is chosen so that `abs(diag(R))` is decreasing.

`[Q,R,E] = qr(A,0)` for full matrix `A`, produces an "economy-size" decomposition in which `E` is a permutation vector, so that `A(:,E) = Q*R`. The column permutation `E` is chosen so that `abs(diag(R))` is decreasing.

`X = qr(A)` for full matrix `A`, returns the output of the LAPACK subroutine `DGEQRF` or `ZGEQRF`. `triu(qr(A))` is `R`.

`R = qr(A)` for sparse matrix `A`, produces only an upper triangular matrix, `R`. The matrix `R` provides a Cholesky factorization for the matrix associated with the normal equations,

```
R'*R = A'*A
```

This approach avoids the loss of numerical information inherent in the computation of `A'*A`. It may be preferred to `[Q,R] = qr(A)` since `Q` is always nearly full.

`[C,R] = qr(A,B)` for sparse matrix `A`, applies the orthogonal transformations to `B`, producing `C = Q'*B` without computing `Q`. `B` and `A` must have the same number of rows.

`R = qr(A,0)` and `[C,R] = qr(A,B,0)` for sparse matrix `A`, produce "economy-size" results.

For sparse matrices, the Q-less QR factorization allows the solution of sparse least squares problems

$$\text{minimize}\|Ax - b\|$$

with two steps

```
[C,R] = qr(A,b)
x = R\C
```

If `A` is sparse but not square, MATLAB software uses the two steps above for the linear equation solving backslash operator, i.e., `x = A\b`.

Examples

Example 1

Start with

```
A = [ 1     2     3
      4     5     6
      7     8     9
     10    11    12 ]
```

This is a rank-deficient matrix; the middle column is the average of the other two columns. The rank deficiency is revealed by the factorization:

```
[Q,R] = qr(A)

Q =

   -0.0776    -0.8331     0.5444     0.0605
   -0.3105    -0.4512    -0.7709     0.3251
   -0.5433    -0.0694    -0.0913    -0.8317
   -0.7762     0.3124     0.3178     0.4461

R =

   -12.8841    -14.5916    -16.2992
          0     -1.0413     -2.0826
          0           0      0.0000
          0           0           0
```

The triangular structure of R gives it zeros below the diagonal; the zero on the diagonal in R(3,3) implies that R, and consequently A, does not have full rank.

Example 2

This examples uses matrix A from the first example. The QR factorization is used to solve linear systems with more equations than unknowns. For example, let

```
b = [1;3;5;7]
```

The linear system $Ax = b$ represents four equations in only three unknowns. The best solution in a least squares sense is computed by

```
x = A\b
```

which produces

```
Warning: Rank deficient, rank = 2, tol = 1.4594E-014
```

```
x =
    0.5000
         0
    0.1667
```

The quantity `tol` is a tolerance used to decide if a diagonal element of `R` is negligible. If `[Q,R,E] = qr(A)`, then

```
tol = max(size(A))*eps*abs(R(1,1))
```

The solution `x` was computed using the factorization and the two steps

```
y = Q'*b;
x = R\y
```

The computed solution can be checked by forming Ax. This equals b to within roundoff error, which indicates that even though the simultaneous equations $Ax = b$ are overdetermined and rank deficient, they happen to be consistent. There are infinitely many solution vectors `x`; the QR factorization has found just one of them.

Algorithm

Inputs of Type Double

For inputs of type `double`, `qr` uses the LAPACK routines listed in the following table to compute the QR decomposition.

Syntax	Real	Complex
`X = qr(A)` `X = qr(A,0)`	DGEQRF	ZGEQRF
`[Q,R] = qr(A)` `[Q,R] = qr(A,0)`	DGEQRF, DORGQR	ZGEQRF, ZUNGQR
`[Q,R,e] = qr(A)` `[Q,R,e] = qr(A,0)`	DGEQP3, DORGQR	ZGEQP3, ZUNGQR

Inputs of Type Single

For inputs of type `single`, `qr` uses the LAPACK routines listed in the following table to compute the QR decomposition.

Syntax	Real	Complex
`R = qr(A)` `R = qr(A,0)`	SGEQRF	CGEQRF
`[Q,R] = qr(A)` `[Q,R] = qr(A,0)`	SGEQRF, SORGQR	CGEQRF, CUNGQR
`[Q,R,e] = qr(A)` `[Q,R,e] = qr(A,0)`	SGEQP3, SORGQR	CGEQP3, CUNGQR

See Also

`lu`, `null`, `orth`, `qrdelete`, `qrinsert`, `qrupdate`

The arithmetic operators `\` and `/`

References

[1] Anderson, E., Z. Bai, C. Bischof, S. Blackford, J. Demmel, J. Dongarra, J. Du Croz, A. Greenbaum, S. Hammarling, A. McKenney, and D. Sorensen, *LAPACK User's Guide* (`http://www.netlib.org/lapack/lug/lapack_lug.html`), Third Edition, SIAM, Philadelphia, 1999.

qrdelete

Purpose

Remove column or row from QR factorization

Syntax

```
[Q1,R1] = qrdelete(Q,R,j)
[Q1,R1] = qrdelete(Q,R,j,'col')
[Q1,R1] = qrdelete(Q,R,j,'row')
```

Description

`[Q1,R1] = qrdelete(Q,R,j)` returns the QR factorization of the matrix `A1`, where `A1` is `A` with the column `A(:,j)` removed and `[Q,R] = qr(A)` is the QR factorization of `A`.

`[Q1,R1] = qrdelete(Q,R,j,'col')` is the same as `qrdelete(Q,R,j)`.

`[Q1,R1] = qrdelete(Q,R,j,'row')` returns the QR factorization of the matrix `A1`, where `A1` is `A` with the row `A(j,:)` removed and `[Q,R] = qr(A)` is the QR factorization of `A`.

Examples

```
A = magic(5);
[Q,R] = qr(A);
j = 3;
[Q1,R1] = qrdelete(Q,R,j,'row');

Q1 =
    0.5274   -0.5197   -0.6697   -0.0578
    0.7135    0.6911    0.0158    0.1142
    0.3102   -0.1982    0.4675   -0.8037
    0.3413   -0.4616    0.5768    0.5811

R1 =
   32.2335   26.0908   19.9482   21.4063   23.3297
         0  -19.7045  -10.9891    0.4318   -1.4873
         0         0   22.7444    5.8357   -3.1977
         0         0         0  -14.5784    3.7796
```

returns a valid QR factorization, although possibly different from

```
A2 = A;
A2(j,:) = [];
[Q2,R2] = qr(A2)
```

```
Q2 =
   -0.5274    0.5197    0.6697   -0.0578
   -0.7135   -0.6911   -0.0158    0.1142
   -0.3102    0.1982   -0.4675   -0.8037
   -0.3413    0.4616   -0.5768    0.5811

R2 =
  -32.2335  -26.0908  -19.9482  -21.4063  -23.3297
         0   19.7045   10.9891   -0.4318    1.4873
         0         0  -22.7444   -5.8357    3.1977
         0         0         0  -14.5784    3.7796
```

Algorithm

The `qrdelete` function uses a series of Givens rotations to zero out the appropriate elements of the factorization.

See Also

`planerot`, `qr`, `qrinsert`

qrinsert

Purpose

Insert column or row into QR factorization

Syntax

```
[Q1,R1] = qrinsert(Q,R,j,x)
[Q1,R1] = qrinsert(Q,R,j,x,'col')
[Q1,R1] = qrinsert(Q,R,j,x,'row')
```

Description

`[Q1,R1] = qrinsert(Q,R,j,x)` returns the QR factorization of the matrix `A1`, where `A1` is `A = Q*R` with the column `x` inserted before `A(:,j)`. If `A` has `n` columns and `j = n+1`, then `x` is inserted after the last column of `A`.

`[Q1,R1] = qrinsert(Q,R,j,x,'col')` is the same as `qrinsert(Q,R,j,x)`.

`[Q1,R1] = qrinsert(Q,R,j,x,'row')` returns the QR factorization of the matrix `A1`, where `A1` is `A = Q*R` with an extra row, `x`, inserted before `A(j,:)`.

Examples

```
A = magic(5);
[Q,R] = qr(A);
j = 3;
x = 1:5;
[Q1,R1] = qrinsert(Q,R,j,x,'row')

Q1 =
    0.5231    0.5039   -0.6750    0.1205    0.0411    0.0225
    0.7078   -0.6966    0.0190   -0.0788    0.0833   -0.0150
    0.0308    0.0592    0.0656    0.1169    0.1527   -0.9769
    0.1231    0.1363    0.3542    0.6222    0.6398    0.2104
    0.3077    0.1902    0.4100    0.4161   -0.7264   -0.0150
    0.3385    0.4500    0.4961   -0.6366    0.1761    0.0225

R1 =
   32.4962   26.6801   21.4795   23.8182   26.0031
         0   19.9292   12.4403    2.1340    4.3271
         0         0   24.4514   11.8132    3.9931
         0         0         0   20.2382   10.3392
```

```
         0         0         0         0   16.1948
         0         0         0         0         0
```

returns a valid QR factorization, although possibly different from

```
A2 = [A(1:j-1,:); x; A(j:end,:)];
[Q2,R2] = qr(A2)

Q2 =
   -0.5231    0.5039    0.6750   -0.1205    0.0411    0.0225
   -0.7078   -0.6966   -0.0190    0.0788    0.0833   -0.0150
   -0.0308    0.0592   -0.0656   -0.1169    0.1527   -0.9769
   -0.1231    0.1363   -0.3542   -0.6222    0.6398    0.2104
   -0.3077    0.1902   -0.4100   -0.4161   -0.7264   -0.0150
   -0.3385    0.4500   -0.4961    0.6366    0.1761    0.0225

R2 =
  -32.4962  -26.6801  -21.4795  -23.8182  -26.0031
         0   19.9292   12.4403    2.1340    4.3271
         0         0  -24.4514  -11.8132   -3.9931
         0         0         0  -20.2382  -10.3392
         0         0         0         0   16.1948
         0         0         0         0         0
```

Algorithm

The `qrinsert` function inserts the values of `x` into the `j`th column (row) of `R`. It then uses a series of Givens rotations to zero out the nonzero elements of `R` on and below the diagonal in the `j`th column (row).

See Also

`planerot`, `qr`, `qrdelete`

qrupdate

Description

Rank 1 update to QR factorization

Syntax

`[Q1,R1] = qrupdate(Q,R,u,v)`

Description

`[Q1,R1] = qrupdate(Q,R,u,v)` when `[Q,R] = qr(A)` is the original QR factorization of `A`, returns the QR factorization of `A + u*v'`, where `u` and `v` are column vectors of appropriate lengths.

Remarks

`qrupdate` works only for full matrices.

Examples

The matrix

```
mu = sqrt(eps)

mu =

   1.4901e-08

A = [ones(1,4); mu*eye(4)];
```

is a well-known example in least squares that indicates the dangers of forming `A'*A`. Instead, we work with the QR factorization – orthonormal Q and upper triangular R.

```
 [Q,R] = qr(A);
```

As we expect, `R` is upper triangular.

```
R =

   -1.0000   -1.0000   -1.0000   -1.0000
         0    0.0000    0.0000    0.0000
         0         0    0.0000    0.0000
         0         0         0    0.0000
         0         0         0         0
```

In this case, the upper triangular entries of R, excluding the first row, are on the order of sqrt(eps).

Consider the update vectors

```
u = [-1 0 0 0 0]'; v = ones(4,1);
```

Instead of computing the rather trivial QR factorization of this rank one update to A from scratch with

```
[QT,RT] = qr(A + u*v')

QT =

     0     0     0     0     1
    -1     0     0     0     0
     0    -1     0     0     0
     0     0    -1     0     0
     0     0     0    -1     0

RT =

   1.0e-007 *

   -0.1490         0         0         0
         0   -0.1490         0         0
         0         0   -0.1490         0
         0         0         0   -0.1490
         0         0         0         0
```

we may use qrupdate.

```
[Q1,R1] = qrupdate(Q,R,u,v)

Q1 =

   -0.0000   -0.0000   -0.0000   -0.0000    1.0000
    1.0000   -0.0000   -0.0000   -0.0000    0.0000
```

```
      0.0000    1.0000   -0.0000   -0.0000    0.0000
      0.0000    0.0000    1.0000   -0.0000    0.0000
     -0.0000   -0.0000   -0.0000    1.0000    0.0000

R1 =

     1.0e-007 *
      0.1490    0.0000    0.0000    0.0000
           0    0.1490    0.0000    0.0000
           0         0    0.1490    0.0000
           0         0         0    0.1490
           0         0         0         0
```

Note that both factorizations are correct, even though they are different.

Algorithm

`qrupdate` uses the algorithm in section 12.5.1 of the third edition of *Matrix Computations* by Golub and van Loan. `qrupdate` is useful since, if we take `N = max(m,n)`, then computing the new QR factorization from scratch is roughly an $O(N^3)$ algorithm, while simply updating the existing factors in this way is an $O(N^2)$ algorithm.

References

[1] Golub, Gene H. and Charles Van Loan, *Matrix Computations*, Third Edition, Johns Hopkins University Press, Baltimore, 1996

See Also

`cholupdate`, `qr`

Purpose

Numerically evaluate integral, adaptive Simpson quadrature

Syntax

```
q = quad(fun,a,b)
q = quad(fun,a,b,tol)
q = quad(fun,a,b,tol,trace)
[q,fcnt] = quad(...)
```

Description

Quadrature is a numerical method used to find the area under the graph of a function, that is, to compute a definite integral.

$$q = \int_a^b f(x)dx$$

`q = quad(fun,a,b)` tries to approximate the integral of function `fun` from `a` to `b` to within an error of `1e-6` using recursive adaptive Simpson quadrature. `fun` is a function handle. See "Function Handles" in the MATLAB Programming documentation for more information. Limits `a` and `b` must be finite. The function `y = fun(x)` should accept a vector argument `x` and return a vector result `y`, the integrand evaluated at each element of `x`.

"Parametrizing Functions", in the MATLAB Mathematics documentation, explains how to provide additional parameters to the function `fun`, if necessary.

`q = quad(fun,a,b,tol)` uses an absolute error tolerance `tol` instead of the default which is `1.0e-6`. Larger values of `tol` result in fewer function evaluations and faster computation, but less accurate results. In MATLAB version 5.3 and earlier, the `quad` function used a less reliable algorithm and a default relative tolerance of `1.0e-3`.

`q = quad(fun,a,b,tol,trace)` with non-zero `trace` shows the values of `[fcnt a b-a Q]` during the recursion.

`[q,fcnt] = quad(...)` returns the number of function evaluations.

The function `quadl` may be more efficient with high accuracies and smooth integrands.

The list below contains information to help you determine which quadrature function in MATLAB to use:

- The quad function may be most efficient for low accuracies with nonsmooth integrands.
- The quadl function may be more efficient than quad at higher accuracies with smooth integrands.
- The quadgk function may be most efficient for high accuracies and oscillatory integrands. It supports infinite intervals and can handle moderate singularities at the endpoints. It also supports contour integration along piecewise linear paths.
- The quadv function vectorizes quad for an array-valued fun.
- If the interval is infinite, [a,Inf), then for the integral of fun(x) to exist, fun(x) must decay as x approaches infinity, and quadgk requires it to decay rapidly. Special methods should be used for oscillatory functions on infinite intervals, but quadgk can be used if fun(x) decays fast enough.
- The quadgk function will integrate functions that are singular at finite endpoints if the singularities are not too strong. For example, it will integrate functions that behave at an endpoint c like log|x-c| or $|x-c|^p$ for p >= -1/2. If the function is singular at points inside (a,b), write the integral as a sum of integrals over subintervals with the singular points as endpoints, compute them with quadgk, and add the results.

Example

To compute the integral

$$\int_0^2 \frac{1}{x^3 - 2x - 5}\,dx$$

write an M-file function myfun that computes the integrand:

```
function y = myfun(x)
y = 1./(x.^3-2*x-5);
```

Then pass `@myfun`, a function handle to `myfun`, to `quad`, along with the limits of integration, `0` to `2`:

```
Q = quad(@myfun,0,2)

Q =

   -0.4605
```

Alternatively, you can pass the integrand to `quad` as an anonymous function handle `F`:

```
F = @(x)1./(x.^3-2*x-5);
Q = quad(F,0,2);
```

Algorithm

`quad` implements a low order method using an adaptive recursive Simpson's rule.

Diagnostics

`quad` may issue one of the following warnings:

`'Minimum step size reached'` indicates that the recursive interval subdivision has produced a subinterval whose length is on the order of roundoff error in the length of the original interval. A nonintegrable singularity is possible.

`'Maximum function count exceeded'` indicates that the integrand has been evaluated more than 10,000 times. A nonintegrable singularity is likely.

`'Infinite or Not-a-Number function value encountered'` indicates a floating point overflow or division by zero during the evaluation of the integrand in the interior of the interval.

See Also

`dblquad`, `quadgk`, `quadl`, `quadv`, `trapz`, `triplequad`, `function_handle` (`@`), "Anonymous Functions"

References

[1] Gander, W. and W. Gautschi, "Adaptive Quadrature – Revisited," BIT, Vol. 40, 2000, pp. 84-101. This document is also available at `http://www.inf.ethz.ch/personal/gander`.

quadgk

Purpose Numerically evaluate integral, adaptive Gauss-Kronrod quadrature

Syntax

```
q = quadgk(fun,a,b)
[q,errbnd] = quadgk(fun,a,b,tol)
[q,errbnd] = quadgk(fun,a,b,param1,val1,param2,val2,...)
```

Description

`q = quadgk(fun,a,b)` attempts to approximate the integral of a scalar-valued function `fun` from `a` to `b` using high-order global adaptive quadrature and default error tolerances. The function `y = fun(x)` should accept a vector argument `x` and return a vector result `y`. The integrand evaluated at each element of `x`. `fun` must be a function handle. See "Function Handles" in the MATLAB Programming documentation for more information. Limits `a` and `b` can be `-Inf` or `Inf`. If both are finite, they can be complex. If at least one is complex, the integral is approximated over a straight line path from `a` to `b` in the complex plane.

, in the MATLAB Mathematics documentation, explains how to provide additional parameters to the function `fun`, if necessary.

`[q,errbnd] = quadgk(fun,a,b,tol)` returns an approximate bound on the absolute error, `|Q - I|`, where `I` denotes the exact value of the integral.

`[q,errbnd] = quadgk(fun,a,b,param1,val1,param2,val2,...)` performs the integration with specified values of optional parameters. The available parameters are

<table>
<tr><th>Parameter</th><th>Description</th><th></th></tr>
<tr><td>'AbsTol'</td><td>Absolute error tolerance.

The default value of 'AbsTol' is 1.e-10 (double), 1.e-5 (single).</td><td rowspan="2">quadgk attempts to satisfy errbnd <= max(AbsTol,RelTol*|Q|) This is absolute error control when |Q| is sufficiently small and relative error control when |Q| is larger. For pure absolute error control use 'AbsTol' > 0 and'RelTol'= 0. For pure relative error control use 'AbsTol' = 0. Except when using pure absolute error control, the minimum relative tolerance is 'RelTol' >= 100*eps(class(Q)).</td></tr>
<tr><td>'RelTol'</td><td>Relative error tolerance.

The default value of 'RelTol' is 1.e-6 (double), 1.e-4 (single).</td></tr>
</table>

Parameter	Description	
'Waypoints'	Vector of integration waypoints.	If fun(x) has discontinuities in the interval of integration, the locations should be supplied as a 'Waypoints' vector. When a, b, and the waypoints are all real, the waypoints must be supplied in strictly increasing or strictly decreasing order, and only the waypoints between a and b are used. Waypoints are not intended for singularities in fun(x). Singular points should be handled by making them endpoints of separate integrations and adding the results. If a, b, or any entry of the waypoints vector is complex, the integration is performed over a sequence of straight line paths in the complex plane, from a to the first waypoint, from the first waypoint to the second, and so forth, and finally from the last waypoint to b.
'MaxIntervalCount'	Maximum number of intervals allowed. The default value is 650.	The 'MaxIntervalCount' parameter limits the number of intervals that quadgk uses at any one time after the first iteration. A warning is issued if quadgk returns early because

The list below contains information to help you determine which quadrature function in MATLAB to use:

- The quad function may be most efficient for low accuracies with nonsmooth integrands.
- The quadl function may be more efficient than quad at higher accuracies with smooth integrands.
- The quadgk function may be most efficient for high accuracies and oscillatory integrands. It supports infinite intervals and can handle moderate singularities at the endpoints. It also supports contour integration along piecewise linear paths.
- The quadv function vectorizes quad for an array-valued fun.
- If the interval is infinite, [a,Inf), then for the integral of fun(x) to exist, fun(x) must decay as x approaches infinity, and quadgk requires it to decay rapidly. Special methods should be used for oscillatory functions on infinite intervals, but quadgk can be used if fun(x) decays fast enough.
- The quadgk function will integrate functions that are singular at finite endpoints if the singularities are not too strong. For example, it will integrate functions that behave at an endpoint c like log|x-c| or $|x-c|^p$ for p >= -1/2. If the function is singular at points inside (a,b), write the integral as a sum of integrals over subintervals with the singular points as endpoints, compute them with quadgk, and add the results.

Examples

Integrand with a singularity at an integration end point

Write an M-file function myfun that computes the integrand:

```
function y = myfun(x)
y = exp(x).*log(x);
```

Then pass @myfun, a function handle to myfun, to quadgk, along with the limits of integration, 0 to 1:

```
Q = quadgk(@myfun,0,1)

Q =

   -1.3179
```

Alternatively, you can pass the integrand to `quadgk` as an anonymous function handle `F`:

```
F = (@(x)exp(x).*log(x));
Q = quadgk(F,0,1);
```

Oscillatory integrand on a semi-infinite interval

Integrate over a semi-infinite interval with specified tolerances, and return the approximate error bound:

```
[q,errbnd] = quadgk(@(x)x.^5.*exp(-x).*sin(x),0,inf,'RelTol',1e-8,'Abs

q =

  -15.0000


errbnd =

  9.4386e-009
```

Contour integration around a pole

Use `Waypoints` to integrate around a pole using a piecewise linear contour:

```
Q = quadgk(@(z)1./(2*z - 1),-1-i,-1-i,'Waypoints',[1-i,1+i,-1+i])

Q =

   0.0000 + 3.1416i
```

Algorithm

quadgk implements adaptive quadrature based on a Gauss-Kronrod pair (15^{th} and 7^{th} order formulas).

Diagnostics

quadgk may issue one of the following warnings:

'Minimum step size reached' indicates that interval subdivision has produced a subinterval whose length is on the order of roundoff error in the length of the original interval. A nonintegrable singularity is possible.

'Reached the limit on the maximum number of intervals in use' indicates that the integration was terminated before meeting the tolerance requirements and that continuing the integration would require more than MaxIntervalCount subintervals. The integral may not exist, or it may be difficult to approximate numerically. Increasing MaxIntervalCount usually does not help unless the tolerance requirements were nearly met when the integration was previously terminated.

'Infinite or Not-a-Number function value encountered' indicates a floating point overflow or division by zero during the evaluation of the integrand in the interior of the interval.

References

[1] L.F. Shampine "Vectorized Adaptive Quadrature in MATLAB," *Journal of Computational and Applied Mathematics*, 211, 2008, pp.131–140.

See Also

dblquad, quadquadl, quadv, triplequad, function_handle (@), "Anonymous Functions"

Purpose

Numerically evaluate integral, adaptive Lobatto quadrature

Syntax

```
q = quadl(fun,a,b)
q = quadl(fun,a,b,tol)
quadl(fun,a,b,tol,trace)
[q,fcnt] = quadl(...)
```

Description

`q = quadl(fun,a,b)` approximates the integral of function `fun` from `a` to `b`, to within an error of 10^{-6} using recursive adaptive Lobatto quadrature. `fun` is a function handle. See "Function Handles" in the MATLAB Programming documentation for more information. `fun` accepts a vector `x` and returns a vector `y`, the function `fun` evaluated at each element of `x`. Limits `a` and `b` must be finite.

"Parametrizing Functions", in the MATLAB Mathematics documentation, explains how to provide additional parameters to the function `fun`, if necessary.

`q = quadl(fun,a,b,tol)` uses an absolute error tolerance of `tol` instead of the default, which is `1.0e-6`. Larger values of `tol` result in fewer function evaluations and faster computation, but less accurate results.

`quadl(fun,a,b,tol,trace)` with non-zero `trace` shows the values of `[fcnt a b-a q]` during the recursion.

`[q,fcnt] = quadl(...)` returns the number of function evaluations.

Use array operators `.*`, `./` and `.^` in the definition of `fun` so that it can be evaluated with a vector argument.

The function `quad` may be more efficient with low accuracies or nonsmooth integrands.

The list below contains information to help you determine which quadrature function in `MATLAB` to use:

- The `quad` function may be most efficient for low accuracies with nonsmooth integrands.

- The `quadl` function may be more efficient than `quad` at higher accuracies with smooth integrands.
- The `quadgk` function may be most efficient for high accuracies and oscillatory integrands. It supports infinite intervals and can handle moderate singularities at the endpoints. It also supports contour integration along piecewise linear paths.
- The `quadv` function vectorizes `quad` for an array-valued `fun`.
- If the interval is infinite, `[a,Inf)`, then for the integral of `fun(x)` to exist, `fun(x)` must decay as `x` approaches infinity, and `quadgk` requires it to decay rapidly. Special methods should be used for oscillatory functions on infinite intervals, but `quadgk` can be used if `fun(x)` decays fast enough.
- The `quadgk` function will integrate functions that are singular at finite endpoints if the singularities are not too strong. For example, it will integrate functions that behave at an endpoint `c` like `log|x-c|` or $|x-c|^p$ for `p >= -1/2`. If the function is singular at points inside `(a,b)`, write the integral as a sum of integrals over subintervals with the singular points as endpoints, compute them with `quadgk`, and add the results.

Examples

Pass M-file function handle `@myfun` to `quadl`:

```
Q = quadl(@myfun,0,2);
```

where the M-file `myfun.m` is

```
function y = myfun(x)
y = 1./(x.^3-2*x-5);
```

Pass anonymous function handle `F` to `quadl`:

```
F = @(x) 1./(x.^3-2*x-5);
Q = quadl(F,0,2);
```

Algorithm

`quadl` implements a high order method using an adaptive Gauss/Lobatto quadrature rule.

Diagnostics

`quadl` may issue one of the following warnings:

`'Minimum step size reached'` indicates that the recursive interval subdivision has produced a subinterval whose length is on the order of roundoff error in the length of the original interval. A nonintegrable singularity is possible.

`'Maximum function count exceeded'` indicates that the integrand has been evaluated more than 10,000 times. A nonintegrable singularity is likely.

`'Infinite or Not-a-Number function value encountered'` indicates a floating point overflow or division by zero during the evaluation of the integrand in the interior of the interval.

See Also

`dblquad`, `quad`, `quadgk`, `triplequad`, `function_handle` (`@`), "Anonymous Functions"

References

[1] Gander, W. and W. Gautschi, "Adaptive Quadrature – Revisited," BIT, Vol. 40, 2000, pp. 84-101. This document is also available at `http://www.inf.ethz.ch/personal/gander`.

Purpose

Vectorized quadrature

Syntax

```
Q = quadv(fun,a,b)
Q = quadv(fun,a,b,tol)
Q = quadv(fun,a,b,tol,trace)
[Q,fcnt] = quadv(...)
```

Description

`Q = quadv(fun,a,b)` approximates the integral of the complex array-valued function `fun` from `a` to `b` to within an error of `1.e-6` using recursive adaptive Simpson quadrature. `fun` is a function handle. See "Function Handles" in the MATLAB Programming documentation for more information. The function `Y = fun(x)` should accept a scalar argument `x` and return an array result `Y`, whose components are the integrands evaluated at `x`. Limits `a` and `b` must be finite.

"Parametrizing Functions", in the MATLAB Mathematics documentation, explains how to provide addition parameters to the function `fun`, if necessary.

`Q = quadv(fun,a,b,tol)` uses the absolute error tolerance `tol` for all the integrals instead of the default, which is `1.e-6`.

Note The same tolerance is used for all components, so the results obtained with `quadv` are usually not the same as those obtained with `quad` on the individual components.

`Q = quadv(fun,a,b,tol,trace)` with non-zero `trace` shows the values of `[fcnt a b-a Q(1)]` during the recursion.

`[Q,fcnt] = quadv(...)` returns the number of function evaluations.

The list below contains information to help you determine which quadrature function in `MATLAB` to use:

- The `quad` function may be most efficient for low accuracies with nonsmooth integrands.

- The `quadl` function may be more efficient than `quad` at higher accuracies with smooth integrands.
- The `quadgk` function may be most efficient for high accuracies and oscillatory integrands. It supports infinite intervals and can handle moderate singularities at the endpoints. It also supports contour integration along piecewise linear paths.
- The `quadv` function vectorizes `quad` for an array-valued `fun`.
- If the interval is infinite, `[a,Inf)`, then for the integral of `fun(x)` to exist, `fun(x)` must decay as `x` approaches infinity, and `quadgk` requires it to decay rapidly. Special methods should be used for oscillatory functions on infinite intervals, but `quadgk` can be used if `fun(x)` decays fast enough.
- The `quadgk` function will integrate functions that are singular at finite endpoints if the singularities are not too strong. For example, it will integrate functions that behave at an endpoint `c` like `log|x-c|` or $|x-c|^p$ for `p >= -1/2`. If the function is singular at points inside `(a,b)`, write the integral as a sum of integrals over subintervals with the singular points as endpoints, compute them with `quadgk`, and add the results.

Example

For the parameterized array-valued function `myarrayfun`, defined by

```
function Y = myarrayfun(x,n)
Y = 1./((1:n)+x);
```

the following command integrates `myarrayfun`, for the parameter value n = 10 between a = 0 and b = 1:

```
Qv = quadv(@(x)myarrayfun(x,10),0,1);
```

The resulting array `Qv` has 10 elements estimating `Q(k) = log((k+1)./(k))`, for `k = 1:10`.

The entries in `Qv` are slightly different than if you compute the integrals using `quad` in a loop:

```
for k = 1:10
 Qs(k) = quadv(@(x)myscalarfun(x,k),0,1);
end
```

where myscalarfun is:

```
function y = myscalarfun(x,k)
y = 1./(k+x);
```

See Also

quad, quadgk, quadl, dblquad, triplequad, function_handle (@)

Purpose

Create and open question dialog box

Syntax

```
button = questdlg('qstring')
button = questdlg('qstring','title')
button = questdlg('qstring','title','default')
button = questdlg('qstring','title','str1','str2','default')
button =  questdlg('qstring','title','str1','str2','str3',
   'default')
```

Description

`button = questdlg('qstring')` displays a modal dialog box presenting the question `'qstring'`. The dialog has three default buttons, **Yes**, **No**, and **Cancel**. If the user presses one of these three buttons, `button` is set to the name of the button pressed. If the user presses the close button on the dialog, `button` is set to the empty string. If the user presses the **Return** key, button is set to `'Yes'`. `'qstring'` is a cell array or a string that automatically wraps to fit within the dialog box.

Note A modal dialog box prevents the user from interacting with other windows before responding. For more information, see `WindowStyle` in the MATLAB Figure Properties.

`button = questdlg('qstring','title')` displays a question dialog with `'title'` displayed in the dialog's title bar.

`button = questdlg('qstring','title','default')` specifies which push button is the default in the event that the **Return** key is pressed. `'default'` must be `'Yes'`, `'No'`, or `'Cancel'`.

`button = questdlg('qstring','title','str1','str2','default')` creates a question dialog box with two push buttons labeled `'str1'` and `'str2'`. `'default'` specifies the default button selection and must be `'str1'` or `'str2'`.

`button = questdlg('qstring','title','str1','str2','str3','default')` creates a question dialog box with three push buttons labeled `'str1'`, `'str2'`, and `'str3'`. `'default'` specifies the default button selection and must be `'str1'`, `'str2'`, or `'str3'`.

In all cases where `'default'` is specified, if `'default'` is not set to one of the button names, pressing the **Enter** key displays a warning and the dialog remains open.

See Also

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

`figure`, `textwrap`, `uiwait`, `uiresume`

"Predefined Dialog Boxes" on page 1-108 for related functions

Purpose

Terminate MATLAB program

GUI Alternatives

As an alternative to the quit function, use the Close box or select **File > Exit MATLAB** in the MATLAB desktop.

Syntax

```
quit
quit cancel
quit force
```

Description

`quit` displays a confirmation dialog box if the confirm upon quitting preference is selected, and if confirmed or if the confirmation preference is not selected, terminates MATLAB after running `finish.m`, if `finish.m` exists. The workspace is not automatically saved by `quit`. To save the workspace or perform other actions when quitting, create a `finish.m` file to perform those actions. For example, you can display a custom dialog box to confirm quitting using a `finish.m` file—see the following examples for details. If an error occurs while `finish.m` is running, `quit` is canceled so that you can correct your `finish.m` file without losing your workspace.

`quit cancel` is for use in `finish.m` and cancels quitting. It has no effect anywhere else.

`quit force` bypasses `finish.m` and terminates MATLAB. Use this to override `finish.m`, for example, if an errant `finish.m` will not let you quit.

Remarks

When using Handle Graphics objects in `finish.m`, use `uiwait`, `waitfor`, or `drawnow` so that figures are visible. See the reference pages for these functions for more information.

If you want MATLAB to display the following confirmation dialog box after running quit, select **File > Preferences > General > Confirmation Dialogs**. Then select the check box for Confirm before exiting MATLAB, and click **OK**.

Examples

Two sample `finish.m` files are included with MATLAB. Use them to help you create your own `finish.m`, or rename one of the files to `finish.m` to use it.

- `finishsav.m`—Saves the workspace to a MAT-file when MATLAB quits.
- `finishdlg.m`—Displays a dialog allowing you to cancel quitting; it uses `quit cancel` and contains the following code:

```
button = questdlg('Ready to quit?', ...
        'Exit Dialog','Yes','No','No');
switch button
            case 'Yes',
              disp('Exiting MATLAB');
              %Save variables to matlab.mat
              save
            case 'No',
              quit cancel;
end
```

See Also

`exit`, `finish`, `save`, `startup`

Quit (COM)

Purpose Terminate MATLAB server

Syntax

MATLAB Client

```
h.Quit
Quit(h)
invoke(h, 'Quit')
```

Method Signature

```
void Quit(void)
```

Microsoft Visual Basic Client

```
Quit
```

Description `Quit` terminates the MATLAB server session attached to handle `h`.

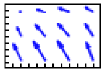
Remarks Server function names, like `Quit`, are case sensitive when using the first syntax shown.

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

COM functions are available on Microsoft Windows systems only.

Purpose

Quiver or velocity plot



GUI Alternatives

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

Syntax

```
quiver(x,y,u,v)
quiver(u,v)
quiver(...,scale)
quiver(...,LineSpec)
quiver(...,LineSpec,'filled')
quiver(axes_handle,...)
h = quiver(...)
hlines = quiver('v6',...)
```

Description

A quiver plot displays velocity vectors as arrows with components `(u,v)` at the points `(x,y)`.

For example, the first vector is defined by components `u(1)`,`v(1)` and is displayed at the point `x(1)`,`y(1)`.

`quiver(x,y,u,v)` plots vectors as arrows at the coordinates specified in each corresponding pair of elements in `x` and `y`. The matrices `x`, `y`, `u`, and `v` must all be the same size and contain corresponding position and velocity components. However, `x` and `y` can also be vectors, as explained in the next section. By default, the arrows are scaled to just not overlap, but you can scale them to be longer or shorter if you want.

Expanding x- and y-Coordinates

MATLAB expands `x` and `y` if they are not matrices. This expansion is equivalent to calling `meshgrid` to generate matrices from vectors:

```
[x,y] = meshgrid(x,y);
quiver(x,y,u,v)
```

In this case, the following must be true:

`length(x)` = `n` and `length(y)` = `m`, where `[m,n]` = `size(u)` = `size(v)`.

The vector `x` corresponds to the columns of `u` and `v`, and vector `y` corresponds to the rows of `u` and `v`.

`quiver(u,v)` draws vectors specified by `u` and `v` at equally spaced points in the *x-y* plane.

`quiver(...,scale)` automatically scales the arrows to fit within the grid and then stretches them by the factor `scale`. `scale` = `2` doubles their relative length, and `scale` = `0.5` halves the length. Use `scale = 0` to plot the velocity vectors without automatic scaling. You can also tune the length of arrows after they have been drawn by choosing the **Plot Edit**  tool, selecting the `quivergroup` object, opening the Property Editor, and adjusting the **Length** slider.

`quiver(...,LineSpec)` specifies line style, marker symbol, and color using any valid `LineSpec`. `quiver` draws the markers at the origin of the vectors.

`quiver(...,LineSpec,'filled')` fills markers specified by `LineSpec`.

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

`h = quiver(...)` returns the handle to the quivergroup object.

Backward-Compatible Version

`hlines = quiver('v6',...)` returns the handles of line objects instead of quivergroup objects for compatibility with MATLAB 6.5 and earlier.

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

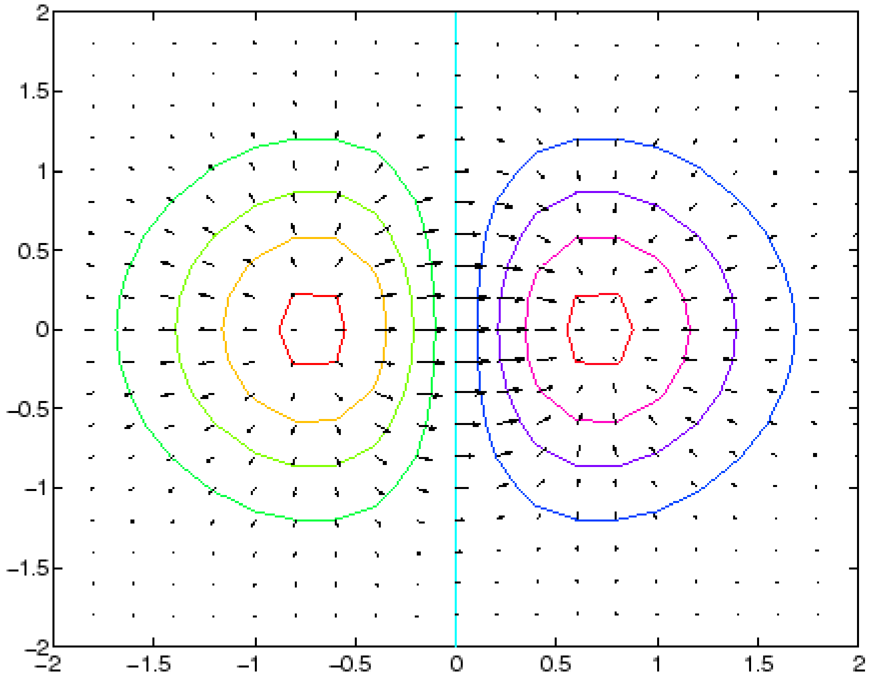
See Plot Objects and Backward Compatibility for more information.

Examples

Showing the Gradient with Quiver Plots

Plot the gradient field of the function $z = xe^{(-x^2 - y^2)}$:

```
[X,Y] = meshgrid(-2:.2:2);
Z = X.*exp(-X.^2 - Y.^2);
[DX,DY] = gradient(Z,.2,.2);
contour(X,Y,Z)
hold on
quiver(X,Y,DX,DY)
colormap hsv
hold off
```



See Also

`contour`, `LineSpec`, `plot`, `quiver3`

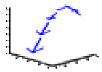
"Direction and Velocity Plots" on page 1-93 for related functions

Two-Dimensional Quiver Plots for more examples

`Quivergroup Properties` for property descriptions

Purpose

3-D quiver or velocity plot



GUI Alternatives

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

Syntax

```
quiver3(x,y,z,u,v,w)
quiver3(z,u,v,w)
quiver3(...,scale)
quiver3(...,LineSpec)
quiver3(...,LineSpec,'filled')
quiver3(axes_handle,...)
h = quiver3(...)
```

Description

A three-dimensional quiver plot displays vectors with components `(u,v,w)` at the points `(x,y,z)`.

`quiver3(x,y,z,u,v,w)` plots vectors with components `(u,v,w)` at the points `(x,y,z)`. The matrices `x,y,z,u,v,w` must all be the same size and contain the corresponding position and vector components.

`quiver3(z,u,v,w)` plots the vectors at the equally spaced surface points specified by matrix `z`. `quiver3` automatically scales the vectors based on the distance between them to prevent them from overlapping.

`quiver3(...,scale)` automatically scales the vectors to prevent them from overlapping, and then multiplies them by `scale`. `scale = 2` doubles their relative length, and `scale = 0.5` halves them. Use `scale = 0` to plot the vectors without the automatic scaling.

`quiver3(...,LineSpec)` specifies line type and color using any valid `LineSpec`.

`quiver3(...,LineSpec,'filled')` fills markers specified by `LineSpec`.

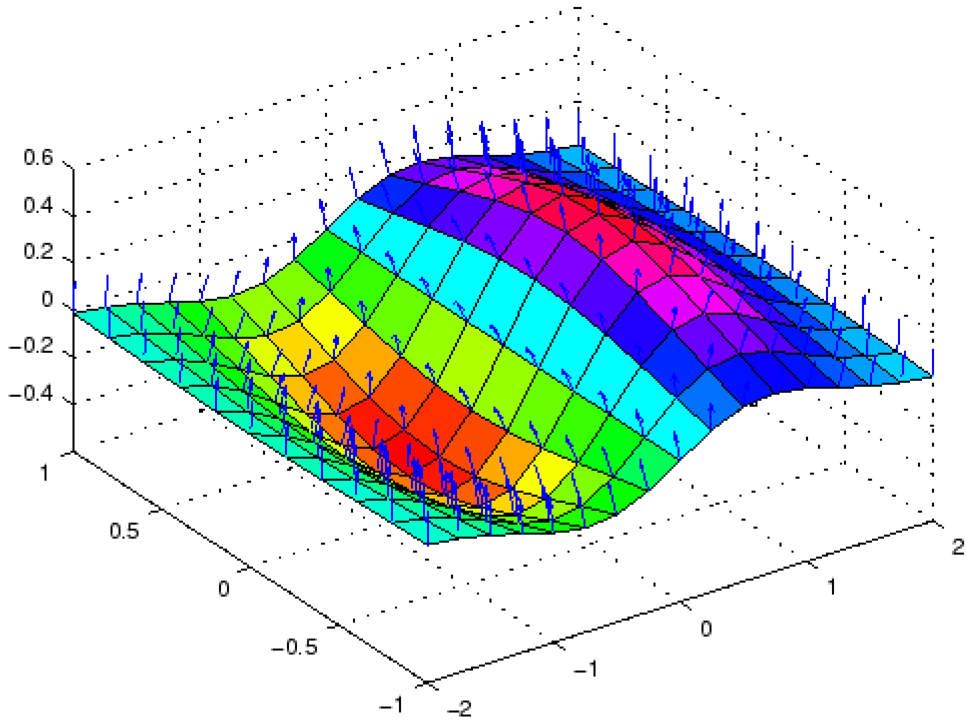
`quiver3(axes_handle,...)` plots into the axes with the handle `axes_handle` instead of into the current axes (`gca`).

`h = quiver3(...)` returns a vector of line handles.

Examples

Plot the surface normals of the function $z = xe^{(-x^2 - y^2)}$.

```
[X,Y] = meshgrid(-2:0.25:2,-1:0.2:1);
Z = X.* exp(-X.^2 - Y.^2);
[U,V,W] = surfnorm(X,Y,Z);
quiver3(X,Y,Z,U,V,W,0.5);
hold on
surf(X,Y,Z);
colormap hsv
view(-35,45)
axis ([-2 2 -1 1 -.6 .6])
hold off
```



See Also

`axis`, `contour`, `LineSpec`, `plot`, `plot3`, `quiver`, `surfnorm`, `view`

“Direction and Velocity Plots” on page 1-93 for related functions

Three-Dimensional Quiver Plots for more examples

Quivergroup Properties

Purpose

Define quivergroup properties

Modifying Properties

You can set and query graphics object properties using the `set` and `get` commands or the Property Editor (`propertyeditor`).

Note that you cannot define default properties for areaseries objects.

See Plot Objects for more information on quivergroup objects.

Quivergroup Property Descriptions

This section provides a description of properties. Curly braces { } enclose default values.

`Annotation`

`hg.Annotation` object Read Only

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

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

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

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

Setting the IconDisplayStyle Property

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

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

Using the IconDisplayStyle Property

See "Controlling Legends" for more information and examples.

`AutoScale`

`{on} | off`

Autoscale arrow length. Based on average spacing in the *x* and *y* directions, `AutoScale` scales the arrow length to fit within the grid-defined coordinate data and keeps the arrows from overlapping. After autoscaling, quiver applies the `AutoScaleFactor` to the arrow length.

`AutoScaleFactor`

scalar (default = 0.9)

User-specified scale factor. When `AutoScale` is on, the `quiver` function applies this user-specified autoscale factor to the arrow length. A value of `2` doubles the length of the arrows; `0.5` halves the length.

`BeingDeleted`

`on | {off}` Read Only

This object is being deleted. The `BeingDeleted` property provides a mechanism that you can use to determine if objects are in the process of being deleted. MATLAB sets the `BeingDeleted` property to `on` when the object's delete function callback is called (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

Callback routine executed during object creation. This property defines a callback that executes when MATLAB creates an object. You must specify the callback during the creation of the object. For example,

```
area(y,'CreateFcn',@CallbackFcn)
```

where `@CallbackFcn` is a function handle that references the callback function.

MATLAB executes this routine after setting all other object properties. Setting this property on an existing object has no effect.

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

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

`DeleteFcn`

string or function handle

Callback executed during object deletion. A callback that executes when this object is deleted (e.g., this might happen when you issue a delete command on the object, its parent axes, or the figure containing it). MATLAB executes the callback before destroying the object's properties so the callback routine can query these values.

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

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

See the BeingDeleted property for related information.

DisplayName

string (default is empty string)

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

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

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.

`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.

`MaxHeadSize`
scalar (default = 0.2

Maximum size of arrowhead. A value determining the maximum size of the arrowhead relative to the length of the arrow.

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

Parent of this object. This property contains the handle of the object's parent. The parent is normally the axes, hggroup, or hgtransform object that contains the object.

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

`Selected`
`on | {off}`

Is object selected? When you set this property to `on`, MATLAB displays selection "handles" at the corners and midpoints if the `SelectionHighlight` property is also `on` (the default). You can, for example, define the `ButtonDownFcn` callback to set this property to `on`, thereby indicating that this particular object is selected. This property is also set to `on` when an object is manually selected in plot edit mode.

`SelectionHighlight`
`{on} | off`

Objects are highlighted when selected. When the `Selected` property is `on`, MATLAB indicates the selected state by drawing four edge handles and four corner handles. When `SelectionHighlight` is `off`, MATLAB does not draw the handles except when in plot edit mode and objects are selected manually.

`ShowArrowHead`
`{on} | off`

Display arrowheads on vectors. When this property is `on`, MATLAB draws arrowheads on the vectors displayed by `quiver`. When you set this property to off, `quiver` draws the vectors as lines without arrowheads.

`Tag`
string

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

For example, you might create an areaseries object and set the `Tag` property.

```
t = area(Y,'Tag','area1')
```

When you want to access objects of a given type, you can use `findobj` to find the object's handle. The following statement changes the `FaceColor` property of the object whose `Tag` is `area1`.

```
set(findobj('Tag','area1'),'FaceColor','red')
```

`Type`

string (read only)

Type of graphics object. This property contains a string that identifies the class of the graphics object. For stem objects, `Type` is `'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.

`UData`

matrix

One dimension of 2-D or 3-D vector components. `UData`, `VData`, and `WData`, together specify the components of the vectors displayed as arrows in the quiver graph. For example, the first vector is defined by components `UData(1)`,`VData(1)`,`WData(1)`.

`UDataSource`

string (MATLAB variable)

Link `UData` to MATLAB variable. Set this property to a MATLAB variable that, by default, is evaluated in the base workspace to generate the `UData`.

MATLAB reevaluates this property only when you set it. Therefore, a change to workspace variables appearing in an expression does not change `UData`.

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

See the `refreshdata` reference page for more information.

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

`VData`

matrix

One dimension of 2-D or 3-D vector components. UData, VData and WData (for 3-D) together specify the components of the vectors displayed as arrows in the quiver graph. For example, the first vector is defined by components UData(1),VData(1),WData(1).

VDataSource

string (MATLAB variable)

Link VData *to MATLAB variable.* Set this property to a MATLAB variable that, by default, is evaluated in the base workspace to generate the VData.

MATLAB reevaluates this property only when you set it. Therefore, a change to workspace variables appearing in an expression does not change VData.

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

See the refreshdata reference page for more information.

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

WData

matrix

One dimension of 2-D or 3-D vector components. UData, VData and WData (for 3-D) together specify the components of the vectors displayed as arrows in the quiver graph. For example, the first vector is defined by components UData(1),VData(1),WData(1).

`WDataSource`

string (MATLAB variable)

Link `WData` *to MATLAB variable.* Set this property to a MATLAB variable that, by default, is evaluated in the base workspace to generate the `WData`.

MATLAB reevaluates this property only when you set it. Therefore, a change to workspace variables appearing in an expression does not change `WData`.

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

See the `refreshdata` reference page for more information.

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

`XData`

vector or matrix

X-axis coordinates of arrows. The `quiver` function draws an individual arrow at each *x*-axis location in the `XData` array.`XData` can be either a matrix equal in size to all other data properties or for 2-D, a vector equal in length to the number of columns in `UData` or `VData`. That is, `length(XData) == size(UData,2)`.

If you do not specify `XData` (i.e., the input argument `X`), the `quiver` function uses the indices of `UData` to create the quiver graph. See the `XDataMode` property for related information.

`XDataMode`

{auto} | manual

Use automatic or user-specified x-axis values. If you specify `XData` (by setting the `XData` property or specifying the input argument `X`), the `quiver` function sets this property to `manual`.

If you set `XDataMode` to `auto` after having specified `XData`, the `quiver` function resets the *x* tick-mark labels to the indices of the `U`, `V`, and `W` data, overwriting any previous values.

`XDataSource`

string (MATLAB variable)

Link `XData` to MATLAB variable. Set this property to a MATLAB variable that is evaluated in the base workspace to generate the `XData`.

MATLAB reevaluates this property only when you set it. Therefore, a change to workspace variables appearing in an expression does not change `XData`.

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

See the `refreshdata` reference page for more information.

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

`YData`
: vector or matrix

Y-axis coordinates of arrows. The quiver function draws an individual arrow at each *y*-axis location in the `YData` array. `YData` can be either a matrix equal in size to all other data properties or for 2-D, a vector equal in length to the number of rows in `UData` or `VData`. That is, `length(YData) == size(UData,1)`.

If you do not specify `YData` (i.e., the input argument `Y`), the `quiver` function uses the indices of `VData` to create the quiver graph. See the `YDataMode` property for related information.

The input argument `y` in the `quiver` function calling syntax assigns values to `YData`.

`YDataMode`
: {auto} | manual

Use automatic or user-specified y-axis values. If you specify `YData` (by setting the `YData` property or specifying the input argument `Y`), MATLAB sets this property to `manual`.

If you set `YDataMode` to auto after having specified `YData`, MATLAB resets the *y* tick-mark labels to the indices of the `U`, `V`, and `W` data, overwriting any previous values.

`YDataSource`
: string (MATLAB variable)

Link `YData` to MATLAB variable. Set this property to a MATLAB variable that is evaluated in the base workspace to generate the `YData`.

MATLAB reevaluates this property only when you set it. Therefore, a change to workspace variables appearing in an expression does not change `YData`.

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

See the `refreshdata` reference page for more information.

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

`ZData`

vector or matrix

Z-axis coordinates of arrows. The quiver function draws an individual arrow at each *z*-axis location in the `ZData` array. `ZData` must be a matrix equal in size to `XData` and `YData`.

The input argument `z` in the `quiver3` function calling syntax assigns values to `ZData`.

Purpose

QZ factorization for generalized eigenvalues

Syntax

```
[AA,BB,Q,Z] = qz(A,B)
[AA,BB,Q,Z,V,W] = qz(A,B)
qz(A,B,flag)
```

Description

The `qz` function gives access to intermediate results in the computation of generalized eigenvalues.

`[AA,BB,Q,Z] = qz(A,B)` for square matrices `A` and `B`, produces upper quasitriangular matrices `AA` and `BB`, and unitary matrices `Q` and `Z` such that `Q*A*Z = AA`, and `Q*B*Z = BB`. For complex matrices, `AA` and `BB` are triangular.

`[AA,BB,Q,Z,V,W] = qz(A,B)` also produces matrices `V` and `W` whose columns are generalized eigenvectors.

`qz(A,B,flag)` for real matrices `A` and `B`, produces one of two decompositions depending on the value of `flag`:

`'complex'`	Produces a possibly complex decomposition with a triangular `AA`. For compatibility with earlier versions, `'complex'` is the default.
`'real'`	Produces a real decomposition with a quasitriangular `AA`, containing 1-by-1 and 2-by-2 blocks on its diagonal.

If `AA` is triangular, the diagonal elements of `AA` and `BB`, $\alpha = \mathrm{diag}(\mathrm{AA})$ and $\beta = \mathrm{diag}(\mathbf{BB})$, are the generalized eigenvalues that satisfy

$$A*V*\beta = \mathbf{B}*V*\alpha$$

$$\beta*W'*A = \alpha*W'*\mathbf{B}$$

The eigenvalues produced by

$$\lambda = \mathrm{eig}(A, \mathbf{B})$$

are the ratios of the αs and βs.

$$\lambda = \alpha./\beta$$

If AA is triangular, the diagonal elements of AA and BB,

```
alpha = diag(AA)
beta = diag(BB)
```

are the generalized eigenvalues that satisfy

```
A*V*diag(beta) = B*V*diag(alpha)
diag(beta)*W'*A = diag(alpha)*W'*B
```

The eigenvalues produced by

```
lambda = eig(A,B)
```

are the element-wise ratios of alpha and beta.

```
lambda = alpha ./ beta
```

If AA is not triangular, it is necessary to further reduce the 2-by-2 blocks to obtain the eigenvalues of the full system.

Algorithm

For full matrices A and B, qz uses the LAPACK routines listed in the following table.

	A and B Real	A or B Complex
A and B double	DGGES, DTGEVC (if you request the fifth output V)	ZGGES, ZTGEVC (if you request the fifth output V)
A or B single	SGGES, STGEVC (if you request the fifth output V)	CGGES, CTGEVC (if you request the fifth output V)

See Also

eig

References

[1] Anderson, E., Z. Bai, C. Bischof, S. Blackford, J. Demmel, J. Dongarra, J. Du Croz, A. Greenbaum, S. Hammarling, A. McKenney, and D. Sorensen, *LAPACK User's Guide* (`http://www.netlib.org/lapack/lug/lapack_lug.html`), Third Edition, SIAM, Philadelphia, 1999.

Purpose

Uniformly distributed pseudorandom numbers

Syntax

```
r = rand(n)
rand(m,n)
rand([m,n])
rand(m,n,p,...)
rand([m,n,p,...])
rand
r = rand(..., 'double')
r = rand(..., 'single')
```

Description

`r = rand(n)` returns an `n`-by-`n` matrix containing pseudorandom values drawn from the standard uniform distribution on the open interval (0,1). `rand(m,n)` or `rand([m,n])` returns an `m`-by-`n` matrix. `rand(m,n,p,...)` or `rand([m,n,p,...])` returns an `m`-by-`n`-by-`p`-by-... array. `rand` returns a scalar. `rand(size(A))` returns an array the same size as `A`.

`r = rand(..., 'double')` or `r = rand(..., 'single')` returns an array of uniform values of the specified class.

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

The sequence of numbers produced by rand is determined by the internal state of the uniform pseudorandom number generator that underlies `rand`, `randi`, and `randn`. The default random number stream properties can be set using `@RandStream` methods. See `@RandStream` for details about controlling the default stream.

Resetting the default stream to the same fixed state allows computations to be repeated. Setting the stream to different states leads to unique computations, however, it does not improve any statistical properties. Since the random number generator is initialized to the same state every time MATLAB software starts up, `rand`, `randn`, and `randi` will generate the same sequence of numbers in each session until the state is changed.

Note In versions of MATLAB prior to 7.7, you controlled the internal state of the random number stream used by `rand` by calling `rand` directly with the `'seed'`, `'state'`, or `'twister'` keywords. That syntax is still supported for backwards compatibility, but is deprecated. For version 7.7, use the default stream as described in the `@RandStream` reference documentation.

Examples

Generate values from the uniform distribution on the interval `[a, b]`.

```
r = a + (b-a).*rand(100,1);
```

Replace the default stream at MATLAB startup, using a stream whose seed is based on `clock`, so that `rand` will return different values in different MATLAB sessions. It is usually not desirable to do this more than once per MATLAB session.

```
RandStream.setDefaultStream
     (RandStream('mt19937ar','seed',sum(100*clock)));
rand(1,5)
```

Save the current state of the default stream, generate 5 values, restore the state, and repeat the sequence.

```
defaultStream = RandStream.getDefaultStream;
savedState = defaultStream.State;
u1 = rand(1,5)
defaultStream.State = savedState;
u2 = rand(1,5) % contains exactly the same values as u1
```

See Also

`randi`, `randn`, `@RandStream`, `rand (RandStream)`, `getDefaultStream (RandStream)`, `sprand`, `sprandn`, `randperm`

rand (RandStream)

Purpose Uniformly distributed random numbers

Class `@RandStream`

Syntax

```
r = rand(s,n)
rand(s,m,n)
rand(s,[m,n])
rand(s,m,n,p,...)
rand(s,[m,n,p,...])
rand(s)
rand(s,size(A))
r = rand(..., 'double')
r = rand(..., 'single')
```

Description

`r = rand(s,n)` returns an `n`-by-`n` matrix containing pseudorandom values drawn from the standard uniform distribution on the open interval (0,1). The values are drawn from the random stream `s`. `rand(s,m,n)` or `rand(s,[m,n])` returns an `m`-by-`n` matrix. `rand(s,m,n,p,...)` or `rand(s,[m,n,p,...])` returns an `m`-by-`n`-by-`p`-by-... array. `rand(s)` returns a scalar. `rand(s,size(A))` returns an array the same size as `A`.

`r = rand(..., 'double')` or `r = rand(..., 'single')` returns an array of uniform values of the specified class.

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

The sequence of numbers produced by `rand` is determined by the internal state of the random number stream `s`. Resetting that stream to the same fixed state allows computations to be repeated. Setting the stream to different states leads to unique computations, however, it does not improve any statistical properties.

See Also

`rand`, `@RandStream`, `randi (RandStream)`, `randn (RandStream)`, `randperm (RandStream)`

randi

Purpose

Uniformly distributed pseudorandom integers

Syntax

```
randi(imax)
r = randi(imax,n)
randi(imax,m,n)
randi(imax,[m,n])
randi(imax,m,n,p,...)
randi(imax,[m,n,p,...])
randi(imax,size(A))
r = randi([imin,imax],...)
r = randi(..., classname)
```

Description

`randi(imax)` returns a random integer on the open interval (0,`imax`). `r = randi(imax,n)` returns an `n`-by-`n` matrix containing pseudorandom integer values drawn from the discrete uniform distribution on `1:imax`. `randi(imax,m,n)` or `randi(imax,[m,n])` returns an `m`-by-`n` matrix. `randi(imax,m,n,p,...)` or `randi(imax,[m,n,p,...])` returns an `m`-by-`n`-by-`p`-by-... array. `randi(imax,size(A))` returns an array the same size as `A`.

`r = randi([imin,imax],...)` returns an array containing integer values drawn from the discrete uniform distribution on `imin:imax`.

`r = randi(..., classname)` returns an array of integer values of class `classname`.

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

The sequence of numbers produced by `randi` is determined by the internal state of the uniform pseudorandom number generator that underlies `rand`, `randi`, and `randn`. `randi` uses one uniform value from that default stream to generate each integer value. Control the default stream using its properties and methods. See `@RandStream` for details about the default stream.

Resetting the default stream to the same fixed state allows computations to be repeated. Setting the stream to different states leads to unique computations, however, it does not improve any statistical properties. Since the random number generator is initialized to the same state every time MATLAB software starts up, `rand`, `randn`, and `randi` will generate the same sequence of numbers in each session until the state is changed.

Examples

Generate integer values from the uniform distribution on the set 1:10.

```
r = randi(10,100,1);
```

Generate an integer array of integers drawn uniformly from 1:10.

```
r = randi(10,100,1,'uint32');
```

Generate integer values drawn uniformly from -10:10.

```
r = randi([-10 10],100,1);
```

Replace the default stream at MATLAB startup, using a stream whose seed is based on `clock`, so that `randi` will return different values in different MATLAB sessions. It is usually not desirable to do this more than once per MATLAB session.

```
RandStream.setDefaultStream
     (RandStream('mt19937ar','seed',sum(100*clock)));
randi(100,1,5)
```

Save the current state of the default stream, generate 5 integer values, restore the state, and repeat the sequence.

```
defaultStream = RandStream.getDefaultStream;
savedState = defaultStream.State;
i1 = randi(10,1,5)
defaultStream.State = savedState;
i2 = randi(10,1,5) %contains exactly the same values as i1
```

See Also

`rand`, `randn`, `@RandStream`, `randi (RandStream)`, `getDefaultStream (RandStream)`

Purpose Uniformly distributed pseudorandom integers

Class `@RandStream`

Syntax

```
r = randi(s,imax,n)
randi(s,imax,m,n)
randi(s,imax,[m,n])
randi(s,imax,m,n,p,...)
randi(s,imax,[m,n,p,...])
randi(s,imax)
randi(s,imax,size(A))
r = randi(s,[imin,imax],...)
r = randi(..., classname)
```

Description

`r = randi(s,imax,n)` returns an `n`-by-`n` matrix containing pseudorandom integer values drawn from the discrete uniform distribution on `1:imax`. `randi` draws those values from the random stream `s`. `randi(s,imax,m,n)` or `randi(s,imax,[m,n])` returns an `m`-by-`n` matrix. `randi(s,imax,m,n,p,...)` or `randi(s,imax,[m,n,p,...])` returns an `m`-by-`n`-by-`p`-by-... array. `randi(s,imax)` returns a scalar. `randi(s,imax,size(A))` returns an array the same size as `A`.

`r = randi(s,[imin,imax],...)` returns an array containing integer values drawn from the discrete uniform distribution on `imin:imax`.

`r = randi(..., classname)` returns an array of integer values of class `classname`.

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

The sequence of numbers produced by `randi` is determined by the internal state of the random stream `s`. `randi` uses one uniform value from `s` to generate each integer value. Resetting `s` to the same fixed state allows computations to be repeated. Setting the stream to different states leads to unique computations, however, it does not improve any statistical properties.

See Also

`rand`, `@RandStream`, `rand (RandStream)`, `randn (RandStream)`, `randperm (RandStream)`

Purpose

Normally distributed pseudorandom numbers

Syntax

```
r = randn(n)
randn(m,n)
randn([m,n])
randn(m,n,p,...)
randn([m,n,p,...])
randn(size(A))
r = randn(..., 'double')
r = randn(..., 'single')
```

Description

`r = randn(n)` returns an `n`-by-`n` matrix containing pseudorandom values drawn from the standard normal distribution. `randn(m,n)` or `randn([m,n])` returns an `m`-by-`n` matrix. `randn(m,n,p,...)` or `randn([m,n,p,...])` returns an `m`-by-`n`-by-`p`-by-... array. `randn` returns a scalar. `randn(size(A))` returns an array the same size as `A`.

`r = randn(..., 'double')` or `r = randn(..., 'single')` returns an array of normal values of the specified class.

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

The sequence of numbers produced by `randn` is determined by the internal state of the uniform pseudorandom number generator that underlies `rand`, `randi`, and `randn`. `randn` uses one or more uniform values from that default stream to generate each normal value. Control the default stream using its properties and methods. See `@RandStream` for details about the default stream.

Resetting the default stream to the same fixed state allows computations to be repeated. Setting the stream to different states leads to unique computations, however, it does not improve any statistical properties. Since the random number generator is initialized to the same state every time MATLAB software starts up, `rand`, `randn`, and `randi` will generate the same sequence of numbers in each session until the state is changed.

Note In versions of MATLAB prior to 7.7, you controlled the internal state of the random number stream used by `randn` by calling `randn` directly with the `'seed'` or `'state'` keywords. That syntax is still supported for backwards compatibility, but is deprecated. For version 7.7, use the default stream as described in the `@RandStream` reference documentation.

Examples

Generate values from a normal distribution with mean 1 and standard deviation 2.

```
r = 1 + 2.*randn(100,1);
```

Generate values from a bivariate normal distribution with specified mean vector and covariance matrix.

```
mu = [1 2];
Sigma = [1 .5; .5 2]; R = chol(Sigma);
z = repmat(mu,100,1) + randn(100,2)*R;
```

Replace the default stream at MATLAB startup, using a stream whose seed is based on `clock`, so that `randn` will return different values in different MATLAB sessions. It is usually not desirable to do this more than once per MATLAB session.

```
RandStream.setDefaultStream
     (RandStream('mt19937ar','seed',sum(100*clock)));
randn(1,5)
```

Save the current state of the default stream, generate 5 values, restore the state, and repeat the sequence.

```
defaultStream = RandStream.getDefaultStream;
savedState = defaultStream.State;
```

```
z1 = randn(1,5)
defaultStream.State = savedState;
z2 = randn(1,5) % contains exactly the same values as z1
```

See Also

`rand`, `randi`, `@RandStream`, `randn (RandStream)`, `getDefaultStream (RandStream)`

randn (RandStream)

Purpose Normally distributed pseudorandom numbers

Class `@RandStream`

Syntax

```
randn(s,m,n)
randn(s,[m,n])
randn(s,m,n,p,...)
randn(s,[m,n,p,...])
randn(s)
randn(s,size(A))
r = randn(..., 'double')
r = randn(..., 'single')
```

Description

`r = randn(s,n)` returns an `n`-by-`n` matrix containing pseudorandom values drawn from the standard normal distribution. `randn` draws those values from the random stream s. `randn(s,m,n)` or `randn(s,[m,n])` returns an `m`-by-`n` matrix. `randn(s,m,n,p,...)` or `randn(s,[m,n,p,...])` returns an `m`-by-`n`-by-`p`-by-... array. `randn(s)` returns a scalar. `randn(s,size(A))` returns an array the same size as `A`.

`r = randn(..., 'double')` or `r = randn(..., 'single')` returns an array of uniform values of the specified class.

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

The sequence of numbers produced by `randn` is determined by the internal state of the random stream `s`. `randn` uses one or more uniform values from `s` to generate each normal value. Resetting that stream to the same fixed state allows computations to be repeated. Setting the stream to different states leads to unique computations, however, it does not improve any statistical properties.

See Also `randn`, `@RandStream`, `rand (RandStream)`, `randi (RandStream)`

Purpose Random permutation

Syntax

```
p = randperm(n)
```

Description `p = randperm(n)` returns a random permutation of the integers `1:n`.

Remarks The `randperm` function calls `rand` and therefore changes the state of the default random number stream.

Examples `randperm(6)` might be the vector

```
[3  2  6  4  1  5]
```

or it might be some other permutation of `1:6`.

See Also `permute`

randperm (RandStream)

Class

@RandStream

Syntax

`randperm(s,n)`

Description

`randperm(s,n)` generates a random permutation of the integers from 1 to `n`. For example, `randperm(s,6)` might be `[2 4 5 6 1 3]`. `randperm(s,n)` uses random values drawn from the random number stream `s`.

See Also

`permute`, `@RandStream`

Purpose

Random number stream

Constructor

`RandStream (RandStream)`

Description

Pseudorandom numbers in MATLAB come from one or more random number streams. The simplest way to generate arrays of random numbers is to use `rand`, `randn`, or `randi`. These functions all rely on the same stream of uniform random numbers, known as the default stream. You can create other stream objects that act separately from the default stream, and you can use their `rand`, `randi`, or `randn` methods to generate arrays of random numbers. You can also create a random number stream and make it the default stream.

To create a single random number stream, use either the `RandStream` constructor or the `RandStream.create` factory method. To create multiple independent random number streams, use `RandStream.create`.

`stream = RandStream.getDefaultStream` returns the default random number stream, that is, the one currently used by the `rand`, `randi`, and `randn` functions.

`prevstream = RandStream.setDefaultStream(stream)` returns the current default stream, and designates the random number stream `stream` as the new default to be used by the `rand`, `randi`, and `randn` functions.

A random number stream `s` has properties that control its behavior. Access or assign to a property using `p= s.Property` or `s.Property = p`. The following table lists defined properties:

Properties

Property	Description
Type	(Read-only) Generator algorithm used by the stream. The list of possible generators is given by `RandStream.list`.

Property	Description
Seed	(Read-only) Seed value used to create the stream.
NumStreams	(Read-only) Number of streams in the group in which the current stream was created.
StreamIndex	(Read-only) Index of the current stream from among the group of streams with which it was created.
State	Internal state of the generator. You should not depend on the format of this property. The value you assign to `S.State` must be a value read from `S.State` previously.
Substream	Index of the substream to which the stream is currently set. The default is 1. Multiple substreams are not supported by all generator types; the multiplicative lagged Fibonacci generator (`mlfg6331_64`) and combined multiple recursive generator (`mrg32k3a`) support multiple streams.
RandnAlg	Algorithm used by `randn(s, ...)` to generate normal pseudorandom values. Possible values are `'Ziggurat'`, `'Polar'`, or `'Inversion'`.

Property	Description
Antithetic	Logical value indicating whether `S` generates antithetic pseudorandom values. For uniform values, these are the usual values subtracted from 1. The default is false.
FullPrecision	Logical value indicating whether `S` generates values using its full precision. Some generators can create pseudorandom values faster, but with fewer random bits, if `FullPrecision` is false. The default is true.

Methods

Method	Description
`RandStream`	Create a random number stream
`create`	Create multiple independent random number streams
`get`	Get the properties of a random stream object
`list`	List available random number generator algorithms
`getDefaultStream`	Get the default random number stream
`setDefaultStream`	Set the default random number stream
`reset`	Reset a stream to its initial internal state

Method	Description
rand	Pseudorandom numbers from a uniform distribution
randn	Pseudorandom numbers from a standard normal distribution
randi	Pseudorandom integers from a uniform discrete distribution
randperm	Random permutation of a set of values

See Also

rand, randn, randi, rand (RandStream), randn (RandStream), randi (RandStream)

Purpose

Random number stream

Class

`@RandStream`

Syntax

```
s = RandStream('gentype')
[...]=RandStream('gentype','param1',val1,'param2',val2,...)
```

Description

`s = RandStream('gentype')` creates a random number stream that uses the uniform pseudorandom number generator algorithm specified by `gentype`.`[...]=RandStream('gentype','param1',val1,'param2',val2,...)` allows you to specify optional parameter name/value pairs to control creation of the stream. Options for `gentype` are given by `RandStream.list`.

Parameters are for `RandStream` are:

Parameter	Description
Seed	Nonnegative scalar integer with which to initialize all streams. Default is 0. Seeds must be an integer between 0 and .
RandnAlg	Algorithm used by `randn(s, ...)` to generate normal pseudorandom values. Possible values are `'Ziggurat'`, `'Polar'`, or `'Inversion'`.

Examples

Construct a random stream object using the combined multiple recursive generator and generate 5 uniformly distributed values from that stream.

```
stream=RandStream('mrg32k3a');
rand(stream,1,5)
```

Construct a random stream object using the multiplicative lagged Fibonacci generator and generate 5 normally distributed values using the polar algorithm.

```
stream=RandStream('mlfg6331_64','RandnAlg','Polar');
randn(stream,1,5)
```

See Also

@RandStream, rand (RandStream), randn (RandStream), randi (RandStream), getDefaultStream (RandStream)

Purpose

Rank of matrix

Syntax

```
k = rank(A)
k = rank(A,tol)
```

Description

The `rank` function provides an estimate of the number of linearly independent rows or columns of a full matrix.

`k = rank(A)` returns the number of singular values of `A` that are larger than the default tolerance, `max(size(A))*eps(norm(A))`.

`k = rank(A,tol)` returns the number of singular values of `A` that are larger than `tol`.

Remark

Use `sprank` to determine the structural rank of a sparse matrix.

Algorithm

There are a number of ways to compute the rank of a matrix. MATLAB software uses the method based on the singular value decomposition, or SVD. The SVD algorithm is the most time consuming, but also the most reliable.

The `rank` algorithm is

```
s = svd(A);
tol = max(size(A))*eps(max(s));
r = sum(s > tol);
```

See Also

`sprank`

References

[1] Anderson, E., Z. Bai, C. Bischof, S. Blackford, J. Demmel, J. Dongarra, J. Du Croz, A. Greenbaum, S. Hammarling, A. McKenney, and D. Sorensen, *LAPACK User's Guide* (`http://www.netlib.org/lapack/lug/lapack_lug.html`), Third Edition, SIAM, Philadelphia, 1999.

Purpose

Rational fraction approximation

Syntax

```
[N,D] = rat(X)
[N,D] = rat(X,tol)
rat(X)
S = rats(X,strlen)
S = rats(X)
```

Description

Even though all floating-point numbers are rational numbers, it is sometimes desirable to approximate them by simple rational numbers, which are fractions whose numerator and denominator are small integers. The `rat` function attempts to do this. Rational approximations are generated by truncating continued fraction expansions. The `rats` function calls `rat`, and returns strings.

`[N,D] = rat(X)` returns arrays `N` and `D` so that `N./D` approximates `X` to within the default tolerance, `1.e-6*norm(X(:),1)`.

`[N,D] = rat(X,tol)` returns `N./D` approximating `X` to within `tol`.

`rat(X)`, with no output arguments, simply displays the continued fraction.

`S = rats(X,strlen)` returns a string containing simple rational approximations to the elements of `X`. Asterisks are used for elements that cannot be printed in the allotted space, but are not negligible compared to the other elements in `X`. `strlen` is the length of each string element returned by the `rats` function. The default is `strlen = 13`, which allows 6 elements in 78 spaces.

`S = rats(X)` returns the same results as those printed by MATLAB with `format rat`.

Examples

Ordinarily, the statement

```
s = 1 - 1/2 + 1/3 - 1/4 + 1/5 - 1/6 + 1/7
```

produces

```
s =
```

```
        0.7595
```

However, with

```
format rat
```

or with

```
rats(s)
```

the printed result is

```
s =
   319/420
```

This is a simple rational number. Its denominator is 420, the least common multiple of the denominators of the terms involved in the original expression. Even though the quantity s is stored internally as a binary floating-point number, the desired rational form can be reconstructed.

To see how the rational approximation is generated, the statement rat(s) produces

```
1 + 1/(-4 + 1/(-6 + 1/(-3 + 1/(-5))))
```

And the statement

```
[n,d] = rat(s)
```

produces

```
n = 319, d = 420
```

The mathematical quantity π is certainly not a rational number, but the MATLAB quantity pi that approximates it is a rational number. pi is the ratio of a large integer and 2^{52}:

```
14148475504056880/4503599627370496
```

However, this is not a simple rational number. The value printed for `pi` with `format rat`, or with `rats(pi)`, is

```
355/113
```

This approximation was known in Euclid's time. Its decimal representation is

```
3.14159292035398
```

and so it agrees with `pi` to seven significant figures. The statement

```
rat(pi)
```

produces

```
3 + 1/(7 + 1/(16))
```

This shows how the `355/113` was obtained. The less accurate, but more familiar approximation `22/7` is obtained from the first two terms of this continued fraction.

Algorithm

The `rat(X)` function approximates each element of `X` by a continued fraction of the form

$$\frac{n}{d} = d_1 + \cfrac{1}{d_2 + \cfrac{1}{\left(d_3 + \ldots + \cfrac{1}{d_k}\right)}}$$

The ds are obtained by repeatedly picking off the integer part and then taking the reciprocal of the fractional part. The accuracy of the approximation increases exponentially with the number of terms and is worst when `X = sqrt(2)`. For `x = sqrt(2)` , the error with `k` terms is about `2.68*(.173)^k`, so each additional term increases the accuracy by less than one decimal digit. It takes 21 terms to get full floating-point accuracy.

See Also

format

rbbox

Purpose

Create rubberband box for area selection

Syntax

```
rbbox
rbbox(initialRect)
rbbox(initialRect,fixedPoint)
rbbox(initialRect,fixedPoint,stepSize)
finalRect = rbbox(...)
```

Description

`rbbox` initializes and tracks a rubberband box in the current figure. It sets the initial rectangular size of the box to 0, anchors the box at the figure's `CurrentPoint`, and begins tracking from this point.

`rbbox(initialRect)` specifies the initial location and size of the rubberband box as `[x y width height]`, where `x` and `y` define the lower left corner, and `width` and `height` define the size. `initialRect` is in the units specified by the current figure's `Units` property, and measured from the lower left corner of the figure window. The corner of the box closest to the pointer position follows the pointer until `rbbox` receives a button-up event.

`rbbox(initialRect,fixedPoint)` specifies the corner of the box that remains fixed. All arguments are in the units specified by the current figure's `Units` property, and measured from the lower left corner of the figure window. `fixedPoint` is a two-element vector, `[x y]`. The tracking point is the corner diametrically opposite the anchored corner defined by `fixedPoint`.

`rbbox(initialRect,fixedPoint,stepSize)` specifies how frequently the rubberband box is updated. When the tracking point exceeds `stepSize` figure units, `rbbox` redraws the rubberband box. The default stepsize is `1`.

`finalRect = rbbox(...)` returns a four-element vector, `[x y width height]`, where `x` and `y` are the x and y components of the lower left corner of the box, and `width` and `height` are the dimensions of the box.

Remarks

`rbbox` is useful for defining and resizing a rectangular region:

- For box definition, `initialRect` is `[x y 0 0]`, where `(x,y)` is the figure's `CurrentPoint`.
- For box resizing, `initialRect` defines the rectangular region that you resize (e.g., a legend). `fixedPoint` is the corner diametrically opposite the tracking point.

`rbbox` returns immediately if a button is not currently pressed. Therefore, you use `rbbox` with `waitforbuttonpress` so that the mouse button is down when `rbbox` is called. `rbbox` returns when you release the mouse button.

Examples

Assuming the current view is `view(2)`, use the current axes' `CurrentPoint` property to determine the extent of the rectangle in dataspace units:

```
k = waitforbuttonpress;
point1 = get(gca,'CurrentPoint');    % button down detected
finalRect = rbbox;                   % return figure units
point2 = get(gca,'CurrentPoint');    % button up detected
point1 = point1(1,1:2);              % extract x and y
point2 = point2(1,1:2);
p1 = min(point1,point2);             % calculate locations
offset = abs(point1-point2);         % and dimensions
x = [p1(1) p1(1)+offset(1) p1(1)+offset(1) p1(1) p1(1)];
y = [p1(2) p1(2) p1(2)+offset(2) p1(2)+offset(2) p1(2)];
hold on
axis manual
plot(x,y)                            % redraw in dataspace units
```

See Also

`axis`, `dragrect`, `waitforbuttonpress`

"View Control" on page 1-103 for related functions

rcond

Purpose

Matrix reciprocal condition number estimate

Syntax

```
c = rcond(A)
```

Description

`c = rcond(A)` returns an estimate for the reciprocal of the condition of `A` in 1-norm using the LAPACK condition estimator. If `A` is well conditioned, `rcond(A)` is near 1.0. If `A` is badly conditioned, `rcond(A)` is near 0.0. Compared to `cond`, `rcond` is a more efficient, but less reliable, method of estimating the condition of a matrix.

Algorithm

For full matrices `A`, `rcond` uses the LAPACK routines listed in the following table to compute the estimate of the reciprocal condition number.

	Real	Complex
`A double`	DLANGE, DGETRF, DGECON	ZLANGE, ZGETRF, ZGECON
`A single`	SLANGE, SGETRF, SGECON	CLANGE, CGETRF, CGECON

See Also

`cond`, `condest`, `norm`, `normest`, `rank`, `svd`

References

[1] Anderson, E., Z. Bai, C. Bischof, S. Blackford, J. Demmel, J. Dongarra, J. Du Croz, A. Greenbaum, S. Hammarling, A. McKenney, and D. Sorensen, *LAPACK User's Guide* (`http://www.netlib.org/lapack/lug/lapack_lug.html`), Third Edition, SIAM, Philadelphia, 1999.

Purpose

Read video frame data from multimedia reader object

Syntax

```
video = read(obj)
video = read(obj, index)
```

Description

`video = read(obj)` reads in video frames from the associated file. `video` is an H-by-W-by-B-by-F matrix where H is the image frame height, W is the image frame width, B is the number of bands in the image (e.g., 3 for RGB), and F is the number of frames read in. The default behavior is to read in all frames unless an index is specified. The type of data returned is always `UINT8` data representing RGB24 video frames.

`video = read(obj, index)` performs the same operation, but reads only the frame(s) specified by `index`, where the first frame number is 1. `index` can be a single index, or a two-element array representing an index range of the video stream.

For example, read only the first frame:

```
video = read(obj, 1);
```

Read the first 10 frames:

```
video = read(obj, [1 10]);
```

You can use `Inf` to represent the last frame in the file:

```
video = read(obj, Inf);
```

Read from frame 50 through the end of the file:

```
video = read(obj, [50 Inf]);
```

If an invalid `index` is specified, the MATLAB software throws an error.

Examples

Construct a multimedia reader object associated with file `xylophone.mpg` and with the user `tag` property set to `'myreader1'`.

```
readerobj = mmreader('xylophone.mpg', 'tag', 'myreader1');
```

Read in all video frames from the file.

```
vidFrames = read(readerobj);
```

Determine the number of frames in the file.

```
numFrames = get(readerobj, 'NumberOfFrames');
```

Create a MATLAB movie struct from the video frames.

```
for k = 1 : numFrames
   mov(k).cdata = vidFrames(:,:,:,k);
   mov(k).colormap = [];
end
```

Create a figure.

```
hf = figure;
```

Resize the figure based on the video's width and height.

```
set(hf, 'position', [150 150 readerobj.Width readerobj.Height])
```

Play back the movie once at the video's frame rate.

```
movie(hf, mov, 1, readerobj.FrameRate);
```

See Also

`get`, `mmreader`, `movie`, `set`

Purpose

Read data asynchronously from device

Syntax

```
readasync(obj)
readasync(obj,size)
```

Description

`readasync(obj)` initiates an asynchronous read operation on the serial port object, `obj`.

`readasync(obj,size)` asynchronously reads, at most, the number of bytes given by `size`. If `size` is greater than the difference between the `InputBufferSize` property value and the `BytesAvailable` property value, an error is returned.

Remarks

Before you can read data, you must connect `obj` to the device with the `fopen` function. A connected serial port object has a `Status` property value of `open`. An error is returned if you attempt to perform a read operation while `obj` is not connected to the device.

You should use `readasync` only when you configure the `ReadAsyncMode` property to `manual`. `readasync` is ignored if used when `ReadAsyncMode` is `continuous`.

The `TransferStatus` property indicates if an asynchronous read or write operation is in progress. You can write data while an asynchronous read is in progress because serial ports have separate read and write pins. You can stop asynchronous read and write operations with the `stopasync` function.

You can monitor the amount of data stored in the input buffer with the `BytesAvailable` property. Additionally, you can use the `BytesAvailableFcn` property to execute an M-file callback function when the terminator or the specified amount of data is read.

Rules for Completing an Asynchronous Read Operation

An asynchronous read operation with `readasync` completes when one of these conditions is met:

- The terminator specified by the `Terminator` property is read.

- The time specified by the Timeout property passes.
- The specified number of bytes is read.
- The input buffer is filled (if size is not specified).

Because readasync checks for the terminator, this function can be slow. To increase speed, you might want to configure ReadAsyncMode to continuous and continuously return data to the input buffer as soon as it is available from the device.

Example

This example creates the serial port object s, connects s to a Tektronix TDS 210 oscilloscope, configures s to read data asynchronously only if readasync is issued, and configures the instrument to return the peak-to-peak value of the signal on channel 1.

```
s = serial('COM1');
fopen(s)
s.ReadAsyncMode = 'manual';
fprintf(s,'Measurement:Meas1:Source CH1')
fprintf(s,'Measurement:Meas1:Type Pk2Pk')
fprintf(s,'Measurement:Meas1:Value?')
```

Begin reading data asynchronously from the instrument using readasync. When the read operation is complete, return the data to the MATLAB workspace using fscanf.

```
readasync(s)
s.BytesAvailable
ans =
     15
out = fscanf(s)
out =
2.0399999619E0
fclose(s)
```

See Also

Functions

fopen, stopasync

Properties

BytesAvailable, BytesAvailableFcn, ReadAsyncMode, Status, TransferStatus

Purpose Real part of complex number

Syntax

```
X = real(Z)
```

Description `X = real(Z)` returns the real part of the elements of the complex array `Z`.

Examples `real(2+3*i)` is `2`.

See Also `abs`, `angle`, `conj`, `i`, `j`, `imag`

Purpose

Natural logarithm for nonnegative real arrays

Syntax

```
Y = reallog(X)
```

Description

`Y = reallog(X)` returns the natural logarithm of each element in array `X`. Array `X` must contain only nonnegative real numbers. The size of `Y` is the same as the size of `X`.

Examples

```
M = magic(4)

M =
    16     2     3    13
     5    11    10     8
     9     7     6    12
     4    14    15     1

reallog(M)

ans =
    2.7726    0.6931    1.0986    2.5649
    1.6094    2.3979    2.3026    2.0794
    2.1972    1.9459    1.7918    2.4849
    1.3863    2.6391    2.7081         0
```

See Also

`log`, `realpow`, `realsqrt`

Purpose

Largest positive floating-point number

Syntax

`n = realmax`

Description

`n = realmax` returns the largest floating-point number representable on your computer. Anything larger overflows.

`realmax('double')` is the same as `realmax` with no arguments.

`realmax('single')` is the largest single precision floating point number representable on your computer. Anything larger overflows to `single(Inf)`.

Examples

`realmax` is one bit less than 2^{1024} or about `1.7977e+308`.

Algorithm

The `realmax` function is equivalent to `pow2(2-eps,maxexp)`, where `maxexp` is the largest possible floating-point exponent.

Execute `type realmax` to see `maxexp` for various computers.

See Also

`eps`, `realmin`, `intmax`

Purpose Smallest positive normalized floating-point number

Syntax

```
n = realmin
```

Description `n = realmin` returns the smallest positive normalized floating-point number on your computer. Anything smaller underflows or is an IEEE "denormal."

`REALMIN('double')` is the same as `REALMIN` with no arguments.

`REALMIN('single')` is the smallest positive normalized single precision floating point number on your computer.

Examples `realmin` is `2^(-1022)` or about `2.2251e-308`.

Algorithm The `realmin` function is equivalent to `pow2(1,minexp)` where `minexp` is the smallest possible floating-point exponent.

Execute `type realmin` to see `minexp` for various computers.

See Also `eps`, `realmax`, `intmin`

realpow

Purpose Array power for real-only output

Syntax `Z = realpow(X,Y)`

Description `Z = realpow(X,Y)` raises each element of array `X` to the power of its corresponding element in array `Y`. Arrays `X` and `Y` must be the same size. The range of `realpow` is the set of all real numbers, i.e., all elements of the output array `Z` must be real.

Examples

```
X = -2*ones(3,3)

X =
     -2     -2     -2
     -2     -2     -2
     -2     -2     -2

Y = pascal(3)

ans =
     1      1      1
     1      2      3
     1      3      6

realpow(X,Y)

ans =
    -2    -2    -2
    -2     4    -8
    -2    -8    64
```

See Also `reallog`, `realsqrt`, `.^` (array power operator)

Purpose Square root for nonnegative real arrays

Syntax

```
Y = realsqrt(X)
```

Description `Y = realsqrt(X)` returns the square root of each element of array `X`. Array `X` must contain only nonnegative real numbers. The size of `Y` is the same as the size of `X`.

Examples

```
M = magic(4)

M =
    16     2     3    13
     5    11    10     8
     9     7     6    12
     4    14    15     1

realsqrt(M)

ans =
    4.0000    1.4142    1.7321    3.6056
    2.2361    3.3166    3.1623    2.8284
    3.0000    2.6458    2.4495    3.4641
    2.0000    3.7417    3.8730    1.0000
```

See Also `reallog`, `realpow`, `sqrt`, `sqrtm`

record

Purpose

Record data and event information to file

Syntax

```
record(obj)
record(obj,'switch')
```

Description

`record(obj)` toggles the recording state for the serial port object, `obj`.

`record(obj,'switch')` initiates or terminates recording for `obj`. *`switch`* can be `on` or `off`. If *`switch`* is `on`, recording is initiated. If *`switch`* is `off`, recording is terminated.

Remarks

Before you can record information to disk, `obj` must be connected to the device with the `fopen` function. A connected serial port object has a `Status` property value of `open`. An error is returned if you attempt to record information while `obj` is not connected to the device. Each serial port object must record information to a separate file. Recording is automatically terminated when `obj` is disconnected from the device with `fclose`.

The `RecordName` and `RecordMode` properties are read-only while `obj` is recording, and must be configured before using `record`.

For a detailed description of the record file format and the properties associated with recording data and event information to a file, refer to Debugging: Recording Information to Disk.

Example

This example creates the serial port object `s`, connects `s` to the device, configures `s` to record information to a file, writes and reads text data, and then disconnects `s` from the device.

```
s = serial('COM1');
fopen(s)
s.RecordDetail = 'verbose';
s.RecordName = 'MySerialFile.txt';
record(s,'on')
fprintf(s,'*IDN?')
out = fscanf(s);
record(s,'off')
```

```
fclose(s)
```

See Also

Functions

`fclose`, `fopen`

Properties

`RecordDetail`, `RecordMode`, `RecordName`, `RecordStatus`, `Status`

Purpose

Create 2-D rectangle object

Syntax

```
rectangle
rectangle('Position',[x,y,w,h])
rectangle(...,'Curvature',[x,y])
h = rectangle(...)
```

Description

`rectangle` draws a rectangle with `Position [0,0,1,1]` and `Curvature [0,0]` (i.e., no curvature).

`rectangle('Position',[x,y,w,h])` draws the rectangle from the point `x`,`y` and having a width of `w` and a height of `h`. Specify values in axes data units.

Note that, to display a rectangle in the specified proportions, you need to set the axes data aspect ratio so that one unit is of equal length along both the x and y axes. You can do this with the command `axis equal` or `daspect([1,1,1])`.

`rectangle(...,'Curvature',[x,y])` specifies the curvature of the rectangle sides, enabling it to vary from a rectangle to an ellipse. The horizontal curvature `x` is the fraction of width of the rectangle that is curved along the top and bottom edges. The vertical curvature `y` is the fraction of the height of the rectangle that is curved along the left and right edges.

The values of `x` and `y` can range from `0` (no curvature) to `1` (maximum curvature). A value of `[0,0]` creates a rectangle with square sides. A value of `[1,1]` creates an ellipse. If you specify only one value for `Curvature`, then the same length (in axes data units) is curved along both horizontal and vertical sides. The amount of curvature is determined by the shorter dimension.

`h = rectangle(...)` returns the handle of the rectangle object created.

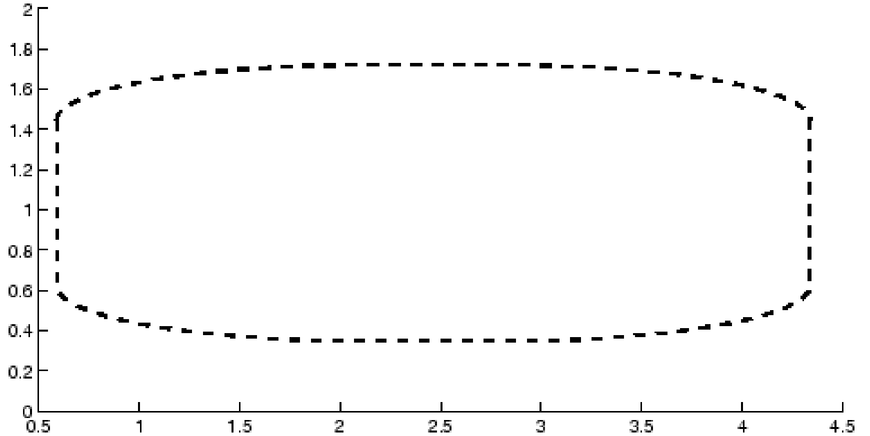
Remarks

Rectangle objects are 2-D and can be drawn in an axes only if the view is `[0 90]` (i.e., `view(2)`). Rectangles are children of axes and are defined in coordinates of the axes data.

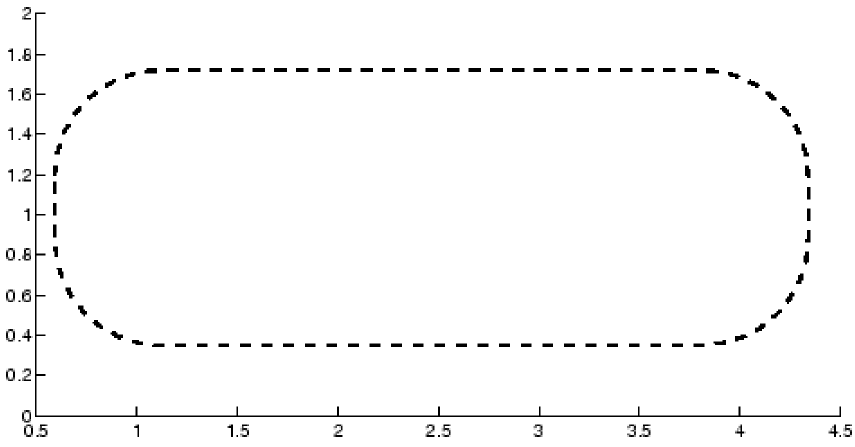
Examples

This example sets the data aspect ratio to `[1,1,1]` so that the rectangle is displayed in the specified proportions (`daspect`). Note that the horizontal and vertical curvature can be different. Also, note the effects of using a single value for `Curvature`.

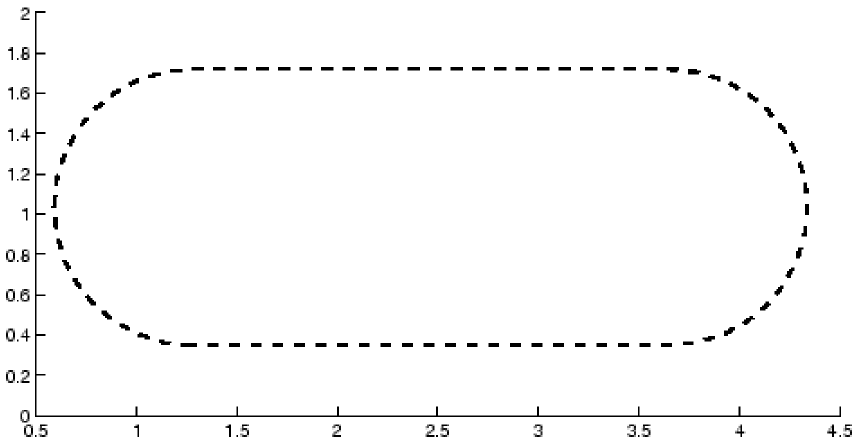
```
rectangle('Position',[0.59,0.35,3.75,1.37],...
          'Curvature',[0.8,0.4],...
         'LineWidth',2,'LineStyle','--')
daspect([1,1,1])
```



Specifying a single value of `[0.4]` for `Curvature` produces



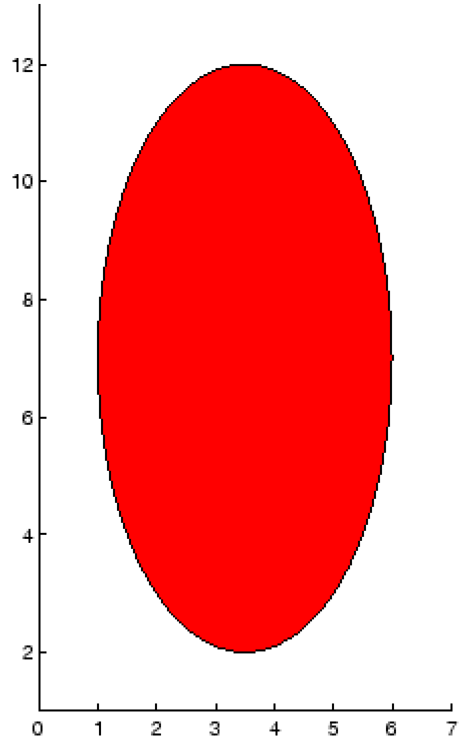
A `Curvature` of `[1]` produces a rectangle with the shortest side completely round:



This example creates an ellipse and colors the face red.

```
rectangle('Position',[1,2,5,10],'Curvature',[1,1],...
          'FaceColor','r')
daspect([1,1,1])
xlim([0,7])
```

```
ylim([1,13])
```



Setting Default Properties

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

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

where *`Property`* is the name of the rectangle property whose default value you want to set and `PropertyValue` is the value you are specifying. Use `set` and `get` to access the surface properties.

See Also

`line`, `patch`

"Object Creation" on page 1-98 for related functions

See the `annotation` function for information about the rectangle annotation object.

`Rectangle Properties` for property descriptions

Purpose

Define rectangle properties

Modifying Properties

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

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

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

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

Rectangle Property Descriptions

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

`Annotation`

`hg.Annotation` object Read Only

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

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

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

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

Setting the IconDisplayStyle property

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

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

Using the IconDisplayStyle property

See "Controlling Legends" for more information and examples.

BeingDeleted

on | {off} read only

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

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

`BusyAction`

`cancel | {queue}`

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

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

`ButtonDownFcn`

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

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

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

Set this property to a function handle that references the callback. The function must define at least two input arguments (handle of object associated with the button down event and an event structure, which is empty for this property)

```
function button_down(src,evnt)
% src - the object that is the source of the event
% evnt - empty for this property
   sel_typ = get(gcbf,'SelectionType')
   switch sel_typ
      case 'normal'
         disp('User clicked left-mouse button')
         set(src,'Selected','on')
      case 'extend'
         disp('User did a shift-click')
         set(src,'Selected','on')
      case 'alt'
         disp('User did a control-click')
         set(src,'Selected','on')
         set(src,'SelectionHighlight','off')
   end
end
```

Suppose `h` is the handle of a rectangle object and that the `button_down` function is on your MATLAB path. The following statement assigns the function above to the `ButtonDownFcn`:

```
set(h,'ButtonDownFcn',@button_down)
```

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

`Children`

vector of handles

The empty matrix; rectangle objects have no children.

`Clipping`

`{on} | off`

Clipping mode. MATLAB clips rectangles to the axes plot box by default. If you set `Clipping` to `off`, rectangles are displayed outside the axes plot box. This can occur if you create a rectangle, set `hold` to `on`, freeze axis scaling (`axis` set to `manual`), and then create a larger rectangle.

`CreateFcn`

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

Callback function executed during object creation. This property defines a callback function that executes when MATLAB creates a rectangle object. You must define this property as a default value for rectangles or in a call to the `rectangle` function to create a new rectangle object. For example, the statement

```
set(0,'DefaultRectangleCreateFcn',@rect_create)
```

defines a default value for the rectangle `CreateFcn` property on the root level that sets the axes `DataAspectRatio` whenever you create a rectangle object. The callback function must be on your MATLAB path when you execute the above statement.

```
function rect_create(src,evnt)
% src - the object that is the source of the event
% evnt - empty for this property
 axh = get(src,'Parent');
 set(axh,'DataAspectRatio',[1,1,1]))
end
```

MATLAB executes this function after setting all rectangle properties. Setting this property on an existing rectangle object has no effect. The function must define at least two input arguments (handle of object created and an event structure, which is empty for this property).

The handle of the object whose `CreateFcn` is being executed is passed by MATLAB as the first argument to the callback function and is also accessible through the root `CallbackObject` property, which you can query using `gcbo`.

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

`Curvature`

one- or two-element vector `[x,y]`

Amount of horizontal and vertical curvature. This property specifies the curvature of the rectangle sides, which enables the shape of the rectangle to vary from rectangular to ellipsoidal. The horizontal curvature `x` is the fraction of width of the rectangle that is curved along the top and bottom edges. The vertical curvature `y` is the fraction of the height of the rectangle that is curved along the left and right edges.

The values of `x` and `y` can range from `0` (no curvature) to `1` (maximum curvature). A value of `[0,0]` creates a rectangle with square sides. A value of `[1,1]` creates an ellipse. If you specify only one value for `Curvature`, then the same length (in axes data units) is curved along both horizontal and vertical sides. The amount of curvature is determined by the shorter dimension.

`DeleteFcn`

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

Delete rectangle callback function. A callback function that executes when you delete the rectangle object (e.g., when you issue a `delete` command or clear the axes `cla` or figure `clf`). For example, the following function displays object property data before the object is deleted.

```
function delete_fcn(src,evnt)
% src - the object that is the source of the event
% evnt - empty for this property
   obj_tp = get(src,'Type');
   disp([obj_tp, ' object deleted'])
   disp('Its user data is:')
   disp(get(src,'UserData'))
```

```
end
```

MATLAB executes the function before deleting the object's properties so these values are available to the callback function. The function must define at least two input arguments (handle of object being deleted and an event structure, which is empty for this property)

The handle of the object whose `DeleteFcn` is being executed is passed by MATLAB as the first argument to the callback function and is also accessible through the root `CallbackObject` property, which you can query using `gcbo`.

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

`DisplayName`
string (default is empty string)

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

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

- To add programmatically a legend that uses the `DisplayName` string, call `legend` with the `toggle` or `show` option.

See "Controlling Legends" for more examples.

`EdgeColor`
`{ColorSpec} | none`

Color of the rectangle edges. This property specifies the color of the rectangle edges as a color or specifies that no edges be drawn.

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

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

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

Color is set to none. This damages objects that are behind the erased rectangle, but rectangles are always properly colored.

Printing with Nonnormal Erase Modes

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

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

FaceColor
: ColorSpec | {none}

Color of rectangle face. This property specifies the color of the rectangle face, which is not colored by default.

HandleVisibility
: {on} | callback | off

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

Handles are always visible when HandleVisibility is on.

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

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

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

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

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

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

`HitTest`

`{on} | off`

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

`Interruptible`
`{on} | off`

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

`LineStyle`
`{-} | — | : | -. | none`

Line style of rectangle edge. This property specifies the line style of the edges. The available line styles are

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

`LineWidth`
scalar

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

`Parent`
handle of axes, hggroup, or hgtransform

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

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

`Position`

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

Location and size of rectangle. This property specifies the location and size of the rectangle in the data units of the axes. The point defined by `x`, `y` specifies one corner of the rectangle, and `width` and `height` define the size in units along the *x*-and *y*-axes respectively.

`Selected`

`on | off`

Is object selected? When this property is `on` MATLAB displays selection handles if the `SelectionHighlight` property is also `on`. You can, for example, define the `ButtonDownFcn` to set this property, allowing users to select the object with the mouse.

`SelectionHighlight`

`{on} | off`

Objects are highlighted when selected. When the `Selected` property is `on`, MATLAB indicates the selected state by drawing handles at each vertex. When `SelectionHighlight` is `off`, MATLAB does not draw the handles.

`Tag`

string

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

`Type`
string (read only)

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

`UIContextMenu`
handle of a uicontextmenu object

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

`UserData`
matrix

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

`Visible`
`{on} | off`

Rectangle visibility. By default, all rectangles are visible. When set to `off`, the rectangle is not visible, but still exists, and you can `get` and `set` its properties.

rectint

Purpose

Rectangle intersection area

Syntax

```
area = rectint(A,B)
```

Description

`area = rectint(A,B)` returns the area of intersection of the rectangles specified by position vectors `A` and `B`.

If `A` and `B` each specify one rectangle, the output `area` is a scalar.

`A` and `B` can also be matrices, where each row is a position vector. `area` is then a matrix giving the intersection of all rectangles specified by `A` with all the rectangles specified by `B.` That is, if `A` is `n`-by-`4` and `B` is `m`-by-`4`, then `area` is an `n`-by-`m` matrix where `area(i,j)` is the intersection area of the rectangles specified by the `i`th row of `A` and the `j`th row of `B`.

Note A position vector is a four-element vector `[x,y,width,height]`, where the point defined by `x` and `y` specifies one corner of the rectangle, and `width` and `height` define the size in units along the x and y axes respectively.

See Also

`polyarea`

Purpose

Set option to move deleted files to recycle folder

Syntax

```
S = recycle
S = recycle state
S = recycle('state')
```

Description

`S = recycle` returns a character array `S` that shows the current state of the file recycling option in the MATLAB application. This state can be either `on` or `off`. When file recycling is `on`, MATLAB moves all files that you delete with the `delete` function to either the recycle bin on Microsoft Windows or Apple Macintosh platforms, or to a temporary directory on UNIX[24] platforms. (To locate this directory on UNIX platforms, see the Remarks section below.) When file recycling is `off`, any files you delete are actually removed from the system. The default recycle state is `off`. You can turn on recycling for all of your MATLAB sessions using preferences. Select **File > Preferences > General**, and for **Default behavior of the delete function**, select **Move files to the Recycle Bin**. For more information, click the **Help** button in General Preferences.

`S = recycle` *`state`* sets the recycle option for MATLAB to the specified state, either `on` or `off`. Return value `S` shows the previous recycle state.

`S = recycle('state')` is the function format.

Remarks

On UNIX platforms, you can locate the system temporary directory by entering the MATLAB function `tempdir`. The recycle directory is a subdirectory of this temporary directory, and is named according to the format

```
MATLAB_Files_<day>-<mo>-<yr>_<hr>_<min>_<sec>
```

For example, files recycled on a UNIX platform at 2:09:28 in the afternoon of November 9, 2007 are copied to a directory named

```
/tmp/MATLAB_Files_09-Nov-2007_14_09_28
```

You can recycle files that are stored on your local computer system, but not files that you access over a network connection. On Windows platforms, when you use the `delete` function on files accessed over a network, MATLAB removes the file entirely, regardless of the recycle state.

Examples

Start from a state where file recycling has been turned off. Check the current recycle state:

```
recycle
```

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

```
ans =
   off
```

Turn file recycling on. Delete a file and verify that it is transferred to the recycle bin or temporary folder:

```
recycle on;
delete myfile.txt
```

See Also

`delete`, `dir`, `ls`, `fileparts`, `mkdir`, `rmdir`

"Managing Files and Working with the Current Directory"

reducepatch

Purpose

Reduce number of patch faces

Syntax

```
nfv = reducepatch(p,r)
nfv = reducepatch(fv,r)
nfv = reducepatch(p) or nfv = reducepatch(fv)
reducepatch(...,'fast')
reducepatch(...,'verbose')
nfv = reducepatch(f,v,r)
[nf,nv] = reducepatch(...)
```

Description

`reducepatch(p,r)` reduces the number of faces of the patch identified by handle `p`, while attempting to preserve the overall shape of the original object. The MATLAB software interprets the reduction factor `r` in one of two ways depending on its value:

- If `r` is less than 1, `r` is interpreted as a fraction of the original number of faces. For example, if you specify `r` as 0.2, then the number of faces is reduced to 20% of the number in the original patch.
- If `r` is greater than or equal to 1, then `r` is the target number of faces. For example, if you specify `r` as 400, then the number of faces is reduced until there are 400 faces remaining.

`nfv = reducepatch(p,r)` returns the reduced set of faces and vertices but does not set the `Faces` and `Vertices` properties of patch `p`. The struct `nfv` contains the faces and vertices after reduction.

`nfv = reducepatch(fv,r)` performs the reduction on the faces and vertices in the struct `fv`.

`nfv = reducepatch(p) or nfv = reducepatch(fv)` uses a reduction value of `0.5`.

`reducepatch(...,'fast')` assumes the vertices are unique and does not compute shared vertices.

`reducepatch(...,'verbose')` prints progress messages to the command window as the computation progresses.

`nfv = reducepatch(f,v,r)` performs the reduction on the faces in `f` and the vertices in `v`.

`[nf,nv] = reducepatch(...)` returns the faces and vertices in the arrays `nf` and `nv`.

Remarks

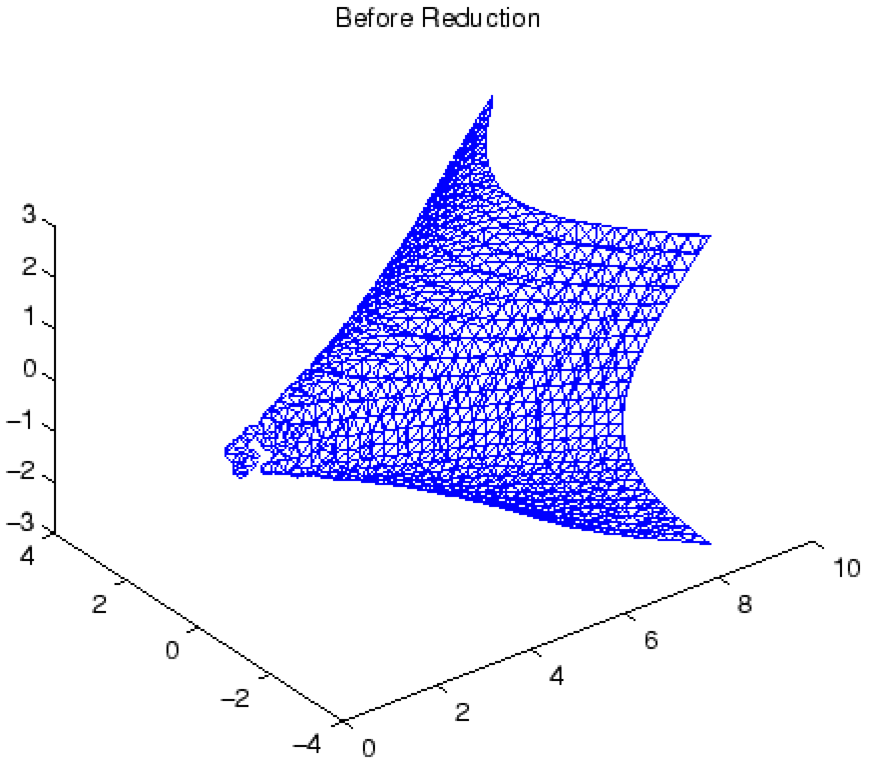
If the patch contains nonshared vertices, MATLAB computes shared vertices before reducing the number of faces. If the faces of the patch are not triangles, MATLAB triangulates the faces before reduction. The faces returned are always defined as triangles.

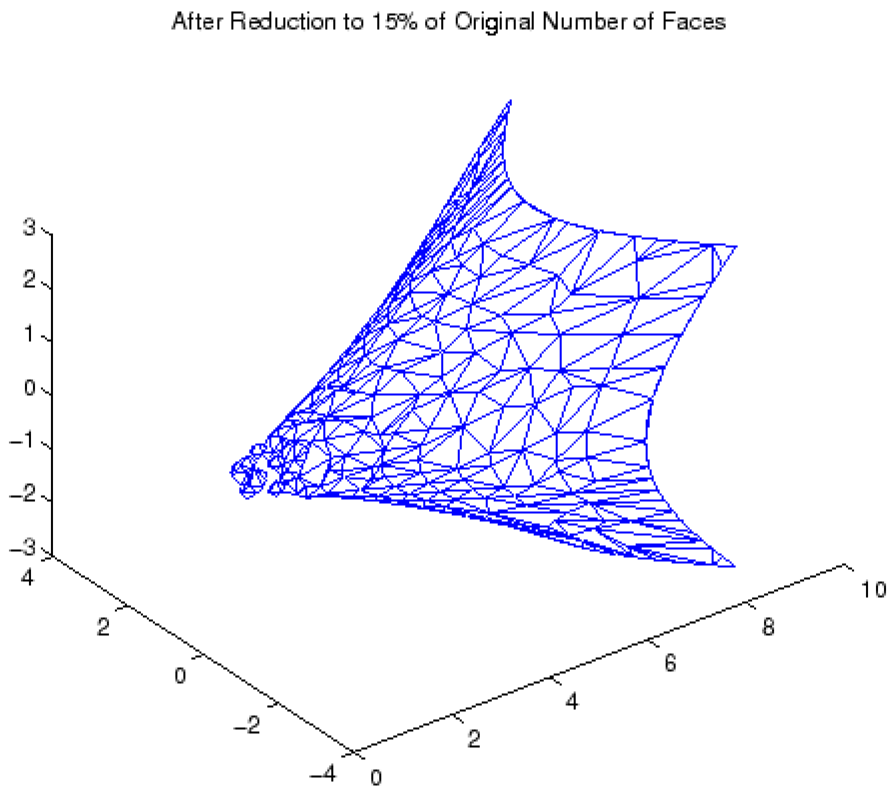
The number of output triangles may not be exactly the number specified with the reduction factor argument (`r`), particularly if the faces of the original patch are not triangles.

Examples

This example illustrates the effect of reducing the number of faces to only 15% of the original value.

```
[x,y,z,v] = flow;
p = patch(isosurface(x,y,z,v,-3));
set(p,'facecolor','w','EdgeColor','b');
daspect([1,1,1])
view(3)
figure;
h = axes;
p2 = copyobj(p,h);
reducepatch(p2,0.15)
daspect([1,1,1])
view(3)
```


Before Reduction
3
2
1
0
–1
–2
–3
4
2
0
–2
–4
0
2
4
6
8
10



See Also isosurface, isocaps, isonormals, smooth3, subvolume, reducevolume

"Volume Visualization" on page 1-106 for related functions

Vector Field Displayed with Cone Plots for another example

reducevolume

Purpose

Reduce number of elements in volume data set

Syntax

```
[nx,ny,nz,nv] = reducevolume(X,Y,Z,V,[Rx,Ry,Rz])
[nx,ny,nz,nv] = reducevolume(V,[Rx,Ry,Rz])
nv = reducevolume(...)
```

Description

`[nx,ny,nz,nv] = reducevolume(X,Y,Z,V,[Rx,Ry,Rz])` reduces the number of elements in the volume by retaining every `Rx`th element in the *x* direction, every `Ry`th element in the *y* direction, and every `Rz`th element in the *z* direction. If a scalar `R` is used to indicate the amount or reduction instead of a three-element vector, the MATLAB software assumes the reduction to be `[R R R]`.

The arrays `X`, `Y`, and `Z` define the coordinates for the volume `V`. The reduced volume is returned in `nv`, and the coordinates of the reduced volume are returned in `nx`, `ny`, and `nz`.

`[nx,ny,nz,nv] = reducevolume(V,[Rx,Ry,Rz])` assumes the arrays `X`, `Y`, and `Z` are defined as `[X,Y,Z] = meshgrid(1:n,1:m,1:p)`, where `[m,n,p] = size(V)`.

`nv = reducevolume(...)` returns only the reduced volume.

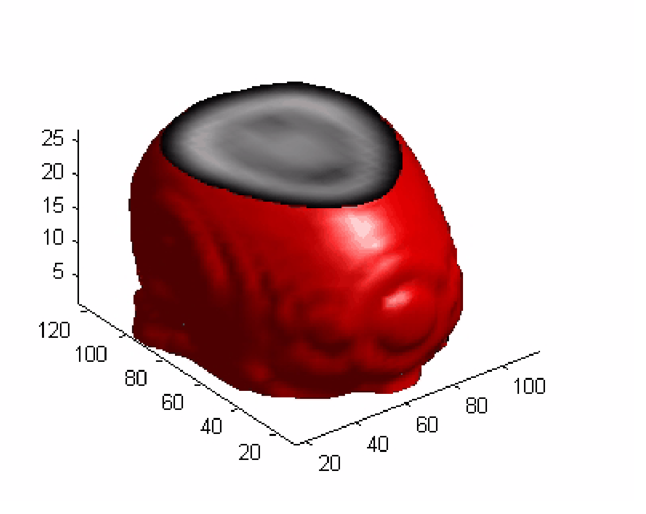
Examples

This example uses a data set that is a collection of MRI slices of a human skull. This data is processed in a variety of ways:

- The 4-D array is squeezed (`squeeze`) into three dimensions and then reduced (`reducevolume`) so that what remains is every fourth element in the *x* and *y* directions and every element in the *z* direction.
- The reduced data is smoothed (`smooth3`).
- The outline of the skull is an isosurface generated as a patch (`p1`) whose vertex normals are recalculated to improve the appearance when lighting is applied (`patch`, `isosurface`, `isonormals`).
- A second patch (`p2`) with an interpolated face color draws the end caps (`FaceColor`, `isocaps`).
- The view of the object is set (`view`, `axis`, `daspect`).

- A 100-element grayscale colormap provides coloring for the end caps (colormap).
- Adding a light to the right of the camera illuminates the object (camlight, lighting).

```
load mri
D = squeeze(D);
[x,y,z,D] = reducevolume(D,[4,4,1]);
D = smooth3(D);
p1 = patch(isosurface(x,y,z,D, 5,'verbose'),...
    'FaceColor','red','EdgeColor','none');
isonormals(x,y,z,D,p1);
p2 = patch(isocaps(x,y,z,D, 5),...
    'FaceColor','interp','EdgeColor','none');
view(3); axis tight; daspect([1,1,.4])
colormap(gray(100))
camlight; lighting gouraud
```



See Also

isosurface, isocaps, isonormals, smooth3, subvolume, reducepatch

"Volume Visualization" on page 1-106 for related functions

Purpose Redraw current figure

Syntax

```
refresh
refresh(h)
```

Description `refresh` erases and redraws the current figure.

`refresh(h)` redraws the figure identified by `h`.

See Also "Figure Windows" on page 1-99 for related functions

refreshdata

Purpose

Refresh data in graph when data source is specified

Syntax

```
refreshdata
refreshdata(figure_handle)
refreshdata(object_handles)
refreshdata(object_handles,'workspace')
```

Description

`refreshdata` evaluates any data source properties (`XDataSource`, `YDataSource`, or `ZDataSource`) on all objects in graphs in the current figure. If the specified data source has changed, the MATLAB software updates the graph to reflect this change.

Note that the variable assigned to the data source property must be in the base workspace.

`refreshdata(figure_handle)` refreshes the data of the objects in the specified figure.

`refreshdata(object_handles)` refreshes the data of the objects specified in `object_handles` or the children of those objects. Therefore, `object_handles` can contain figure, axes, or plot object handles.

`refreshdata(object_handles,'workspace')` enables you to specify whether the data source properties are evaluated in the base workspace or the workspace of the function in which `refreshdata` was called. *`workspace`* is a string that can be

- `base` — Evaluate the data source properties in the base workspace.
- `caller` — Evaluate the data source properties in the workspace of the function that called refreshdata.

Remarks

The Linked Plots feature (see documentation for `linked`) sets up data sources for graphs and synchronizes them with the workspace variables they display. When you use this feature, you do not also need to call `refreshdata`, as it is essentially automatically triggered every time a data source changes.

If you are not using the Linked Plots feature, you need to set the XDataSource, YDataSource, and/or ZDataSource properties of a graph in order to use refreshdata. You can do that programmatically, as shown in the examples below, or use the Property Editor, one of the plotting tools. In the Property Editor, select the graph (e.g., a lineseries object) and type in (or select from the drop-down choices) the name(s) of the workspace variable(s) from which you want the plot to refresh, in the fields labelled **X Data Source**, **Y Data Source**, and/or **Z Data Source**. The call to refreshdata causes the graph to update.

Examples

Plot a sine wave, identify data sources, and then modify its YDataSource:

```
x = 0:.1:8;
y = sin(x);
h = plot(x,y)
set(h,'YDataSource','y')
set(h,'XDataSource','x')
y = sin(x.^3);
refreshdata
```

Create a surface plot, identify a ZDataSource for it, and change the data to a different size.

```
Z = peaks(5);
h = surf(Z)
set(h,'ZDataSource','Z')
pause(3)
Z = peaks(25);
refreshdata
```

See Also

The [X,Y,Z]DataSource properties of plot objects.

regexp, regexpi

Purpose

Match regular expression

Syntax

```
regexp('str', 'expr')
[start_idx, end_idx, extents, matches, tokens, names,
   splits] = regexp('str', 'expr')
[v1, v2, ...] = regexp('str', 'expr', q1, q2, ...)
[v1 v2 ...] = regexp('str', 'expr', ..., options)
```

Each of these syntaxes applies to both `regexp` and `regexpi`. The `regexp` function is case sensitive in matching regular expressions to a string, and `regexpi` is case insensitive.

Description

The following descriptions apply to both `regexp` and `regexpi`:

`regexp('str', 'expr')` returns a row vector containing the starting index of each substring of `str` that matches the regular expression string `expr`. If no matches are found, `regexp` returns an empty array. The `str` and `expr` arguments can also be cell arrays of strings. See "Regular Expressions" in the MATLAB Programming Fundamentals documentation for more information.

To specify more than one string to parse or more than one expression to match, see the guidelines listed below under "Multiple Strings or Expressions" on page 2-2969.

`[start_idx, end_idx, extents, matches, tokens, names, splits] = regexp('str', 'expr')` returns up to six values, one for each output variable you specify, and in the default order (as shown in the table below).

Note The `str` and `expr` inputs are required and must be entered as the first and second arguments, respectively. Any other input arguments (all are described below) are optional and can be entered following the two required inputs in any order.

[v1, v2, ...] = regexp('str', 'expr', q1, q2, ...) returns up to six values, one for each output variable you specify, and ordered according to the order of the qualifier arguments, q1, q2, etc.

Return Values for Regular Expressions

Default Order	Description	Qualifier
1	Row vector containing the starting index of each substring of str that matches expr.	**start**
2	Row vector containing the ending index of each substring of str that matches expr.	**end**
3	Cell array containing the starting and ending indices of each substring of str that matches a token in expr. (This is a double array when used with 'once'.)	**tokenExtents**
4	Cell array containing the text of each substring of str that matches expr. (This is a string when used with 'once'.)	**match**
5	Cell array of cell arrays of strings containing the text of each token captured by regexp. (This is a cell array of strings when used with 'once'.)	**tokens**
6	Structure array containing the name and text of each *named* token captured by regexp. If there are no named tokens in expr, regexp returns a structure array with no fields. Field names of the returned structure are set to the token names, and field values are the text of those tokens. Named tokens are generated by the expression (?<tokenname>).	**names**
7	Cell array containing those parts of the input string that are delimited by substrings returned when using the regexp 'match' option.	**split**

Tip When using the `split` option, `regexp` always returns one more string than it does with the `match` option. Also, you can always put the original input string back together from the substrings obtained from both `split` and `match`. See "Example 4 — Splitting the Input String" on page 2-2970.

`[v1 v2 ...] = regexp('str', 'expr', ..., *options*)` calls `regexp` with one or more of the nondefault options listed in the following table. These options must follow `str` and `expr` in the input argument list.

Option	Description
`mode`	See the section on "Modes" on page 2-2966 below.
'**`once`**'	Return only the first match found.
'**`warnings`**'	Display any hidden warning messages issued by MATLAB during the execution of the command. This option only enables warnings for the one command being executed. See "Example 11 — Displaying Parsing Warnings" on page 2-2976.

Modes

You can specify one or more of the following modes with the `regexp`, `regexpi`, and `regexprep` functions. You can enable or disable any of these modes using the mode specifier keyword (e.g., `'lineanchors'`) or the mode flag (e.g., `(?m)`). Both are shown in the tables that follow. Use the keyword to enable or disable the mode for the entire string being parsed. Use the flag to both enable and disable the mode for selected pieces of the string.

Case-Sensitivity Mode

Use the Case-Sensitivity mode to control whether or not MATLAB considers letter case when matching an expression to a string. "Example 7 — Using the Case-Sensitive Mode" on page 2-2973 illustrates this mode.

Mode Keyword	Flag	Description
'**matchcase**'	(?-i)	Letter case must match when matching patterns to a string. (The default for regexp).
'**ignorecase**'	(?i)	Do not consider letter case when matching patterns to a string. (The default for regexpi).

Dot Matching Mode

Use the Dot Matching mode to control whether or not MATLAB includes the newline (\n) character when matching the dot (.) metacharacter in a regular expression. "Example 8 — Using the Dot Matching Mode" on page 2-2974 illustrates the Dot Matching mode.

Mode Keyword	Flag	Description
'**dotall**'	(?s)	Match dot ('.') in the pattern string with any character. (This is the default).
'**dotexceptnewline**'	(?-s)	Match dot in the pattern with any character that is not a newline.

Anchor Type Mode

Use the Anchor Type mode to control whether MATLAB considers the ^ and $ metacharacters to represent the beginning and end of a string or the beginning and end of a line. "Example 9 — Using the Anchor Type Mode" on page 2-2974 illustrates the Anchor mode.

Mode Keyword	Flag	Description
'stringanchors'	(?-m)	Match the ^ and $ metacharacters at the beginning and end of a string. (This is the default).
'lineanchors'	(?m)	Match the ^ and $ metacharacters at the beginning and end of a line.

Spacing Mode

Use the Spacing mode to control how MATLAB interprets space characters and comments within the parsing string. Note that spacing mode applies to the parsing string (the second input argument that contains the metacharacters (e.g., `\w`) and not the string being parsed. "Example 10 — Using the Spacing Mode" on page 2-2975 illustrates the Spacing mode.

Mode Keyword	Flag	Description
'literalspacing'	(?-x)	Parse space characters and comments (the # character and any text to the right of it) in the same way as any other characters in the string. (This is the default).
'freespacing'	(?x)	Ignore spaces and comments when parsing the string. (You must use `'\ '` and `'\#'` to match space and # characters.)

Remarks

See "Regular Expressions" in the MATLAB Programming Fundamentals documentation for a listing of all regular expression elements supported by MATLAB.

Multiple Strings or Expressions

Either the `str` or `expr` argument, or both, can be a cell array of strings, according to the following guidelines:

- If `str` is a cell array of strings, then each of the `regexp` outputs is a cell array having the same dimensions as `str`.
- If `str` is a single string but `expr` is a cell array of strings, then each of the `regexp` outputs is a cell array having the same dimensions as `expr`.
- If both `str` and `expr` are cell arrays of strings, these two cell arrays must contain the same number of elements.

Examples

Example 1 — Matching a Simple Pattern

Return a row vector of indices that match words that start with `c`, end with `t`, and contain one or more vowels between them. Make the matches insensitive to letter case (by using `regexpi`):

```
str = 'bat cat can car COAT court cut ct CAT-scan';
regexpi(str, 'c[aeiou]+t')
ans =
     5    17    28    35
```

Example 2 — Parsing Multiple Input Strings

Return a cell array of row vectors of indices that match capital letters and white spaces in the cell array of strings `str`:

```
str = {'Madrid, Spain' 'Romeo and Juliet' 'MATLAB is great'};
s1 = regexp(str, '[A-Z]');
s2 = regexp(str, '\s');
```

Capital letters, `'[A-Z]'`, were found at these `str` indices:

```
s1{:}
ans =
     1     9
ans =
```

```
     1    11
ans =
     1     2     3     4     5     6
```

Space characters, `'\s'`, were found at these `str` indices:

```
s2{:}
ans =
     8
ans =
     6    10
ans =
     7    10
```

Example 3 — Selecting Return Values

Return the text and the starting and ending indices of words containing the letter `x`:

```
str = 'regexp helps you relax';
[m s e] = regexp(str, '\w*x\w*', 'match', 'start', 'end')
m =
    'regexp'    'relax'
s =
     1    18
e =
     6    22
```

Example 4 — Splitting the Input String

Find the substrings delimited by the `^` character:

```
s1 = ['Use REGEXP to split ^this string into ' ...
      'several ^individual pieces'];

s2 = regexp(s1, '\^', 'split');

s2(:)
ans =
    'Use REGEXP to split '
```

```
    'this string into several '
    'individual pieces'
```

The split option returns those parts of the input string that are not returned when using the 'match' option. Note that when you match the beginning or ending characters in a string (as is done in this example), the first (or last) return value is always an empty string:

```
str = 'She sells sea shells by the seashore.';

[matchstr splitstr] = regexp(str, '[Ss]h.', 'match', ...
                              'split')
matchstr =
    'She'    'she'    'sho'
splitstr =
     ''    ' sells sea '    'lls by the sea'    're.'
```

For any string that has been split, you can reassemble the pieces into the initial string using the command

```
j = [splitstr; [matchstr {''}]]; [j{:}]

ans =
   She sells sea shells by the seashore.
```

Example 5 — Using Tokens

Search a string for opening and closing HTML tags. Use the expression <(\w+) to find the opening tag (e.g., '<tagname') and to create a token for it. Use the expression </\1> to find another occurrence of the same token, but formatted as a closing tag (e.g., '</tagname>'):

```
str = ['if <code>A</code> == x<sup>2</sup>, ' ...
       '<em>disp(x)</em>']
str =
if <code>A</code> == x<sup>2</sup>, <em>disp(x)</em>

expr = '<(\w+).*?>.*?</\1>';
```

```
[tok mat] = regexp(str, expr, 'tokens', 'match');

tok{:}
ans =
    'code'
ans =
    'sup'
ans =
    'em'

mat{:}
ans =
    <code>A</code>
ans =
    <sup>2</sup>
ans =
    <em>disp(x)</em>
```

See “Tokens” in the MATLAB Programming Fundamentals documentation for information on using tokens.

Example 6 — Using Named Capture

Enter a string containing two names, the first and last names being in a different order:

```
str = sprintf('John Davis\nRogers, James')
str =
    John Davis
    Rogers, James
```

Create an expression that generates first and last name tokens, assigning the names `first` and `last` to the tokens. Call `regexp` to get the text and names of each token found:

```
expr = ...
  '(?<first>\w+)\s+(?<last>\w+)|(?<last>\w+),\s+(?<first>\w+)';

[tokens names] = regexp(str, expr, 'tokens', 'names');
```

Examine the `tokens` cell array that was returned. The first and last name tokens appear in the order in which they were generated: first name–last name, then last name–first name:

```
tokens{:}
ans =
    'John'    'Davis'
ans =
    'Rogers'    'James'
```

Now examine the `names` structure that was returned. First and last names appear in a more usable order:

```
names(:,1)
ans =
    first: 'John'
     last: 'Davis'

names(:,2)
ans =
    first: 'James'
     last: 'Rogers'
```

Example 7 — Using the Case-Sensitive Mode

Given a string that has both uppercase and lowercase letters,

```
str = 'A string with UPPERCASE and lowercase text.';
```

Use the `regexp` default mode (case-sensitive) to locate only the lowercase instance of the word `case`:

```
regexp(str, 'case', 'match')
ans =
    'case'
```

Now disable case-sensitive matching to find both instances of `case`:

```
regexp(str, 'case', 'ignorecase', 'match')
ans =
```

```
    'CASE'    'case'
```

Match 5 letters that are followed by 'CASE'. Use the (?-i) flag to turn on case-sensitivity for the first match and (?i) to turn it off for the second:

```
M = regexp(str, {'(?-i)\w{5}(?=CASE)', ...
                 '(?i)\w{5}(?=CASE)'}, 'match');

M{:}
ans =
    'UPPER'
ans =
    'UPPER'    'lower'
```

Example 8 — Using the Dot Matching Mode

Parse the following string that contains a newline (\n) character:

```
str = sprintf('abc\ndef')
str =
   abc
   def
```

When you use the default mode, dotall, MATLAB includes the newline in the characters matched:

```
regexp(str, '.', 'match')
ans =
   'a'   'b'   'c'   [1x1 char]   'd'   'e'   'f'
```

When you use the dotexceptnewline mode, MATLAB skips the newline character:

```
regexp(str, '.', 'match', 'dotexceptnewline')
ans =
   'a'   'b'   'c'   'd'   'e'   'f'
```

Example 9 — Using the Anchor Type Mode

Given the following two-line string,

```
str = sprintf('%s\n%s', 'Here is the first line', ...
              'followed by the second line')
str =
   Here is the first line
   followed by the second line
```

In `stringanchors` mode, MATLAB interprets the `$` metacharacter as an end-of-string specifier, and thus finds the last two words of the entire *string*:

```
regexp(str, '\w+\W\w+$', 'match', 'stringanchors')
ans =
    'second line'
```

While in `lineanchors` mode, MATLAB interprets `$` as an end-of-line specifier, and finds the last two words of each *line*:

```
regexp(str, '\w+\W\w+$', 'match', 'lineanchors')
ans =
    'first line'    'second line'
```

Example 10 — Using the Spacing Mode

Create a file called `regexp_str.txt` containing the following text.

```
(?x)    # turn on freespacing.

# This pattern matches a string with a repeated letter.

\w*     # First, match any number of preceding word characters.

(       # Mark a token.
.       # Match a character of any type.
)       # Finish capturing said token.
\1      # Backreference to match what token #1 matched.

\w*     # Finally, match the remainder of the word.
```

Because the first line enables freespacing mode, MATLAB ignores all spaces and comments that appear in the file. Here is the string to parse:

```
str = ['Looking for words with letters that ' ...
       'appear twice in succession.'];
```

Use the pattern expression read from the file to find those words that have consecutive matching letters:

```
patt = fileread('regexp_str.txt');
regexp(str, patt, 'match')
ans =
    'Looking'    'letters'    'appear'    'succession'
```

Example 11 — Displaying Parsing Warnings

To help debug problems in parsing a string with `regexp`, `regexpi`, or `regexprep`, use the ’`warnings`’ option to view all warning messages:

```
regexp('$.', '[a-]','warnings')
Warning: Unbound range.
 [a-]
   |
```

See Also

`regexprep`, `regexptranslate`, `strfind`, `findstr`, `strmatch`, `strcmp`, `strcmpi`, `strncmp`, `strncmpi`

Purpose

Replace string using regular expression

Syntax

```
s = regexprep('str', 'expr', 'repstr')
s = regexprep('str', 'expr', 'repstr', options)
```

Description

`s = regexprep('str', 'expr', 'repstr')` replaces all occurrences of the regular expression `expr` in string `str` with the string `repstr`. The new string is returned in `s`. If no matches are found, return string `s` is the same as input string `str`. You can use character representations (e.g., `'\t'` for tab, or `'\n'` for newline) in replacement string `repstr`. See "Regular Expressions" in the MATLAB Programming Fundamentals documentation for more information.

If `str` is a cell array of strings, then the `regexprep` return value `s` is always a cell array of strings having the same dimensions as `str`.

To specify more than one expression to match or more than one replacement string, see the guidelines listed below under "Multiple Expressions or Replacement Strings" on page 2-2978.

You can capture parts of the input string as tokens and then reuse them in the replacement string. Specify the parts of the string to capture using the `(...)` operator. Specify the tokens to use in the replacement string using the operators `$1`, `$2`, `$N` to reference the first, second, and `N`th tokens captured. (See "Tokens" and the example "Using Tokens in a Replacement String" in the MATLAB Programming Fundamentals documentation for information on using tokens.)

`s = regexprep('str', 'expr', 'repstr', *options*)` By default, `regexprep` replaces all matches and is case sensitive. You can use one or more of the following options with `regexprep`.

Option	Description
`mode`	See `mode` descriptions on the `regexp` reference page.
`N`	Replace only the `N`th occurrence of `expr` in `str`.
'**`once`**'	Replace only the first occurrence of `expr` in `str`.

Option	Description
'ignorecase'	Ignore case when matching and when replacing.
'preservecase'	Ignore case when matching (as with 'ignorecase'), but override the case of replace characters with the case of corresponding characters in str when replacing.
'warnings'	Display any hidden warning messages issued by MATLAB during the execution of the command. This option only enables warnings for the one command being executed.

Remarks

See "Regular Expressions" in the MATLAB Programming Fundamentals documentation for a listing of all regular expression metacharacters supported by MATLAB.

Multiple Expressions or Replacement Strings

In the case of multiple expressions and/or replacement strings, `regexprep` attempts to make all matches and replacements. The first match is against the initial input string. Successive matches are against the string resulting from the previous replacement.

The `expr` and `repstr` inputs follow these rules:

- If `expr` is a cell array of strings and `repstr` is a single string, `regexprep` uses the same replacement string on each expression in `expr`.
- If `expr` is a single string and `repstr` is a cell array of N strings, `regexprep` attempts to make N matches and replacements.
- If both `expr` and `repstr` are cell arrays of strings, then `expr` and `repstr` must contain the same number of elements, and `regexprep` pairs each `repstr` element with its matching element in `expr`.

Examples

Example 1 — Making a Case-Sensitive Replacement

Perform a case-sensitive replacement on words starting with m and ending with y:

```
str = 'My flowers may bloom in May';
pat = 'm(\w*)y';
regexprep(str, pat, 'April')
ans =
   My flowers April bloom in May
```

Replace all words starting with m and ending with y, regardless of case, but maintain the original case in the replacement strings:

```
regexprep(str, pat, 'April', 'preservecase')
ans =
   April flowers april bloom in April
```

Example 2 — Using Tokens In the Replacement String

Replace all variations of the words 'walk up' using the letters following walk as a token. In the replacement string

```
str = 'I walk up, they walked up, we are walking up.';
pat = 'walk(\w*) up';
regexprep(str, pat, 'ascend$1')
ans =
   I ascend, they ascended, we are ascending.
```

Example 3 — Operating on Multiple Strings

This example operates on a cell array of strings. It searches for consecutive matching letters (e.g., 'oo') and uses a common replacement value ('--') for all matches. The function returns a cell array of strings having the same dimensions as the input cell array:

```
str = {                                    ...
'Whose woods these are I think I know.' ; ...
'His house is in the village though;'   ; ...
'He will not see me stopping here'      ; ...
'To watch his woods fill up with snow.'};
```

```
a = regexprep(str, '(.)\1', '--', 'ignorecase')
a =
    'Whose w--ds these are I think I know.'
    'His house is in the vi--age though;'
    'He wi-- not s-- me sto--ing here'
    'To watch his w--ds fi-- up with snow.'
```

See Also

regexp, regexpi, regexptranslate, strfind, findstr, strmatch, strcmp, strcmpi, strncmp, strncmpi

Purpose

Translate string into regular expression

Syntax

```
s2 = regexptranslate(type, s1)
```

Description

s2 = regexptranslate(type, s1) translates string s1 into a regular expression string s2 that you can then use as input into one of the MATLAB regular expression functions such as regexp. The type input can be either one of the following strings that define the type of translation to be performed. See “Regular Expressions” in the MATLAB Programming Fundamentals documentation for more information.

Type	Description
'escape'	Translate all special characters (e.g., '$', '.', '?', '[') in string s1 so that they are treated as literal characters when used in the regexp and regexprep functions. The translation inserts an escape character ('\') before each special character in s1. Return the new string in s2.
'wildcard'	Translate all wildcard and '.' characters in string s1 so that they are treated as literal wildcards and periods when used in the regexp and regexprep functions. The translation replaces all instances of '*' with '.*', all instances of '?' with '.', and all instances of '.' with '\.'. Return the new string in s2.

Examples

Example 1 — Using the 'escape' Option

Because regexp interprets the sequence '\n' as a newline character, it cannot locate the two consecutive characters '\' and 'n' in this string:

```
str = 'The sequence \n generates a new line';
pat = '\n';

regexp(str, pat)
ans =
     []
```

To have `regexp` interpret the expression `expr` as the characters '\' and 'n', first translate the expression using `regexptranslate`:

```
pat2 = regexptranslate('escape', pat)
pat2 =
   \\n

regexp(str, pat2)
ans =
    14
```

Example 2 — Using 'escape' In a Replacement String

Replace the word '`walk`' with '`ascend`' in this string, treating the characters '`$1`' as a token designator:

```
str = 'I walk up, they walked up, we are walking up.';
pat = 'walk(\w*) up';

regexprep(str, pat, 'ascend$1')
ans =
   I ascend, they ascended, we are ascending.
```

Make another replacement on the same string, this time treating the '`$1`' as literal characters:

```
regexprep(str, pat, regexptranslate('escape', 'ascend$1'))
ans =
   I ascend$1, they ascend$1, we are ascend$1.
```

Example 3 — Using the 'wildcard' Option

Given the following string of filenames, pick out just the MAT-files. Use `regexptranslate` to interpret the '*' wildcard as '\w+' instead of as a regular expression quantifier:

```
files = ['test1.mat, myfile.mat, newfile.txt, ' ...
         'jan30.mat, table3.xls'];
regexp(str, regexptranslate('wildcard', '*.mat'), 'match')
ans =
```

```
    'test1.mat' 'myfile.mat' 'jan30.mat'
```

To see the translation, you can type

```
regexptranslate('wildcard','*.mat')
ans =
   \w+\.mat
```

See Also

regexp, regexpi, regexprep

Purpose Register event handler for COM object event at run-time

Syntax

```
h.registerevent(event_handler)
registerevent(h, event_handler)
```

Description `h.registerevent(event_handler)` registers certain event handler routines with their corresponding events. Once an event is registered, the object responds to the occurrence of that event by invoking its event handler routine. The `event_handler` argument can be either a string that specifies the name of the event handler function, or a function handle that maps to that function. Strings used in the `event_handler` argument are not case sensitive.

`registerevent(h, event_handler)` is an alternate syntax for the same operation.

You can either register events at the time you create the control (using `actxcontrol`), or register them dynamically at any time after the control has been created (using `registerevent`). The `event_handler` argument specifies both events and event handlers (see "Writing Event Handlers" in the External Interfaces documentation).

Remarks COM functions are available on Microsoft Windows systems only.

Examples

Register Events Using Function Name Example

Create an `mwsamp` control and list all events associated with the control:

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

h.events
```

MATLAB software displays (output is formatted):

```
Click = void Click()
DblClick = void DblClick()
MouseDown = void MouseDown(int16 Button, int16 Shift,
```

```
    Variant x, Variant y)
  Event_Args = void Event_Args(int16 typeshort,
    int32 typelong, double typedouble, string typestring,
    bool typebool)
```

Register all events with the same event handler routine, `sampev`. Use `eventlisteners` to see the event handler used by each event:

```
h.registerevent('sampev');
h.eventlisteners
```

MATLAB displays:

```
ans =
    'Click'          'sampev'
    'DblClick'       'sampev'
    'MouseDown'      'sampev'
    'Event_Args'     'sampev'
```

Unregister these events. Now register the `Click` and `DblClick` events with the event handlers `myclick` and `my2click`, respectively. Note that the strings in the argument list are not case sensitive.

```
h.unregisterallevents;
h.registerevent({'click' 'myclick'; ...
                 'dblclick' 'my2click'});
h.eventlisteners
```

MATLAB displays:

```
ans =
    'click'        'myclick'
    'dblclick'     'my2click'
```

Register Events Using Function Handle Example

Register all events with the same event handler routine, `sampev`, but use a function handle (`@sampev`) instead of the function name:

```
h = actxcontrol('mwsamp.mwsampctrl.2', [0 0 200 200]);
registerevent(h, @sampev);
```

Register Workbook Events Example

Create a Microsoft Excel `Workbook` object.

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

Register all events with the same event handler routine, `AllEventHandler`.

```
wb.registerevent('AllEventHandler')
wb.eventlisteners
```

The MATLAB displays the list of all Workbook events, registered with `AllEventHandler`.

```
ans =

    'Open'                  'AllEventHandler'
    'Activate'              'AllEventHandler'
    'Deactivate'            'AllEventHandler'
    'BeforeClose'           'AllEventHandler'
                 .
                 .
```

See Also

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

Purpose

Refresh function and file system path caches

Syntax

```
rehash
rehash path
rehash toolbox
rehash pathreset
rehash toolboxreset
rehash toolboxcache
```

Description

`rehash` with no arguments updates the MATLAB list of known files and classes for directories on the search path that are not in *matlabroot*/`toolbox`. It compares the timestamps for loaded functions against their timestamps on disk. It clears loaded functions if the files on disk are newer. All of this normally happens each time MATLAB displays the Command Window prompt. Use `rehash` with no arguments only when you run an M-file that updates a second M-file, and the calling file needs to reuse the updated version of the second M-file before the calling file has finished running.

`rehash` **`path`** performs the same updates as `rehash`, but uses a different technique for detecting the files and directories that require updates. Run `rehash path` only if you receive a warning during MATLAB startup notifying you that MATLAB could not tell if a directory has changed, and you encounter problems with MATLAB not using the most current versions of your M-files.

`rehash` **`toolbox`** performs the same updates as rehash path, except it updates the list of known files and classes for *all* directories on the search path, including those in *matlabroot*/`toolbox`. Run `rehash toolbox` when you change, add, or remove files in *matlabroot*/`toolbox` during a session. Typically, you should not make changes to files and directories in *matlabroot*/`toolbox`.

`rehash` **`pathreset`** performs the same updates as `rehash` **`path`**, and also ensures the known files and classes list follows precedence rules for shadowed functions.

`rehash` **`toolboxreset`** performs the same updates as `rehash` **`toolbox`**, and also ensures the known files and classes list follows precedence rules for shadowed functions.

`rehash` **`toolboxcache`** performs the same updates as `rehash` **`toolbox`**, and also updates the cache file. This is the equivalent of clicking the **Update Toolbox Path Cache** button in the General Preferences dialog box.

See Also

`addpath`, `clear`, `matlabroot`, `path`, `rmpath`

"Toolbox Path Caching in the MATLAB Program" and "Search Path" in the MATLAB Desktop Tools and Development Environment documentation

Purpose

Release COM interface

Syntax

```
h.release
release(h)
```

Description

`h.release` releases the interface and all resources used by the interface. Each interface handle must be released when you are finished manipulating its properties and invoking its methods. Once an interface has been released, it is no longer valid. Subsequent operations on the MATLAB object that represents that interface will result in errors.

`release(h)` is an alternate syntax for the same operation.

Note Releasing the interface does not delete the control itself (see `delete`), since other interfaces on that object may still be active. See Releasing Interfaces in the External Interfaces documentation for more information.

Remarks

COM functions are available on Microsoft Windows systems only.

Examples

Create a Microsoft 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.Name = 'Viva BoldExtraExtended';
TFont.Bold = 0;
```

When you're finished working with the title font, release the `TitleFont` interface:

```
TFont.release;
```

Now create a GridFont interface and use it to modify the size of the calendar's date numerals:

```
GFont = cal.GridFont;
GFont.Size = 16;
```

When you're done, delete the cal object and the figure window:

```
cal.delete;
delete(f);
clear f;
```

See Also

delete (COM), save (COM), load (COM), actxcontrol, actxserver

Purpose

Equality and sorting of handle objects

Syntax

```
TF = eq(H1,H2)
TF = ne(H1,H2)
TF = lt(H1,H2)
TF = le(H1,H2)
TF = gt(H1,H2)
TF = ge(H1,H2)
```

Description

`TF = eq(H1,H2)`

`TF = ne(H1,H2)`

`TF = lt(H1,H2)`

`TF = le(H1,H2)`

`TF = gt(H1,H2)`

`TF = ge(H1,H2)`

For each pair of input arrays (`H1` and `H2`), a logical array of the same size is returned in which each element is an element-wise equality or comparison test result. These methods perform scalar expansion in the same way as the MATLAB built-in functions. See `relationaloperators` for more information.

You can make the following assumptions about the result of a handle comparison:

- The same two handles always compare as equal and the repeated comparison of any two handles always yields the same result in the same MATLAB session.
- Different handles are always not-equal.
- The order of handle values is purely arbitrary and has no connection to the state of the handle objects being compared.
- If the input arrays belong to different classes (including the case where one input array belongs to a non-handle class such as `double`) then the comparison is always false.

- If a comparison is made between a handle object and an object of a dominant class, the method of the dominant class is invoked. You should generally test only like objects because a dominant class might not define one of these methods.
- An error occurs if the input arrays are not the same size and neither is scalar.

See Also

`handle`, `meta.class`

Purpose

Remainder after division

Syntax

```
R = rem(X,Y)
```

Description

`R = rem(X,Y)` if `Y ~= 0`, returns `X - n.*Y` where `n = fix(X./Y)`. If `Y` is not an integer and the quotient `X./Y` is within roundoff error of an integer, then `n` is that integer. The inputs `X` and `Y` must be real arrays of the same size, or real scalars.

The following are true by convention:

- `rem(X,0)` is `NaN`
- `rem(X,X)` for `X~=0` is `0`
- `rem(X,Y)` for `X~=Y` and `Y~=0` has the same sign as `X`.

Remarks

`mod(X,Y)` for `X~=Y` and `Y~=0` has the same sign as `Y`.

`rem(X,Y)` and `mod(X,Y)` are equal if `X` and `Y` have the same sign, but differ by `Y` if `X` and `Y` have different signs.

The `rem` function returns a result that is between 0 and `sign(X)*abs(Y)`. If `Y` is zero, `rem` returns `NaN`.

See Also

`mod`

remove (Map)

Purpose Remove key-value pairs from containers.Map

Syntax

```
remove(M, keys)
```

Description remove(M, keys) erases all specified keys, and the values associated with them, from Map object M.keys can be a scalar key or a cell array of keys.

Using remove changes the count of the elements in the map.

Read more about Map Containers in the MATLAB Programming Fundamentals documentation.

Examples Create a Map object containing the names of several US states and the capital city of each:

```
US_Capitals = containers.Map( ...
{'Arizona', 'Nebraska', 'Nevada', 'New York', ...
 'Georgia', 'Alaska', 'Vermont', 'Oregon'}, ...
{'Phoenix', 'Lincoln', 'Carson City', 'Albany', ...
 'Atlanta', 'Juneau', 'Montpelier', 'Salem'});
```

After checking how many keys there are in the US_Capitals map, remove the key-value pair with key name Oregon from it:

```
US_Capitals.Count
ans =
    8

remove(US_Capitals, 'Oregon');

US_Capitals.Count
ans =
    7
```

Remove three more key-value pairs from the map:

```
remove(US_Capitals, {'Nebraska', 'Nevada', 'New York'});
US_Capitals.Count
ans =
    4
```

See Also

containers.Map, keys(Map), values(Map), size(Map), length(Map)isKey(Map),handle

Purpose

Remove `timeseries` objects from `tscollection` object

Syntax

```
tsc = removets(tsc,Name)
```

Description

`tsc = removets(tsc,Name)` removes one or more `timeseries` objects with the name specified in `Name` from the `tscollection` object tsc. `Name` can either be a string or a cell array of strings.

Examples

The following example shows how to remove a time series from a `tscollection`.

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

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

2 Create a `tscollection` object `tsc`, which includes `ts1` and `ts2`.

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

3 To view the members of `tsc`, type the following at the MATLAB prompt:

```
tsc
```

The response is

```
Time Series Collection Object: unnamed

Time vector characteristics

      Start time            1 seconds
      End time              5 seconds

Member Time Series Objects:
```

```
acceleration
speed
```

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

4 Remove `ts2` from `tsc`.

```
tsc=removets(tsc,'speed');
```

5 To view the current members of `tsc`, type the following at the MATLAB prompt:

```
tsc
```

The response is

```
Time Series Collection Object: unnamed

Time vector characteristics

      Start time            1 seconds
      End time              5 seconds

Member Time Series Objects:
      acceleration
```

The remaining member of `tsc` is `acceleration`. The `timeseries` `speed` has been removed.

See Also

`addts`, `tscollection`

Purpose

Rename file on FTP server

Syntax

`rename(f,'oldname','newname')`

Description

`rename(f,'oldname','newname')` changes the name of the file `oldname` to `newname` in the current directory of the FTP server `f`, where `f` was created using `ftp`.

Examples

Connect to server `testsite`, view the contents, and change the name of `testfile.m` to `showresults.m`.

```
test=ftp('ftp.testsite.com');
dir(test)
.             ..      testfile.m
rename(test,'testfile.m','showresults.m')
dir(test)
.             ..      showresults.m
```

See Also

`dir (ftp)`, `delete (ftp)`, `ftp`, `mget`, `mput`

Purpose

Replicate and tile array

Syntax

```
B = repmat(A,m,n)
B = repmat(A,[m n])
B = repmat(A,[m n p...])
```

Description

`B = repmat(A,m,n)` creates a large matrix `B` consisting of an `m`-by-`n` tiling of copies of `A`. The size of `B` is `[size(A,1)*m, (size(A,2)*n]`. The statement `repmat(A,n)` creates an `n`-by-`n` tiling.

`B = repmat(A,[m n])` accomplishes the same result as `repmat(A,m,n)`.

`B = repmat(A,[m n p...])` produces a multidimensional array `B` composed of copies of `A`. The size of `B` is `[size(A,1)*m, size(A,2)*n, size(A,3)*p, ...]`.

Remarks

`repmat(A,m,n)`, when `A` is a scalar, produces an `m`-by-`n` matrix filled with `A`'s value and having `A`'s `class`. For certain values, you can achieve the same results using other functions, as shown by the following examples:

- `repmat(NaN,m,n)` returns the same result as `NaN(m,n)`.
- `repmat(single(inf),m,n)` is the same as `inf(m,n,'single')`.
- `repmat(int8(0),m,n)` is the same as `zeros(m,n,'int8')`.
- `repmat(uint32(1),m,n)` is the same as `ones(m,n,'uint32')`.
- `repmat(eps,m,n)` is the same as `eps(ones(m,n))`.

Examples

In this example, `repmat` replicates 12 copies of the second-order identity matrix, resulting in a "checkerboard" pattern.

```
B = repmat(eye(2),3,4)

B =
      1     0     1     0     1     0     1     0
      0     1     0     1     0     1     0     1
      1     0     1     0     1     0     1     0
```

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

The statement `N = repmat(NaN,[2 3])` creates a 2-by-3 matrix of `NaN`s.

See Also

`bsxfun`, `NaN`, `Inf`, `ones`, `zeros`

resample (timeseries)

Purpose

Select or interpolate timeseries data using new time vector

Syntax

```
ts = resample(ts,Time)
ts = resample(ts,Time,interp_method)
ts = resample(ts,Time,interp_method,code)
```

Description

`ts = resample(ts,Time)` resamples the `timeseries` object ts using the new Time vector. When `ts` uses date strings and Time is numeric, Time is treated as specified relative to the `ts.TimeInfo.StartDate` property and in the same units that ts uses. The `resample` operation uses the default interpolation method, which you can view by using the `getinterpmethod(ts)` syntax.

`ts = resample(ts,Time,interp_method)` resamples the `timeseries` object ts using the interpolation method given by the string interp_method. Valid interpolation methods include `'linear'` and `'zoh'` (zero-order hold).

`ts = resample(ts,Time,interp_method,code)` resamples the `timeseries` object ts using the interpolation method given by the string interp_method. The integer code is a user-defined `Quality` code for resampling, applied to all samples.

Examples

The following example shows how to resample a `timeseries` object.

1 Create a `timeseries` object.

```
ts=timeseries([1.1 2.9 3.7 4.0 3.0],1:5,'Name','speed');
```

2 Transpose `ts` to make the data columnwise.

```
ts=transpose(ts)
```

The display in the MATLAB Command Window is

```
Time Series Object: speed

Time vector characteristics
```

```
      Length                5
      Start time            1 seconds
      End time              5 seconds

Data characteristics

      Interpolation method  linear
      Size                  [5  1]
      Data type             double

Time             Data             Quality
-------------------------------------------
1                1.1
2                2.9
3                3.7
4                4
5                3
```

Note that the interpolation method is set to `linear`, by default.

3 Resample `ts` using its default interpolation method.

```
res_ts=resample(ts,[1 1.5 3.5 4.5 4.9])
```

The resampled time series displays as follows:

```
Time Series Object: speed

Time vector characteristics

      Length                5
      Start time            1 seconds
      End time              4.900000e+000 seconds
```

```
Data characteristics

      Interpolation method  linear
      Size                  [5  1]
      Data type             double

Time                Data                Quality
-------------------------------------------
1                   1.1
1.5                 2
3.5                 3.85
4.5                 3.5
4.9                 3.1
```

See Also

getinterpmethod, setinterpmethod, synchronize, timeseries

resample (tscollection)

Purpose

Select or interpolate data in `tscollection` using new time vector

Syntax

```
tsc = resample(tsc,Time)
tsc = resample(tsc,Time,interp_method)
tsc = resample(tsc,Time,interp_method,code)
```

Description

`tsc = resample(tsc,Time)` resamples the `tscollection` object tsc on the new Time vector. When `tsc` uses date strings and Time is numeric, Time is treated as numerical specified relative to the `tsc.TimeInfo.StartDate` property and in the same units that tsc uses. The `resample` method uses the default interpolation method for each time series member.

`tsc = resample(tsc,Time,interp_method)` resamples the `tscollection` object tsc using the interpolation method given by the string interp_method. Valid interpolation methods include `'linear'` and `'zoh'` (zero-order hold).

`tsc = resample(tsc,Time,interp_method,code)` resamples the `tscollection` object tsc using the interpolation method given by the string interp_method. The integer code is a user-defined quality code for resampling, applied to all samples.

Examples

The following example shows how to resample a `tscollection` that consists of two `timeseries` members.

1 Create two `timeseries` objects.

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

2 Create a `tscollection` `tsc`.

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

The time vector of the collection `tsc` is [1:5], which is the same as for `ts1` and `ts2` (individually).

3 Get the interpolation method for `acceleration` by typing

```
tsc.acceleration
```

MATLAB responds with

```
Time Series Object: acceleration

Time vector characteristics

      Length                 5
      Start time             1 seconds
      End time               5 seconds

Data characteristics

      Interpolation method  linear
      Size                  [1  1  5]
      Data type             double
```

4 Set the interpolation method for `speed` to zero-order hold by typing

```
setinterpmethod(tsc.speed,'zoh')
```

MATLAB responds with

```
Time Series Object: acceleration

Time vector characteristics

      Length                 5
      Start time             1 seconds
      End time               5 seconds
```

```
Data characteristics

      Interpolation method  zoh
      Size                  [1  1  5]
      Data type             double
```

5 Resample the time-series collection `tsc` by individually resampling each time-series member of the collection and using its interpolation method.

```
res_tsc=resample(tsc,[1 1.5 3.5 4.5 4.9])
```

See Also

`getinterpmethod`, `setinterpmethod`, `tscollection`

Purpose

Reset graphics object properties to their defaults

Syntax

```
reset(h)
```

Description

`reset(h)` resets all properties having factory defaults on the object identified by `h`. To see the list of factory defaults, use the statement

```
get(0,'factory')
```

If `h` is a `figure`, the MATLAB software does not reset `Position`, `Units`, `Windowstyle`, or `PaperUnits`. If `h` is an `axes`, MATLAB does not reset `Position` and `Units`.

Examples

`reset(gca)` resets the properties of the current axes.

`reset(gcf)` resets the properties of the current figure.

See Also

`cla`, `clf`, `gca`, `gcf`, `hold`

"Object Manipulation" on page 1-104 for related functions

reset (RandStream)

Purpose

Reset a random stream

Class

`@RandStream`

Syntax

```
reset(s)
reset(s,seed)
```

Description

`reset(s)` resets the generator for the random stream `s` to its initial internal state. This is similar to clearing `s` and recreating it using `RandStream('type',...)`, except `reset` does not set the stream's `RandnAlg`, `Antithetic`, and `FullPrecision` properties to their original values.

`reset(s,seed)` resets the generator for the random stream `s` to the initial internal state corresponding to the seed `seed`. Resetting a stream's seed can invalidate independence with other streams.

Note Resetting a stream should be used primarily for reproducing results.

Examples

1 Create a random stream object.

```
s=RandStream('mt19937ar')
```

2 Make it the default stream.

```
RandStream.setDefaultStream(s)
```

3 Reset the stream object you just created and generate 5 uniform random values using the `rand` method.

```
rand(s,1,5)

ans =

    0.3631    0.4048    0.1490    0.9438    0.1247
```

4 Reset the stream.

```
reset(s)
```

5 Generate the same 5 random values from the default stream.

```
rand(s,1,5)

ans =

    0.3631    0.4048    0.1490    0.9438    0.1247
```

See Also

`@RandStream`

Purpose

Reshape array

Syntax

```
B = reshape(A,m,n)
B = reshape(A,m,n,p,...)
B = reshape(A,[m n p ...])
B = reshape(A,...,[],...)
B = reshape(A,siz)
```

Description

`B = reshape(A,m,n)` returns the `m`-by-`n` matrix `B` whose elements are taken column-wise from `A`. An error results if `A` does not have `m*n` elements.

`B = reshape(A,m,n,p,...)` or `B = reshape(A,[m n p ...])` returns an n-dimensional array with the same elements as `A` but reshaped to have the size `m`-by-`n`-by-`p`-by-`...`. The product of the specified dimensions, `m*n*p*`..., must be the same as `prod(size(A))`.

`B = reshape(A,...,[],...)` calculates the length of the dimension represented by the placeholder `[]`, such that the product of the dimensions equals `prod(size(A))`. The value of `prod(size(A))` must be evenly divisible by the product of the specified dimensions. You can use only one occurrence of `[]`.

`B = reshape(A,siz)` returns an n-dimensional array with the same elements as `A`, but reshaped to `siz`, a vector representing the dimensions of the reshaped array. The quantity `prod(siz)` must be the same as `prod(size(A))`.

Examples

Reshape a `3`-by-`4` matrix into a `2`-by-`6` matrix.

```
A =
    1     4     7    10
    2     5     8    11
    3     6     9    12

B = reshape(A,2,6)

B =
```

```
    1     3     5     7     9    11
    2     4     6     8    10    12
B = reshape(A,2,[])

B =
    1     3     5     7     9    11
    2     4     6     8    10    12
```

See Also

`shiftdim`, `squeeze`

The colon operator `:`

residue

Purpose

Convert between partial fraction expansion and polynomial coefficients

Syntax

```
[r,p,k] = residue(b,a)
[b,a] = residue(r,p,k)
```

Description

The `residue` function converts a quotient of polynomials to pole-residue representation, and back again.

`[r,p,k] = residue(b,a)` finds the residues, poles, and direct term of a partial fraction expansion of the ratio of two polynomials, $b(s)$ and $a(s)$, of the form

$$\frac{b(s)}{a(s)} = \frac{b_1 s^m + b_2 s^{m-1} + b_3 s^{m-2} + \ldots + b_{m+1}}{a_1 s^n + a_2 s^{n-1} + a_3 s^{n-2} + \ldots + a_{n+1}}$$

where b_j and a_j are the `j`th elements of the input vectors `b` and `a`.

`[b,a] = residue(r,p,k)` converts the partial fraction expansion back to the polynomials with coefficients in `b` and `a`.

Definition

If there are no multiple roots, then

$$\frac{b(s)}{a(s)} = \frac{r_1}{s-p_1} + \frac{r_2}{s-p_2} + \ldots + \frac{r_n}{s-p_n} + k(s)$$

The number of poles `n` is

```
n = length(a)-1 = length(r) = length(p)
```

The direct term coefficient vector is empty if `length(b) < length(a)`; otherwise

```
length(k) = length(b)-length(a)+1
```

If `p(j) = ...  = p(j+m-1)` is a pole of multiplicity `m`, then the expansion includes terms of the form

$$\frac{r_j}{s-p_j} + \frac{r_{j+1}}{(s-p_j)^2} + \ldots + \frac{r_{j+m-1}}{(s-p_j)^m}$$

Arguments

`b,a`	Vectors that specify the coefficients of the polynomials in descending powers of s
`r`	Column vector of residues
`p`	Column vector of poles
`k`	Row vector of direct terms

Algorithm

It first obtains the poles with `roots`. Next, if the fraction is nonproper, the direct term `k` is found using `deconv`, which performs polynomial long division. Finally, the residues are determined by evaluating the polynomial with individual roots removed. For repeated roots, `resi2` computes the residues at the repeated root locations.

Limitations

Numerically, the partial fraction expansion of a ratio of polynomials represents an ill-posed problem. If the denominator polynomial, $a(s)$, is near a polynomial with multiple roots, then small changes in the data, including roundoff errors, can make arbitrarily large changes in the resulting poles and residues. Problem formulations making use of state-space or zero-pole representations are preferable.

Examples

If the ratio of two polynomials is expressed as

$$\frac{b(s)}{a(s)} = \frac{5s^3 + 3s^2 - 2s + 7}{-4s^3 + 8s + 3}$$

then

```
b = [ 5 3 -2 7]
a = [-4 0 8 3]
```

and you can calculate the partial fraction expansion as

```
[r, p, k] = residue(b,a)

r =
   -1.4167
   -0.6653
    1.3320

p =
    1.5737
   -1.1644
   -0.4093

k =
   -1.2500
```

Now, convert the partial fraction expansion back to polynomial coefficients.

```
[b,a] = residue(r,p,k)

b =
   -1.2500   -0.7500    0.5000   -1.7500

a =
    1.0000   -0.0000   -2.0000   -0.7500
```

The result can be expressed as

$$\frac{b(s)}{a(s)} = \frac{-1.25s^3 - 0.75s^2 + 0.50s - 1.75}{s^3 - 2.00s - 0.75}$$

Note that the result is normalized for the leading coefficient in the denominator.

See Also `deconv`, `poly`, `roots`

References

[1] Oppenheim, A.V. and R.W. Schafer, *Digital Signal Processing*, Prentice-Hall, 1975, p. 56.

restoredefaultpath

Purpose

Restore default search path

Syntax

```
restoredefaultpath
restoredefaultpath; matlabrc
```

Description

`restoredefaultpath` sets the search path to include only installed products from The MathWorks. Run `restoredefaultpath` if you are having problems with the search path. If `restoredefaultpath` seems to correct the problem, run `savepath`. Start the MATLAB program again to be sure the problem does not reappear.

`restoredefaultpath; matlabrc` sets the search path to include only installed products from The MathWorks and corrects path problems encountered during startup. Run `restoredefaultpath; matlabrc` if you are having problems with the search path and if `restoredefaultpath` by itself does not correct the problem. After the problem seems to be resolved, run `savepath`. Start MATLAB again to be sure the problem does not reappear.

See Also

`addpath`, `path`, `rmpath`, `savepath`

Search Path in the MATLAB Desktop Tools and Development Environment documentation

Purpose

Reissue error

Syntax

```
rethrow(err)
```

Description

`rethrow(err)` reissues the error specified by `err`. The currently running M-file terminates and control returns to the keyboard (or to any enclosing `catch` block). The `err` argument must be a MATLAB structure containing at least one of the following fields.

Fieldname	Description
`message`	Text of the error message
`identifier`	Message identifier of the error message
`stack`	Information about the error from the program stack

See "Message Identifiers" in the MATLAB documentation for more information on the syntax and usage of message identifiers.

A convenient way to get a valid `err` structure for the last error issued is by using the `lasterror` function.

Remarks

The `err` input can contain the field `stack`, identical in format to the output of the `dbstack` command. If the `stack` field is present, the stack of the rethrown error will be set to that value. Otherwise, the stack will be set to the line at which the rethrow occurs.

Examples

`rethrow` is usually used in conjunction with `try-catch` statements to reissue an error from a `catch` block after performing `catch`-related operations. For example,

```
try
   do_something
catch
   do_cleanup
   rethrow(lasterror)
end
```

See Also `error`, `lasterror`, `try`, `catch`, `dbstop`

Purpose

Reissue existing exception

Syntax

`rethrow(ME)`

Description

`rethrow(ME)` terminates the currently running function, reissues an exception that is based on `MException` object `ME` that has been caught within a `try-catch` block, and returns control to the keyboard or to any enclosing `catch` block.

`rethrow` differs from the `throw` and `throwAsCaller` methods in that it does not modify the `stack` field. Call stack information in the `ME` object is kept as it was when the exception was first thrown.

`rethrow` can only issue a previously caught exception. If an exception that was not previously thrown is passed to the `rethrow` method, the MATLABsoftware generates a new exception.

You might use `rethrow` from the `catch` part of a `try-catch` block, for example, after performing some required cleanup tasks following an error.

Examples

This variation of the MATLAB `surf` function catches an error in the input arguments, gives the user the opportunity to correct the error, and rethrows the error if the user does not use that opportunity:

```
function surf2(varargin)
try
   surf(varargin{:})
catch ME
   ME.message      % Display the error.
   % Give user another try to enter input arguments.
   newargs = input('\nEnter argument list: ','s');
   if ~isempty(newargs)
      surf(eval(newargs));
   else
   % If no response from user, rethrow the error.
      rethrow(ME);
   end
```

```
end
```

When asked to correct the error, the user presses **Enter**. MATLAB rethrows the original error:

```
surf2
ans =
Not enough input arguments.

Enter argument list:
??? Error using ==> surf at 54
Not enough input arguments.

Error in ==> surf2 at 3
   surf(varargin{:});
```

This time, the user enters valid input and MATLAB successfully displays the output plot:

```
surf2
ans =
Not enough input arguments.

Enter argument list: peaks(30)
```

See Also

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

Purpose

Return to invoking function

Syntax

```
return
```

Description

`return` causes a normal return to the invoking function or to the keyboard. It also terminates keyboard mode.

Examples

If the determinant function were an M-file, it might use a `return` statement in handling the special case of an empty matrix, as follows:

```
function d = det(A)
%DET det(A) is the determinant of A.
if isempty(A)
    d = 1;
    return
else
    ...
end
```

See Also

`break`, `continue`, `disp`, `end`, `error`, `for`, `if`, `keyboard`, `switch`, `while`

Purpose

Convert RGB colormap to HSV colormap

Syntax

```
cmap = rgb2hsv(M)
hsv_image = rgb2hsv(rgb_image)
```

Description

`cmap = rgb2hsv(M)` converts an RGB colormap `M` to an HSV colormap `cmap`. Both colormaps are *m*-by-3 matrices. The elements of both colormaps are in the range 0 to 1.

The columns of the input matrix `M` represent intensities of red, green, and blue, respectively. The columns of the output matrix `cmap` represent hue, saturation, and value, respectively.

`hsv_image = rgb2hsv(rgb_image)` converts the RGB image to the equivalent HSV image. RGB is an m-by-n-by-3 image array whose three planes contain the red, green, and blue components for the image. HSV is returned as an m-by-n-by-3 image array whose three planes contain the hue, saturation, and value components for the image.

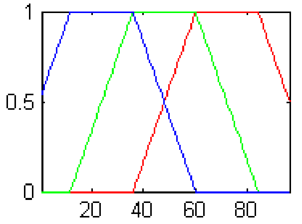
See Also

`brighten`, `colormap`, `hsv2rgb`, `rgbplot`

"Color Operations" on page 1-102 for related functions

Purpose

Plot colormap



Syntax

`rgbplot(cmap)`

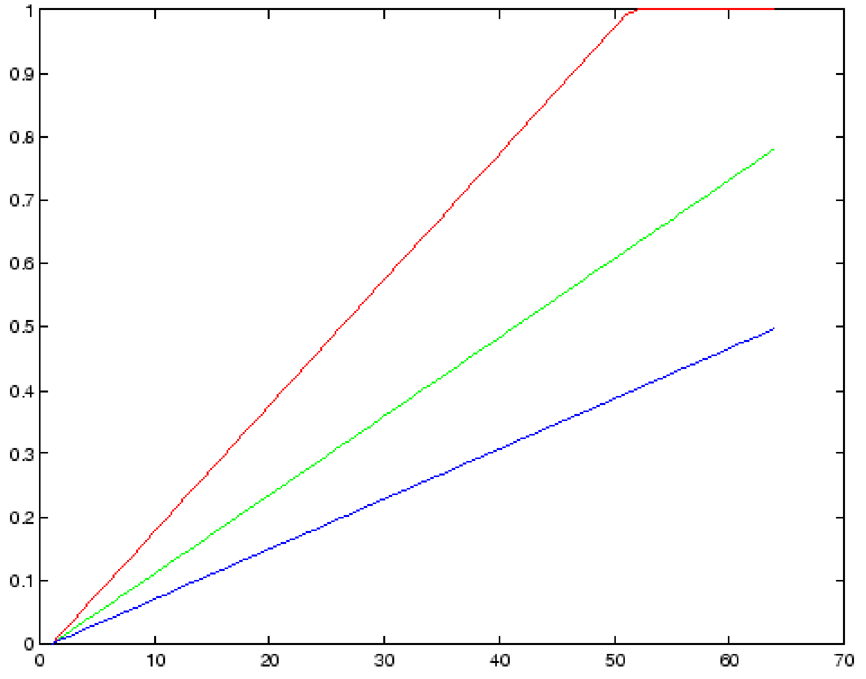
Description

`rgbplot(cmap)` plots the three columns of `cmap`, where `cmap` is an m-by-3 colormap matrix. `rgbplot` draws the first column in red, the second in green, and the third in blue.

Examples

Plot the RGB values of the `copper` colormap.

```
rgbplot(copper)
```



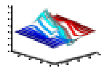
See Also

`colormap`

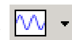
"Color Operations" on page 1-102 for related functions

Purpose

Ribbon plot



GUI Alternatives

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

Syntax

```
ribbon(Y)
ribbon(X,Y)
ribbon(X,Y,width)
ribbon(axes_handle,...)
h = ribbon(...)
```

Description

`ribbon(Y)` plots the columns of `Y` as undulating three-dimensional ribbons of uniform width using `X = 1:size(Y,1)`. Ribbons advance along the *x*-axis centered on tick marks at unit intervals, three-quarters of a unit in width. Ribbons are assigned colors from the current colormap in sequence from minimum `X` to maximum `X` (the axes `colororder` property, used by `plot` and `plot3`, does not apply to ribbon or other surface plots).

`ribbon(X,Y)` plots `X` versus the columns of `Y` as three-dimensional strips. `X` and `Y` are vectors of the same size or matrices of the same size. Additionally, `X` can be a row or a column vector, and `Y` a matrix with `length(X)` rows. `ribbon(X,Y)` is the same as `plot(X,Y)` except that the columns of `Y` are plotted as separated ribbons in 3-D. The *y* and *z*-axes of `ribbon(X,Y)` correspond to the *x* and *y*-axes of `plot(X,Y)`.

`ribbon(X,Y,width)` specifies the width of the ribbons. The default is `0.75`. If `width = 1`, the ribbons touch, leaving no space between them when viewed down the *z*-axis. If `width > 1`, ribbons overlap and can intersect.

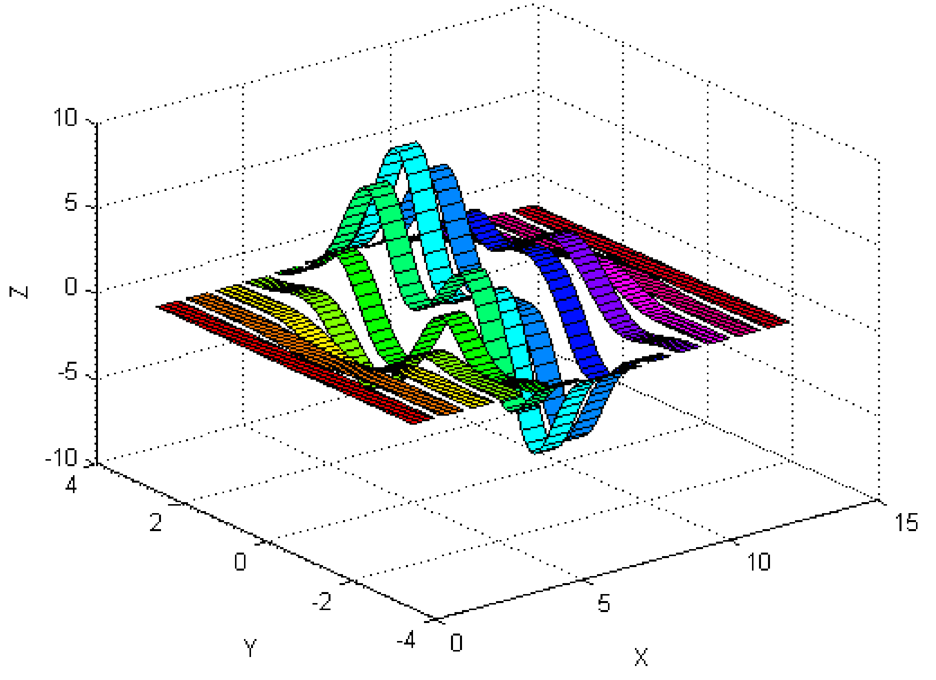
`ribbon(axes_handle,...)` plots into the axes with handle `axes_handle` instead of the current axes (`gca`).

`h = ribbon(...)` returns a vector of handles to surface graphics objects. `ribbon` returns one handle per strip.

Examples

Create a ribbon plot of the `peaks` function.

```
[x,y] = meshgrid(-3:.5:3,-3:.1:3);
z = peaks(x,y);
ribbon(y,z)
xlabel('X')
ylabel('Y')
zlabel('Z')
colormap hsv
```



See Also

`plot`, `plot3`, `surface`, `waterfall`

"Polygons and Surfaces" on page 1-94 for related functions

rmappdata

Purpose Remove application-defined data

Syntax `rmappdata(h,name)`

Description `rmappdata(h,name)` removes the application-defined data `name` from the object specified by handle `h`.

Remarks Application data is data that is meaningful to or defined by your application which you attach to a figure or any GUI component (other than ActiveX controls) through its `AppData` property. Only Handle Graphics MATLAB objects use this property.

See Also `getappdata`, `isappdata`, `setappdata`

Purpose

Remove directory

Graphical Interface

As an alternative to the rmdir function, use the delete feature in the Current Directory browser.

Syntax

```
rmdir('dirname')
rmdir('dirname','s')
[status, message, messageid] = rmdir('dirname','s')
```

Description

rmdir('dirname') removes the directory dirname from the current directory. If the directory is not empty, you must use the **s** argument. If dirname is not in the current directory, specify the relative path to the current directory or the full path for dirname.

rmdir('dirname','s') removes the directory dirname and its contents from the current directory. This removes all subdirectories and files in the current directory regardless of their write permissions.

[status, message, messageid] = rmdir('dirname','s') removes the directory dirname and its contents from the current directory, returning the status, a message, and the MATLAB error message ID (see error and lasterror). Here, status is 1 for success and is 0 for error, and message, messageid, and the **s** input argument are optional.

Remarks

When attempting to remove multiple directories, either by including a wildcard in the directory name or by specifying the 's' flag in the rmdir command, MATLAB throws an error if it is unable remove all directories to which the command applies. The error message contains a listing of those directories and files that MATLAB could not remove.

Examples

Remove Empty Directory

To remove myfiles from the current directory, where myfiles is empty, type

```
rmdir('myfiles')
```

If the current directory is `matlabr13/work`, and `myfiles` is in `d:/matlabr13/work/project/`, use the relative path to `myfiles`:

```
rmdir('project/myfiles')
```

or the full path to `myfiles`:

```
rmdir('d:/matlabr13/work/project/myfiles')
```

Remove Directory and All Contents

To remove `myfiles`, its subdirectories, and all files in the directories, assuming `myfiles` is in the current directory, type

```
rmdir('myfiles','s')
```

Remove Directory and Return Results

To remove `myfiles` from the current directory, type

```
[stat, mess, id]=rmdir('myfiles')
```

MATLAB returns

```
stat =
     0

mess =

The directory is not empty.

id =

MATLAB:RMDIR:OSError
```

indicating the directory `myfiles` is not empty.

To remove `myfiles` and its contents, run

```
[stat, mess]=rmdir('myfiles','s')
```

and MATLAB returns

```
stat =
     1

mess =

     ''
```

indicating `myfiles` and its contents have been removed.

See Also

`cd`, `copyfile`, `delete`, `dir`, `error`, `fileattrib`, `filebrowser`, `lasterror`, `mkdir`, `movefile`

"Managing Files and Working with the Current Directory"

rmdir (ftp)

Purpose Remove directory on FTP server

Syntax `rmdir(f,'dirname')`

Description `rmdir(f,'dirname')` removes the directory `dirname` from the current directory of the FTP server `f`, where `f` was created using `ftp`.

Examples Connect to server `testsite`, view the contents of `testdir`, and remove the directory `newdir` from the directory `testdir`.

```
test=ftp('ftp.testsite.com');
cd(test,'testdir');
dir(test)
.              ..       newdir
dir(test,'newdir')
.              ..
rmdir(test,'newdir');
dir(test,'testdir')
.              ..
```

See Also `cd (ftp)`, `delete (ftp)`, `dir (ftp)`, `ftp`, `mkdir (ftp)`

Purpose

Remove fields from structure

Syntax

```
s = rmfield(s, 'fieldname')
s = rmfield(s, fields)
```

Description

`s = rmfield(s, 'fieldname')` removes the specified field from the structure array `s`.

`s = rmfield(s, fields)` removes more than one field at a time. `fields` is a character array of field names or cell array of strings.

See Also

`fieldnames`, `setfield`, `getfield`, `isfield`, `orderfields`, “Using Dynamic Field Names”

Purpose

Remove directories from search path

GUI Alternatives

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

Syntax

```
rmpath('directory')
rmpath directory
```

Description

`rmpath('directory')` removes the specified directory from the current MATLAB search path . Use the full pathname for `directory`.

`rmpath directory` is the command form of the syntax.

Examples

Remove `/usr/local/matlab/mytools` from the search path.

```
rmpath /usr/local/matlab/mytools
```

See Also

`addpath`, `cd`, `dir`, `genpath`, `matlabroot`, `partialpath`, `path`, `pathsep`, `pathtool`, `rehash`, `restoredefaultpath`, `savepath`, `userpath`, `what`

Search Path in the MATLAB Desktop Tools and Development Environment documentation

Purpose

Remove preference

Syntax

```
rmpref('group','pref')
rmpref('group',{'pref1','pref2',...'prefn'})
rmpref('group')
```

Description

`rmpref('group','pref')` removes the preference specified by `group` and `pref`. It is an error to remove a preference that does not exist.

`rmpref('group',{'pref1','pref2',...'prefn'})` removes each preference specified in the cell array of preference names. It is an error if any of the preferences do not exist.

`rmpref('group')` removes all the preferences for the specified `group`. It is an error to remove a group that does not exist.

Examples

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

See Also

`addpref`, `getpref`, `ispref`, `setpref`, `uigetpref`, `uisetpref`

Purpose

Root object properties

Description

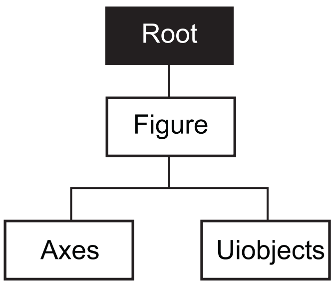
The root is a graphics object that corresponds to the computer screen. There is only one root object and it has no parent. The children of the root object are figures.

The root object exists when you start MATLAB; you never have to create it and you cannot destroy it. Use `set` and `get` to access the root properties.

See Also

`diary`, `echo`, `figure`, `format`, `gcf`, `get`, `set`

Object Hierarchy



Purpose

Root properties

Modifying Properties

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

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

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

Root Properties

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

`BusyAction`
`cancel | {queue}`

Not used by the root object.

`ButtonDownFcn`
string

Not used by the root object.

`CallbackObject`
handle (read only)

Handle of current callback's object. This property contains the handle of the object whose callback routine is currently executing. If no callback routines are executing, this property contains the empty matrix [ ]. See also the `gco` command.

`CaptureMatrix`
(obsolete)

This property has been superseded by the `getframe` command.

`CaptureRect`
(obsolete)

This property has been superseded by the `getframe` command.

`Children`
vector of handles

Handles of child objects. A vector containing the handles of all nonhidden figure objects (see `HandleVisibility` for more information). You can change the order of the handles and thereby change the stacking order of the figures on the display.

`Clipping`
`{on} | off`

Clipping has no effect on the root object.

`CommandWindowSize`
[columns rows]

Current size of command window. This property contains the size of the MATLAB command window in a two-element vector. The first element is the number of columns wide and the second element is the number of rows tall.

`CreateFcn`
The root does not use this property.

`CurrentFigure`
figure handle

Handle of the current figure window, which is the one most recently created, clicked in, or made current with the statement

```
figure(h)
```

which restacks the figure to the top of the screen, or

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

which does not restack the figures. In these statements, `h` is the handle of an existing figure. If there are no figure objects,

```
get(0,'CurrentFigure')
```

returns the empty matrix. Note, however, that `gcf` always returns a figure handle, and creates one if there are no figure objects.

`DeleteFcn`
string

This property is not used, because you cannot delete the root object.

`Diary`
`on | {off}`

Diary file mode. When this property is `on`, MATLAB maintains a file (whose name is specified by the `DiaryFile` property) that saves a copy of all keyboard input and most of the resulting output. See also the `diary` command.

`DiaryFile`
string

Diary filename. The name of the diary file. The default name is `diary`.

`Echo`
`on | {off}`

Script echoing mode. When `Echo` is `on`, MATLAB displays each line of a script file as it executes. See also the `echo` command.

`ErrorMessage`
string

Text of last error message. This property contains the last error message issued by MATLAB.

`FixedWidthFontName`

font name

Fixed-width font to use for axes, text, and uicontrols whose `FontName` *is set to* `FixedWidth`. MATLAB uses the font name specified for this property as the value for axes, text, and uicontrol `FontName` properties when their `FontName` property is set to `FixedWidth`. Specifying the font name with this property eliminates the need to hardcode font names in MATLAB applications and thereby enables these applications to run without modification in locales where non-ASCII character sets are required. In these cases, MATLAB attempts to set the value of `FixedWidthFontName` to the correct value for a given locale.

MATLAB application developers should not change this property, but should create axes, text, and uicontrols with `FontName` properties set to `FixedWidth` when they want to use a fixed-width font for these objects.

MATLAB end users can set this property if they do not want to use the preselected value. In locales where Latin-based characters are used, Courier is the default.

`Format`

`short | {shortE} | long | longE | bank |`
`hex | + | rat`

Output format mode. This property sets the format used to display numbers. See also the `format` command.

- `short` — Fixed-point format with 5 digits
- `shortE` — Floating-point format with 5 digits
- `shortG` — Fixed- or floating-point format displaying as many significant figures as possible with 5 digits
- `long` — Scaled fixed-point format with 15 digits
- `longE` — Floating-point format with 15 digits

- `longG` — Fixed- or floating-point format displaying as many significant figures as possible with 15 digits
- `bank` — Fixed-format of dollars and cents
- `hex` — Hexadecimal format
- `+` — Displays + and – symbols
- `rat` — Approximation by ratio of small integers

`FormatSpacing`
`compact | {loose}`

Output format spacing (see also `format` command).

- `compact` — Suppress extra line feeds for more compact display.
- `loose` — Display extra line feeds for a more readable display.

`HandleVisibility`
`{on} | callback | off`

This property is not useful on the root object.

`HitTest`
`{on} | off`

This property is not useful on the root object.

`Interruptible`
`{on} | off`

This property is not useful on the root object.

`Language`
string

System environment setting.

`MonitorPosition`
`[x y width height;x y width height]`

Width and height of primary and secondary monitors, in pixels. This property contains the width and height of each monitor connnected to your computer. The x and y values for the primary monitor are 0, 0 and the width and height of the monitor are specified in pixels.

The secondary monitor position is specified as

```
x = primary monitor width + 1
y = primary monitor height + 1
```

Querying the value of the figure MonitorPosition on a multiheaded system returns the position for each monitor on a separate line.

```
v = get(0,'MonitorPosition')
v =
 x y width height % Primary monitor
 x y width height % Secondary monitor
```

The value of the ScreenSize property is inconsistent when using multiple monitors. If you want specific and consistent values, use the MonitorPosition property.

Parent
handle

Handle of parent object. This property always contains the empty matrix, because the root object has no parent.

PointerLocation
[x,y]

Current location of pointer. A vector containing the *x*- and *y*-coordinates of the pointer position, measured from the lower left corner of the screen. You can move the pointer by changing the values of this property. The Units property determines the units of this measurement.

This property always contains the current pointer location, even if the pointer is not in a MATLAB window. A callback routine querying the `PointerLocation` can get a value different from the location of the pointer when the callback was triggered. This difference results from delays in callback execution caused by competition for system resources.

On Macintosh platforms, you cannot change the pointer location using the `set` command.

`PointerWindow`
handle (read only)

Handle of window containing the pointer. MATLAB sets this property to the handle of the figure window containing the pointer. If the pointer is not in a MATLAB window, the value of this property is 0. A callback routine querying the `PointerWindow` can get the wrong window handle if you move the pointer to another window before the callback executes. This error results from delays in callback execution caused by competition for system resources.

`RecursionLimit`
integer

Number of nested M-file calls. This property sets a limit to the number of nested calls to M-files MATLAB will make before stopping (or potentially running out of memory). By default the value is set to a large value. Setting this property to a smaller value (something like 150, for example) should prevent MATLAB from running out of memory and will instead cause MATLAB to issue an error when the limit is reached.

`ScreenDepth`
bits per pixel

Screen depth. The depth of the display bitmap (i.e., the number of bits per pixel). The maximum number of simultaneously displayed colors on the current graphics device is 2 raised to this power.

`ScreenDepth` supersedes the `BlackAndWhite` property. To override automatic hardware checking, set this property to `1`. This value causes MATLAB to assume the display is monochrome. This is useful if MATLAB is running on color hardware but is being displayed on a monochrome terminal. Such a situation can cause MATLAB to determine erroneously that the display is color.

`ScreenPixelsPerInch`
Display resolution

DPI setting for your display. This property contains the setting of your display resolution specified in your system preferences.

`ScreenSize`
four-element rectangle vector (read only)

Screen size. A four-element vector,

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

that defines the display size. `left` and `bottom` are `0` for all `Units` except `pixels`, in which case `left` and `bottom` are `1`. `width` and `height` are the screen dimensions in units specified by the `Units` property.

Determining Screen Size

Note that the screen size in absolute units (e.g., inches) is determined by dividing the number of pixels in width and height by the screen DPI (see the `ScreenPixelPerInch` property). This value is approximate and might not represent the actual size of the screen.

Note that the `ScreenSize` property is static. Its values are read only at MATLAB startup and not updated if system display settings change. Also, the values returned might not represent the usable screen size for application developers due to the presence of other GUIs, such as the Microsoft Windows task bar.

`Selected`
`on | off`

This property has no effect on the root level.

`SelectionHighlight`
`{on} | off`

This property has no effect on the root level.

`ShowHiddenHandles`
`on | {off}`

Show or hide handles marked as hidden. When set to `on`, this property disables handle hiding and exposes all object handles regardless of the setting of an object's `HandleVisibility` property. When set to `off`, all objects so marked remain hidden within the graphics hierarchy.

`Tag`
string

User-specified object label. The `Tag` property provides a means to identify graphics objects with a user-specified label. While it is not necessary to identify the root object with a tag (since its handle is always `0`), you can use this property to store any string value that you can later retrieve using `set`.

`Type`
string (read only)

Class of graphics object. For the root object, `Type` is always `'root'`.

`UIContextMenu`
handle

This property has no effect on the root level.

`Units`

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

Unit of measurement. This property specifies the units MATLAB uses to interpret size and location data. All units are measured from the lower left corner of the screen. Normalized units map the lower left corner of the screen to (0,0) and the upper right corner to (1.0,1.0). `inches`, `centimeters`, and `points` are absolute units (one point equals 1/72 of an inch). Characters are units defined by characters from the default system font; the width of one unit is the width of the letter x, the height of one character is the distance between the baselines of two lines of text.

This property affects the `PointerLocation` and `ScreenSize` properties. If you change the value of `Units`, it is good practice to return it to its default value after completing your operation, so as not to affect other functions that assume `Units` is set to the default value.

`UserData`
matrix

User-specified data. This property can be any data you want to associate with the root object. MATLAB does not use this property, but you can access it using the `set` and `get` functions.

`Visible`
`{on} | off`

Object visibility. This property has no effect on the root object.

Purpose

Polynomial roots

Syntax

```
r = roots(c)
```

Description

`r = roots(c)` returns a column vector whose elements are the roots of the polynomial `c`.

Row vector `c` contains the coefficients of a polynomial, ordered in descending powers. If `c` has `n+1` components, the polynomial it represents is $c_1 s^n + \ldots + c_n s + c_{n+1}$.

Remarks

Note the relationship of this function to `p = poly(r)`, which returns a row vector whose elements are the coefficients of the polynomial. For vectors, `roots` and `poly` are inverse functions of each other, up to ordering, scaling, and roundoff error.

Examples

The polynomial $s^3 - 6s^2 - 72s - 27$ is represented in MATLAB software as

```
p = [1 -6 -72 -27]
```

The roots of this polynomial are returned in a column vector by

```
r = roots(p)

r =
    12.1229
    -5.7345
    -0.3884
```

Algorithm

The algorithm simply involves computing the eigenvalues of the companion matrix:

```
A = diag(ones(n-1,1),-1);
A(1,:) = -c(2:n+1)./c(1);
eig(A)
```

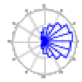
It is possible to prove that the results produced are the exact eigenvalues of a matrix within roundoff error of the companion matrix `A`, but this does not mean that they are the exact roots of a polynomial with coefficients within roundoff error of those in `c`.

See Also

`fzero`, `poly`, `residue`

Purpose

Angle histogram plot



GUI Alternatives

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

Syntax

```
rose(theta)
rose(theta,x)
rose(theta,nbins)
rose(axes_handle,...)
h = rose(...)
[tout,rout] = rose(...)
```

Description

`rose(theta)` creates an angle histogram, which is a polar plot showing the distribution of values grouped according to their numeric range, showing the distribution of `theta` in 20 angle bins or less. The vector `theta`, expressed in radians, determines the angle of each bin from the origin. The length of each bin reflects the number of elements in `theta` that fall within a group, which ranges from 0 to the greatest number of elements deposited in any one bin.

`rose(theta,x)` uses the vector `x` to specify the number and the locations of bins. `length(x)` is the number of bins and the values of `x` specify the center angle of each bin. For example, if `x` is a five-element vector, `rose` distributes the elements of `theta` in five bins centered at the specified `x` values.

`rose(theta,nbins)` plots `nbins` equally spaced bins in the range `[0, 2*pi]`. The default is `20`.

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

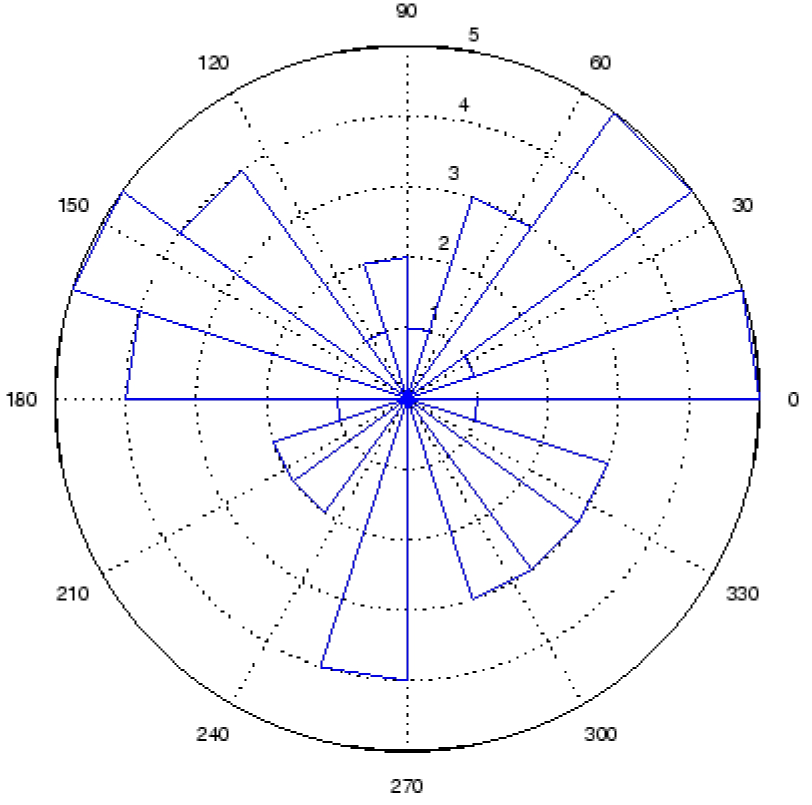
`h = rose(...)` returns the handles of the line objects used to create the graph.

`[tout,rout] = rose(...)` returns the vectors `tout` and `rout` so `polar(tout,rout)` generates the histogram for the data. This syntax does not generate a plot.

Example

Create a rose plot showing the distribution of 50 random numbers.

```
theta = 2*pi*rand(1,50);
rose(theta)
```



See Also `compass`, `feather`, `hist`, `line`, `polar`

"Histograms" on page 1-94 for related functions

Histograms in Polar Coordinates for another example

Purpose Classic symmetric eigenvalue test problem

Syntax

```
A = rosser
```

Description `A = rosser` returns the Rosser matrix. This matrix was a challenge for many matrix eigenvalue algorithms. But LAPACK's `DSYEV` routine used in MATLAB software has no trouble with it. The matrix is 8-by-8 with integer elements. It has:

- A double eigenvalue
- Three nearly equal eigenvalues
- Dominant eigenvalues of opposite sign
- A zero eigenvalue
- A small, nonzero eigenvalue

Examples

```
rosser

ans =

   611   196  -192   407    -8   -52   -49    29
   196   899   113  -192   -71   -43    -8   -44
  -192   113   899   196    61    49     8    52
   407  -192   196   611     8    44    59   -23
    -8   -71    61     8   411  -599   208   208
   -52   -43    49    44  -599   411   208   208
   -49    -8     8    59   208   208    99  -911
    29   -44    52   -23   208   208  -911    99
```

Purpose

Rotate matrix 90 degrees

Syntax

```
B = rot90(A)
B = rot90(A,k)
```

Description

`B = rot90(A)` rotates matrix `A` counterclockwise by 90 degrees.

`B = rot90(A,k)` rotates matrix `A` counterclockwise by `k*90` degrees, where `k` is an integer.

Examples

The matrix

```
X =
     1     2     3
     4     5     6
     7     8     9
```

rotated by 90 degrees is

```
Y = rot90(X)
Y =
     3     6     9
     2     5     8
     1     4     7
```

See Also

`flipdim`, `fliplr`, `flipud`

Purpose Rotate object in specified direction

Syntax

```
rotate(h,direction,alpha)
rotate(...,origin)
```

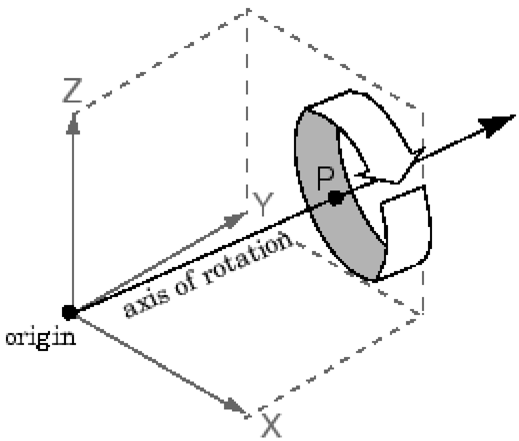
Description The `rotate` function rotates a graphics object in three-dimensional space, according to the right-hand rule.

`rotate(h,direction,alpha)` rotates the graphics object `h` by `alpha` degrees. `direction` is a two- or three-element vector that describes the axis of rotation in conjunction with the origin.

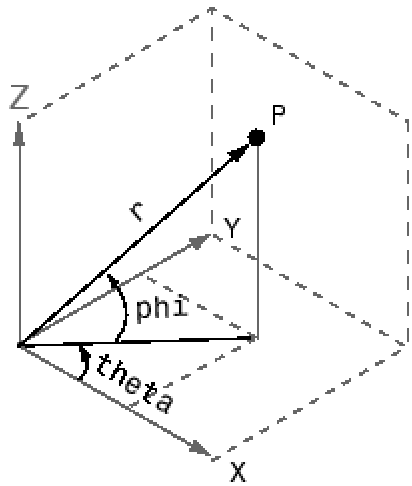
`rotate(...,origin)` specifies the origin of the axis of rotation as a three-element vector. The default origin is the center of the plot box.

Remarks The graphics object you want rotated must be a child of the same axes. The object's data is modified by the rotation transformation. This is in contrast to `view` and `rotate3d`, which only modify the viewpoint.

The axis of rotation is defined by an origin and a point *P* relative to the origin. *P* is expressed as the spherical coordinates `[theta phi]` or as Cartesian coordinates.



The two-element form for `direction` specifies the axis direction using the spherical coordinates `[theta phi]`. `theta` is the angle in the *x*-*y* plane counterclockwise from the positive *x*-axis. `phi` is the elevation of the direction vector from the *x*-*y* plane.



The three-element form for `direction` specifies the axis direction using Cartesian coordinates. The direction vector is the vector from the origin to (X,Y,Z).

Examples

Rotate a graphics object 180° about the *x*-axis.

```
h = surf(peaks(20));
rotate(h,[1 0 0],180)
```

Rotate a surface graphics object 45° about its center in the *z* direction.

```
h = surf(peaks(20));
zdir = [0 0 1];
center = [10 10 0];
rotate(h,zdir,45,center)
```

Remarks

rotate changes the Xdata, Ydata, and Zdata properties of the appropriate graphics object.

See Also

rotate3d, sph2cart, view

The axes CameraPosition, CameraTarget, CameraUpVector, CameraViewAngle

"Object Manipulation" on page 1-104 for related functions

Purpose

Rotate 3-D view using mouse

GUI Alternatives

Use the Rotate3D tool  on the figure toolbar to enable and disable rotate3D mode on a plot, or select **Rotate 3D** from the figure's **Tools** menu. For details, see "Rotate 3D — Interactive Rotation of 3-D Views" in the MATLAB Graphics documentation.

Syntax

```
rotate3d on
rotate3d off
rotate3d
rotate3d(figure_handle,...)
rotate3d(axes_handle,...)
h = rotate3d(figure_handle)
```

Description

rotate3d on enables mouse-base rotation on all axes within the current figure.

rotate3d off disables interactive axes rotation in the current figure.

rotate3d toggles interactive axes rotation in the current figure.

rotate3d(figure_handle,...) enables rotation within the specified figure instead of the current figure.

rotate3d(axes_handle,...) enables rotation only in the specified axes.

h = rotate3d(figure_handle) returns a rotate3d *mode object* for figure figure_handle for you to customize the mode's behavior.

Using Rotate Mode Objects

You access the following properties of rotate mode objects via get and modify some of them using set.

- FigureHandle <handle> — The associated figure handle, a read-only property that cannot be set
- *Enable* 'on'|'off' — Specifies whether this figure mode is currently enabled on the figure

- *RotateStyle* 'orbit'|'box' — Sets the method of rotation

  'orbit' rotates the entire axes; 'box' rotates a plot-box outline of the axes.

Rotate3D Mode Callbacks

You can program the following callbacks for rotate3d mode operations.

- ButtonDownFilter <function_handle> — Function to intercept ButtonDown events

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

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

- ActionPreCallback <function_handle> — Function to execute before rotating

  Set this callback to listen to when a rotate operation will start. The input function handle should reference a function with two implicit arguments (similar to Handle Graphics object callbacks):

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

  The event data has the following field:

Axes	The handle of the axes that is being panned

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

  Set this callback to listen to when a rotate operation has finished. The input function handle should reference a function with two implicit arguments (similar to Handle Graphics object callbacks):

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

Rotate3D Mode Utility Functions

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

- `flags = isAllowAxesRotate(h,axes)` — Function querying permission to rotate axes

  Calling the function `isAllowAxesRotate` on the rotate3d object, `h`, with a vector of axes handles, `axes`, as input will return a logical array of the same dimension as the axes handle vector which indicate whether a rotate operation is permitted on the axes objects.

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

  Calling the function `setAllowAxesRotate` on the rotate3d object, `h`, with a vector of axes handles, `axes`, and a logical scalar, `flag`, will either allow or disallow a rotate operation on the axes objects.

Examples

Example 1

Simple 3-D rotation

```
surf(peaks);
rotate3d on
% rotate the plot using the mouse pointer.
```

Example 2

Rotate the plot using the "Plot Box" rotate style:

```
surf(peaks);
h = rotate3d;
set(h,'RotateStyle','box','Enable','on');
% Rotate the plot.
```

Example 3

Create two axes as subplots and then prevent one from rotating:

```
ax1 = subplot(1,2,1);
surf(peaks);
h = rotate3d;
ax2 = subplot(1,2,2);
surf(membrane);
setAllowAxesRotate(h,ax2,false);
% rotate the plots.
```

Example 4

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

```
function demo
% Allow a line to have its own 'ButtonDownFcn' callback.
hLine = plot(rand(1,10));
set(hLine,'ButtonDownFcn','disp(''This executes'')');
set(hLine,'Tag','DoNotIgnore');
h = rotate3d;
set(h,'ButtonDownFilter',@mycallback);
set(h,'Enable','on');
% mouse-click on the line
%
```

```
function [flag] = mycallback(obj,event_obj)
% If the tag of the object is 'DoNotIgnore', then return true.
objTag = get(obj,'Tag');
if strcmpi(objTag,'DoNotIgnore')
   flag = true;
else
   flag = false;
end
```

Example 5

Create callbacks for pre- and post-buttonDown events for rotate3D mode objects to trigger. Copy the following code to a new M-file, execute it, and observe rotation behavior:

```
function demo
% Listen to rotate events
surf(peaks);
h = rotate3d;
set(h,'ActionPreCallback',@myprecallback);
set(h,'ActionPostCallback',@mypostcallback);
set(h,'Enable','on');
%
function myprecallback(obj,evd)
disp('A rotation is about to occur.');
%
function mypostcallback(obj,evd)
newView = round(get(evd.Axes,'View'));
msgbox(sprintf('The new view is [%d %d].',newView));
```

Remarks

When enabled, `rotate3d` provides continuous rotation of axes and the objects it contains through mouse movement. A numeric readout appears in the lower left corner of the figure during rotation, showing the current azimuth and elevation of the axes. Releasing the mouse button removes the animated box and the readout. This differs from the `camorbit` function in that while the `rotate3d` tool modifies the `View` property of the axes, the `cameraorbit` function fixes the aspect ratio and modifies the `CameraTarget`, `CameraPosition` and `CameraUpVector` properties of the axes. See `Axes Properties` for more information.

You can also enable 3-D rotation from the figure **Tools** menu or the figure toolbar.

You can create a `rotate3D` mode object once and use it to customize the behavior of different axes, as example 3 illustrates. You can also change its callback functions on the fly.

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

When you assign different 3-D rotation behaviors to different `subplot` axes via a mode object and then link them using the `linkaxes` function, the behavior of the axes you manipulate with the mouse will carry over to the linked axes, regardless of the behavior you previously set for the other axes.

See Also

`camorbit`, `pan`, `rotate`, `view`, `zoom`

Object Manipulation for related functions

`Axes Properties` for related properties

Purpose

Round to nearest integer

Syntax

```
Y = round(X)
```

Description

`Y = round(X)` rounds the elements of `X` to the nearest integers. For complex `X`, the imaginary and real parts are rounded independently.

Examples

```
a = [-1.9, -0.2, 3.4, 5.6, 7.0, 2.4+3.6i]

a =
  Columns 1 through 4
  -1.9000            -0.2000             3.4000              5.6000
  Columns 5 through 6
   7.0000             2.4000 + 3.6000i

round(a)

ans =
  Columns 1 through 4
  -2.0000                  0             3.0000              6.0000
  Columns 5 through 6
   7.0000             2.0000 + 4.0000i
```

See Also

`ceil`, `fix`, `floor`

Purpose

Reduced row echelon form

Syntax

```
R = rref(A)
[R,jb] = rref(A)
[R,jb] = rref(A,tol)
```

Description

`R = rref(A)` produces the reduced row echelon form of `A` using Gauss Jordan elimination with partial pivoting. A default tolerance of (`max(size(A))*eps *norm(A,inf)`) tests for negligible column elements.

`[R,jb] = rref(A)` also returns a vector `jb` such that:

- `r = length(jb)` is this algorithm's idea of the rank of `A`.
- `x(jb)` are the pivot variables in a linear system `Ax = b`.
- `A(:,jb)` is a basis for the range of `A`.
- `R(1:r,jb)` is the `r`-by-`r` identity matrix.

`[R,jb] = rref(A,tol)` uses the given tolerance in the rank tests.

Roundoff errors may cause this algorithm to compute a different value for the rank than `rank`, `orth` and `null`.

Examples

Use `rref` on a rank-deficient magic square:

```
A = magic(4), R = rref(A)

A =
    16     2     3    13
     5    11    10     8
     9     7     6    12
     4    14    15     1

R =
     1     0     0     1
     0     1     0     3
```

```
0     0     1    -3
0     0     0     0
```

See Also

`inv`, `lu`, `rank`

rsf2csf

Purpose

Convert real Schur form to complex Schur form

Syntax

```
[U,T] = rsf2csf(U,T)
```

Description

The *complex Schur form* of a matrix is upper triangular with the eigenvalues of the matrix on the diagonal. The *real Schur form* has the real eigenvalues on the diagonal and the complex eigenvalues in 2-by-2 blocks on the diagonal.

`[U,T] = rsf2csf(U,T)` converts the real Schur form to the complex form.

Arguments `U` and `T` represent the unitary and Schur forms of a matrix `A`, respectively, that satisfy the relationships: `A = U*T*U'` and `U'*U = eye(size(A))`. See `schur` for details.

Examples

Given matrix `A`,

```
  1     1     1     3
  1     2     1     1
  1     1     3     1
 -2     1     1     4
```

with the eigenvalues

```
4.8121    1.9202 + 1.4742i    1.9202 + 1.4742i    1.3474
```

Generating the Schur form of `A` and converting to the complex Schur form

```
[u,t] = schur(A);
[U,T] = rsf2csf(u,t)
```

yields a triangular matrix `T` whose diagonal (underlined here for readability) consists of the eigenvalues of `A`.

```
U =
```

```
-0.4916       -0.2756 - 0.4411i    0.2133 + 0.5699i   -0.3428
-0.4980       -0.1012 + 0.2163i   -0.1046 + 0.2093i    0.8001
-0.6751        0.1842 + 0.3860i   -0.1867 - 0.3808i   -0.4260
-0.2337        0.2635 - 0.6481i    0.3134 - 0.5448i    0.2466

T =

4.8121        -0.9697 + 1.0778i   -0.5212 + 2.0051i   -1.0067
     0         1.9202 + 1.4742i    2.3355              0.1117 + 1.6547i
     0              0              1.9202 - 1.4742i    0.8002 + 0.2310i
     0              0                   0              1.3474
```

See Also

schur

Purpose Run script that is not on current path

Syntax `run scriptname`

Description `run scriptname` runs the MATLAB script specified by `scriptname`. If `scriptname` contains the full pathname to the script file, then `run` changes the current directory to be the one in which the script file resides, executes the script, and sets the current directory back to what it was. The script is run within the caller's workspace.

`run` is a convenience function that runs scripts that are not currently on the path. Typically, you just type the name of a script at the MATLAB prompt to execute it. This works when the script is on your path. Use the `cd` or `addpath` function to make a script executable by entering the script name alone.

See Also `cd`, `addpath`

Purpose

Save workspace variables to disk

Graphical Interface

As an alternative to the `save` function, select **Save Workspace As** from the **File** menu in the MATLAB desktop, or use the Workspace browser.

Syntax

```
save
save filename
save filename content
save filename options
save filename content options
save('filename', 'var1', 'var2', ...)
```

Description

`save` stores all variables from the current MATLAB workspace in a MATLAB formatted file (MAT-file) named `matlab.mat` that resides in the current working directory. Use the `load` function to retrieve data stored in MAT-files. By default, MAT-files are double-precision, binary files. You can create a MAT-file on one machine and then load it on another machine using a different floating-point format, and retaining as much accuracy and range as the different formats allow. MAT-files can also be manipulated by other programs external to MATLAB.

`save filename` stores all variables in the current workspace in the file `filename`. If you do not specify an extension to the filename, MATLAB uses `.mat`. The file must be writable. To save to another directory, use a full pathname for the `filename`.

`save filename` *`content`* stores only those variables specified by *`content`* in file `filename`. If `filename` is not specified, MATLAB stores the data in a file called `matlab.mat`. See the following table.

Values for *content*	Description
`varlist`	Save only those variables that are in `varlist`. You can use the `*` wildcard to save only those variables that match the specified pattern. For example, `save('A*')` saves all variables that start with `A`.

Values for *content*	Description
-regexp exprlist	Save those variables that match any of the regular expressions in exprlist. See the Remarks section below.
-struct s	Save as individual variables all fields of the scalar structure s.
-struct s fieldlist	Save as individual variables only the specified fields of structure s.

In this table, the terms varlist, exprlist, and fieldlist refer to one or more variable names, regular expressions, or structure field names separated by either spaces or commas, depending on whether you are using the MATLAB command or function format. See the examples below:

Command format:

```
save firstname lastname street town
```

Function format:

```
save('firstname', 'lastname', 'street', 'town')
```

save filename *options* stores all variables from the MATLAB workspace in file filename according to one or more of the following options. If filename is not specified, MATLAB stores the data in a file called matlab.mat.

Values for *options*	Description
-append	Add new variables to those already stored in an existing MAT-file.

Values for *options*	Description
-format	Save using the specified binary or ASCII format. See the section on, "MAT-File Format Options" on page 2-3071, below.
-version	Save in a format that can be loaded into an earlier version of MATLAB. See the section on "Version Compatibility Options" on page 2-3071, below.

`save filename` *`content options`* stores only those variables specified by *`content`* in file `filename`, also applying the specified *`options`*. If `filename` is not specified, MATLAB stores the data in a file called `matlab.mat`.

`save('filename', 'var1', 'var2', ...)` is the function form of the syntax.

MAT-File Format Options

The following table lists the valid *`MAT-file format`* options.

MAT-file format Options	How Data Is Stored
`-ascii`	Save data in 8-digit ASCII format.
`-ascii -tabs`	Save data in 8-digit ASCII format delimited with tabs.
`-ascii -double`	Save data in 16-digit ASCII format.
`-ascii -double -tabs`	Save data in 16-digit ASCII format delimited with tabs.
`-mat`	Binary MAT-file form (default).

Version Compatibility Options

The following table lists version compatibility options. These options enable you to save your workspace data to a MAT-file that can then be loaded into an earlier version of MATLAB software. The resulting

MAT-file supports only those data items and features that were available in this earlier version of MATLAB. (See the second table below for what is supported in each version.)

`version` Option	Use When Running ...	To Save a MAT-File That You Can Load In ...
`-v7.3`	Version 7.3 or later	Version 7.3 or later
`-v7`	Version 7.3 or later	Versions 7.0 through 7.2 (or later)
`-v6`	Version 7 or later	Versions 5 and 6 (or later)
`-v4`	Version 5 or later	Versions 1 through 4 (or later)

The default version option is the value specified in the **Preferences** dialog box. Select **File > Preferences** in the Command Window, click **General**, and then **MAT-Files** to view or change the default.

The next table shows what data items and features are supported in different versions of MATLAB. You can use this information to determine which of the version compatibility options shown above to use.

MATLAB Versions	Data Items or Features Supported
4 and earlier	Support for 2D double, character, and sparse
5 and 6	Version 4 capability plus support for ND arrays, structs, and cells
7.0 through 7.2	Version 6 capability plus support for data compression and Unicode character encoding
7.3 and later	Version 7.2 capability plus support for data items greater than or equal to 2GB

Remarks

When using the `-regexp` switch, `save` considers all variables in the argument list, with the exception of the optional filename and structure name variables, to be regular expressions. The filename, if specified, is always the first argument in the argument list, provided that this argument is a variable name. The structure name, if specified, is always the first argument following the `-struct` keyword, provided that the argument list includes that keyword.

When working on 64-bit platforms, you can have data items in your workspace that occupy more than 2 GB. To save data of this size, you must use the HDF5-based version of the MATLAB MAT-file. Use the `v7.3` option to do this:

```
save -v7.3 myfile v1 v2
```

If you are running MATLAB on a 64-bit computer system and you attempt to save a variable that is too large for a version 7 (or earlier) MAT-file, that is, you save without using the `-v7.3` option, MATLAB skips that variable during the save operation and issues a warning message to that effect.

If you are running MATLAB on a 32-bit computer system and attempt to load a variable from a `-v7.3` MAT-file that is too large to fit in 32–bit address space, MATLAB skips that variable and issues a warning message to that effect.

MAT-files saved with compression and Unicode encoding cannot be loaded into versions of MATLAB prior to MATLAB Version 7.0. If you save data to a MAT-file that you intend to load using MATLAB Version 6 or earlier, you must specify the `-v6` option when saving. This disables compression and Unicode encoding for that particular `save` operation.

If you want to save to a file that you can then load into a Version 4 MATLAB session, you must use the `-v4` option when saving. When you use this option, variables that are incompatible with MATLAB Version 4 are not saved to the MAT-file. For example, ND arrays, structs, cells, etc. cannot be saved to a MATLAB Version 4 MAT-file. Also, variables with names that are longer than 19 characters cannot be saved to a MATLAB Version 4 MAT-file.

For information on any of the following topics related to saving to MAT-files, see “Exporting Data to MAT-Files” in the MATLAB Programming Fundamentals documentation:

- Appending variables to an existing MAT-file
- Compressing data in the MAT-file
- Saving in ASCII format
- Saving in MATLAB Version 4 format
- Saving with Unicode character encoding
- Data storage requirements
- Saving from external programs

For information on saving figures, see the documentation for `hgsave` and `saveas`. For information on exporting figures to other graphics formats, see the documentation for `print`.

Examples

Example 1

Save all variables from the workspace in binary MAT-file `test.mat`:

```
save test.mat
```

Example 2

Save variables `p` and `q` in binary MAT-file `test.mat`.

In this example, the file name is stored in a variable, `savefile`. You must call `save` using the function syntax of the command if you intend to reference the file name through a variable.

```
savefile = 'test.mat';
p = rand(1, 10);
q = ones(10);
save(savefile, 'p', 'q')
```

Example 3

Save the values of variables `vol` and `temp` in ASCII format to a file named `june10`:

```
save('d:\mymfiles\june10','vol','temp','-ASCII')
```

Example 4

Save the fields of structure `s1` as individual variables rather than as an entire structure.

```
s1.a = 12.7;  s1.b = {'abc', [4 5; 6 7]};  s1.c = 'Hello!';
save newstruct.mat -struct s1;
clear
```

Check what was saved to `newstruct.mat`:

```
whos -file newstruct.mat
  Name      Size                   Bytes  Class

  a         1x1                        8  double array
  b         1x2                      158  cell array
  c         1x6                       12  char array

Grand total is 16 elements using 178 bytes
```

Read only the `b` field into the MATLAB workspace.

```
str = load('newstruct.mat', 'b')
str =
    b: {'abc'  [2x2 double]}
```

Example 5

Using regular expressions, save in MAT-file `mydata.mat` those variables with names that begin with `Mon`, `Tue`, or `Wed`:

```
save('mydata', '-regexp', '^Mon|^Tue|^Wed');
```

Here is another way of doing the same thing. In this case, there are three separate expression arguments:

```
save('mydata', '-regexp', '^Mon', '^Tue', '^Wed');
```

Example 6

Save a 3000-by-3000 matrix uncompressed to file `c1.mat`, and compressed to file `c2.mat`. The compressed file uses about one quarter the disk space required to store the uncompressed data:

```
x = ones(3000);
y = uint32(rand(3000) * 100);

save -v6 c1 x y     % Save without compression
save -v7 c2 x y     % Save with compression

d1 = dir('c1.mat');
d2 = dir('c2.mat');

d1.bytes
ans =
    45000240      % Size of the uncompressed data in bytes.
d2.bytes
ans =
    11985283      % Size of the compressed data in bytes.

d2.bytes/d1.bytes
ans =
    0.2663        % Ratio of compressed to uncompressed
```

See Also

`load`, `clear`, `diary`, `fprintf`, `fwrite`, `genvarname`, `who`, `whos`, `workspace`, `regexp`

Purpose

Serialize control object to file

Syntax

```
h.save('filename')
save(h, 'filename')
```

Description

`h.save('filename')` saves the COM control object, `h`, to the file specified in the string, `filename`.

`save(h, 'filename')` is an alternate syntax for the same operation.

Note The COM `save` function is only supported for controls at this time.

Remarks

COM functions are available on Microsoft Windows systems only.

Examples

Create an `mwsamp` control and save its original state to the file `mwsample`:

```
f = figure('position', [100 200 200 200]);
h = actxcontrol('mwsamp.mwsampctrl.2', [0 0 200 200], f);
h.save('mwsample')
```

Now, alter the figure by changing its label and the radius of the circle:

```
h.Label = 'Circle';
h.Radius = 50;
h.Redraw;
```

Using the `load` function, you can restore the control to its original state:

```
h.load('mwsample');
h.get
```

MATLAB displays the original values:

```
ans =
     Label: 'Label'
    Radius: 20
```

See Also

`load (COM)`, `actxcontrol`, `actxserver`, `release`, `delete (COM)`

Purpose

Save serial port objects and variables to MAT-file

Syntax

```
save filename
save filename obj1 obj2...
```

Description

`save filename` saves all MATLAB variables to the MAT-file `filename`. If an extension is not specified for `filename`, then the `.mat` extension is used.

`save filename obj1 obj2...` saves the serial port objects `obj1 obj2...` to the MAT-file `filename`.

Remarks

You can use `save` in the functional form as well as the command form shown above. When using the functional form, you must specify the filename and serial port objects as strings. For example. to save the serial port object `s` to the file `MySerial.mat`

```
s = serial('COM1');
save('MySerial','s')
```

Any data that is associated with the serial port object is not automatically stored in the MAT-file. For example, suppose there is data in the input buffer for `obj`. To save that data to a MAT-file, you must bring it into the MATLAB workspace using one of the synchronous read functions, and then save to the MAT-file using a separate variable name. You can also save data to a text file with the `record` function.

You return objects and variables to the MATLAB workspace with the `load` command. Values for read-only properties are restored to their default values upon loading. For example, the `Status` property is restored to `closed`. To determine if a property is read-only, examine its reference pages.

Example

This example illustrates how to use the command and functional form of `save`.

```
s = serial('COM1');
set(s,'BaudRate',2400,'StopBits',1)
```

```
save MySerial1 s
set(s,'BytesAvailableFcn',@mycallback)
save('MySerial2','s')
```

See Also

Functions

load, record

Properties

Status

Purpose

Save figure or Simulink block diagram using specified format

GUI Alternative

Use **File —> Save As** on the figure window menu to access the Save As dialog, in which you can select a graphics format. For details, see "Exporting in a Specific Graphics Format" in the MATLAB Graphics documentation. Note that sizes of files written to image formats by this GUI and by `saveas` can differ, due to disparate resolution settings.

Syntax

```
saveas(h,'filename.ext')
saveas(h,'filename','format')
```

Description

`saveas(h,'filename.ext')` saves the figure or Simulink block diagram with the handle `h` to the file `filename.ext`. The format of the file is determined by the extension, `ext`. Allowable values for `ext` are listed in this table.

You can pass the handle of any Handle Graphics object to `saveas`, which then saves the parent figure to the object you specified should `h` not be a figure handle. This means that `saveas` cannot save a subplot without also saving all subplots in its parent figure.

ext Value	Format
`ai`	Adobe® Illustrator '88
`bmp`	Windows bitmap
`emf`	Enhanced metafile
`eps`	EPS Level 1
`fig`	MATLAB figure (invalid for Simulink block diagrams)
`jpg`	JPEG image (invalid for Simulink block diagrams)
`m`	MATLAB M-file (invalid for Simulink block diagrams)
`pbm`	Portable bitmap

ext Value	Format
pcx	Paintbrush 24-bit
pdf	Portable Document Format
pgm	Portable Graymap
png	Portable Network Graphics
ppm	Portable Pixmap
tif	TIFF image, compressed

`saveas(h,'filename','format')` saves the figure or Simulink block diagram with the handle `h` to the file called `filename` using the specified `format`. The filename can have an extension, but the extension is not used to define the file format. If no extension is specified, the standard extension corresponding to the specified format is automatically appended to the filename.

Allowable values for `format` are the extensions in the table above and the device drivers and graphic formats supported by `print`. The drivers and graphic formats supported by `print` include additional file formats not listed in the table above. When using a `print` device type to specify format for `saveas`, do not prefix it with `-d`.

Remarks

You can use `open` to open files saved using `saveas` with an `m` or `fig` extension. Other `saveas` and `print` formats are not supported by `open`. Both the **Save As** and **Export** dialog boxes that you access from a figure's **File** menu use `saveas` with the `format` argument, and support all device and file types listed above.

If you want to control the size or resolution of figures saved in image (bitmapped) formats (such as `BMP` or `JPG`), use the `print` command and specify dots-per-inch resolution with the `r` switch.

Examples

Example 1: Specify File Extension

Save the current figure that you annotated using the Plot Editor to a file named pred_prey using the MATLAB fig format. This allows you to open the file pred_prey.fig at a later time and continue editing it with the Plot Editor.

```
saveas(gcf,'pred_prey.fig')
```

Example 2: Specify File Format but No Extension

Save the current figure, using Adobe Illustrator format, to the file logo. Use the ai extension from the above table to specify the format. The file created is logo.ai.

```
saveas(gcf,'logo', 'ai')
```

This is the same as using the Adobe Illustrator format from the print devices table, which is -dill; use doc print or help print to see the table for print device types. The file created is logo.ai. MATLAB automatically appends the ai extension for an Illustrator format file because no extension was specified.

```
saveas(gcf,'logo', 'ill')
```

Example 3: Specify File Format and Extension

Save the current figure to the file star.eps using the Level 2 Color PostScript format. If you use doc print or help print, you can see from the table for print device types that the device type for this format is -dpsc2. The file created is star.eps.

```
saveas(gcf,'star.eps', 'psc2')
```

In another example, save the current Simulink block diagram to the file trans.tiff using the TIFF format with no compression. From the table for print device types, you can see that the device type for this format is -dtiffn. The file created is trans.tiff.

```
saveas(gcf,'trans.tiff', 'tiffn')
```

See Also

`hgsave`, `open`, `print`

"Printing" on page 1-96 for related functions

Simulink users, see also `save_system`

Purpose

Method called by `save` function for user-defined objects

Syntax

`B = saveobj(A)`

Description

`B = saveobj(A)` is called by the MATLAB `save` function when object `A` is saved to a MAT-file. This call executes the object's `saveobj` method, if such a method exists. The returned value `B` is used by `save` to populate the MAT-file.

You can define a `saveobj` method to modify the object before the save operation. For example, you might define a `saveobj` method that saves related data along with the object.

Remarks

A subclass object does not inherit the `saveobj` method of its superclass. `saveobj` is invoked separately for each object to be saved.

Examples

The following example shows a `saveobj` method that determines if an object has already been assigned an account number from a previous `save` operation. If not, `saveobj` calls the object's `getAccountNumber` method to obtain an account number and assigns it to the `AccountNumber` property. The value returned by `saveobj` (`b`) is saved to the MAT-file.

```
function b = saveobj(a)
   if isempty(a.AccountNumber)
      a.AccountNumber = getAccountNumber(a);
   end
   b = a;
end
```

See Also

`save`, `load`, `loadobj`

savepath

Purpose

Save current search path

GUI Alternatives

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

Syntax

```
savepath
savepath directory/pathdef.m
```

Description

`savepath` saves the current search path for the MATLAB program so you can use it in a future session. MATLAB saves the search path to the `pathdef.m` file from which it created the search path at startup. If there is a `pathdef.m` file located in the current directory, `savepath` saves the current search path to it instead of the search path it created at startup. Consider using `savepath` in your `finish.m` file to automatically save the search path when you exit MATLAB.

`savepath` *`directory`*/**`pathdef.m`** saves the current search path to `pathdef.m` located in *`directory`*. Use this form of the syntax if you want an alternative to the standard path for use in a future session. If you do not specify *`directory`*, MATLAB saves `pathdef.m` in the current directory. *`directory`* can be a relative or absolute path. If you want to use the saved path in a future session, make *`directory`* be the startup directory for MATLAB.

Examples

The statement

```
savepath I:\my_matlab_files\pathdef.m
```

saves the current search path to `pathdef.m`, located in `I:\my_matlab_files`.

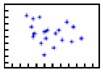
See Also

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

Search Path and "Startup Directory for the MATLAB Program" in the MATLAB Desktop Tools and Development Environment documentation

Purpose

Scatter plot



GUI Alternatives

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

Syntax

```
scatter(X,Y,S,C)
scatter(X,Y)
scatter(X,Y,S)
scatter(...,markertype)
scatter(...,'filled')
scatter(...,'PropertyName',propertyvalue)
scatter(axes_handles,...)
h = scatter(...)
hpatch = scatter('v6',...)
```

Description

`scatter(X,Y,S,C)` displays colored circles at the locations specified by the vectors `X` and `Y` (which must be the same size).

`S` determines the area of each marker (specified in points^2). `S` can be a vector the same length as `X` and `Y` or a scalar. If `S` is a scalar, MATLAB draws all the markers the same size. If `S` is empty, the default size is used.

`C` determines the color of each marker. When `C` is a vector the same length as `X` and `Y`, the values in `C` are linearly mapped to the colors in the current colormap. When `C` is a `length(X)`-by-3 matrix, it specifies the colors of the markers as RGB values. `C` can also be a color string (see `ColorSpec` for a list of color string specifiers).

`scatter(X,Y)` draws the markers in the default size and color.

`scatter(X,Y,S)` draws the markers at the specified sizes (`S`) with a single color. This type of graph is also known as a bubble plot.

`scatter(...,`*`markertype`*`)` uses the marker type specified instead of `'o'` (see `LineSpec` for a list of marker specifiers).

`scatter(...,'filled')` fills the markers.

`scatter(...,'`*`PropertyName`*`',propertyvalue)` creates the scatter graph, applying the specified property settings. See `scattergroup` properties for a description of properties.

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

`h = scatter(...)` returns the handle of the scattergroup object created.

Backward-Compatible Version

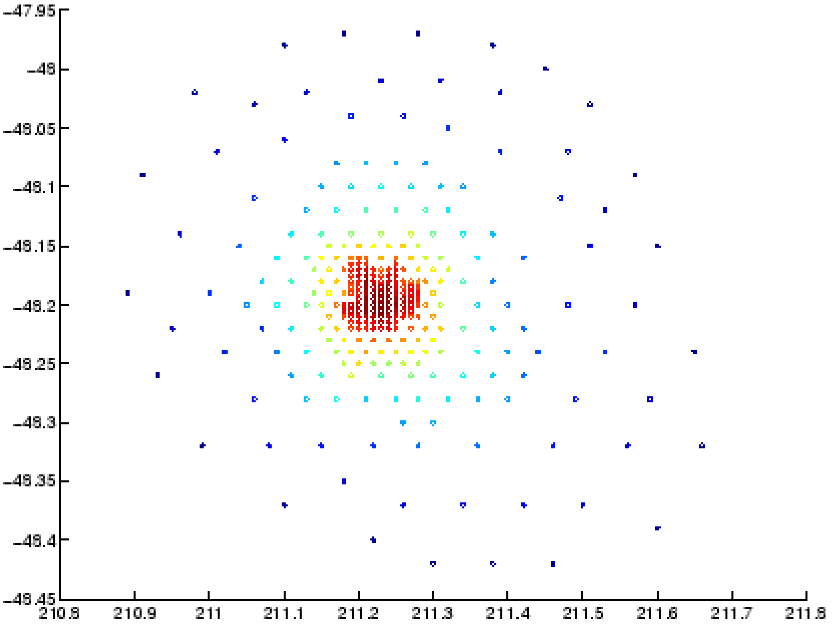
`hpatch = scatter('v6',...)` returns the handles to the patch objects created by `scatter` (see `Patch` Properties for a list of properties you can specify using the object handles and `set`).

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

See Plot Objects and Backward Compatibility for more information.

Example

```
load seamount
scatter(x,y,5,z)
```



See Also

`scatter3`, `plot3`

"Scatter/Bubble Plots" on page 1-95 for related functions

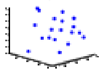
See "Scattered Data" for related information.

See `Scattergroup Properties` for property descriptions.

scatter3

Purpose

3-D scatter plot



GUI Alternatives

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

Syntax

```
scatter3(X,Y,Z,S,C)
scatter3(X,Y,Z)
scatter3(X,Y,Z,S)
scatter3(...,markertype)
scatter3(...,'filled')
scatter3(...,'PropertyName',propertyvalue)
h = scatter3(...)
hpatch = scatter3('v6',...)
```

Description

`scatter3(X,Y,Z,S,C)` displays colored circles at the locations specified by the vectors `X`, `Y`, and `Z` (which must all be the same size).

`S` determines the size of each marker (specified in points). `S` can be a vector the same length as `X`, `Y`, and `Z` or a scalar. If `S` is a scalar, MATLAB draws all the markers the same size.

`C` determines the colors of each marker. When `C` is a vector the same length as `X`, `Y`, and `Z`, the values in `C` are linearly mapped to the colors in the current colormap. When `C` is a `length(X)`-by-3 matrix, it specifies the colors of the markers as RGB values. `C` can also be a color string (see `ColorSpec` for a list of color string specifiers).

`scatter3(X,Y,Z)` draws the markers in the default size and color.

`scatter3(X,Y,Z,S)` draws markers at the specified sizes (`S`) in a single color.

`scatter3(...,markertype)` uses the marker type specified instead of 'o' (see `LineSpec` for a list of marker specifiers).

`scatter3(...,'filled')` fills the markers.

`scatter3(...,'`*`PropertyName`*`',propertyvalue)` creates the scatter graph, applying the specified property settings. See `scattergroup` properties for a description of properties.

`h = scatter3(...)` returns handles to the scattergroup objects created by `scatter3`. See `Scattergroup Properties` for property descriptions.

Backward-Compatible Version

`hpatch = scatter3('v6',...)` returns the handles to the patch objects created by `scatter3` (see `Patch` for a list of properties you can specify using the object handles and `set`).

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

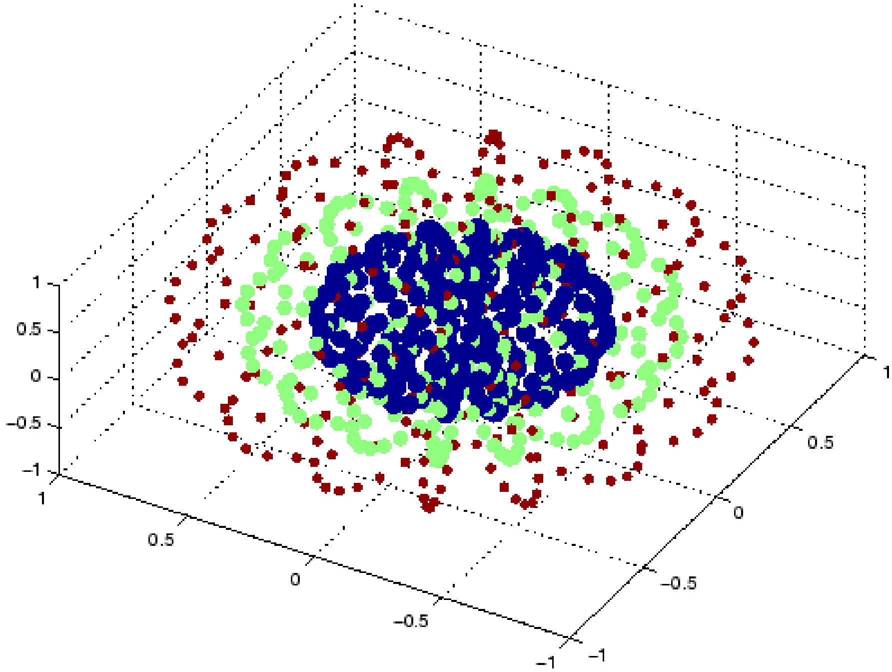
See Plot Objects and Backward Compatibility for more information.

Remarks

Use `plot3` for single color, single marker size 3-D scatter plots.

Examples

```
[x,y,z] = sphere(16);
X = [x(:)*.5 x(:)*.75 x(:)];
Y = [y(:)*.5 y(:)*.75 y(:)];
Z = [z(:)*.5 z(:)*.75 z(:)];
S = repmat([1 .75 .5]*10,prod(size(x)),1);
C = repmat([1 2 3],prod(size(x)),1);
scatter3(X(:),Y(:),Z(:),S(:),C(:),'filled'), view(-60,60)
```



See Also

`scatter`, `plot3`

See `Scattergroup Properties` for property descriptions

"Scatter/Bubble Plots" on page 1-95 for related functions

Purpose

Define scattergroup properties

Modifying Properties

You can set and query graphics object properties using the `set` and `get` commands or the Property Editor (`propertyeditor`).

Note that you cannot define default property values for scattergroup objects.

See Plot Objects for information on scattergroup objects.

Scattergroup Property Descriptions

This section provides a description of properties. Curly braces { } enclose default values.

`Annotation`

`hg.Annotation` object Read Only

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

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

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

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

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

Setting the IconDisplayStyle Property

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

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

Using the IconDisplayStyle Property

See "Controlling Legends" for more information and examples.

`BeingDeleted`

`on | {off}` Read Only

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

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

`BusyAction`
: `cancel | {queue}`

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

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

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

`ButtonDownFcn`
: string or function handle

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

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

This property can be

- A string that is a valid MATLAB expression
- The name of an M-file

- A function handle

Set this property to a function handle that references the callback. The expressions execute in the MATLAB workspace.

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

`CData`
vector, m-by-3 matrix, `ColorSpec`

Color of markers. When `CData` is a vector the same length as `XData` and `YData`, the values in `CData` are linearly mapped to the colors in the current colormap. When `CData` is a `length(XData)`-by-3 matrix, it specifies the colors of the markers as RGB values.

`CDataSource`
string (MATLAB variable)

Link YData to MATLAB variable. Set this property to a MATLAB variable that, by default, is evaluated in the base workspace to generate the `CData`.

MATLAB reevaluates this property only when you set it. Therefore, a change to workspace variables appearing in an expression does not change `CData`.

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

See the `refreshdata` reference page for more information.

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

`Children`

array of graphics object handles

Children of this object. The handle of a patch object that is the child of this object (whether visible or not).

Note that if a child object's `HandleVisibility` property is set to `callback` or `off`, its handle does not show up in this object's `Children` property unless you set the root `ShowHiddenHandles` property to `on`:

```
set(0,'ShowHiddenHandles','on')
```

`Clipping`

`{on} | off`

Clipping mode. MATLAB clips graphs to the axes plot box by default. If you set `Clipping` to `off`, portions of graphs can be displayed outside the axes plot box. This can occur if you create a plot object, set `hold` to `on`, freeze axis scaling (`axis manual`), and then create a larger plot object.

`CreateFcn`

string or function handle

Callback routine executed during object creation. This property defines a callback that executes when MATLAB creates an object. You must specify the callback during the creation of the object. For example,

```
area(y,'CreateFcn',@CallbackFcn)
```

where `@CallbackFcn` is a function handle that references the callback function.

MATLAB executes this routine after setting all other object properties. Setting this property on an existing object has no effect.

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

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

`DeleteFcn`
string or function handle

Callback executed during object deletion. A callback that executes when this object is deleted (e.g., this might happen when you issue a `delete` command on the object, its parent axes, or the figure containing it). MATLAB executes the callback before destroying the object's properties so the callback routine can query these values.

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

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

See the `BeingDeleted` property for related information.

`DisplayName`
string (default is empty string)

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

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

See "Controlling Legends" for more examples.

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

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

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

- 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.

`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 `CData` property.

`MarkerFaceColor`

`ColorSpec | {none} | auto`

Marker face color. The fill color for markers that are closed shapes (circle, square, diamond, pentagram, hexagram, and the four triangles). `ColorSpec` defines the color to use. `none` makes the interior of the marker transparent, allowing the background to show through. `auto` sets the fill color to the axes color, or to the figure color if the axes `Color` property is set to `none` (which is the factory default for axes objects).

`Parent`

handle of parent axes, hggroup, or hgtransform

Parent of this object. This property contains the handle of the object's parent. The parent is normally the axes, hggroup, or hgtransform object that contains the object.

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

`Selected`

`on | {off}`

Is object selected? When you set this property to `on`, MATLAB displays selection "handles" at the corners and midpoints if the `SelectionHighlight` property is also `on` (the default). You can, for example, define the `ButtonDownFcn` callback to set this property to `on`, thereby indicating that this particular object is selected. This property is also set to `on` when an object is manually selected in plot edit mode.

`SelectionHighlight`

`{on} | off`

Objects are highlighted when selected. When the `Selected` property is `on`, MATLAB indicates the selected state by drawing four edge handles and four corner handles. When `SelectionHighlight` is `off`, MATLAB does not draw the handles except when in plot edit mode and objects are selected manually.

`SizeData`
square points

Size of markers in square points. This property specifies the area of the marker in the scatter graph in units of points. Since there are 72 points to one inch, to specify a marker that has an area of one square inch you would use a value of `72^2`.

`Tag`
string

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

For example, you might create an areaseries object and set the `Tag` property.

```
t = area(Y,'Tag','area1')
```

When you want to access objects of a given type, you can use `findobj` to find the object's handle. The following statement changes the `FaceColor` property of the object whose `Tag` is `area1`.

```
set(findobj('Tag','area1'),'FaceColor','red')
```

`Type`
string (read only)

Type of graphics object. This property contains a string that identifies the class of the graphics object. For stemseries objects, `Type` is '`hggroup`'. The following statement finds all the hggroup objects in the current axes.

```
t = findobj(gca,'Type','hggroup');
```

`UIContextMenu`
handle of a uicontextmenu object

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

`UserData`
array

User-specified data. This property can be any data you want to associate with this object (including cell arrays and structures). The object does not set values for this property, but you can access it using the `set` and `get` functions.

`Visible`
`{on} | off`

Visibility of this object and its children. By default, a new object's visibility is `on`. This means all children of the object are visible unless the child object's `Visible` property is set to `off`. Setting an object's `Visible` property to `off` prevents the object from being displayed. However, the object still exists and you can set and query its properties.

`XData`
array

X-coordinates of scatter markers. The scatter function draws individual markers at each *x*-axis location in the `XData` array.

The input argument `x` in the `scatter` function calling syntax assigns values to `XData`.

`XDataSource`

string (MATLAB variable)

Link `XData` to MATLAB variable. Set this property to a MATLAB variable that is evaluated in the base workspace to generate the `XData`.

MATLAB reevaluates this property only when you set it. Therefore, a change to workspace variables appearing in an expression does not change `XData`.

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

See the `refreshdata` reference page for more information.

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

`YData`

scalar, vector, or matrix

Y-coordinates of scatter markers. The scatter function draws individual markers at each *y*-axis location in the `YData` array.

The input argument `y` in the `scatter` function calling syntax assigns values to `YData`.

`YDataSource`
string (MATLAB variable)

Link `YData` *to MATLAB variable.* Set this property to a MATLAB variable that is evaluated in the base workspace to generate the `YData`.

MATLAB reevaluates this property only when you set it. Therefore, a change to workspace variables appearing in an expression does not change `YData`.

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

See the `refreshdata` reference page for more information.

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

`ZData`
vector of coordinates

Z-coordinates. A vector defining the *z*-coordinates for the graph. `XData` and `YData` must be the same length and have the same number of rows.

`ZDataSource`
string (MATLAB variable)

Link `ZData` to MATLAB variable. Set this property to a MATLAB variable that is evaluated in the base workspace to generate the `ZData`.

MATLAB reevaluates this property only when you set it. Therefore, a change to workspace variables appearing in an expression does not change `ZData`.

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

See the `refreshdata` reference page for more information.

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

Purpose

Schur decomposition

Syntax

```
T = schur(A)
T = schur(A,flag)
[U,T] = schur(A,...)
```

Description

The `schur` command computes the Schur form of a matrix.

`T = schur(A)` returns the Schur matrix `T`.

`T = schur(A,flag)` for real matrix A, returns a Schur matrix `T` in one of two forms depending on the value of `flag`:

`'complex'`	`T` is triangular and is complex if `A` has complex eigenvalues.
`'real'`	`T` has the real eigenvalues on the diagonal and the complex eigenvalues in 2-by-2 blocks on the diagonal. `'real'` is the default.

If `A` is complex, `schur` returns the complex Schur form in matrix `T`. The complex Schur form is upper triangular with the eigenvalues of `A` on the diagonal.

The function `rsf2csf` converts the real Schur form to the complex Schur form.

`[U,T] = schur(A,...)` also returns a unitary matrix `U` so that `A = U*T*U'` and `U'*U = eye(size(A))`.

Examples

`H` is a 3-by-3 eigenvalue test matrix:

```
H = [ -149    -50   -154
       537    180    546
       -27     -9    -25 ]
```

Its Schur form is

```
schur(H)
```

```
ans =
     1.0000   -7.1119 -815.8706
          0    2.0000  -55.0236
          0         0    3.0000
```

The eigenvalues, which in this case are 1, 2, and 3, are on the diagonal. The fact that the off-diagonal elements are so large indicates that this matrix has poorly conditioned eigenvalues; small changes in the matrix elements produce relatively large changes in its eigenvalues.

Algorithm

Input of Type Double

If A has type double, schur uses the LAPACK routines listed in the following table to compute the Schur form of a matrix:

Matrix A	Routine
Real symmetric	DSYTRD, DSTEQR DSYTRD, DORGTR, DSTEQR (with output U)
Real nonsymmetric	DGEHRD, DHSEQR DGEHRD, DORGHR, DHSEQR (with output U)
Complex Hermitian	ZHETRD, ZSTEQR ZHETRD, ZUNGTR, ZSTEQR (with output U)
Non-Hermitian	ZGEHRD, ZHSEQR ZGEHRD, ZUNGHR, ZHSEQR (with output U)

Input of Type Single

If A has type single, schur uses the LAPACK routines listed in the following table to compute the Schur form of a matrix:

Matrix A	Routine
Real symmetric	SSYTRD, SSTEQR SSYTRD, SORGTR, SSTEQR (with output U)

Matrix A	Routine
Real nonsymmetric	SGEHRD, SHSEQR SGEHRD, SORGHR, SHSEQR (with output U)
Complex Hermitian	CHETRD, CSTEQR CHETRD, CUNGTR, CSTEQR (with output U)
Non-Hermitian	CGEHRD, CHSEQR CGEHRD, CUNGHR, CHSEQR (with output U)

See Also

`eig`, `hess`, `qz`, `rsf2csf`

References

[1] Anderson, E., Z. Bai, C. Bischof, S. Blackford, J. Demmel, J. Dongarra, J. Du Croz, A. Greenbaum, S. Hammarling, A. McKenney, and D. Sorensen, *LAPACK User's Guide* (`http://www.netlib.org/lapack/lug/lapack_lug.html`), Third Edition, SIAM, Philadelphia, 1999.

script

Purpose

Script M-file description

Description

A script file is an external file that contains a sequence of MATLAB statements. By typing the filename, you can obtain subsequent MATLAB input from the file. Script files have a filename extension of `.m` and are often called M-files.

Scripts are the simplest kind of M-file. They are useful for automating blocks of MATLAB commands, such as computations you have to perform repeatedly from the command line. Scripts can operate on existing data in the workspace, or they can create new data on which to operate. Although scripts do not return output arguments, any variables that they create remain in the workspace, so you can use them in further computations. In addition, scripts can produce graphical output using commands like `plot`.

Scripts can contain any series of MATLAB statements. They require no declarations or begin/end delimiters.

Like any M-file, scripts can contain comments. Any text following a percent sign (`%`) on a given line is comment text. Comments can appear on lines by themselves, or you can append them to the end of any executable line.

See Also

`echo`, `function`, `type`

Purpose

Secant of argument in radians

Syntax

```
Y = sec(X)
```

Description

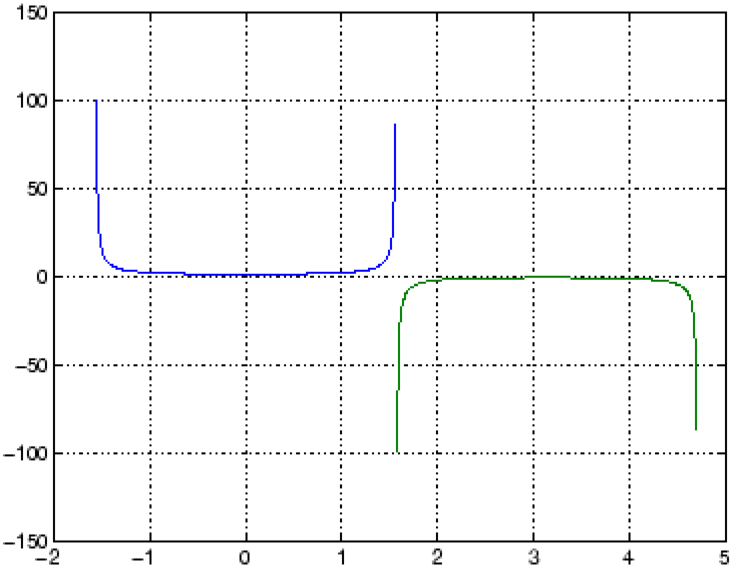
The `sec` function operates element-wise on arrays. The function's domains and ranges include complex values. All angles are in radians.

`Y = sec(X)` returns an array the same size as `X` containing the secant of the elements of `X`.

Examples

Graph the secant over the domains $-\pi/2 < x < \pi/2$ and $\pi/2 < x < 3\pi/2$.

```
x1 = -pi/2+0.01:0.01:pi/2-0.01;
x2 = pi/2+0.01:0.01:(3*pi/2)-0.01;
plot(x1,sec(x1),x2,sec(x2)), grid on
```



The expression `sec(pi/2)` does not evaluate as infinite but as the reciprocal of the floating-point accuracy `eps`, because `pi` is a floating-point approximation to the exact value of π.

Definition

The secant can be defined as

$$\sec(z) = \frac{1}{\cos(z)}$$

Algorithm

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

See Also

`secd`, `sech`, `asec`, `asecd`, `asech`

Purpose

Secant of argument in degrees

Syntax

```
Y = secd(X)
```

Description

`Y = secd(X)` is the secant of the elements of `X`, expressed in degrees. For odd integers `n`, `secd(n*90)` is infinite, whereas `sec(n*pi/2)` is large but finite, reflecting the accuracy of the floating point value of `pi`.

See Also

`sec`, `sech`, `asec`, `asecd`, `asech`

Purpose Hyperbolic secant

Syntax

```
Y = sech(X)
```

Description

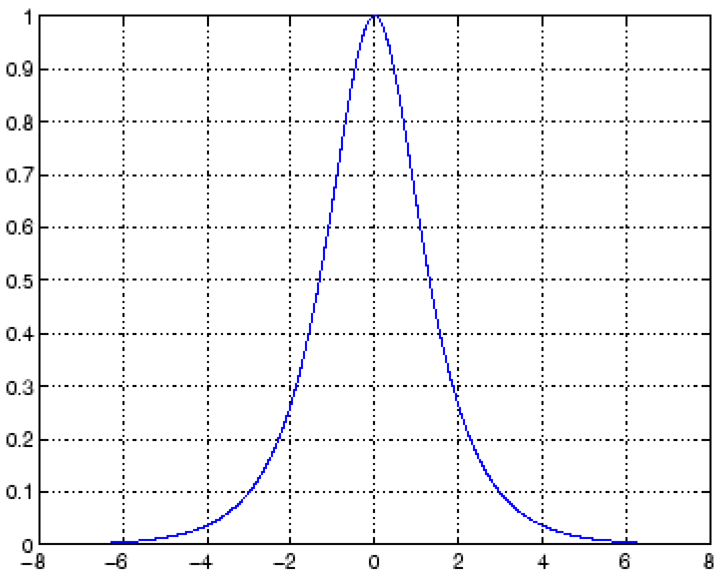
The `sech` function operates element-wise on arrays. The function's domains and ranges include complex values. All angles are in radians.

`Y = sech(X)` returns an array the same size as `X` containing the hyperbolic secant of the elements of `X`.

Examples

Graph the hyperbolic secant over the domain $-2\pi \leq x \leq 2\pi$.

```
x = -2*pi:0.01:2*pi;
plot(x,sech(x)), grid on
```



Algorithm

sech uses this algorithm.

$$\operatorname{sech}(z) = \frac{1}{\cosh(z)}$$

Definition

The secant can be defined as

$$\operatorname{sech}(z) = \frac{1}{\cosh(z)}$$

Algorithm

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

See Also

asec, asech, sec

selectmoveresize

Purpose

Select, move, resize, or copy axes and uicontrol graphics objects

Syntax

```
A = selectmoveresize
set(gca,'ButtonDownFcn','selectmoveresize')
```

Description

`selectmoveresize` is useful as the callback routine for axes and uicontrol button down functions. When executed, it selects the object and allows you to move, resize, and copy it.

`A = selectmoveresize` returns a structure array containing

- `A.Type`: a string containing the action type, which can be `Select`, `Move`, `Resize`, or `Copy`
- `A.Handles`: a list of the selected handles, or, for a `Copy`, an m-by-2 matrix containing the original handles in the first column and the new handles in the second column

`set(gca,'ButtonDownFcn','selectmoveresize')` sets the `ButtonDownFcn` property of the current axes to selectmoveresize:

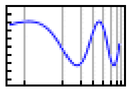
See Also

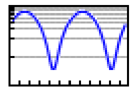
The `ButtonDownFcn` property of `axes` and `uicontrol` objects

"Object Manipulation" on page 1-104 for related functions

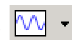
Purpose

Semilogarithmic plots





GUI Alternatives

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

Syntax

```
semilogx(Y)
semilogy(...)
semilogx(X1,Y1,...)
semilogx(X1,Y1,LineSpec,...)
semilogx(...,'PropertyName',PropertyValue,...)
h = semilogx(...)
h = semilogy(...)
hlines = semilogx('v6',...)
```

Description

`semilogx` and `semilogy` plot data as logarithmic scales for the *x*- and *y*-axis, respectively.

`semilogx(Y)` creates a plot using a base 10 logarithmic scale for the *x*-axis and a linear scale for the *y*-axis. It plots the columns of `Y` versus their index if `Y` contains real numbers. `semilogx(Y)` is equivalent to `semilogx(real(Y), imag(Y))` if `Y` contains complex numbers. `semilogx` ignores the imaginary component in all other uses of this function.

`semilogy(...)` creates a plot using a base 10 logarithmic scale for the *y*-axis and a linear scale for the *x*-axis.

`semilogx(X1,Y1,...)` plots all `Xn` versus `Yn` pairs. If only `Xn` or `Yn` is a matrix, `semilogx` plots the vector argument versus the rows or columns of the matrix, depending on whether the vector's row or column dimension matches the matrix.

`semilogx(X1,Y1,LineSpec,...)` plots all lines defined by the `Xn,Yn,LineSpec` triples. `LineSpec` determines line style, marker symbol, and color of the plotted lines.

`semilogx(...,'PropertyName',PropertyValue,...)` sets property values for all `lineseries` graphics objects created by `semilogx`.

`h = semilogx(...)` and `h = semilogy(...)` return a vector of handles to lineseries graphics objects, one handle per line.

Backward-Compatible Version

`hlines = semilogx('v6',...)` and `hlines = semilogy('v6',...)` return the handles to line objects instead of lineseries objects.

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

See Plot Objects and Backward Compatibility for more information.

Remarks

If you do not specify a color when plotting more than one line, `semilogx` and `semilogy` automatically cycle through the colors and line styles in the order specified by the current axes `ColorOrder` and `LineStyleOrder` properties.

You can mix `Xn,Yn` pairs with `Xn,Yn,LineSpec` triples; for example,

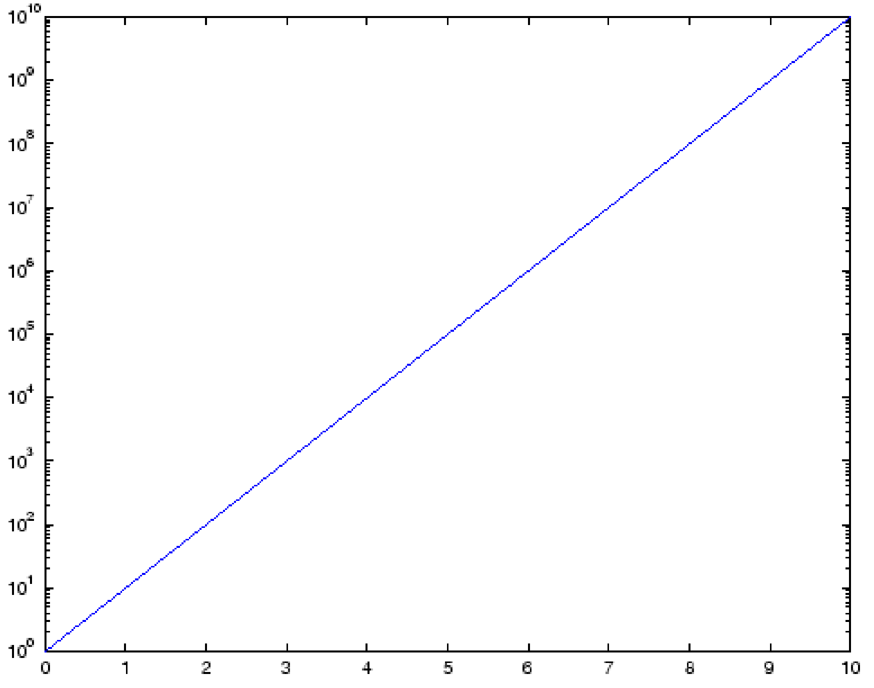
```
semilogx(X1,Y1,X2,Y2,LineSpec,X3,Y3)
```

If you attempt to add a `loglog`, `semilogx`, or `semilogy` plot to a linear axis mode graph with `hold on`, the axis mode will remain as it is and the new data will plot as linear.

Examples

Create a simple semilogy plot.

```
x = 0:.1:10;
semilogy(x,10.^x)
```



See Also

line, LineSpec, loglog, plot

"Basic Plots and Graphs" on page 1-90 for related functions

sendmail

Purpose

Send e-mail message to address list

Syntax

```
sendmail('recipients','subject')
sendmail('recipients','subject','message','attachments')
```

Description

`sendmail('recipients','subject')` sends e-mail to `recipients` with the specified `subject`. For `recipients`, use a string for a single address, or a cell array of strings for multiple addresses.

`sendmail('recipients','subject','message','attachments')` sends `message` to `recipients` with the specified `subject`. For `recipients`, use a string for a single address, or a cell array of strings for multiple addresses. For `message`, use a string or cell array. When `message` is a string, the text automatically wraps at 75 characters. When `message` is a cell array, it does not wrap but rather each cell is a new line. To force text to start on a new line in strings or cells, use `10`, as shown in the "Example of sendmail with New Lines Specified" on page 2-3125. Specify `attachments` as a cell array of files to send along with `message`.

To use `sendmail`, you must set the preferences for your e-mail server (Internet SMTP server) and your e-mail address must be set. The MATLAB software tries to read the SMTP mail server from your system registry, but if it cannot, it results in an error. In this event, identify the outgoing mail server for your electronic mail application, which is usually listed in the application's preferences, or, consult your e-mail system administrator. Then provide the information to MATLAB using:

```
setpref('Internet','SMTP_Server','myserver.myhost.com');
```

If you cannot easily determine your e-mail server, try using `mail`, as in:

```
setpref('Internet','SMTP_Server','mail');
```

which might work because `mail` is often a default for mail systems.

Similarly, if MATLAB cannot determine your e-mail address and produces an error, specify your e-mail address using:

```
setpref('Internet','E_mail','myaddress@example.com');
```

Note The `sendmail` function does not support e-mail servers that require authentication.

Examples

Example of sendmail with Two Attachments

```
sendmail('user@otherdomain.com',...
         'Test subject','Test message',...
         {'directory/attach1.html','attach2.doc'});
```

Example of sendmail with New Lines Specified

This mail message forces the message to start new lines after each `10`.

```
sendmail('user@otherdomain.com','New subject', ...
['Line1 of message' 10 'Line2 of message' 10 ...
 'Line3 of message' 10 'Line4 of message']);
```

The resulting message is:

```
Line1 of message
Line2 of message
Line3 of message
Line4 of message
```

See Also

`getpref`, `setpref`

Purpose Create serial port object

Syntax

```
obj = serial('port')
obj = serial('port','PropertyName',PropertyValue,...)
```

Description

`obj = serial('port')` creates a serial port object associated with the serial port specified by `port`. If `port` does not exist, or if it is in use, you will not be able to connect the serial port object to the device.

`obj = serial('port','PropertyName',PropertyValue,...)` creates a serial port object with the specified property names and property values. If an invalid property name or property value is specified, an error is returned and the serial port object is not created.

Remarks

When you create a serial port object, these property values are automatically configured:

- The `Type` property is given by `serial`.
- The `Name` property is given by concatenating `Serial` with the port specified in the `serial` function.
- The `Port` property is given by the port specified in the `serial` function.

You can specify the property names and property values using any format supported by the `set` function. For example, you can use property name/property value cell array pairs. Additionally, you can specify property names without regard to case, and you can make use of property name completion. For example, the following commands are all valid.

```
s = serial('COM1','BaudRate',4800);
s = serial('COM1','baudrate',4800);
s = serial('COM1','BAUD',4800);
```

Refer to Configuring Property Values for a list of serial port object properties that you can use with `serial`.

Before you can communicate with the device, it must be connected to `obj` with the `fopen` function. A connected serial port object has a `Status` property value of `open`. An error is returned if you attempt a read or write operation while the object is not connected to the device. You can connect only one serial port object to a given serial port.

Example

This example creates the serial port object `s1` associated with the serial port COM1.

```
s1 = serial('COM1');
```

The `Type`, `Name`, and `Port` properties are automatically configured.

```
get(s1,{'Type','Name','Port'})
ans =
    'serial'    'Serial-COM1'    'COM1'
```

To specify properties during object creation

```
s2 = serial('COM2','BaudRate',1200,'DataBits',7);
```

See Also

Functions

`fclose`, `fopen`

Properties

`Name`, `Port`, `Status`, `Type`

serialbreak

Purpose

Send break to device connected to serial port

Syntax

```
serialbreak(obj)
serialbreak(obj,time)
```

Description

`serialbreak(obj)` sends a break of 10 milliseconds to the device connected to the serial port object, `obj`.

`serialbreak(obj,time)` sends a break to the device with a duration, in milliseconds, specified by `time`. Note that the duration of the break might be inaccurate under some operating systems.

Remarks

For some devices, the break signal provides a way to clear the hardware buffer.

Before you can send a break to the device, it must be connected to `obj` with the `fopen` function. A connected serial port object has a `Status` property value of `open`. An error is returned if you attempt to send a break while `obj` is not connected to the device.

`serialbreak` is a synchronous function, and blocks the command line until execution is complete.

If you issue `serialbreak` while data is being asynchronously written, an error is returned. In this case, you must call the `stopasync` function or wait for the write operation to complete.

See Also

Functions

`fopen`, `stopasync`

Properties

`Status`

Purpose

Set Handle Graphics object properties

Syntax

```
set(H,'PropertyName',PropertyValue,...)
set(H,a)
set(H,pn,pv,...)
set(H,pn,MxN_pv)
a = set(h)
pv = set(h,'PropertyName')
```

Description

Note Do not use the `set` function on Java objects as it will cause a memory leak. For more information, see "Accessing Private and Public Data"

`set(H,'PropertyName',PropertyValue,...)` sets the named properties to the specified values on the object(s) identified by `H`. `H` can be a vector of handles, in which case `set` sets the properties' values for all the objects.

`set(H,a)` sets the named properties to the specified values on the object(s) identified by `H`. `a` is a structure array whose field names are the object property names and whose field values are the values of the corresponding properties.

`set(H,pn,pv,...)` sets the named properties specified in the cell array `pn` to the corresponding value in the cell array `pv` for all objects identified in `H`.

`set(H,pn,MxN_pv)` sets `n` property values on each of `m` graphics objects, where `m = length(H)` and `n` is equal to the number of property names contained in the cell array `pn`. This allows you to set a given group of properties to different values on each object.

`a = set(h)` returns the user-settable properties and possible values for the object identified by `h`. `a` is a structure array whose field names are the object's property names and whose field values are the possible values of the corresponding properties. If you do not specify an output argument, the MATLAB software displays the information on the screen. `h` must be scalar.

`pv = set(h,'PropertyName')` returns the possible values for the named property. If the possible values are strings, `set` returns each in a cell of the cell array `pv`. For other properties, `set` returns a statement indicating that `PropertyName` does not have a fixed set of property values. If you do not specify an output argument, MATLAB displays the information on the screen. `h` must be scalar.

Remarks

You can use any combination of property name/property value pairs, structure arrays, and cell arrays in one call to `set`.

Setting Property Units

Note that if you are setting both the `FontSize` and the `FontUnits` properties in one function call, you must set the `FontUnits` property first so that the MATLAB software can correctly interpret the specified `FontSize`. The same applies to figure and axes uints — always set the `Units` property before setting properties whose values you want to be interpreted in those units. For example,

```
f = figure('Units','characters',...
        'Position',[30 30 120 35]);
```

Examples

Set the Color property of the current axes to blue.

```
axes;
set(gca,'Color','b')
```

Change all the `lines` in a plot to black.

```
plot(peaks)
set(findobj('Type','line'),'Color','k')
```

You can define a group of properties in a structure to better organize your code. For example, these statements define a structure called `active`, which contains a set of property definitions used for the uicontrol objects in a particular figure. When this figure becomes the current figure, MATLAB changes the colors and enables the controls.

```
active.BackgroundColor = [.7 .7 .7];
active.Enable = 'on';
active.ForegroundColor = [0 0 0];

if gcf == control_fig_handle
 set(findobj(control_fig_handle,'Type','uicontrol'),active)
end
```

You can use cell arrays to set properties to different values on each object. For example, these statements define a cell array to set three properties,

```
PropName(1) = {'BackgroundColor'};
PropName(2) = {'Enable'};
PropName(3) = {'ForegroundColor'};
```

These statements define a cell array containing three values for each of three objects (i.e., a 3-by-3 cell array).

```
PropVal(1,1) = {[.5 .5 .5]};
PropVal(1,2) = {'off'};
PropVal(1,3) = {[.9 .9 .9]};
PropVal(2,1) = {[1 0 0]};
PropVal(2,2) = {'on'};
PropVal(2,3) = {[1 1 1]};
PropVal(3,1) = {[.7 .7 .7]};
PropVal(3,2) = {'on'};
PropVal(3,3) = {[0 0 0]};
```

Now pass the arguments to `set`,

```
set(H,PropName,PropVal)
```

where `length(H) = 3` and each element is the handle to a uicontrol.

Setting Different Values for the Same Property on Multiple Objects

Suppose you want to set the value of the `Tag` property on five line objects, each to a different value. Note how the value cell array needs to be transposed to have the proper shape.

```
h = plot(rand(5));
set(h,{'Tag'},{'line1','line2','line3','line4','line5'}')
```

See Also

`findobj`, `gca`, `gcf`, `gco`, `gcbo`, `get`

"Graphics Object Identification" on page 1-97 for related functions

Purpose

Set object or interface property to specified value

Syntax

```
h.set('pname', value)
h.set('pname1', value1, 'pname2', value2, ...)
set(h, ...)
```

Description

`h.set('pname', value)` sets the property specified in the string `pname` to the given `value`.

`h.set('pname1', value1, 'pname2', value2, ...)` sets each property specified in the `pname` strings to the given `value`.

`set(h, ...)` is an alternate syntax for the same operation.

See "Handling COM Data in MATLAB Software" in the External Interfaces documentation for information on how MATLAB converts workspace matrices to COM data types.

Remarks

COM functions are available on Microsoft Windows systems only.

Examples

Create an `mwsamp` control and use `set` to change the `Label` and `Radius` properties:

```
f = figure ('position', [100 200 200 200]);
h = actxcontrol ('mwsamp.mwsampctrl.1', [0 0 200 200], f);

h.set('Label', 'Click to fire event', 'Radius', 40);
h.invoke('Redraw');
```

Here is another way to do the same thing, only without `set` and `invoke`:

```
h.Label = 'Click to fire event';
h.Radius = 40;
h.Redraw;
```

See Also

`get (COM)`, `inspect`, `isprop`, `addproperty`, `deleteproperty`

set (hgsetget)

Purpose Assign property values to handle objects derived from `hgsetget` class

Syntax

```
set(H,'PropertyName',value,...)
pv = set(h,'PropertyName')
S = set(h)
```

Description `set(H,'PropertyName',value,...)` sets the named property to the specified value for the objects in the handle array `H`.

`pv = set(h,'`*`PropertyName`*`')` returns the possible values for the named property.

`S = set(h)` returns the user-settable properties and possible values for the handle object `h`. `S` is a `struct` whose field names are the object's property names and whose field values are cell arrays containing the possible values of the corresponding properties having finite possible values.

See Also See "Implementing a Set/Get Interface for Properties"

`handle`, `hgsetget`, `set`, `get (hgsetget)`

Purpose Set a random stream property

Class `@RandStream`

Syntax

```
s = set(s,'PropertyName',value)
s = set(s,'Property1',Value1,'Property2',Value2,...)
set(s,'Property')
set(s)
```

Description `s = set(s,'PropertyName',value)` sets the property `'PropertyName'` of the random stream `s` to the value `value`.

`s = set(s,'Property1',Value1,'Property2',Value2,...)` sets multiple random stream property values with a single statement.

`set(s,'Property')` displays possible values for the specified property of `s`.

`set(s)` displays all properties of `s` and their possible values.

See Also `@RandStream`, `get (RandStream)`, `rand`, `randn`, `randi`

set (serial)

Purpose

Configure or display serial port object properties

Syntax

```
set(obj)
props = set(obj)
set(obj,'PropertyName')
props = set(obj,'PropertyName')
set(obj,'PropertyName',PropertyValue,...)
set(obj,PN,PV)
set(obj,S)
```

Description

`set(obj)` displays all configurable properties values for the serial port object, `obj`. If a property has a finite list of possible string values, then these values are also displayed.

`props = set(obj)` returns all configurable properties and their possible values for `obj` to `props`. `props` is a structure whose field names are the property names of `obj`, and whose values are cell arrays of possible property values. If the property does not have a finite set of possible values, then the cell array is empty.

`set(obj,'`*`PropertyName`*`')` displays the valid values for *`PropertyName`* if it possesses a finite list of string values.

`props = set(obj,'`*`PropertyName`*`')` returns the valid values for *`PropertyName`* `to props`. `props` is a cell array of possible string values or an empty cell array if *`PropertyName`* does not have a finite list of possible values.

`set(obj,'`*`PropertyName`*`',PropertyValue,...)` configures multiple property values with a single command.

`set(obj,PN,PV)` configures the properties specified in the cell array of strings `PN` to the corresponding values in the cell array `PV`. `PN` must be a vector. `PV` can be m-by-n where m is equal to the number of serial port objects in `obj` and n is equal to the length of `PN`.

`set(obj,S)` configures the named properties to the specified values for `obj`. `S` is a structure whose field names are serial port object properties, and whose field values are the values of the corresponding properties.

Remarks

Refer to Configuring Property Values for a list of serial port object properties that you can configure with `set`.

You can use any combination of property name/property value pairs, structures, and cell arrays in one call to `set`. Additionally, you can specify a property name without regard to case, and you can make use of property name completion. For example, if `s` is a serial port object, then the following commands are all valid.

```
set(s,'BaudRate')
set(s,'baudrate')
set(s,'BAUD')
```

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

```
help serial/set
```

Examples

This example illustrates some of the ways you can use `set` to configure or return property values for the serial port object `s`.

```
s = serial('COM1');
set(s,'BaudRate',9600,'Parity','even')
set(s,{'StopBits','RecordName'},{2,'sydney.txt'})
set(s,'Parity')
[ {none} | odd | even | mark | space ]
```

See Also

Functions

`get`

Purpose

Configure or display timer object properties

Syntax

```
set(obj)
prop_struct = set(obj)
set(obj,'PropertyName')
prop_cell=set(obj,'PropertyName')
set(obj,'PropertyName',PropertyValue,...)
set(obj,S)
set(obj,PN,PV)
```

Description

`set(obj)` displays property names and their possible values for all configurable properties of timer object `obj`. `obj` must be a single timer object.

`prop_struct = set(obj)` returns the property names and their possible values for all configurable properties of timer object `obj`. `obj` must be a single timer object. The return value, `prop_struct`, is a structure whose field names are the property names of `obj`, and whose values are cell arrays of possible property values or empty cell arrays if the property does not have a finite set of possible string values.

`set(obj,'`*`PropertyName`*`')` displays the possible values for the specified property, *`PropertyName`*, of timer object `obj`. `obj` must be a single timer object.

`prop_cell=set(obj,'`*`PropertyName`*`')` returns the possible values for the specified property, *`PropertyName`*, of timer object `obj`. `obj` must be a single timer object. The returned array, `prop_cell`, is a cell array of possible value strings or an empty cell array if the property does not have a finite set of possible string values.

`set(obj,'`*`PropertyName`*`',PropertyValue,...)` configures the property, *`PropertyName`*, to the specified value, `PropertyValue`, for timer object `obj`. You can specify multiple property name/property value pairs in a single statement. `obj` can be a single timer object or a vector of timer objects, in which case `set` configures the property values for all the timer objects specified.

`set(obj,S)` configures the properties of `obj`, with the values specified in `S`, where `S` is a structure whose field names are object property names.

`set(obj,PN,PV)` configures the properties specified in the cell array of strings, `PN`, to the corresponding values in the cell array `PV`, for the timer object `obj`. `PN` must be a vector. If `obj` is an array of timer objects, `PV` can be an M-by-N cell array, where M is equal to the length of timer object array and N is equal to the length of `PN`. In this case, each timer object is updated with a different set of values for the list of property names contained in `PN`.

Note When specifying parameter/value pairs, you can use any mixture of strings, structures, and cell arrays in the same call to `set`.

Examples

Create a timer object.

```
t = timer;
```

Display all configurable properties and their possible values.

```
set(t)
    BusyMode: [ {drop} | queue | error ]
    ErrorFcn: string -or- function handle -or- cell array
    ExecutionMode: [ {singleShot} | fixedSpacing | fixedDelay | fixedRate ]
    Name
    ObjectVisibility: [ {on} | off ]
    Period
    StartDelay
    StartFcn: string -or- function handle -or- cell array
    StopFcn: string -or- function handle -or- cell array
    Tag
    TasksToExecute
    TimerFcn: string -or- function handle -or- cell array
    UserData
```

View the possible values of the `ExecutionMode` property.

```
set(t, 'ExecutionMode')
[ {singleShot} | fixedSpacing | fixedDelay | fixedRate ]
```

Set the value of a specific timer object property.

```
set(t, 'ExecutionMode', 'FixedRate')
```

Set the values of several properties of the timer object.

```
set(t, 'TimerFcn', 'callbk', 'Period', 10)
```

Use a cell array to specify the names of the properties you want to set and another cell array to specify the values of these properties.

```
set(t, {'StartDelay', 'Period'}, {30, 30})
```

See Also

`timer`, `get(timer)`

Purpose

Set properties of `timeseries` object

Syntax

```
set(ts,'Property',Value)
set(ts,'Property1',Value1,'Property2',Value2,...)
set(ts,'Property')
set(ts)
```

Description

`set(ts,'Property',Value)` sets the property `'Property'` of the `timeseries` object `ts` to the value `Value`. The following syntax is equivalent:

```
ts.Property = Value
```

`set(ts,'Property1',Value1,'Property2',Value2,...)` sets multiple property values for `ts` with a single statement.

`set(ts,'Property')` displays values for the specified property of the `timeseries` object ts.

`set(ts)` displays all properties and values of the `timeseries` object `ts`.

See Also

`get (timeseries)`

set (tscollection)

Purpose

Set properties of `tscollection` object

Syntax

```
set(tsc,'Property',Value)
set(tsc,'Property1',Value1,'Property2',Value2,...)
set(tsc,'Property')
```

Description

`set(tsc,'Property',Value)` sets the property `'Property'` of the `tscollection` `tsc` to the value `Value`. The following syntax is equivalent:

```
tsc.Property = Value
```

`set(tsc,'Property1',Value1,'Property2',Value2,...)` sets multiple property values for `tsc` with a single statement.

`set(tsc,'Property')` displays values for the specified property in the time-series collection `tsc`.

`set(tsc)` displays all properties and values of the `tscollection` object `tsc`.

See Also

`get (tscollection)`

setabstime (timeseries)

Purpose

Set times of `timeseries` object as date strings

Syntax

```
ts = setabstime(ts,Times)
ts = setabstime(ts,Times,Format)
```

Description

`ts = setabstime(ts,Times)` sets the times in `ts` to the date strings specified in `Times`. Times must either be a cell array of strings, or a `char` array containing valid date or time values in the same date format.

`ts = setabstime(ts,Times,Format)` explicitly specifies the date-string format used in Times.

Examples

1 Create a time-series object.

```
ts = timeseries(rand(3,1))
```

2 Set the absolute time vector.

```
ts = setabstime(ts,{'12-DEC-2005 12:34:56',...
     '12-DEC-2005 13:34:56','12-DEC-2005 14:34:56'})
```

See Also

`datestr`, `getabstime (timeseries)`, `timeseries`

setabstime (tscollection)

Purpose Set times of `tscollection` object as date strings

Syntax

```
tsc = setabstime(tsc,Times)
tsc = setabstime(tsc,Times,format)
```

Description

`tsc = setabstime(tsc,Times)` sets the times in tsc using the date strings Times. Times must be either a cell array of strings, or a `char` array containing valid date or time values in the same date format.

`tsc = setabstime(tsc,Times,format)` specifies the date-string format used in Times explicitly.

Examples

1 Create a `tscollection` object.

```
tsc = tscollection(timeseries(rand(3,1)))
```

2 Set the absolute time vector.

```
tsc = setabstime(tsc,{'12-DEC-2005 12:34:56',...
      '12-DEC-2005 13:34:56','12-DEC-2005 14:34:56'})
```

See Also `datestr`, `getabstime (tscollection)`, `tscollection`

Purpose Specify application-defined data

Syntax `setappdata(h,'name',value)`

Description `setappdata(h,'name',value)` sets application-defined data for the object with handle `h`. The application-defined data, which is created if it does not already exist, is assigned the specified `name` and `value`. The `value` can be any type of data.

Remarks Application data is data that is meaningful to or defined by your application which you attach to a figure or any GUI component (other than ActiveX controls) through its `AppData` property. Only Handle Graphics MATLAB objects use this property.

See Also `getappdata`, `isappdata`, `rmappdata`

setDefaultStream (RandStream)

Purpose

Set the default random number stream

Syntax

`prevstream = RandStream.setDefaultStream(stream)`

Description

`prevstream = RandStream.setDefaultStream(stream)` returns the current default random number stream, and designates the random number stream `stream` as the new default to be used by the `rand`, `randi`, and `randn` functions.

`rand`, `randi`, and `randn` all rely on the same stream of uniform pseudorandom numbers, known as the default stream. `randi` uses one uniform value from the default stream to generate each integer value. `randn` uses one or more uniform values from the default stream to generate each normal value. Note that there are also `rand`, `randi`, and `randn` methods for which you specify a specific random stream from which to draw values.

See Also

`getDefaultStream (RandStream)`, `@RandStream`, `rand (RandStream)`, `randn (RandStream)`, `randperm (RandStream)`

Purpose

Find set difference of two vectors

Syntax

```
c = setdiff(A, B)
c = setdiff(A, B, 'rows')
[c,i] = setdiff(...)
```

Description

`c = setdiff(A, B)` returns the values in `A` that are not in `B`. In set theory terms, `c = A - B`. Inputs `A` and `B` can be numeric or character vectors or cell arrays of strings. The resulting vector is sorted in ascending order.

`c = setdiff(A, B, 'rows')`, when `A` and `B` are matrices with the same number of columns, returns the rows from `A` that are not in `B`.

`[c,i] = setdiff(...)` also returns an index vector `index` such that `c = a(i)` or `c = a(i,:)`.

Remarks

Because NaN is considered to be not equal to itself, it is always in the result `c` if it is in `A`.

Examples

```
A = magic(5);
B = magic(4);
[c, i] = setdiff(A(:), B(:));
c' =    17    18    19    20    21    22    23    24    25
i' =     1    10    14    18    19    23     2     6    15
```

See Also

`intersect`, `ismember`, `issorted`, `setxor`, `union`, `unique`

setdisp (hgsetget)

Purpose Override to change command window display

Syntax `setdisp(H)`

Description `setdisp(H)` called by `set` when `set` is called with no output arguments and a single input argument that is a handle array. Override this `hgsetget` class method in a subclass to change how property information is displayed in the command window.

See Also See "Implementing a Set/Get Interface for Properties"

`hgsetget`, `set (hgsetget)`

Purpose Set environment variable

Syntax

```
setenv(name, value)
setenv(name)
```

Description

`setenv(name, value)` sets the value of an environment variable belonging to the underlying operating system. Inputs `name` and `value` are both strings. If `name` already exists as an environment variable, then `setenv` replaces its current value with the string given in `value`. If `name` does not exist, `setenv` creates a new environment variable called `name` and assigns `value` to it.

`setenv(name)` is equivalent to `setenv(name, '')` and assigns a null value to the variable `name`. On the Microsoft Windows platform, this is equivalent to undefining the variable. On most UNIX[25] platforms, it is possible to have an environment variable defined as empty.

The maximum number of characters in `name` is 2^{15} - 2 (or 32766). If `name` contains the character =, `setenv` throws an error. The behavior of environment variables with = in the name is not well-defined.

On all platforms, `setenv` passes the `name` and `value` strings to the operating system unchanged. Special characters such as `;`, `/`, `:`, `$`, `%`, etc. are left unexpanded and intact in the variable value.

Values assigned to variables using `setenv` are picked up by any process that is spawned using the MATLAB `system`, `unix`, `dos` or `!` functions. You can retrieve any value set with `setenv` by using `getenv(name)`.

Examples

% Set and retrieve a new value for the environment variable `TEMP`:

```
setenv('TEMP', 'C:\TEMP');
getenv('TEMP')
```

% Append the `Perl\bin` directory to your system `PATH` variable:

```
setenv('PATH', [getenv('PATH') ';D:\Perl\bin']);
```

See Also

`getenv`, `system`, `unix`, `dos`, `!`

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

Purpose

Set value of structure array field

Syntax

```
s = setfield(s, 'field', v)
s = setfield(s, {i,j}, 'field', {k}, v)
```

Description

`s = setfield(s, 'field', v)`, where `s` is a 1-by-1 structure, sets the contents of the specified field to the value `v`. If `field` is not an existing field in structure `s`, the MATLAB software creates that field and assigns the value `v` to it. This is equivalent to the syntax `s.field = v`.

`s = setfield(s, {i,j}, 'field', {k}, v)` sets the contents of the specified field to the value `v`. If `field` is not an existing field in structure `s`, MATLAB creates that field and assigns the value `v` to it. This is equivalent to the syntax `s(i,j).field(k) = v`. All subscripts must be passed as cell arrays — that is, they must be enclosed in curly braces (similar to `{i,j}` and `{k}` above). Pass field references as strings.

See "Naming conventions for Structure Field Names" for guidelines to creating valid field names.

Remarks

In many cases, you can use dynamic field names in place of the `getfield` and `setfield` functions. Dynamic field names express structure fields as variable expressions that MATLAB evaluates at run-time. See Solution 1-19QWG for information about using dynamic field names versus the `getfield` and `setfield` functions.

Examples

Given the structure

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

You can change the `name` field of `mystr(2,1)` using

```
mystr = setfield(mystr, {2,1}, 'name', 'ted');
mystr(2,1).name
```

```
ans =

ted
```

The following example sets fields of a structure using `setfield` with variable and quoted field names and additional subscripting arguments.

```
class = 5;   student = 'John_Doe';
grades_Doe = [85, 89, 76, 93, 85, 91, 68, 84, 95, 73];
grades = [];

grades = setfield(grades, {class}, student, 'Math', ...
   {10, 21:30}, grades_Doe);
```

You can check the outcome using the standard structure syntax.

```
grades(class).John_Doe.Math(10, 21:30)

ans =

    85    89    76    93    85    91    68    84    95    73
```

See Also

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

Purpose Set default interpolation method for `timeseries` object

Syntax

```
ts = setinterpmethod(ts,Method)
ts = setinterpmethod(ts,FHandle)
ts = setinterpmethod(ts,InterpObj),
```

Description

`ts = setinterpmethod(ts,Method)` sets the default interpolation method for `timeseries` object `ts`, where `Method` is a string. `Method` in `ts`. `Method` is either `'linear'` or `'zoh'` (zero-order hold). For example:

```
ts = timeseries(rand(100,1),1:100);
ts = setinterpmethod(ts,'zoh');
```

`ts = setinterpmethod(ts,FHandle)` sets the default interpolation method for `timeseries` object `ts`, where FHandle is a function handle to the interpolation method defined by the function handle FHandle. For example:

```
ts = timeseries(rand(100,1),1:100);
myFuncHandle = @(new_Time,Time,Data)...
               interp1(Time,Data,new_Time,...
                       'linear','extrap');
ts = setinterpmethod(ts,myFuncHandle);
ts = resample(ts,[-5:0.1:10]);
plot(ts);
```

Note For FHandle, you must use three input arguments. The order of input arguments must be `new_Time`, `Time`, and `Data`. The single output argument must be the interpolated data only.

`ts = setinterpmethod(ts,InterpObj),` where InterpObj is a `tsdata.interpolation` object that directly replaces the interpolation object stored in `ts`. For example:

```
ts = timeseries(rand(100,1),1:100);
```

```
myFuncHandle = @(new_Time,Time,Data)...
               interp1(Time,Data,new_Time,...
                       'linear','extrap');
myInterpObj = tsdata.interpolation(myFuncHandle);
ts = setinterpmethod(ts,myInterpObj);
```

This method is case sensitive.

See Also

getinterpmethod, timeseries, tsprops

Purpose

Set component position in pixels

Syntax

```
setpixelposition(handle,position)
setpixelposition(handle,position,recursive)
```

Description

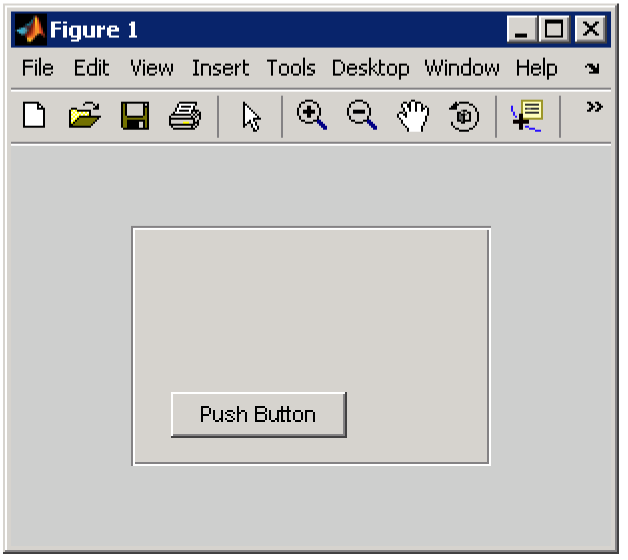
`setpixelposition(handle,position)` sets the position of the component specified by `handle`, to the specified pixel position relative to its parent. `position` is a four-element vector that specifies the location and size of the component: [distance from left, distance from bottom, width, height].

`setpixelposition(handle,position,recursive)` sets the position as above. If `recursive` is true, the position is set relative to the parent figure of `handle`.

Example

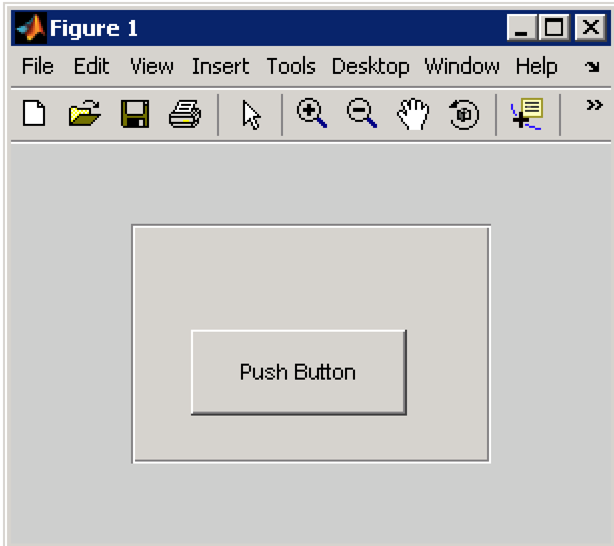
This example first creates a push button within a panel.

```
f = figure('Position',[300 300 300 200]);
p = uipanel('Position',[.2 .2 .6 .6];
h1 = uicontrol(p,'Style','PushButton','Units','Nomalized',...
               'String','Push Button','Position',[.1 .1 .5 .2]);
```



The example then retrieves the position of the push button and changes its position with respect to the panel.

```
pos1 = getpixelposition(h1);
setpixelposition(h1,pos1 + [10 10 25 25]);
```



See Also

getpixelposition, uicontrol, uipanel

setpref

Purpose

Set preference

Syntax

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

Description

`setpref('group','pref',val)` sets the preference specified by `group` and `pref` to the value `val`. Setting a preference that does not yet exist causes it to be created.

`group` labels a related collection of preferences. You can choose any name that is a legal variable name, and is descriptive enough to be unique, e.g., `'MathWorks_GUIDE_ApplicationPrefs'`. The input argument `pref` identifies an individual preference in that group, and must be a legal variable name.

`setpref('group',{'pref1','pref2',...,'prefn'},{val1,val2,...,valn})` sets each preference specified in the cell array of names to the corresponding value.

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

Examples

```
addpref('mytoolbox','version','0.0')
setpref('mytoolbox','version','1.0')
getpref('mytoolbox','version')

ans =
     1.0
```

See Also

`addpref`, `getpref`, `ispref`, `rmpref`, `uigetpref`, `uisetpref`

Purpose Set string flag

Description This MATLAB 4 function has been renamed `char` in MATLAB 5.

settimeseriesnames

Purpose Change name of `timeseries` object in `tscollection`

Syntax

```
tsc = settimeseriesnames(tsc,old,new)
```

Description `tsc = settimeseriesnames(tsc,old,new)` replaces the `old` name of `timeseries` object with the new name in tsc.

See Also `tscollection`

Purpose

Find set exclusive OR of two vectors

Syntax

```
c = setxor(A, B)
c = setxor(A, B, 'rows')
[c, ia, ib] = setxor(...)
```

Description

`c = setxor(A, B)` returns the values that are not in the intersection of `A` and `B`. Inputs `A` and `B` can be numeric or character vectors or cell arrays of strings. The resulting vector is sorted.

`c = setxor(A, B, 'rows')`, when `A` and `B` are matrices with the same number of columns, returns the rows that are not in the intersection of `A` and `B`.

`[c, ia, ib] = setxor(...)` also returns index vectors `ia` and `ib` such that `c` is a sorted combination of the elements `c = a(ia)` and `c = b(ib)` or, for row combinations, `c = a(ia,:)` and `c = b(ib,:)`.

Examples

```
a = [-1 0 1 Inf -Inf NaN];
b = [-2 pi 0 Inf];
c = setxor(a, b)

c =
    -Inf   -2.0000   -1.0000    1.0000    3.1416    NaN
```

See Also

`intersect`, `ismember`, `issorted`, `setdiff`, `union`, `unique`

shading

Purpose

Set color shading properties

Syntax

```
shading flat
shading faceted
shading interp
shading(axes_handle,...)
```

Description

The `shading` function controls the color shading of surface and patch graphics objects.

`shading flat` each mesh line segment and face has a constant color determined by the color value at the endpoint of the segment or the corner of the face that has the smallest index or indices.

`shading faceted` flat shading with superimposed black mesh lines. This is the default shading mode.

`shading interp` varies the color in each line segment and face by interpolating the colormap index or true color value across the line or face.

`shading(axes_handle,...)` applies the shading type to the objects in the axes specified by `axes_handle`, instead of the current axes.

Examples

Compare a flat, faceted, and interpolated-shaded sphere.

```
subplot(3,1,1)
sphere(16)
axis square
shading flat
title('Flat Shading')

subplot(3,1,2)
sphere(16)
axis square
shading faceted
title('Faceted Shading')

subplot(3,1,3)
```

```
sphere(16)
axis square
shading interp
title('Interpolated Shading')
```

Algorithm

shading sets the EdgeColor and FaceColor properties of all surface and patch graphics objects in the current axes. shading sets the appropriate values, depending on whether the surface or patch objects represent meshes or solid surfaces.

See Also

fill, fill3, hidden, light, lighting, mesh, patch, pcolor, surf

The EdgeColor and FaceColor properties for patch and surface graphics objects.

"Color Operations" on page 1-102 for related functions

Purpose

Show most recent graph window

Syntax

```
shg
```

Description

`shg` makes the current figure visible and raises it above all other figures on the screen. This is identical to using the command `figure(gca)`.

See Also

`figure`, `gca`, `gcf`

Purpose

Shift dimensions

Syntax

```
B = shiftdim(X,n)
[B,nshifts] = shiftdim(X)
```

Description

`B = shiftdim(X,n)` shifts the dimensions of `X` by `n`. When `n` is positive, `shiftdim` shifts the dimensions to the left and wraps the `n` leading dimensions to the end. When `n` is negative, `shiftdim` shifts the dimensions to the right and pads with singletons.

`[B,nshifts] = shiftdim(X)` returns the array `B` with the same number of elements as `X` but with any leading singleton dimensions removed. A singleton dimension is any dimension for which `size(A,dim) = 1`. `nshifts` is the number of dimensions that are removed.

If `X` is a scalar, `shiftdim` has no effect.

Examples

The `shiftdim` command is handy for creating functions that, like `sum` or `diff`, work along the first nonsingleton dimension.

```
a = rand(1,1,3,1,2);
[b,n]  = shiftdim(a); % b is 3-by-1-by-2 and n is 2.
c = shiftdim(b,-n);   % c == a.
d = shiftdim(a,3);    % d is 1-by-2-by-1-by-1-by-3.
```

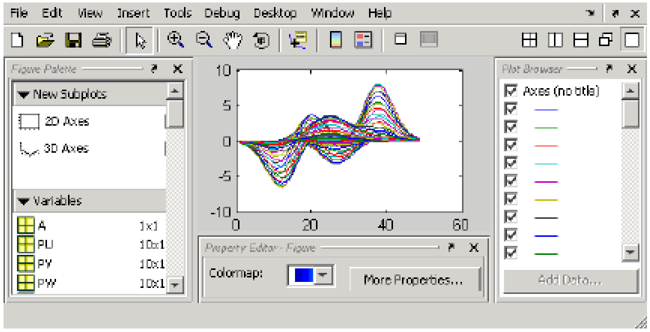
See Also

`circshift`, `reshape`, `squeeze`, `permute`, `ipermute`

showplottool

Purpose

Show or hide figure plot tool



GUI Alternatives

Click the larger Plotting Tools icon  on the figure toolbar to collectively enable plotting tools, and the smaller icon  to collectively disable them. Individually select the **Figure Palette**, **Plot Browser**, and **Property Editor** tools from the figure's **View** menu. For details, see "Plotting Tools — Interactive Plotting" in the MATLAB Graphics documentation.

Syntax

```
showplottool('tool')
showplottool('on','tool')
showplottool('off','tool')
showplottool('toggle','tool')
showplottool(figure_handle,...)
```

Description

`showplottool('tool')` shows the specified plot tool on the current figure. *`tool`* can be one of the following strings:

- `figurepalette`
- `plotbrowser`
- `propertyeditor`

`showplottool('on','tool')` shows the specified plot tool on the current figure.

`showplottool('off','tool')` hides the specified plot tool on the current figure.

`showplottool('toggle','tool')` toggles the visibility of the specified plot tool on the current figure.

`showplottool(figure_handle,...)` operates on the specified figure instead of the current figure.

Note When you dock, undock, resize, or reposition a plotting tool and then close it, it will still be configured as you left it the next time you open it. There is no command to reset plotting tools to their original, default locations.

See Also

`figurepalette`, `plotbrowser`, `plottools`, `propertyeditor`

shrinkfaces

Purpose

Reduce size of patch faces

Syntax

```
shrinkfaces(p,sf)
nfv = shrinkfaces(p,sf)
nfv = shrinkfaces(fv,sf)
shrinkfaces(p)
nfv = shrinkfaces(f,v,sf)
[nf,nv] = shrinkfaces(...)
```

Description

`shrinkfaces(p,sf)` shrinks the area of the faces in patch `p` to shrink factor `sf`. A shrink factor of 0.6 shrinks each face to 60% of its original area. If the patch contains shared vertices, the MATLAB software creates nonshared vertices before performing the face-area reduction.

`nfv = shrinkfaces(p,sf)` returns the face and vertex data in the struct `nfv`, but does not set the `Faces` and `Vertices` properties of patch `p`.

`nfv = shrinkfaces(fv,sf)` uses the face and vertex data from the struct `fv`.

`shrinkfaces(p)` and `shrinkfaces(fv)` (without specifying a shrink factor) assume a shrink factor of 0.3.

`nfv = shrinkfaces(f,v,sf)` uses the face and vertex data from the arrays `f` and `v`.

`[nf,nv] = shrinkfaces(...)` returns the face and vertex data in two separate arrays instead of a struct.

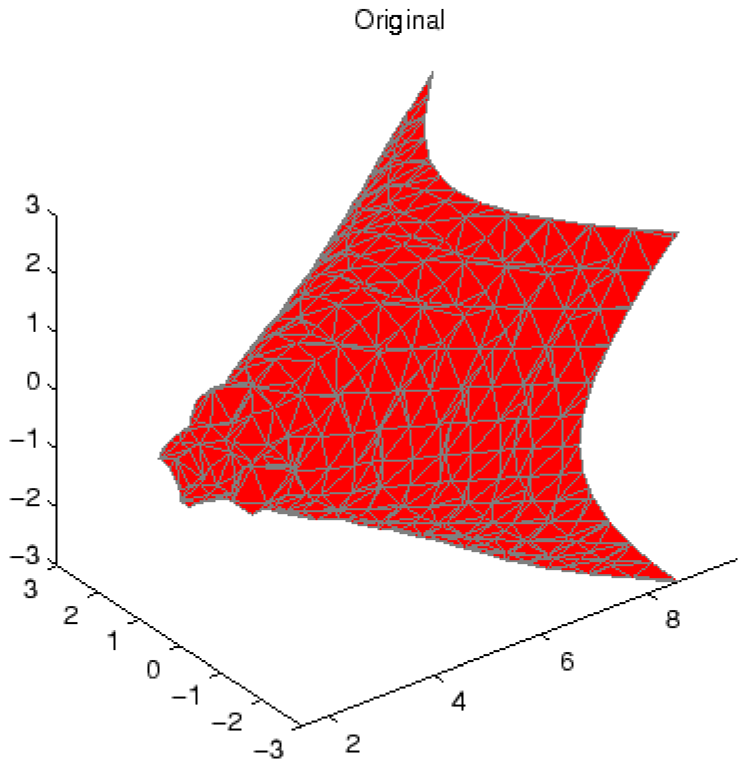
Examples

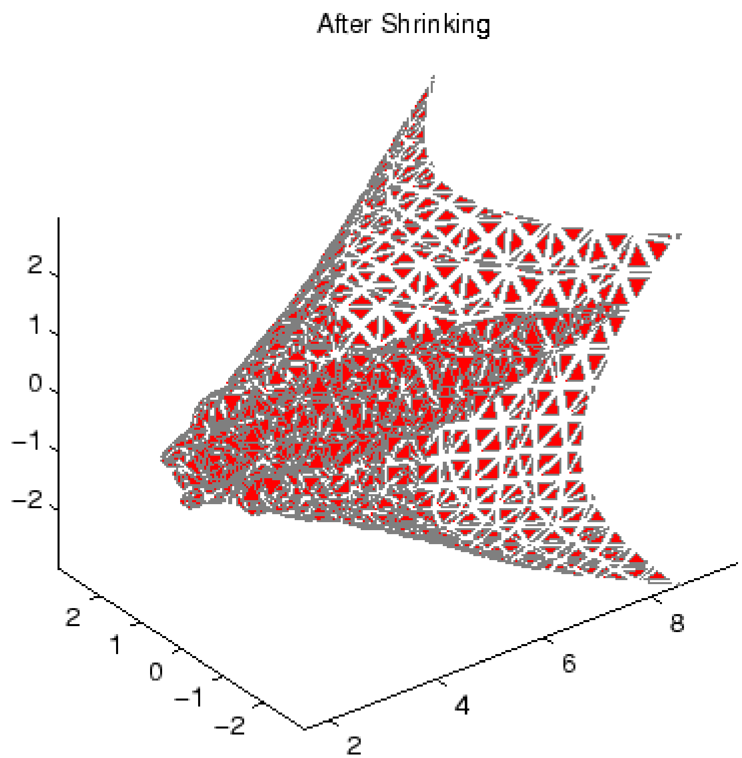
This example uses the flow data set, which represents the speed profile of a submerged jet within an infinite tank (type `help flow` for more information). Two isosurfaces provide a before and after view of the effects of shrinking the face size.

- First `reducevolume` samples the flow data at every other point and then `isosurface` generates the faces and vertices data.

- The patch command accepts the face/vertex struct and draws the first (p1) isosurface.
- Use the daspect, view, and axis commands to set up the view and then add a title.
- The shrinkfaces command modifies the face/vertex data and passes it directly to patch.

```
[x,y,z,v] = flow;
[x,y,z,v] = reducevolume(x,y,z,v,2);
fv = isosurface(x,y,z,v,-3);
p1 = patch(fv);
set(p1,'FaceColor','red','EdgeColor',[.5,.5,.5]);
daspect([1 1 1]); view(3); axis tight
title('Original')

figure
p2 = patch(shrinkfaces(fv,.3));
set(p2,'FaceColor','red','EdgeColor',[.5,.5,.5]);
daspect([1 1 1]); view(3); axis tight
title('After Shrinking')
```


Original
3
2
1
0
−1
−2
−3
3
2
1
0
−1
−2
−3
2
4
6
8



See Also

`isosurface`, `patch`, `reducevolume`, `daspect`, `view`, `axis`

"Volume Visualization" on page 1-106 for related functions

Purpose Signum function

Syntax

```
Y = sign(X)
```

Description `Y = sign(X)` returns an array `Y` the same size as `X`, where each element of `Y` is:

- `1` if the corresponding element of `X` is greater than zero
- `0` if the corresponding element of `X` equals zero
- `-1` if the corresponding element of `X` is less than zero

For nonzero complex `X`, `sign(X) = X./abs(X)`.

See Also `abs`, `conj`, `imag`, `real`

Purpose

Sine of argument in radians

Syntax

```
Y = sin(X)
```

Description

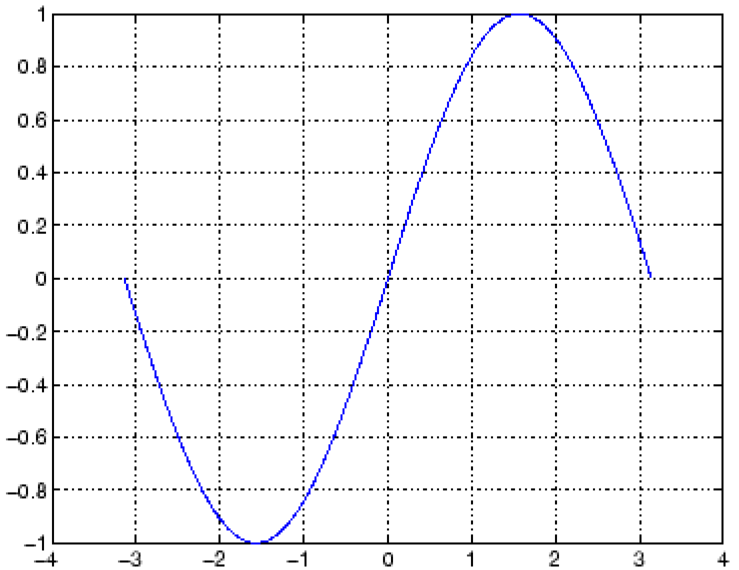
The `sin` function operates element-wise on arrays. The function's domains and ranges include complex values. All angles are in radians.

`Y = sin(X)` returns the circular sine of the elements of `X`.

Examples

Graph the sine function over the domain $-\pi \le x \le \pi$.

```
x = -pi:0.01:pi;
plot(x,sin(x)), grid on
```



The expression `sin(pi)` is not exactly zero, but rather a value the size of the floating-point accuracy `eps`, because `pi` is only a floating-point approximation to the exact value of π.

Definition

The sine can be defined as

$$\sin(x + iy) = \sin(x)\cosh(y) + i\cos(x)\sinh(y)$$

$$\sin(z) = \frac{e^{iz} - e^{-iz}}{2i}$$

Algorithm

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

See Also

`sind`, `sinh`, `asin`, `asind`, `asinh`

Purpose Sine of argument in degrees

Syntax

```
Y = sind(X)
```

Description `Y = sind(X)` is the sine of the elements of `X`, expressed in degrees. For integers `n`, `sind(n*180)` is exactly zero, whereas `sin(n*pi)` reflects the accuracy of the floating point value of `pi`.

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

Purpose

Convert to single precision

Syntax

```
B = single(A)
```

Description

`B = single(A)` converts the matrix `A` to single precision, returning that value in `B`. `A` can be any numeric object (such as a `double`). If `A` is already single precision, `single` has no effect. Single-precision quantities require less storage than double-precision quantities, but have less precision and a smaller range.

The `single` class is primarily meant to be used to store single-precision values. Hence most operations that manipulate arrays without changing their elements are defined. Examples are `reshape`, `size`, the relational operators, subscripted assignment, and subscripted reference.

You can define your own methods for the `single` class by placing the appropriately named method in an `@single` directory within a directory on your path.

Examples

```
a = magic(4);
b = single(a);

whos
  Name      Size          Bytes  Class

  a         4x4             128  double array
  b         4x4              64  single array
```

See Also

`double`

Purpose

Hyperbolic sine of argument in radians

Syntax

```
Y = sinh(X)
```

Description

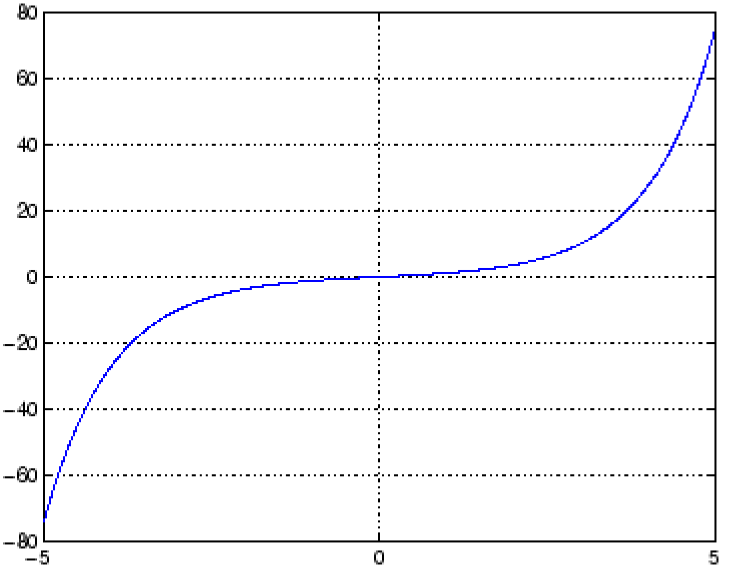
The `sinh` function operates element-wise on arrays. The function's domains and ranges include complex values. All angles are in radians.

`Y = sinh(X)` returns the hyperbolic sine of the elements of `X`.

Examples

Graph the hyperbolic sine function over the domain $-5 \le x \le 5$.

```
x = -5:0.01:5;
plot(x,sinh(x)), grid on
```



Definition

The hyperbolic sine can be defined as

$$\sinh(z) = \frac{e^z - e^{-z}}{2}$$

Algorithm

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

See Also

sin, sind, asin, asinh, asind

Purpose

Array dimensions

Syntax

```
d = size(X)
[m,n] = size(X)
m = size(X,dim)
[d1,d2,d3,...,dn] = size(X),
```

Description

`d = size(X)` returns the sizes of each dimension of array `X` in a vector `d` with `ndims(X)` elements. If `X` is a scalar, which MATLAB software regards as a 1-by-1 array, `size(X)` returns the vector `[1 1]`.

`[m,n] = size(X)` returns the size of matrix `X` in separate variables `m` and `n`.

`m = size(X,dim)` returns the size of the dimension of `X` specified by scalar `dim`.

`[d1,d2,d3,...,dn] = size(X),` for `n` > 1, returns the sizes of the dimensions of the array `X` in the variables d1,d2,d3,...,dn, provided the number of output arguments `n` equals `ndims(X)`. If `n` does not equal `ndims(X)`, the following exceptions hold:

`n < ndims(X)`	`di` equals the size of the `i`th dimension of `X` for $1 \le i < n$, but `dn` equals the product of the sizes of the remaining dimensions of `X`, that is, dimensions `n` through `ndims(X)`.
`n > ndims(X)`	`size` returns ones in the "extra" variables, that is, those corresponding to `ndims(X)+1` through `n`.

Note For a Java array, `size` returns the length of the Java array as the number of rows. The number of columns is always 1. For a Java array of arrays, the result describes only the top level array.

Examples

Example 1

The size of the second dimension of `rand(2,3,4)` is 3.

```
m = size(rand(2,3,4),2)

m =
     3
```

Here the size is output as a single vector.

```
d = size(rand(2,3,4))

d =
     2     3     4
```

Here the size of each dimension is assigned to a separate variable.

```
[m,n,p] = size(rand(2,3,4))
m =
     2

n =
     3

p =
     4
```

Example 2

If `X = ones(3,4,5)`, then

```
[d1,d2,d3] = size(X)

d1 =        d2 =        d3 =
     3           4           5
```

But when the number of output variables is less than `ndims(X)`:

```
[d1,d2] = size(X)

d1 =        d2 =
     3           20
```

The "extra" dimensions are collapsed into a single product.

If `n > ndims(X)`, the "extra" variables all represent singleton dimensions:

```
[d1,d2,d3,d4,d5,d6] = size(X)

d1 =        d2 =        d3 =
     3           4           5

d4 =        d5 =        d6 =
     1           1           1
```

See Also

`exist`, `length`, `numel`, `whos`

size (Map)

Purpose

size of `containers.Map` object

Syntax

```
d = size(M)
d = size(M, dim)
[d1, d2, ..., dn] = size(M)
```

Description

`d = size(M)` returns the number of key-value pairs in dimensions 1 and 2 of map `M`. Output `d` is a two-element row vector `[n,1]`, where `n` is the number of key-value pairs.

`d = size(M, dim)` returns the number of key-value pairs if `dim` is 1, and otherwise returns 1.

`[d1, d2, ..., dn] = size(M)` returns `[n, 1, ..., 1]` where `n` is the number of key-value pairs in map `M`.

Read more about Map Containers in the MATLAB Programming Fundamentals documentation.

Examples

Create a `Map` object containing the names of several US states and the capital city of each:

```
US_Capitals = containers.Map( ...
{'Arizona', 'Nebraska', 'Nevada', 'New York', ...
 'Georgia', 'Alaska', 'Vermont', 'Oregon'}, ...
{'Phoenix', 'Lincoln', 'Carson City', 'Albany', ...
 'Atlanta', 'Juneau', 'Montpelier', 'Salem'})
```

Get the dimensions of the `Map` object array:

```
size(US_Capitals)
ans =
     8     1
```

Use the map to find the capital of one of these states:

```
state = 'Georgia';
sprintf('   The capital of %s is %s', ...
        state, US_Capitals(state))
```

```
ans =
   The capital of Georgia is Atlanta
```

See Also

containers.Map, keys(Map), values(Map), length(Map), isKey(Map), remove(Map), handle

size (serial)

Purpose

Size of serial port object array

Syntax

```
d = size(obj)
[m,n] = size(obj)
[m1,m2,m3,...,mn] = size(obj)
m = size(obj,dim)
```

Description

`d = size(obj)` returns the two-element row vector `d` containing the number of rows and columns in the serial port object, `obj`.

`[m,n] = size(obj)` returns the number of rows, `m` and columns, `n` in separate output variables.

`[m1,m2,m3,...,mn] = size(obj)` returns the length of the first `n` dimensions of `obj`.

`m = size(obj,dim)` returns the length of the dimension specified by the scalar `dim`. For example, `size(obj,1)` returns the number of rows.

See Also

Functions

`length`

Purpose Size of `timeseries` object

Syntax `size(ts)`

Description `size(ts)` returns `[n 1]`, where `n` is the length of the time vector for `timeseries` object `ts`.

Remarks If you want the size of the whole data set, use the following syntax:

```
size(ts.data)
```

If you want the size of each data sample, use the following syntax:

```
getdatasamplesize(ts)
```

See Also `getdatasamplesize`, `isempty (timeseries)`, `length (timeseries)`

size (tscollection)

Purpose Size of `tscollection` object

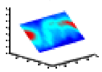
Syntax `size(tsc)`

Description `size(tsc)` returns `[n m]`, where `n` is the length of the time vector and `m` is the number of `tscollection` members.

See Also `length (tscollection)`, `isempty (tscollection)`, `tscollection`

Purpose

Volumetric slice plot



GUI Alternatives

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

Syntax

```
slice(V,sx,sy,sz)
slice(X,Y,Z,V,sx,sy,sz)
slice(V,XI,YI,ZI)
slice(X,Y,Z,V,XI,YI,ZI)
slice(...,'method')
slice(axes_handle,...)
h = slice(...)
```

Description

`slice` displays orthogonal slice planes through volumetric data.

`slice(V,sx,sy,sz)` draws slices along the *x*, *y*, *z* directions in the volume `V` at the points in the vectors `sx`, `sy`, and `sz`. `V` is an *m*-by-*n*-by-*p* volume array containing data values at the default location `X = 1:n, Y = 1:m, Z = 1:p`. Each element in the vectors `sx`, `sy`, and `sz` defines a slice plane in the *x*-, *y*-, or *z*-axis direction.

`slice(X,Y,Z,V,sx,sy,sz)` draws slices of the volume `V`. `X`, `Y`, and `Z` are three-dimensional arrays specifying the coordinates for `V`. `X`, `Y`, and `Z` must be monotonic and orthogonally spaced (as if produced by the function `meshgrid`). The color at each point is determined by 3-D interpolation into the volume `V`.

`slice(V,XI,YI,ZI)` draws data in the volume `V` for the slices defined by `XI`, `YI`, and `ZI`. `XI`, `YI`, and `ZI` are matrices that define a surface, and the volume is evaluated at the surface points. `XI`, `YI`, and `ZI` must all be the same size.

`slice(X,Y,Z,V,XI,YI,ZI)` draws slices through the volume `V` along the surface defined by the arrays `XI`, `YI`, `ZI`.

`slice(...,'method')` specifies the interpolation method. `'method'` is `'linear'`, `'cubic'`, or `'nearest'`.

- `linear` specifies trilinear interpolation (the default).
- `cubic` specifies tricubic interpolation.
- `nearest` specifies nearest-neighbor interpolation.

`slice(axes_handle,...)` plots into the axes with the handle `axes_handle` instead of into the current axes object (`gca`). The axes `clim` property is set to span the finite values of `V`.

`h = slice(...)` returns a vector of handles to surface graphics objects.

Remarks

The color drawn at each point is determined by interpolation into the volume `V`.

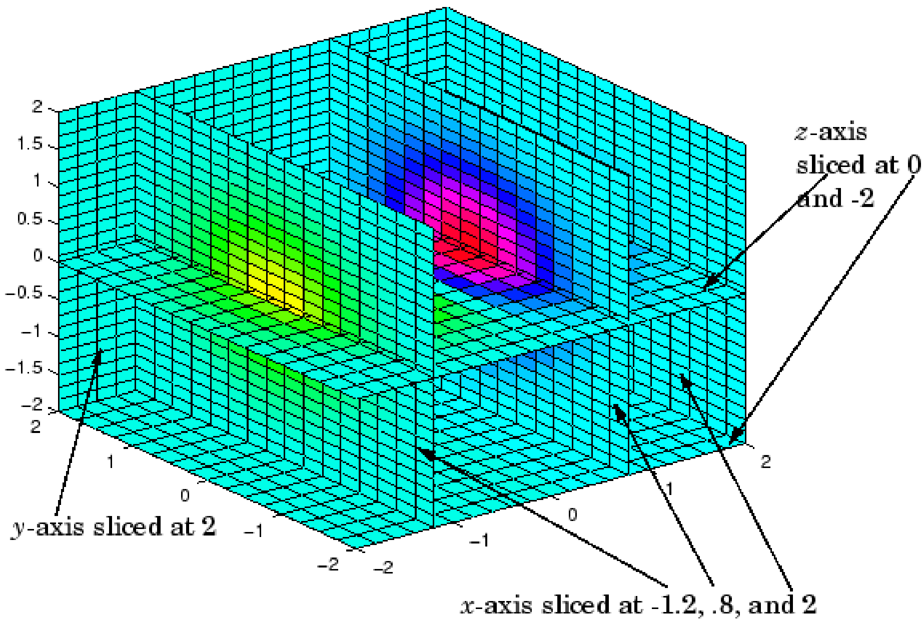
Examples

Visualize the function

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

over the range $-2 \leq x \leq 2$, $-2 \leq y \leq 2$, $-2 \leq z \leq 2$:

```
[x,y,z] = meshgrid(-2:.2:2,-2:.25:2,-2:.16:2);
v = x.*exp(-x.^2-y.^2-z.^2);
xslice = [-1.2,.8,2]; yslice = 2; zslice = [-2,0];
slice(x,y,z,v,xslice,yslice,zslice)
colormap hsv
```



Slicing At Arbitrary Angles

You can also create slices that are oriented in arbitrary planes. To do this,

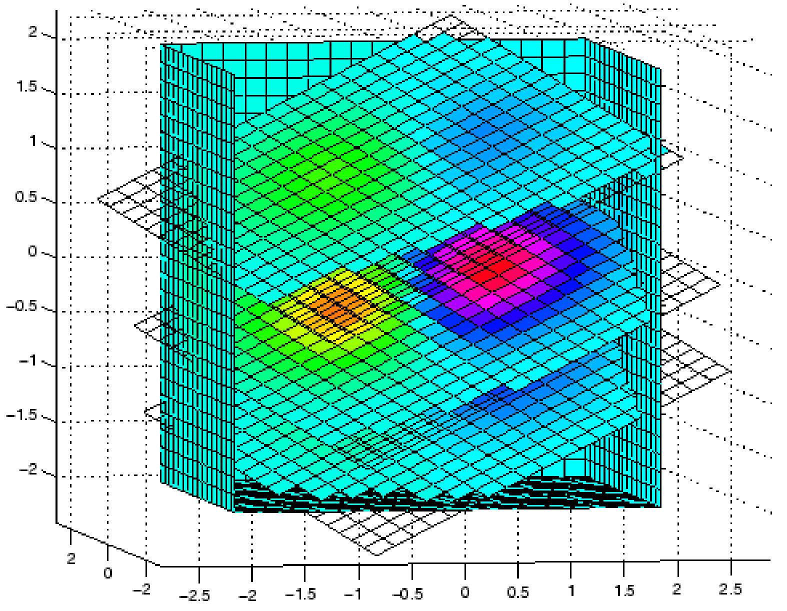
- Create a slice surface in the domain of the volume (`surf`, `linspace`).
- Orient this surface with respect to the axes (`rotate`).
- Get the `XData`, `YData`, and `ZData` of the surface (`get`).
- Use this data to draw the slice plane within the volume.

For example, these statements slice the volume in the first example with a rotated plane. Placing these commands within a `for` loop "passes" the plane through the volume along the *z*-axis.

```
for i = -2:.5:2
 hsp = surf(linspace(-2,2,20),linspace(-2,2,20),zeros(20)+i);
```

```
    rotate(hsp,[1,-1,1],30)
    xd = get(hsp,'XData');
    yd = get(hsp,'YData');
    zd = get(hsp,'ZData');
    delete(hsp)
    slice(x,y,z,v,[-2,2],2,-2) % Draw some volume boundaries
    hold on
    slice(x,y,z,v,xd,yd,zd)
    hold off
    axis tight
    view(-5,10)
    drawnow
  end
```

The following picture illustrates three positions of the same slice surface as it passes through the volume.

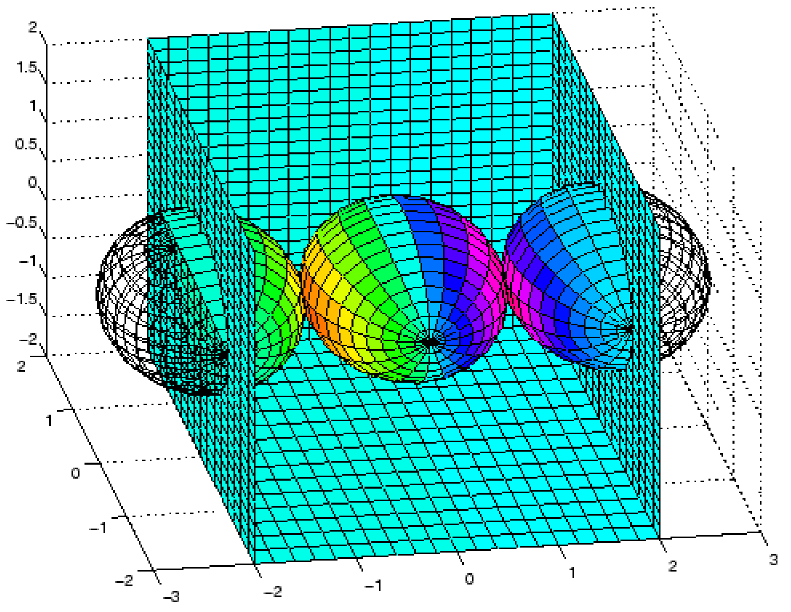


Slicing with a Nonplanar Surface

You can slice the volume with any surface. This example probes the volume created in the previous example by passing a spherical slice surface through the volume.

```
[xsp,ysp,zsp] = sphere;
slice(x,y,z,v,[-2,2],2,-2)  % Draw some volume boundaries

for i = -3:.2:3
 hsp = surface(xsp+i,ysp,zsp);
 rotate(hsp,[1 0 0],90)
 xd = get(hsp,'XData');
 yd = get(hsp,'YData');
 zd = get(hsp,'ZData');
 delete(hsp)
 hold on
 hslicer = slice(x,y,z,v,xd,yd,zd);
 axis tight
 xlim([-3,3])
 view(-10,35)
 drawnow
 delete(hslicer)
 hold off
end
```

The following picture illustrates three positions of the spherical slice surface as it passes through the volume.



See Also

`interp3`, `meshgrid`

"Volume Visualization" on page 1-106 for related functions

Exploring Volumes with Slice Planes for more examples

Purpose

Smooth 3-D data

Syntax

Description

`W = smooth3(V)` smooths the input data `V` and returns the smoothed data in `W`.

`W = smooth3(V,'`*`filter`*`')` *`filter`* determines the convolution kernel and can be the strings

- `'gaussian'`
- `'box'` (default)

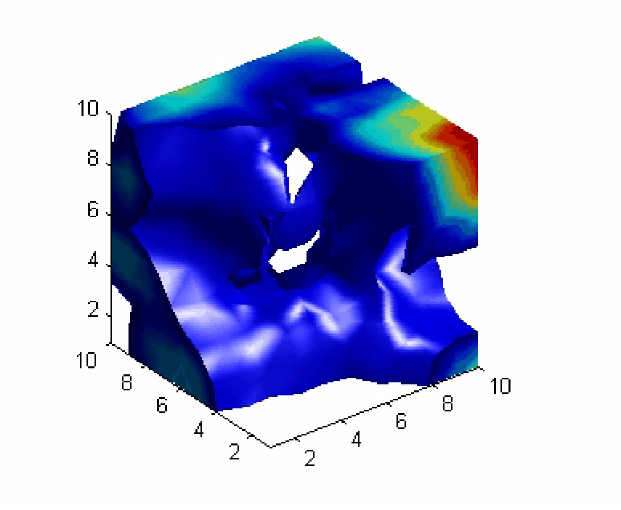
`W = smooth3(V,'`*`filter`*`',size)` sets the size of the convolution kernel (default is `[3 3 3]`). If `size` is scalar, then `size` is interpreted as [`size`, `size`, `size`].

`W = smooth3(V,'`*`filter`*`',size,sd)` sets an attribute of the convolution kernel. When *`filter`* is `gaussian`, `sd` is the standard deviation (default is .65).

Examples

This example smooths some random 3-D data and then creates an isosurface with end caps.

```
rand('seed',0)
data = rand(10,10,10);
data = smooth3(data,'box',5);
p1 = patch(isosurface(data,.5), ...
   'FaceColor','blue','EdgeColor','none');
p2 = patch(isocaps(data,.5), ...
    'FaceColor','interp','EdgeColor','none');
isonormals(data,p1)
view(3); axis vis3d tight
camlight; lighting phong
```



See Also

`isocaps`, `isonormals`, `isosurface`, `patch`

"Volume Visualization" on page 1-106 for related functions

See Displaying an Isosurface for another example.

Purpose

Force snapshot of image for inclusion in published document

GUI Alternative

As an alternative to `snapnow`, open an M-File and select **Cell > Insert Text Markup > Force Snapshot** to insert the `snapnow` command into the M-File.

Syntax

```
snapnow
```

Description

The `snapnow` command forces a snapshot of the image or plot that the code has most recently generated for presentation in a published document. The output appears in the published document at the end of the cell that contains the `snapnow` command. When used outside the context of publishing an M-File, `snapnow` has the same behavior as `drawnow`. That is, if you run a file that contains the `snapnow` command, the MATLAB software interprets it as though it were a `drawnow` command.

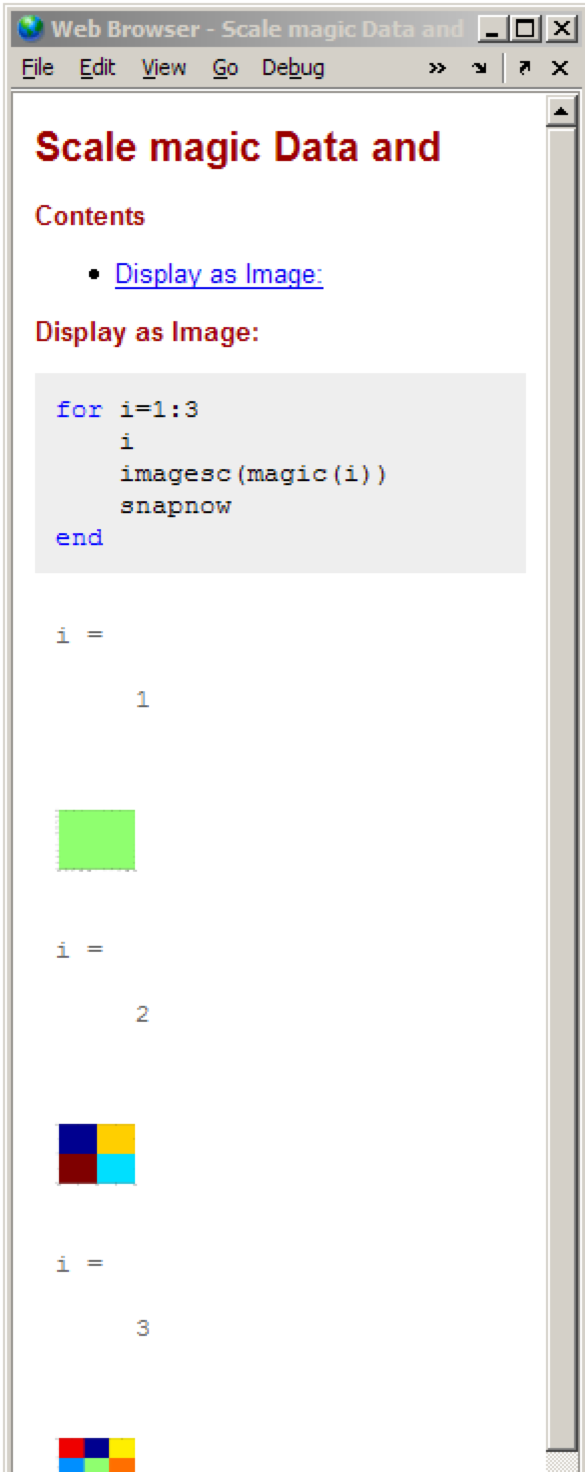
Example

This example demonstrates the difference between publishing code that contains the `snapnow` command and running that code. The first image shows the results of publishing the code and the second image shows the results of running the code.

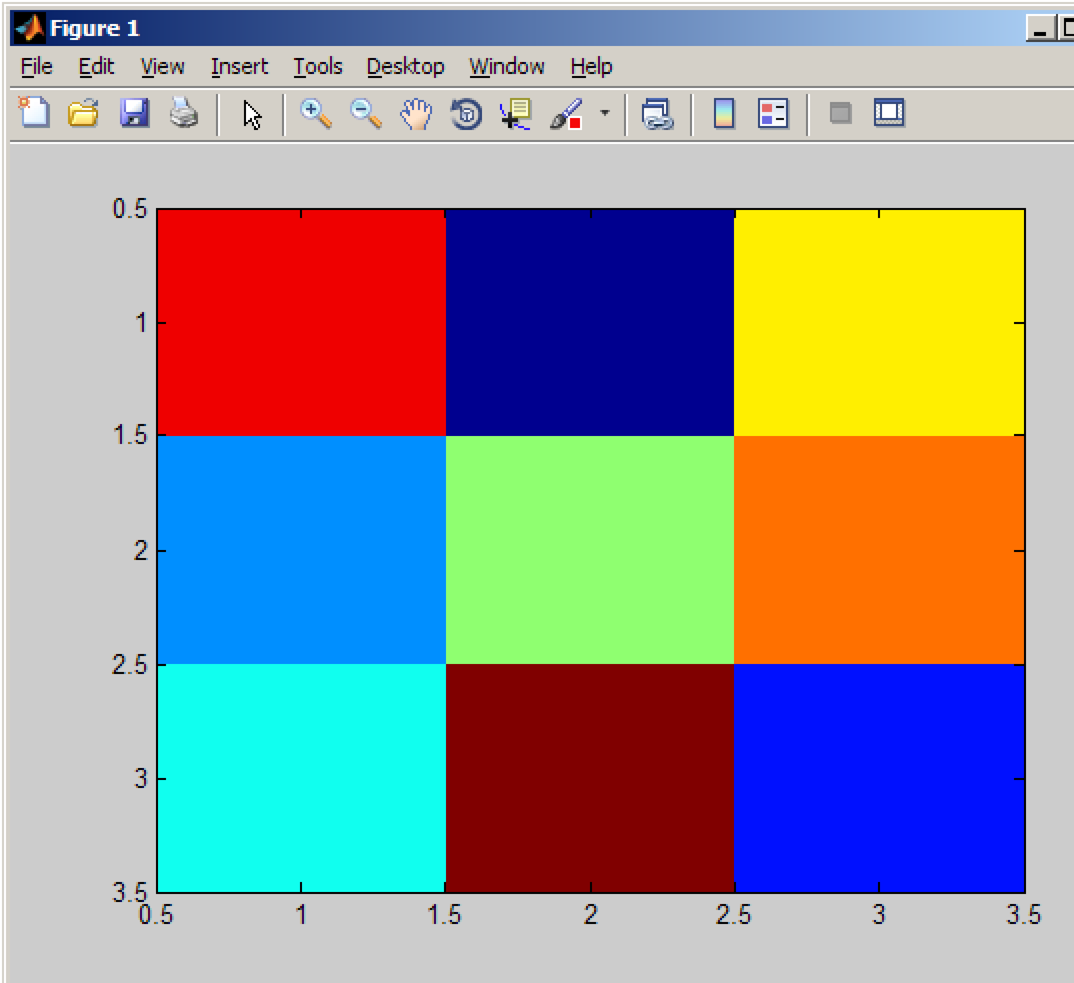
Suppose you have an M-file that contains the following code:

```
%% Scale magic Data and
%% Display as Image:

for i=1:3
    i
    imagesc(magic(i))
    snapnow
end
```

When you publish the code to HTML, the published document contains a title, a table of contents, the commented text, the code, and each of the three images produced by the `for` loop, along with a display of the value of `i` corresponding to each image. (In the published document shown, the size of the images have been reduced.)


Web Browser - Scale magic Data and
File Edit View Go Debug
Scale magic Data and
Contents
Display as Image:
Display as Image:
for i=1:3
i
imagesc(magic(i))
snapnow
end
i =
1
i =
2
i =
3

When you run the code, a single Figure window opens and MATLAB updates the image within this window as it evaluates each iteration of the `for` loop. (Concurrently, the Command Window displays the value of `i`.) Each successive image replaces the one that preceded it, so that the Figure window appears as follows when the code evaluation completes.



See Also

`drawnow`

"Forcing a Snapshot of Output in M-Files for Publishing"

Purpose

Sort array elements in ascending or descending order

Syntax

```
B = sort(A)
B = sort(A,dim)
B = sort(...,mode)
[B,IX] = sort(A,...)
```

Description

`B = sort(A)` sorts the elements along different dimensions of an array, and arranges those elements in ascending order.

If A is a ...	sort(A) ...
Vector	Sorts the elements of `A`.
Matrix	Sorts each column of `A`.
Multidimensional array	Sorts `A` along the first non-singleton dimension, and returns an array of sorted vectors.
Cell array of strings	Sorts the strings in ASCII dictionary order.

Integer, floating-point, logical, and character arrays are permitted. Floating-point arrays can be complex. For elements of A with identical values, the order of these elements is preserved in the sorted list. When `A` is complex, the elements are sorted by magnitude, i.e., `abs(A)`, and where magnitudes are equal, further sorted by phase angle, i.e., `angle(A)`, on the interval $[-\pi, \pi]$. If `A` includes any `NaN` elements, `sort` places these at the high end.

`B = sort(A,dim)` sorts the elements along the dimension of `A` specified by a scalar `dim`.

`B = sort(...,mode)` sorts the elements in the specified direction, depending on the value of `mode`.

`'ascend'`	Ascending order (default)
`'descend'`	Descending order

`[B,IX] = sort(A,...)` also returns an array of indices `IX`, where `size(IX) == size(A)`. If `A` is a vector, `B = A(IX)`. If `A` is an `m`-by-`n` matrix, then each column of `IX` is a permutation vector of the corresponding column of `A`, such that

```
for j = 1:n
    B(:,j) = A(IX(:,j),j);
end
```

If `A` has repeated elements of equal value, the returned indices preserve the original ordering.

Sorting Complex Entries

If `A` has complex entries `r` and `s`, `sort` orders them according to the following rule: `r` appears before `s` in `sort(A)` if either of the following hold:

- `abs(r) < abs(s)`
- `abs(r) = abs(s)` and `angle(r)<angle(s)`

  where $-\pi < angle(r) \leq \pi$

For example,

```
v = [1 -1 i -i];
angle(v)

ans =

         0    3.1416    1.5708   -1.5708
sort(v)

ans =

        0 - 1.0000i   1.0000
        0 + 1.0000i  -1.0000
```

Note `sort` uses a different rule for ordering complex numbers than do the relational operators. See the Relational Operators reference page for more information. For more information about how MATLAB software treats complex numbers, see "Numbers" in the *MATLAB Getting Started Guide*.

Examples

Example 1

This example sorts a matrix `A` in each dimension, and then sorts it a third time, returning an array of indices for the sorted result.

```
A = [ 3 7 5
      0 4 2 ];

sort(A,1)

ans =
     0     4     2
     3     7     5

sort(A,2)

ans =
     3     5     7
     0     2     4

[B,IX] = sort(A,2)

B =
     3     5     7
     0     2     4

IX =
     1     3     2
     1     3     2
```

Example 2

This example sorts each column of a matrix in descending order.

```
A = [ 3  7  5
      6  8  3
      0  4  2 ];

sort(A,1,'descend')

ans =
     6   8   5
     3   7   3
     0   4   2
```

This is equivalent to

```
sort(A,'descend')

ans =
     6   8   5
     3   7   3
     0   4   2
```

See Also

`issorted`, `max`, `mean`, `median`, `min`, `sortrows`, `unique`

sortrows

Purpose

Sort rows in ascending order

Syntax

```
B = sortrows(A)
B = sortrows(A,column)
[B,index] = sortrows(A,...)
```

Description

`B = sortrows(A)` sorts the rows of `A` in ascending order. Argument `A` must be either a matrix or a column vector.

For strings, this is the familiar dictionary sort. When `A` is complex, the elements are sorted by magnitude, and, where magnitudes are equal, further sorted by phase angle on the interval $[-\pi, \pi]$.

`B = sortrows(A,column)` sorts the matrix based on the columns specified in the vector `column`. If an element of `column` is positive, the MATLAB software sorts the corresponding column of matrix `A` in ascending order; if an element of `column` is negative, MATLAB sorts the corresponding column in descending order. For example, `sortrows(A,[2 -3])` sorts the rows of `A` first in ascending order for the second column, and then by descending order for the third column.

`[B,index] = sortrows(A,...)` also returns an index vector `index`.

If `A` is a column vector, then `B = A(index)`. If `A` is an `m`-by-`n` matrix, then `B = A(index,:)`.

Examples

Start with a mostly random matrix, `A`:

```
rand('state',0)
A = floor(rand(6,7) * 100);
A(1:4,1)=95;  A(5:6,1)=76;  A(2:4,2)=7;  A(3,3)=73
A =
    95    45    92    41    13     1    84
    95     7    73    89    20    74    52
    95     7    73     5    19    44    20
    95     7    40    35    60    93    67
    76    61    93    81    27    46    83
    76    79    91     0    19    41     1
```

When called with only a single input argument, `sortrows` bases the sort on the first column of the matrix. For any rows that have equal elements in a particular column, (e.g., `A(1:4,1)` for this matrix), sorting is based on the column immediately to the right, (`A(1:4,2)` in this case):

```
B = sortrows(A)
B =
    76    61    93    81    27    46    83
    76    79    91     0    19    41     1
    95     7    40    35    60    93    67
    95     7    73     5    19    44    20
    95     7    73    89    20    74    52
    95    45    92    41    13     1    84
```

When called with two input arguments, `sortrows` bases the sort entirely on the column specified in the second argument. Rows that have equal elements in the specified column, (e.g., `A(2:4,:)`, if sorting matrix `A` by column 2) remain in their original order:

```
C = sortrows(A,2)
C =
    95     7    73    89    20    74    52
    95     7    73     5    19    44    20
    95     7    40    35    60    93    67
    95    45    92    41    13     1    84
    76    61    93    81    27    46    83
    76    79    91     0    19    41     1
```

This example specifies two columns to sort by: columns 1 and 7. This tells `sortrows` to sort by column 1 first, and then for any rows with equal values in column 1, to sort by column 7:

```
D = sortrows(A,[1 7])
D =
    76    79    91     0    19    41     1
    76    61    93    81    27    46    83
    95     7    73     5    19    44    20
    95     7    73    89    20    74    52
```

```
    95     7    40    35    60    93    67
    95    45    92    41    13     1    84
```

Sort the matrix using the values in column 4 this time and in reverse order:

```
E = sortrows(A, -4)
E =
    95     7    73    89    20    74    52
    76    61    93    81    27    46    83
    95    45    92    41    13     1    84
    95     7    40    35    60    93    67
    95     7    73     5    19    44    20
    76    79    91     0    19    41     1
```

See Also

`issorted`, `sort`

Purpose

Convert vector into sound

Syntax

```
sound(y,Fs)
sound(y)
sound(y,Fs,bits)
```

Description

`sound(y,Fs)` sends the signal in vector `y` (with sample frequency `Fs`, in hertz) to the speaker on Microsoft Windows and most UNIX platforms. Values in `y` are assumed to be in the range $-1.0 \leq y \leq 1.0$. Values outside that range are clipped. Stereo sound is played on platforms that support it when `y` is an `n`-by-2 matrix. The values in column 1 are assigned to the left channel, and those in column 2 to the right.

Note The playback duration that results from setting `Fs` depends on the sound card you have installed. Most sound cards support sample frequencies in the range of approximately 5 kHz to 44.1 kHz. Sample frequencies outside this range can produce unexpected results.

`sound(y)` plays the sound at the default sample rate or 8192 Hz.

`sound(y,Fs,bits)` plays the sound using `bits` number of bits/sample, if possible. Most platforms support `bits = 8` or `bits = 16`.

Remarks

MATLAB software supports all sound devices compatible with Windows operating systems. Additional sound acquisition and generation capability is available in Data Acquisition Toolbox software. The toolbox functionality includes the ability to buffer the acquisition so that you can analyze the data as it is being acquired. See the examples on MATLAB sound acquisition and sound generation.

See Also

`auread`, `auwrite`, `soundsc`, `audioplayer`, `wavread`, `wavwrite`

soundsc

Purpose

Scale data and play as sound

Syntax

```
soundsc(y,Fs)
soundsc(y)
soundsc(y,Fs,bits)
soundsc(y,...,slim)
```

Description

`soundsc(y,Fs)` sends the signal in vector `y` (with sample frequency `Fs`) to the speaker on PC and most UNIX platforms. The signal `y` is scaled to the range $-1.0 \le y \le 1.0$ before it is played, resulting in a sound that is played as loud as possible without clipping.

Note The playback duration that results from setting `Fs` depends on the sound card you have installed. Most sound cards support sample frequencies of approximately 5-10 kHz to 44.1 kHz. Sample frequencies outside this range can produce unexpected results.

`soundsc(y)` plays the sound at the default sample rate or 8192 Hz.

`soundsc(y,Fs,bits)` plays the sound using `bits` number of bits/sample if possible. Most platforms support `bits = 8` or `bits = 16`.

`soundsc(y,...,slim)`, where `slim = [slow shigh]`, maps the values in `y` between `slow` and `shigh` to the full sound range. The default value is `slim = [min(y) max(y)]`.

Remarks

MATLAB software supports all Windows-compatible sound devices.

See Also

`auread`, `auwrite`, `sound`, `wavread`, `wavwrite`

Purpose

Allocate space for sparse matrix

Syntax

```
S = spalloc(m,n,nzmax)
```

Description

`S = spalloc(m,n,nzmax)` creates an all zero sparse matrix `S` of size `m`-by-`n` with room to hold `nzmax` nonzeros. The matrix can then be generated column by column without requiring repeated storage allocation as the number of nonzeros grows.

`spalloc(m,n,nzmax)` is shorthand for

```
sparse([],[],[],m,n,nzmax)
```

Examples

To generate efficiently a sparse matrix that has an average of at most three nonzero elements per column

```
S = spalloc(n,n,3*n);
for j = 1:n
    S(:,j) = [zeros(n-3,1)' round(rand(3,1))']';end
```

Purpose

Create sparse matrix

Syntax

```
S = sparse(A)
S = sparse(i,j,s,m,n,nzmax)
S = sparse(i,j,s,m,n)
S = sparse(i,j,s)
S = sparse(m,n)
```

Description

The `sparse` function generates matrices in the MATLAB sparse storage organization.

`S = sparse(A)` converts a full matrix to sparse form by squeezing out any zero elements. If `S` is already sparse, `sparse(S)` returns `S`.

`S = sparse(i,j,s,m,n,nzmax)` uses vectors `i`, `j`, and `s` to generate an `m`-by-`n` sparse matrix such that `S(i(k),j(k)) = s(k)`, with space allocated for `nzmax` nonzeros. Vectors `i`, `j`, and `s` are all the same length. Any elements of `s` that are zero are ignored, along with the corresponding values of `i` and `j`. Any elements of `s` that have duplicate values of `i` and `j` are added together.

Note If any value in `i` or `j` is larger than the maximum integer size, `2^31-1`, then the sparse matrix cannot be constructed.

To simplify this six-argument call, you can pass scalars for the argument `s` and one of the arguments `i` or `j`—in which case they are expanded so that `i`, `j`, and `s` all have the same length.

`S = sparse(i,j,s,m,n)` uses `nzmax = length(s)`.

`S = sparse(i,j,s)` uses `m = max(i)` and `n = max(j)`. The maxima are computed before any zeros in `s` are removed, so one of the rows of `[i j s]` might be `[m n 0]`.

`S = sparse(m,n)` abbreviates `sparse([],[],[],m,n,0)`. This generates the ultimate sparse matrix, an `m`-by-`n` all zero matrix.

Remarks

All of the MATLAB built-in arithmetic, logical, and indexing operations can be applied to sparse matrices, or to mixtures of sparse and full matrices. Operations on sparse matrices return sparse matrices and operations on full matrices return full matrices.

In most cases, operations on mixtures of sparse and full matrices return full matrices. The exceptions include situations where the result of a mixed operation is structurally sparse, for example, `A.*S` is at least as sparse as `S`.

Examples

`S = sparse(1:n,1:n,1)` generates a sparse representation of the `n`-by-`n` identity matrix. The same `S` results from `S = sparse(eye(n,n))`, but this would also temporarily generate a full `n`-by-`n` matrix with most of its elements equal to zero.

`B = sparse(10000,10000,pi)` is probably not very useful, but is legal and works; it sets up a `10000`-by-`10000` matrix with only one nonzero element. Don't try `full(B)`; it requires 800 megabytes of storage.

This dissects and then reassembles a sparse matrix:

```
[i,j,s] = find(S);
[m,n] = size(S);
S = sparse(i,j,s,m,n);
```

So does this, if the last row and column have nonzero entries:

```
[i,j,s] = find(S);
S = sparse(i,j,s);
```

See Also

`diag`, `find`, `full`, `issparse`, `nnz`, `nonzeros`, `nzmax`, `spones`, `sprandn`, `sprandsym`, `spy`

The `sparfun` directory

Purpose Form least squares augmented system

Syntax

```
S = spaugment(A,c)
S = spaugment(A)
```

Description `S = spaugment(A,c)` creates the sparse, square, symmetric indefinite matrix `S = [c*I A; A' 0]`. The matrix `S` is related to the least squares problem

```
min norm(b - A*x)
```

by

```
r = b - A*x
S * [r/c; x] = [b; 0]
```

The optimum value of the residual scaling factor `c`, involves `min(svd(A))` and `norm(r)`, which are usually too expensive to compute.

`S = spaugment(A)` without a specified value of `c`, uses `max(max(abs(A)))/1000`.

Note In previous versions of MATLAB product, the augmented matrix was used by sparse linear equation solvers, \ and /, for nonsquare problems. Now, MATLAB software performs a least squares solve using the `qr` factorization of `A` instead.

See Also `spparms`

Purpose

Import matrix from sparse matrix external format

Syntax

```
S = spconvert(D)
```

Description

`spconvert` is used to create sparse matrices from a simple sparse format easily produced by non-MATLAB sparse programs. `spconvert` is the second step in the process:

1. Load an ASCII data file containing `[i,j,v]` or `[i,j,re,im]` as rows into a MATLAB variable.
2. Convert that variable into a MATLAB sparse matrix.

`S = spconvert(D)` converts a matrix `D` with rows containing `[i,j,s]` or `[i,j,r,s]` to the corresponding sparse matrix. `D` must have an `nnz` or `nnz+1` row and three or four columns. Three elements per row generate a real matrix and four elements per row generate a complex matrix. A row of the form `[m n 0]` or `[m n 0 0]` anywhere in `D` can be used to specify `size(S)`. If `D` is already sparse, no conversion is done, so `spconvert` can be used after `D` is loaded from either a MAT-file or an ASCII file.

Examples

Suppose the ASCII file `uphill.dat` contains

```
1     1     1.000000000000000
1     2     0.500000000000000
2     2     0.333333333333333
1     3     0.333333333333333
2     3     0.250000000000000
3     3     0.200000000000000
1     4     0.250000000000000
2     4     0.200000000000000
3     4     0.166666666666667
4     4     0.142857142857143
4     4     0.000000000000000
```

Then the statements

```
load uphill.dat
H = spconvert(uphill)

H =
   (1,1)       1.0000
   (1,2)       0.5000
   (2,2)       0.3333
   (1,3)       0.3333
   (2,3)       0.2500
   (3,3)       0.2000
   (1,4)       0.2500
   (2,4)       0.2000
   (3,4)       0.1667
   (4,4)       0.1429
```

recreate `sparse(triu(hilb(4)))`, possibly with roundoff errors. In this case, the last line of the input file is not necessary because the earlier lines already specify that the matrix is at least 4-by-4.

Purpose

Extract and create sparse band and diagonal matrices

Syntax

```
B = spdiags(A)
[B,d] = spdiags(A)
B = spdiags(A,d)
A = spdiags(B,d,A)
A = spdiags(B,d,m,n)
```

Description

The `spdiags` function generalizes the function `diag`. Four different operations, distinguished by the number of input arguments, are possible.

`B = spdiags(A)` extracts all nonzero diagonals from the `m`-by-`n` matrix `A`. `B` is a `min(m,n)`-by-`p` matrix whose columns are the `p` nonzero diagonals of `A`.

`[B,d] = spdiags(A)` returns a vector `d` of length `p`, whose integer components specify the diagonals in `A`.

`B = spdiags(A,d)` extracts the diagonals specified by `d`.

`A = spdiags(B,d,A)` replaces the diagonals specified by `d` with the columns of `B`. The output is sparse.

`A = spdiags(B,d,m,n)` creates an `m`-by-`n` sparse matrix by taking the columns of `B` and placing them along the diagonals specified by `d`.

Note In this syntax, if a column of `B` is longer than the diagonal it is replacing, and `m >= n`, `spdiags` takes elements of super-diagonals from the lower part of the column of `B`, and elements of sub-diagonals from the upper part of the column of `B`. However, if `m < n` , then super-diagonals are from the upper part of the column of `B`, and sub-diagonals from the lower part. (See "Example 5A" on page 2-3221 and "Example 5B" on page 2-3223, below).

Arguments

The `spdiags` function deals with three matrices, in various combinations, as both input and output.

A	An m-by-n matrix, usually (but not necessarily) sparse, with its nonzero or specified elements located on p diagonals.
B	A min(m,n)-by-p matrix, usually (but not necessarily) full, whose columns are the diagonals of A.
d	A vector of length p whose integer components specify the diagonals in A.

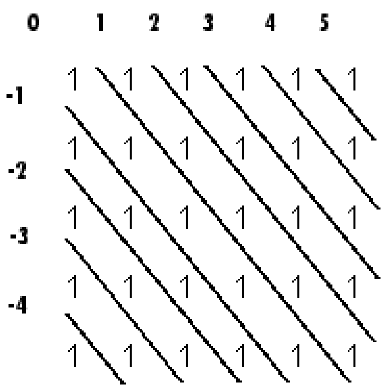
Roughly, A, B, and d are related by

```
for k = 1:p
    B(:,k) = diag(A,d(k))
end
```

Some elements of B, corresponding to positions outside of A, are not defined by these loops. They are not referenced when B is input and are set to zero when B is output.

How the Diagonals of A are Listed in the Vector d

An m-by-n matrix A has m+n-1diagonals. These are specified in the vector d using indices from -m+1 to n-1. For example, if A is 5-by-6, it has 10 diagonals, which are specified in the vector d using the indices -4, -3 , ... 4, 5. The following diagram illustrates this for a vector of all ones.



Examples

Example 1

For the following matrix,

```
A=[0 5 0 10 0 0;...
0 0 6 0 11 0;...
3 0 0 7 0 12;...
1 4 0 0 8 0;...
0 2 5 0 0 9]

A =

     0     5     0    10     0     0
     0     0     6     0    11     0
     3     0     0     7     0    12
     1     4     0     0     8     0
     0     2     5     0     0     9
```

the command

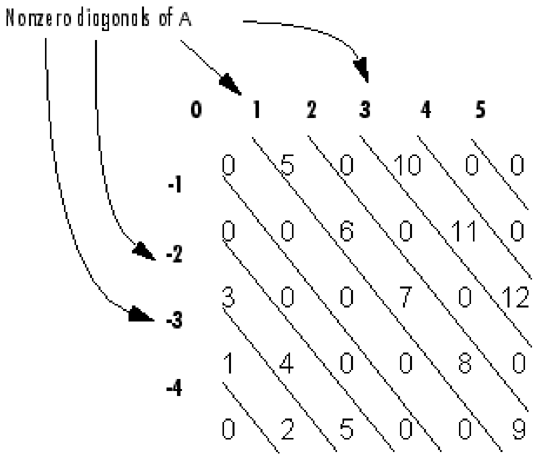
```
[B, d]  =spdiags(A)
```

returns

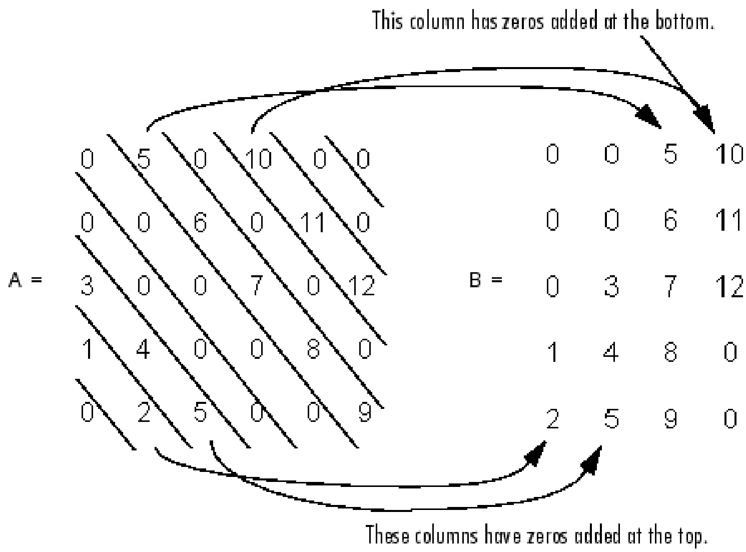
```
B =

     0     0     5    10
     0     0     6    11
     0     3     7    12
     1     4     8     0
     2     5     9     0


d =


    -3
    -2
     1
```

3

The columns of the first output B contain the nonzero diagonals of A. The second output d lists the indices of the nonzero diagonals of A, as shown in the following diagram. See "How the Diagonals of A are Listed in the Vector d" on page 2-3216.



Note that the longest nonzero diagonal in A is contained in column 3 of B. The other nonzero diagonals of A have extra zeros added to their corresponding columns in B, to give all columns of B the same length. For the nonzero diagonals below the main diagonal of A, extra zeros are added at the tops of columns. For the nonzero diagonals above the main diagonal of A, extra zeros are added at the bottoms of columns. This is illustrated by the following diagram.



Example 2

This example generates a sparse tridiagonal representation of the classic second difference operator on `n` points.

```
e = ones(n,1);
A = spdiags([e -2*e e], -1:1, n, n)
```

Turn it into Wilkinson's test matrix (see `gallery`):

```
A = spdiags(abs(-(n-1)/2:(n-1)/2)',0,A)
```

Finally, recover the three diagonals:

```
B = spdiags(A)
```

Example 3

The second example is not square.

```
A = [11    0   13    0
      0   22    0   24
```

```
  0     0    33     0
 41     0     0    44
  0    52     0     0
  0     0    63     0
  0     0     0    74]
```

Here `m =7`, `n = 4`, and `p = 3`.

The statement `[B,d] = spdiags(A)` produces `d = [-3 0 2]'` and

```
B = [41   11    0
     52   22    0
     63   33   13
     74   44   24]
```

Conversely, with the above `B` and `d`, the expression `spdiags(B,d,7,4)` reproduces the original `A`.

Example 4

This example shows how `spdiags` creates the diagonals when the columns of `B` are longer than the diagonals they are replacing.

```
B = repmat((1:6)',[1 7])

B =

    1   1   1   1   1   1   1
    2   2   2   2   2   2   2
    3   3   3   3   3   3   3
    4   4   4   4   4   4   4
    5   5   5   5   5   5   5
    6   6   6   6   6   6   6

d = [-4 -2 -1 0 3 4 5];
A = spdiags(B,d,6,6);
full(A)

ans =
```

```
1   0   0   4   5   6
1   2   0   0   5   6
1   2   3   0   0   6
0   2   3   4   0   0
1   0   3   4   5   0
0   2   0   4   5   6
```

Example 5A

This example illustrates the use of the syntax `A = spdiags(B,d,m,n)`, under three conditions:

- `m` is equal to `n`
- `m` is greater than `n`
- `m` is less than `n`

The command used in this example is

```
A = full(spdiags(B, [-2 0 2], m, n))
```

where `B` is the 5-by-3 matrix shown below. The resulting matrix `A` has dimensions `m`-by-`n`, and has nonzero diagonals at `[-2 0 2]` (a sub-diagonal at `-2`, the main diagonal, and a super-diagonal at `2`).

```
B =
    1     6    11
    2     7    12
    3     8    13
    4     9    14
    5    10    15
```

The first and third columns of matrix `B` are used to create the sub- and super-diagonals of `A` respectively. In all three cases though, these two outer columns of `B` are longer than the resulting diagonals of `A`. Because of this, only a part of the columns is used in `A`.

When m == n or m > n, spdiags takes elements of the super-diagonal in A from the lower part of the corresponding column of B, and elements of the sub-diagonal in A from the upper part of the corresponding column of B.

When m < n, spdiags does the opposite, taking elements of the super-diagonal in A from the upper part of the corresponding column of B, and elements of the sub-diagonal in A from the lower part of the corresponding column of B.

Part 1 — m is equal to n.

```
A = full(spdiags(B, [-2 0 2], 5, 5))
 Matrix B                        Matrix A

1    6   11                   6    0   13    0    0
2    7   12                   0    7    0   14    0
3    8   13  == spdiags =>    1    0    8    0   15
4    9   14                   0    2    0    9    0
5   10   15                   0    0    3    0   10
```

A(3,1), A(4,2), and A(5,3) are taken from the upper part of B(:,1).

A(1,3), A(2,4), and A(3,5) are taken from the lower part of B(:,3).

Part 2 — m is greater than n.

```
A = full(spdiags(B, [-2 0 2], 5, 4))
 Matrix B                        Matrix A

1    6   11                   6    0   13    0
2    7   12                   0    7    0   14
3    8   13  == spdiags =>    1    0    8    0
4    9   14                   0    2    0    9
5   10   15                   0    0    3    0
```

Same as in Part A.

Part 3 — m is less than n.

```
A = full(spdiags(B, [-2 0 2], 4, 5))
 Matrix B                              Matrix A

1    6   11                      6    0   11    0    0
2    7   12                      0    7    0   12    0
3    8   13   == spdiags =>      3    0    8    0   13
4    9   14                      0    4    0    9    0
5   10   15
```

`A(3,1)` and `A(4,2)` are taken from the lower part of `B(:,1)`.

`A(1,3)`, `A(2,4)`, and `A(3,5)` are taken from the upper part of `B(:,3)`.

Example 5B

Extract the diagonals from the first part of this example back into a column format using the command

```
B = spdiags(A)
```

You can see that in each case the original columns are restored (minus those elements that had overflowed the super- and sub-diagonals of matrix A).

Part 1.

```
        Matrix A                              Matrix B

6    0   13    0    0                      1    6    0
0    7    0   14    0                      2    7    0
1    0    8    0   15   == spdiags =>      3    8   13
0    2    0    9    0                      0    9   14
0    0    3    0   10                      0   10   15
```

Part 2.

```
      Matrix A                             Matrix B
```

```
6    0   13    0                  1    6    0
0    7    0   14                  2    7    0
1    0    8    0  == spdiags =>   3    8   13
0    2    0    9                  0    9   14
0    0    3    0
```

Part 3.

```
        Matrix A                              Matrix B

6    0   11    0    0                  0    6   11
0    7    0   12    0                  0    7   12
3    0    8    0   13  == spdiags =>   3    8   13
0    4    0    9    0                  4    9    0
```

See Also

`diag`, `speye`

Purpose

Calculate specular reflectance

Syntax

```
R = specular(Nx,Ny,Nz,S,V)
```

Description

`R = specular(Nx,Ny,Nz,S,V)` returns the reflectance of a surface with normal vector components `[Nx,Ny,Nz]`. `S` and `V` specify the direction to the light source and to the viewer, respectively. You can specify these directions as three vectors`[x,y,z]` or two vectors `[Theta Phi` (in spherical coordinates).

The specular highlight is strongest when the normal vector is in the direction of `(S+V)/2` where `S` is the source direction, and `V` is the view direction.

The surface spread exponent can be specified by including a sixth argument as in `specular(Nx,Ny,Nz,S,V,spread)`.

Purpose

Sparse identity matrix

Syntax

```
S = speye(m,n)
S = speye(n)
```

Description

`S = speye(m,n)` forms an `m`-by-`n` sparse matrix with `1`s on the main diagonal.

`S = speye(n)` abbreviates `speye(n,n)`.

Examples

`I =s peye(1000)` forms the sparse representation of the 1000-by-1000 identity matrix, which requires only about 16 kilobytes of storage. This is the same final result as `I = sparse(eye(1000,1000))`, but the latter requires eight megabytes for temporary storage for the full representation.

See Also

`spalloc`, `spones`, `spdiags`, `sprand`, `sprandn`

Purpose

Apply function to nonzero sparse matrix elements

Syntax

`f = spfun(fun,S)`

Description

The `spfun` function selectively applies a function to only the *nonzero* elements of a sparse matrix `S`, preserving the sparsity pattern of the original matrix (except for underflow or if `fun` returns zero for some nonzero elements of `S`).

`f = spfun(fun,S)` evaluates `fun(S)` on the nonzero elements of `S`. `fun` is a function handle. See "Function Handles" in the MATLAB Programming documentation for more information.

"Parametrizing Functions" in the MATLAB Mathematics documentation, explains how to provide additional parameters to the function `fun`, if necessary.

Remarks

Functions that operate element-by-element, like those in the `elfun` directory, are the most appropriate functions to use with `spfun`.

Examples

Given the 4-by-4 sparse diagonal matrix

```
S = spdiags([1:4]',0,4,4)

S =
   (1,1)        1
   (2,2)        2
   (3,3)        3
   (4,4)        4
```

Because `fun` returns nonzero values for all nonzero element of `S`, `f = spfun(@exp,S)` has the same sparsity pattern as `S`.

```
f =
   (1,1)       2.7183
   (2,2)       7.3891
   (3,3)      20.0855
   (4,4)      54.5982
```

whereas `exp(S)` has 1s where `S` has 0s.

```
full(exp(S))

ans =
    2.7183    1.0000    1.0000    1.0000
    1.0000    7.3891    1.0000    1.0000
    1.0000    1.0000   20.0855    1.0000
    1.0000    1.0000    1.0000   54.5982
```

See Also

`function_handle` (@)

Purpose

Transform spherical coordinates to Cartesian

Syntax

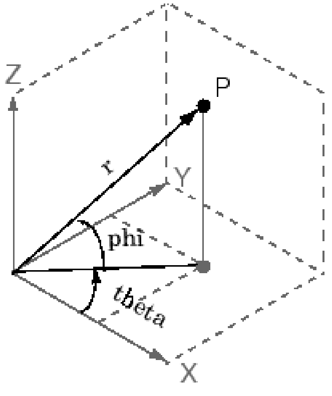
```
[x,y,z] = sph2cart(THETA,PHI,R)
```

Description

`[x,y,z] = sph2cart(THETA,PHI,R)` transforms the corresponding elements of spherical coordinate arrays to Cartesian, or *xyz*, coordinates. `THETA`, `PHI`, and `R` must all be the same size (or any of them can be scalar). `THETA` and `PHI` are angular displacements in radians from the positive *x*-axis and from the *x*-*y* plane, respectively.

Algorithm

The mapping from spherical coordinates to three-dimensional Cartesian coordinates is



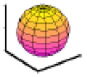

```
x = r .* cos(phi) .* cos(theta)
y = r .* cos(phi) .* sin(theta)
      z = r .* sin(phi)
```

See Also

`cart2pol`, `cart2sph`, `pol2cart`

sphere

Purpose Generate sphere



Syntax

```
sphere
sphere(n)
[X,Y,Z] = sphere(n)
```

Description The `sphere` function generates the *x*-, *y*-, and *z*-coordinates of a unit sphere for use with `surf` and `mesh`.

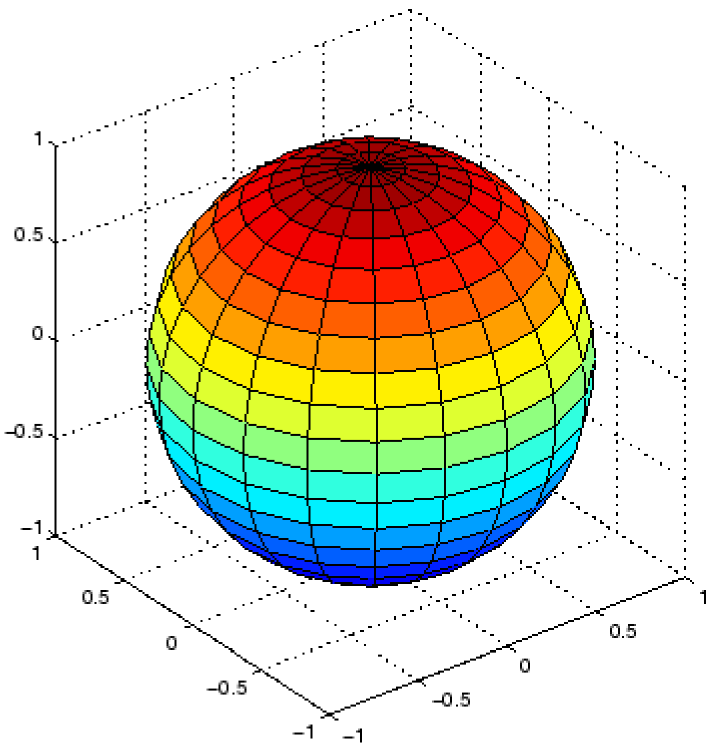
`sphere` generates a sphere consisting of 20-by-20 faces.

`sphere(n)` draws a `surf` plot of an `n`-by-`n` sphere in the current figure.

`[X,Y,Z] = sphere(n)` returns the coordinates of a sphere in three matrices that are `(n+1)`-by-`(n+1)` in size. You draw the sphere with `surf(X,Y,Z)` or `mesh(X,Y,Z)`.

Examples Generate and plot a sphere.

```
sphere
axis equal
```



See Also

`cylinder`, `axis` equal

"Polygons and Surfaces" on page 1-94 for related functions

spinmap

Purpose

Spin colormap

Syntax

```
spinmap
spinmap(t)
spinmap(t,inc)
spinmap('inf')
```

Description

The `spinmap` function shifts the colormap RGB values by some incremental value. For example, if the increment equals 1, color 1 becomes color 2, color 2 becomes color 3, etc.

`spinmap` cyclically rotates the colormap for approximately five seconds using an incremental value of 2.

`spinmap(t)` rotates the colormap for approximately 10`*t` seconds. The amount of time specified by `t` depends on your hardware configuration (e.g., if you are running MATLAB software over a network).

`spinmap(t,inc)` rotates the colormap for approximately 10`*t` seconds and specifies an increment `inc` by which the colormap shifts. When `inc` is 1, the rotation appears smoother than the default (i.e., 2). Increments greater than 2 are less smooth than the default. A negative increment (e.g., –2) rotates the colormap in a negative direction.

`spinmap('inf')` rotates the colormap for an infinite amount of time. To break the loop, press **Ctrl+C**.

See Also

`colormap`, `colormapeditor`

"Color Operations" on page 1-102 for related functions

Purpose

Cubic spline data interpolation

Syntax

```
pp = spline(x,Y)
yy = spline(x,Y,xx)
```

Description

`pp = spline(x,Y)` returns the piecewise polynomial form of the cubic spline interpolant for later use with `ppval` and the spline utility `unmkpp`. `x` must be a vector. `Y` can be a scalar, a vector, or an array of any dimension, subject to the following conditions:

- If `Y` is a scalar or vector, it must have the same length as `x`. A scalar value for `x` or `Y` is expanded to have the same length as the other. See Exceptions (1) for an exception to this rule, in which the not-a-knot end conditions are used.
- If `Y` is an array that is not a vector, the size of `Y` must have the form `[d1,d2,...,dk,n]`, where `n` is the length of `x`. The interpolation is performed for each `d1`-by-`d2`-by-...-`dk` value in `Y`. See Exceptions (2) for an exception to this rule.

`yy = spline(x,Y,xx)` is the same as `yy = ppval(spline(x,Y),xx)`, thus providing, in `yy`, the values of the interpolant at `xx`. `xx` can be a scalar, a vector, or a multidimensional array. The sizes of `xx` and `yy` are related as follows:

- If `Y` is a scalar or vector, `yy` has the same size as `xx`.
- If `Y` is an array that is not a vector,
  - If `xx` is a scalar or vector, `size(yy)` equals `[d1, d2, ..., dk, length(xx)]`.
  - If `xx` is an array of size `[m1,m2,...,mj]`, `size(yy)` equals `[d1,d2,...,dk,m1,m2,...,mj]`.

Exceptions

1. If `Y` is a vector that contains two more values than `x` has entries, the first and last value in `Y` are used as the endslopes for the cubic spline. If `Y` is a vector, this means
   - `f(x) = Y(2:end-1)`
   - `df(min(x)) = Y(1)`
   - `df(max(x)) = Y(end)`
2. If `Y` is a matrix or an `N`-dimensional array with `size(Y,N)` equal to `length(x)+2`, the following hold:
   - `f(x(j))` matches the value `Y(:,...,:,j+1)` for `j=1:length(x)`
   - `Df(min(x))` matches `Y(:,:,...:,1)`
   - `Df(max(x))` matches `Y(:,:,...:,end)`

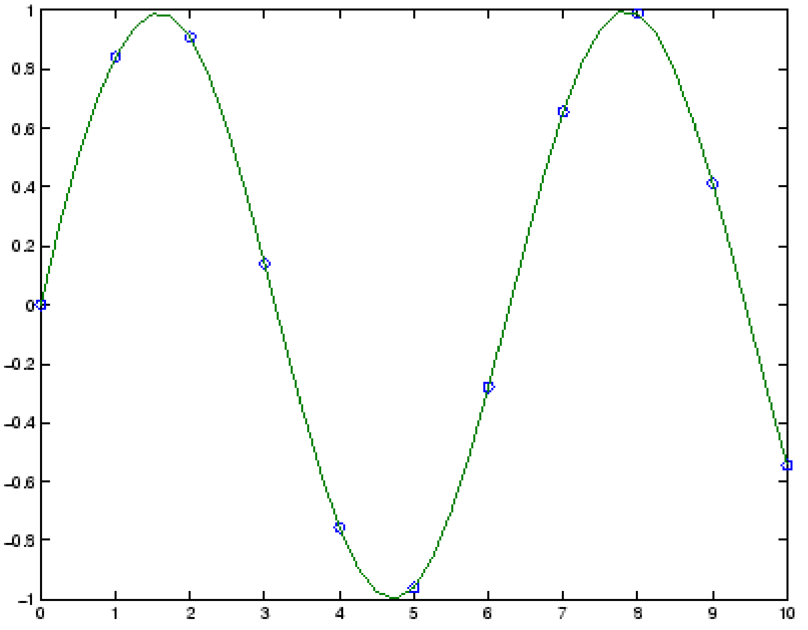
Note You can also perform spline interpolation using the `interp1` function with the command `interp1(x,y,xx,'spline')`. Note that while `spline` performs interpolation on rows of an input matrix, `interp1` performs interpolation on columns of an input matrix.

Examples

Example 1

This generates a sine curve, then samples the spline over a finer mesh.

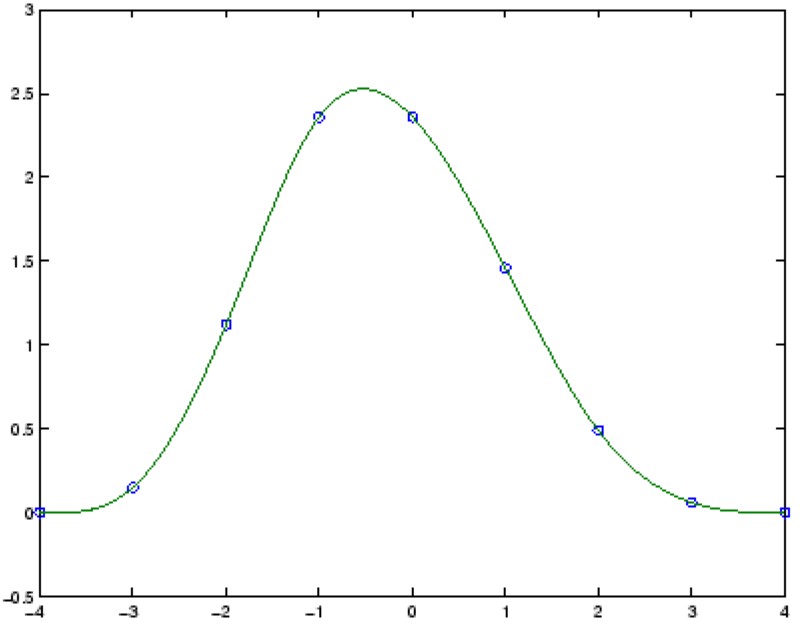
```
x = 0:10;
y = sin(x);
xx = 0:.25:10;
yy = spline(x,y,xx);
plot(x,y,'o',xx,yy)
```



Example 2

This illustrates the use of clamped or complete spline interpolation where end slopes are prescribed. Zero slopes at the ends of an interpolant to the values of a certain distribution are enforced.

```
x = -4:4;
y = [0 .15 1.12 2.36 2.36 1.46 .49 .06 0];
cs = spline(x,[0 y 0]);
xx = linspace(-4,4,101);
plot(x,y,'o',xx,ppval(cs,xx),'-');
```



Example 3

The two vectors

```
t = 1900:10:1990;
p = [ 75.995  91.972  105.711  123.203  131.669 ...
     150.697 179.323  203.212  226.505  249.633 ];
```

represent the census years from 1900 to 1990 and the corresponding United States population in millions of people. The expression

```
spline(t,p,2000)
```

uses the cubic spline to extrapolate and predict the population in the year 2000. The result is

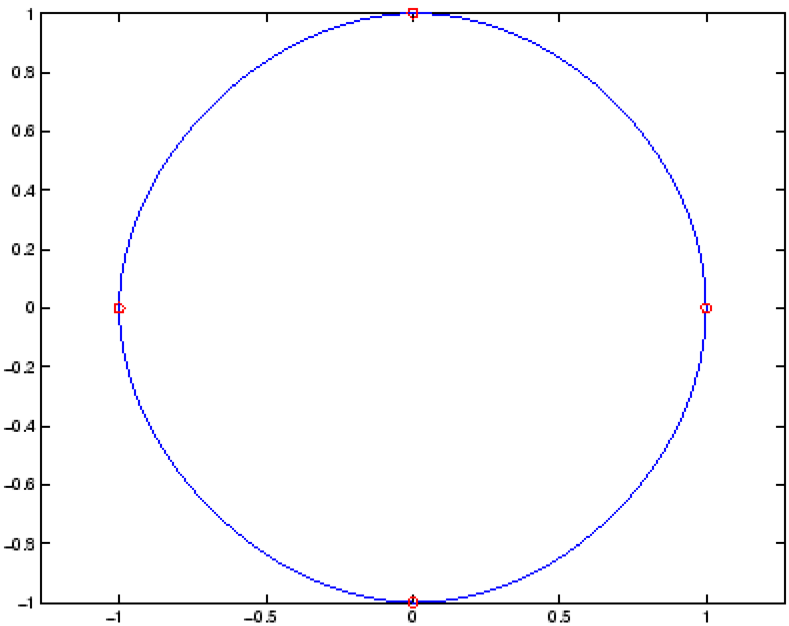
```
ans =
    270.6060
```

Example 4

The statements

```
x = pi*[0:.5:2];
y = [0  1  0 -1  0  1  0;
     1  0  1  0 -1  0  1];
pp = spline(x,y);
yy = ppval(pp, linspace(0,2*pi,101));
plot(yy(1,:),yy(2,:),'-b',y(1,2:5),y(2,2:5),'or'), axis equal
```

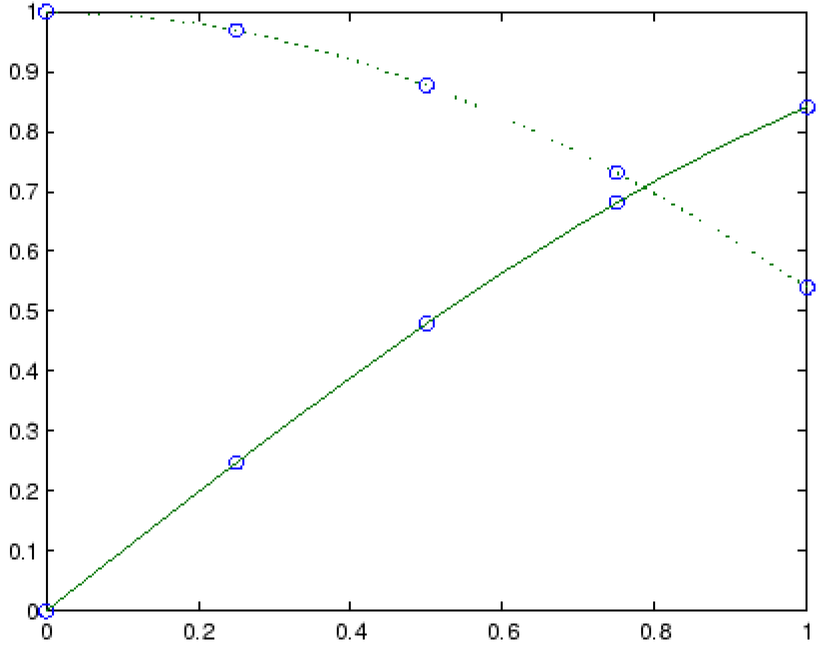
generate the plot of a circle, with the five data points `y(:,2),...,y(:,6)` marked with o's. Note that this `y` contains two more values (i.e., two more columns) than does `x`, hence `y(:,1)` and `y(:,end)` are used as endslopes.



Example 5

The following code generates sine and cosine curves, then samples the splines over a finer mesh.

```
x = 0:.25:1;
Y = [sin(x); cos(x)];
xx = 0:.1:1;
YY = spline(x,Y,xx);
plot(x,Y(1,:),'o',xx,YY(1,:),'-'); hold on;
plot(x,Y(2,:),'o',xx,YY(2,:),':'); hold off;
```



Algorithm

A tridiagonal linear system (with, possibly, several right sides) is being solved for the information needed to describe the coefficients of the various cubic polynomials which make up the interpolating spline. `spline` uses the functions `ppval`, `mkpp`, and `unmkpp`. These routines form a small suite of functions for working with piecewise polynomials. For access to more advanced features, see the M-file help for these functions and the Spline Toolbox.

See Also

`interp1`, `ppval`, `mkpp`, `pchip`, `unmkpp`

References

[1] de Boor, C., *A Practical Guide to Splines*, Springer-Verlag, 1978.

spones

Purpose

Replace nonzero sparse matrix elements with ones

Syntax

```
R = spones(S)
```

Description

`R = spones(S)` generates a matrix `R` with the same sparsity structure as `S`, but with `1`'s in the nonzero positions.

Examples

`c = sum(spones(S))` is the number of nonzeros in each column.

`r = sum(spones(S'))'` is the number of nonzeros in each row.

`sum(c)` and `sum(r)` are equal, and are equal to `nnz(S)`.

See Also

`nnz`, `spalloc`, `spfun`

Purpose

Set parameters for sparse matrix routines

Syntax

```
spparms('key',value)
spparms
values = spparms
[keys,values] = spparms
spparms(values)
value = spparms('key')
spparms('default')
spparms('tight')
```

Description

`spparms('key',value)` sets one or more of the *tunable* parameters used in the sparse routines, particularly the minimum degree orderings, `colmmd` and `symmmd`, and also within sparse backslash. In ordinary use, you should never need to deal with this function.

The meanings of the `key` parameters are

`'spumoni'`	Sparse Monitor flag:
`0`	Produces no diagnostic output, the default
`1`	Produces information about choice of algorithm based on matrix structure, and about storage allocation
`2`	Also produces very detailed information about the sparse matrix algorithms
`'thr_rel'`, `'thr_abs'`	Minimum degree threshold is `thr_rel*mindegree + thr_abs`.
`'exact_d'`	Nonzero to use exact degrees in minimum degree. Zero to use approximate degrees.
`'supernd'`	If positive, minimum degree amalgamates the supernodes every `supernd` stages.

`'rreduce'`	If positive, minimum degree does row reduction every `rreduce` stages.
`'wh_frac'`	Rows with `density > wh_frac` are ignored in `colmmd`.
`'autommd'`	Nonzero to use minimum degree (MMD) orderings with QR-based \ and `/`.
`'autoamd'`	Nonzero to use `colamd` ordering with the UMFPACK LU-based \ and /, and to use `amd` with CHOLMOD Cholesky-based \ and /.
`'piv_tol'`	Pivot tolerance used by the UMFPACK LU-based \ and /.
`'bandden'`	Band density used by LAPACK-based \ and / for banded matrices. Band density is defined as (# nonzeros in the band)/(# nonzeros in a full band). If `bandden = 1.0`, never use band solver. If `bandden = 0.0`, always use band solver. Default is `0.5`.
`'umfpack'`	Nonzero to use UMFPACK instead of the v4 LU-based solver in `\` and `/`.
`'sym_tol'`	Symmetric pivot tolerance used by UMFPACK. See `lu` for more information about the role of the symmetric pivot tolerance.

Note LU-based \ and / (UMFPACK) on square matrices use a modified `colamd` or `amd`. Cholesky-based \ and / (CHOLMOD) on symmetric positive definite matrices use `amd`. QR-based \ and / on rectangular matrices use `colmmd`.

`spparms`, by itself, prints a description of the current settings.

`values = spparms` returns a vector whose components give the current settings.

`[keys,values] = spparms` returns that vector, and also returns a character matrix whose rows are the keywords for the parameters.

`spparms(values)`, with no output argument, sets all the parameters to the values specified by the argument vector.

`value = spparms('key')` returns the current setting of one parameter.

`spparms('default')` sets all the parameters to their default settings.

`spparms('tight')` sets the minimum degree ordering parameters to their *tight* settings, which can lead to orderings with less fill-in, but which make the ordering functions themselves use more execution time.

The key parameters for `default` and `tight` settings are

	Keyword	Default	Tight
values(1)	'spumoni'	0.0	
values(2)	'thr_rel'	1.1	1.0
values(3)	'thr_abs'	1.0	0.0
values(4)	'exact_d'	0.0	1.0
values(5)	'supernd'	3.0	1.0
values(6)	'rreduce'	3.0	1.0
values(7)	'wh_frac'	0.5	0.5
values(8)	'autommd'	1.0	
values(9)	'autoamd'	1.0	
values(10)	'piv_tol'	0.1	
values(11)	'bandden'	0.5	
values(12)	'umfpack'	1.0	
values(13)	'sym_tol'	0.001	

Notes

Sparse A\b on Symmetric Positive Definite A

Sparse `A\b` on symmetric positive definite `A` uses CHOLMOD in conjunction with the `amd` reordering routine.

The parameter `'autoamd'` turns the `amd` reordering on or off within the solver.

Sparse A\b on General Square A

Sparse `A\b` on general square `A` usually uses UMFPACK in conjunction with `amd` or a modified `colamd` reordering routine.

The parameter `'umfpack'` turns the use of the UMFPACK software on or off within the solver.

If UMFPACK is used,

- The parameter `'piv_tol'` controls pivoting within the solver.
- The parameter `'autoamd'` turns `amd` and the modified `colamd` on or off within the solver.

If UMFPACK is not used,

- An LU-based solver is used in conjunction with the `colmmd` reordering routine.
- If UMFPACK is not used, then the parameter `'autommd'` turns the `colmmd` reordering routine on or off within the solver.
- If UMFPACK is not used and `colmmd` is used within the solver, then the minimum degree parameters affect the reordering routine within the solver.

Sparse A\b on Rectangular A

Sparse `A\b` on rectangular `A` uses a QR-based solve in conjunction with the `colmmd` reordering routine.

The parameter `'autommd'` turns the `colmmd` reordering on or off within the solver.

If `colmmd` is used within the solver, then the minimum degree parameters affect the reordering routine within the solver.

See Also

`\`, `chol`, `lu`, `qr`, `colamdsymamd`

References

[1] Gilbert, John R., Cleve Moler, and Robert Schreiber, "Sparse Matrices in MATLAB: Design and Implementation," *SIAM Journal on Matrix Analysis and Applications*, Vol. 13, 1992, pp. 333-356.

[2] Davis, T. A., *UMFPACK Version 4.6 User Guide* (`http://www.cise.ufl.edu/research/sparse/umfpack/`), Dept. of Computer and Information Science and Engineering, Univ. of Florida, Gainesville, FL, 2002.

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

sprand

Purpose

Sparse uniformly distributed random matrix

Syntax

```
R = sprand(S)
R = sprand(m,n,density)
R = sprand(m,n,density,rc)
```

Description

`R = sprand(S)` has the same sparsity structure as `S`, but uniformly distributed random entries.

`R = sprand(m,n,density)` is a random, `m`-by-`n`, sparse matrix with approximately `density*m*n` uniformly distributed nonzero entries (`0 <= density <= 1`).

`R = sprand(m,n,density,rc)` also has reciprocal condition number approximately equal to `rc`. `R` is constructed from a sum of matrices of rank one.

If `rc` is a vector of length `lr`, where `lr <= min(m,n)`, then `R` has `rc` as its first `lr` singular values, all others are zero. In this case, `R` is generated by random plane rotations applied to a diagonal matrix with the given singular values. It has a great deal of topological and algebraic structure.

`sprand` uses the internal state information set with the `rand` function.

See Also

`sprandn`, `sprandsym`

Purpose

Sparse normally distributed random matrix

Syntax

```
R = sprandn(S)
R = sprandn(m,n,density)
R = sprandn(m,n,density,rc)
```

Description

`R = sprandn(S)` has the same sparsity structure as `S`, but normally distributed random entries with mean `0` and variance `1`.

`R = sprandn(m,n,density)` is a random, `m`-by-`n`, sparse matrix with approximately `density*m*n` normally distributed nonzero entries (`(0 <= density <= 1`).

`R = sprandn(m,n,density,rc)` also has reciprocal condition number approximately equal to `rc`. `R` is constructed from a sum of matrices of rank one.

If `rc` is a vector of length `lr`, where `lr <= min(m,n)`, then `R` has `rc` as its first `lr` singular values, all others are zero. In this case, `R` is generated by random plane rotations applied to a diagonal matrix with the given singular values. It has a great deal of topological and algebraic structure.

`sprandn` uses the internal state information set with the `randn` function.

See Also

`sprand`, `sprandsym`

sprandsym

Purpose

Sparse symmetric random matrix

Syntax

```
R = sprandsym(S)
R = sprandsym(n,density)
R = sprandsym(n,density,rc)
R = sprandsym(n,density,rc,kind)
```

Description

`R = sprandsym(S)` returns a symmetric random matrix whose lower triangle and diagonal have the same structure as `S`. Its elements are normally distributed, with mean `0` and variance `1`.

`R = sprandsym(n,density)` returns a symmetric random, `n`-by-`n`, sparse matrix with approximately `density*n*n` nonzeros; each entry is the sum of one or more normally distributed random samples, and (`0 <= density <= 1`).

`R = sprandsym(n,density,rc)` returns a matrix with a reciprocal condition number equal to `rc`. The distribution of entries is nonuniform; it is roughly symmetric about 0; all are in $[-1, 1]$.

If `rc` is a vector of length `n`, then `R` has eigenvalues `rc`. Thus, if `rc` is a positive (nonnegative) vector then `R` is a positive definite matrix. In either case, `R` is generated by random Jacobi rotations applied to a diagonal matrix with the given eigenvalues or condition number. It has a great deal of topological and algebraic structure.

`R = sprandsym(n,density,rc,kind)` returns a positive definite matrix. Argument `kind` can be:

- `1` to generate `R` by random Jacobi rotation of a positive definite diagonal matrix. `R` has the desired condition number exactly.
- `2` to generate an `R` that is a shifted sum of outer products. `R` has the desired condition number only approximately, but has less structure.
- `3` to generate an `R` that has the same structure as the matrix `S` and approximate condition number `1/rc`. `density` is ignored.

See Also

`sprand`, `sprandn`

Purpose

Structural rank

Syntax

```
r = sprank(A)
```

Description

`r = sprank(A)` is the structural rank of the sparse matrix `A`. For all values of `A`,

```
sprank(A) >= rank(full(A))
```

In exact arithmetic, `sprank(A) == rank(full(sprandn(A)))` with a probability of one.

Examples

```
A = [1    0    2    0
     2    0    4    0 ];

A = sparse(A);

sprank(A)

ans =
     2

rank(full(A))

ans =
     1
```

See Also

`dmperm`

sprintf

Purpose Write formatted data to string

Syntax

```
[s, errmsg] = sprintf(format, A, ...)
```

Description

`[s, errmsg] = sprintf(format, A, ...)` formats the data in matrix `A` (and in any additional matrix arguments) under control of the specified `format` string and returns it in the MATLAB string variable `s`. The `sprintf` function returns an error message string `errmsg` if an error occurred. `errmsg` is an empty matrix if no error occurred.

`sprintf` is the same as `fprintf` except that it returns the data in a MATLAB string variable rather than writing it to a file.

See "Formatting Strings" in the MATLAB Programming Fundamentals documentation for more detailed information on using string formatting commands.

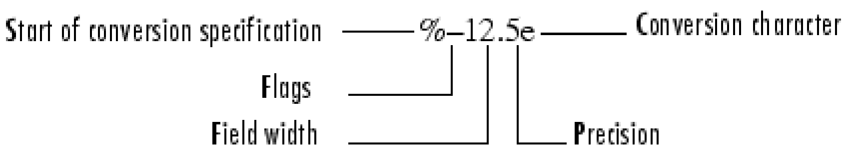
Format String

The `format` argument is a string containing ordinary characters and/or C language conversion specifications. A conversion specification controls the notation, alignment, significant digits, field width, and other aspects of output format. The format string can contain escape characters to represent nonprinting characters such as newline characters and tabs.

Conversion specifications begin with the `%` character and contain these optional and required elements:

- Flags (optional)
- Width and precision fields (optional)
- A subtype specifier (optional)
- Conversion character (required)

You specify these elements in the following order:



Flags

You can control the alignment of the output using any of these optional flags.

Character	Description	Example
A minus sign (-)	Left-justifies the converted argument in its field	`% 5.2d`
A plus sign (+)	Always prints a sign character (+ or –)	`%+5.2d`
Zero (0)	Pad with zeros rather than spaces.	`%05.2f`

Field Width and Precision Specifications

You can control the width and precision of the output by including these options in the format string.

Character	Description	Example
Field width	A string specifying the minimum number of characters to be printed. This includes a plus or minus sign, any leading zeros, numeric digits, and decimal point.	`%6f`
Precision	A string including a period (.) specifying the number of digits to be printed to the right of the decimal point	`%6.2f`

Conversion Characters

Conversion characters specify the notation of the output.

Specifier	Description
%c	Single character
%d	Decimal notation (signed)
%e	Exponential notation (using a lowercase e as in 3.1415e+00)
%E	Exponential notation (using an uppercase E as in 3.1415E+00)
%f	Fixed-point notation
%g	The more compact of %e or %f, as defined in [2]. Insignificant zeros do not print.
%G	Same as %g, but using an uppercase E
%o	Octal notation (unsigned)
%s	String of characters
%u	Decimal notation (unsigned)
%x	Hexadecimal notation (using lowercase letters a–f)
%X	Hexadecimal notation (using uppercase letters A–F)

The following tables describe the nonalphanumeric characters found in format specification strings.

Escape Characters

This table lists the escape character sequences you use to specify non-printing characters in a format specification.

Character	Description
\b	Backspace
\f	Form feed

Character	Description
`\n`	New line
`\r`	Carriage return
`\t`	Horizontal tab
`\\`	Backslash
`\''`(two single quotes)	Single quotation mark
`%%`	Percent character

Remarks

The `sprintf` function behaves like its ANSI C language namesake with these exceptions and extensions.

- If you use `sprintf` to convert a MATLAB double into an integer, and the double contains a value that cannot be represented as an integer (for example, it contains a fraction), MATLAB ignores the specified conversion and outputs the value in exponential format. To successfully perform this conversion, use the `fix`, `floor`, `ceil`, or `round` functions to change the value in the double into a value that can be represented as an integer before passing it to `sprintf`.
- The following nonstandard subtype specifiers are supported for the conversion characters `%o`, `%u`, `%x`, and `%X`.

`b`	The underlying C data type is a double rather than an unsigned integer. For example, to print a double-precision value in hexadecimal, use a format like `'%bx'`.
`t`	The underlying C data type is a float rather than an unsigned integer.

  For example, to print a double value in hexadecimal use the format `'%bx'`.

- The `sprintf` function is vectorized for nonscalar arguments. The function recycles the format string through the elements of `A` (columnwise) until all the elements are used up. The function then continues in a similar manner through any additional matrix arguments.

- If `%s` is used to print part of a nonscalar double argument, the following behavior occurs:

  1. Successive values are printed as long as they are integers and in the range of a valid character. The first invalid character terminates the printing for this `%s` specifier and is used for a later specifier. For example, `pi` terminates the string below and is printed using `%f` format.

     ```
     Str = [65 66 67 pi];
     sprintf('%s %f', Str)
     ans =
     ABC 3.141593
     ```

  2. If the first value to print is not a valid character, then just that value is printed for this `%s` specifier using an `e` conversion as a warning to the user. For example, `pi` is formatted by `%s` below in exponential notation, and `65`, though representing a valid character, is formatted as fixed-point (`%f`).

     ```
     Str = [pi 65 66 67];
     sprintf('%s %f %s', Str)
     ans =
     3.141593e+000 65.000000 BC
     ```

  3. One exception is zero, which is a valid character. If zero is found first, `%s` prints nothing and the value is skipped. If zero is found after at least one valid character, it terminates the printing for this `%s` specifier and is used for a later specifier.

- `sprintf` prints exponents differently on some platforms, as shown in the following table:

Exponents Printed with %e, %E, %g, or %G

Platform	Minimum Digits in Exponent	Example
PC	3	`1.23e+004`
UNIX	2	`1.23e+04`

You can resolve this difference in exponents by postprocessing the results of `sprintf`. For example, to make the PC output look like that of UNIX, use

```
a = sprintf('%e', 12345.678);
if ispc, a = strrep(a, 'e+0', 'e+');   end
```

Examples

Command	Result
`sprintf('%0.5g',(1+sqrt(5))/2)`	`1.618`
`sprintf('%0.5g',1/eps)`	`4.5036e+15`
`sprintf('%15.5f',1/eps)`	`4503599627370496.00000`
`sprintf('%d',round(pi))`	`3`
`sprintf('%s','hello')`	`hello`
`sprintf('The array is %dx%d.',2,3)`	`The array is 2x3`
`sprintf('\n')`	Line termination character on all platforms

See Also

`int2str`, `num2str`, `sscanf`

References

[1] Kernighan, B.W., and D.M. Ritchie, *The C Programming Language, Second Edition*, Prentice-Hall, Inc., 1988.

[2] ANSI specification X3.159-1989: “Programming Language C,” ANSI, 1430 Broadway, New York, NY 10018.

Purpose

Visualize sparsity pattern

Syntax

```
spy(S)
spy(S,markersize)
spy(S,'LineSpec')
spy(S,'LineSpec',markersize)
```

Description

plots the

`spy(S)` sparsity pattern of any matrix `S`.

`spy(S,markersize)`, where `markersize` is an integer, plots the sparsity pattern using markers of the specified point size.

`spy(S,'LineSpec')`, where `LineSpec` is a string, uses the specified plot marker type and color.

`spy(S,'LineSpec',markersize)` uses the specified type, color, and size for the plot markers.

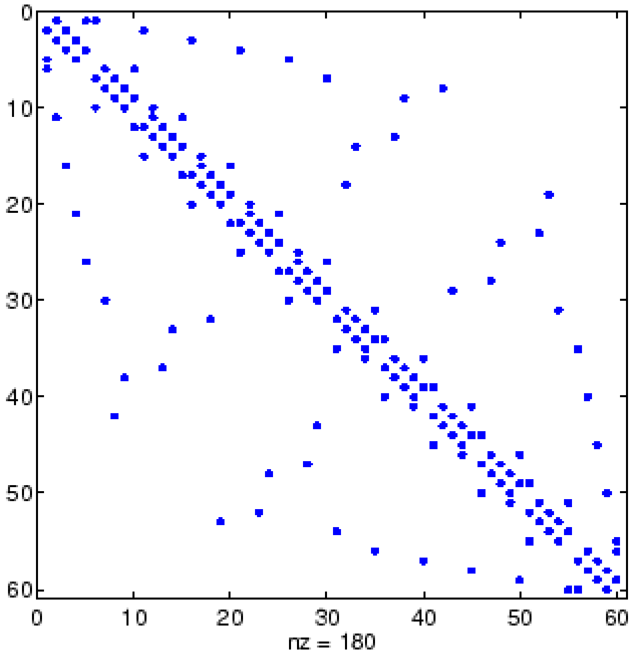
`S` is usually a sparse matrix, but full matrices are acceptable, in which case the locations of the nonzero elements are plotted.

Note `spy` replaces `format +`, which takes much more space to display essentially the same information.

Examples

This example plots the 60-by-60 sparse adjacency matrix of the connectivity graph of the Buckminster Fuller geodesic dome. This matrix also represents the soccer ball and the carbon-60 molecule.

```
B = bucky;
spy(B)
```



See Also find, gplot, LineSpec, symamd, symrcm

Purpose Square root

Syntax

```
B = sqrt(X)
```

Description `B = sqrt(X)` returns the square root of each element of the array `X`. For the elements of `X` that are negative or complex, `sqrt(X)` produces complex results.

Remarks See `sqrtm` for the matrix square root.

Examples

```
sqrt((-2:2)')
ans =
      0 + 1.4142i
      0 + 1.0000i
      0
 1.0000
 1.4142
```

See Also `sqrtm`, `realsqrt`

Purpose

Matrix square root

Syntax

```
X = sqrtm(A)
[X, resnorm] = sqrtm(A)
[X, alpha, condest] = sqrtm(A)
```

Description

`X = sqrtm(A)` is the principal square root of the matrix `A`, i.e. `X*X = A`.

`X` is the unique square root for which every eigenvalue has nonnegative real part. If `A` has any eigenvalues with negative real parts then a complex result is produced. If `A` is singular then `A` may not have a square root. A warning is printed if exact singularity is detected.

`[X, resnorm] = sqrtm(A)` does not print any warning, and returns the residual, `norm(A-X^2,'fro')/norm(A,'fro')`.

`[X, alpha, condest] = sqrtm(A)` returns a stability factor `alpha` and an estimate `condest` of the matrix square root condition number of `X`. The residual `norm(A-X^2,'fro')/norm(A,'fro')` is bounded approximately by `n*alpha*eps` and the Frobenius norm relative error in `X` is bounded approximately by `n*alpha*condest*eps`, where `n = max(size(A))`.

Remarks

If `X` is real, symmetric and positive definite, or complex, Hermitian and positive definite, then so is the computed matrix square root.

Some matrices, like `X = [0 1; 0 0]`, do not have any square roots, real or complex, and `sqrtm` cannot be expected to produce one.

Examples

Example 1

A matrix representation of the fourth difference operator is

```
X =
      5    -4     1     0     0
     -4     6    -4     1     0
      1    -4     6    -4     1
      0     1    -4     6    -4
      0     0     1    -4     5
```

This matrix is symmetric and positive definite. Its unique positive definite square root, Y = sqrtm(X), is a representation of the second difference operator.

```
Y =
     2    -1    -0    -0    -0
    -1     2    -1     0    -0
     0    -1     2    -1     0
    -0     0    -1     2    -1
    -0    -0    -0    -1     2
```

Example 2

The matrix

```
X =
     7    10
    15    22
```

has four square roots. Two of them are

```
Y1 =
    1.5667    1.7408
    2.6112    4.1779
```

and

```
Y2 =
     1     2
     3     4
```

The other two are -Y1 and -Y2. All four can be obtained from the eigenvalues and vectors of X.

```
[V,D] = eig(X);
D =
    0.1386          0
         0    28.8614
```

The four square roots of the diagonal matrix D result from the four choices of sign in

```
S =
    -0.3723          0
          0    -5.3723
```

All four Ys are of the form

```
Y = V*S/V
```

The sqrtm function chooses the two plus signs and produces Y1, even though Y2 is more natural because its entries are integers.

See Also expm, funm, logm

Purpose

Remove singleton dimensions

Syntax

```
B = squeeze(A)
```

Description

`B = squeeze(A)` returns an array `B` with the same elements as `A`, but with all singleton dimensions removed. A singleton dimension is any dimension for which `size(A,dim) = 1`. Two-dimensional arrays are unaffected by `squeeze`; if `A` is a row or column vector or a scalar (1-by-1) value, then `B = A`.

Examples

Consider the 2-by-1-by-3 array `Y = rand(2,1,3)`. This array has a singleton column dimension — that is, there's only one column per page.

```
Y =

Y(:,:,1) =      Y(:,:,2) =
       0.5194          0.0346
       0.8310          0.0535

Y(:,:,3) =
       0.5297
       0.6711
```

The command `Z = squeeze(Y)` yields a 2-by-3 matrix:

```
Z =
    0.5194    0.0346    0.5297
    0.8310    0.0535    0.6711
```

Consider the 1-by-1-by-5 array `mat=repmat(1,[1,1,5])`. This array has only one scalar value per page.

```
mat =

mat(:,:,1) =  mat(:,:,2) =

     1         1
```

```
mat(:,:,3) =   mat(:,:,4) =

     1        1

mat(:,:,5) =

     1
```

The command squeeze(mat) yields a 5-by-1 matrix:

```
squeeze(mat)

ans =

     1
     1
     1
     1
     1

size(squeeze(mat))

ans =

    5     1
```

See Also

reshape, shiftdim

Purpose

Convert state-space filter parameters to transfer function form

Syntax

```
[b,a] = ss2tf(A,B,C,D,iu)
```

Description

`ss2tf` converts a state-space representation of a given system to an equivalent transfer function representation.

`[b,a] = ss2tf(A,B,C,D,iu)` returns the transfer function

$$H(s) = \frac{B(s)}{A(s)} = C(sI - A)^{-1}B + D$$

of the system

$$\begin{aligned} \dot{x} &= Ax + Bu \\ y &= Cx + Du \end{aligned}$$

from the `iu`-th input. Vector `a` contains the coefficients of the denominator in descending powers of s. The numerator coefficients are returned in array `b` with as many rows as there are outputs y. `ss2tf` also works with systems in discrete time, in which case it returns the z-transform representation.

The `ss2tf` function is part of the standard MATLAB language.

Algorithm

The `ss2tf` function uses `poly` to find the characteristic polynomial det(sI-A) and the equality:

$$H(s) = C(sI - A)^{-1}B = \frac{\det(sI - A + BC) - \det(sI - A)}{\det(sI - A)}$$

sscanf

Purpose

Read formatted data from string

Syntax

```
A = sscanf(s, format)
A = sscanf(s, format, size)
[A, count, errmsg, nextindex] = sscanf(...)
```

Description

`A = sscanf(s, format)` reads data from the MATLAB string `s`, converts it according to the specified `format` string, and returns it in matrix `A`. `format` is a string specifying the format of the data to be read. See "Remarks" for details. `sscanf` is the same as `fscanf` except that it reads the data from a MATLAB string rather than reading it from a file. If `s` is a character array with more than one row, `sscanf` reads the characters in column order.

`A = sscanf(s, format, size)` reads the amount of data specified by `size` and converts it according to the specified `format` string. `size` is an argument that determines how much data is read. Valid options are

`n`	Read at most `n` numbers, characters, or strings.
`inf`	Read to the end of the input string.
`[m,n]`	Read at most `(m*n)` numbers, characters, or strings. Fill a matrix of at most `m` rows in column order. `n` can be `inf`, but `m` cannot.

Characteristics of the output matrix `A` depend on the values read from the input string and on the `size` argument. If `sscanf` reads only numbers, and if `size` is not of the form `[m,n]`, matrix `A` is a column vector of numbers. If `sscanf` reads only characters or strings, and if `size` is not of the form `[m,n]`, matrix `A` is a row vector of characters. See the Remarks section for more information.

`sscanf` differs from its C language namesake `scanf()` in an important respect — it is *vectorized* to return a matrix argument. The `format` string is cycled through the input string until the first of these conditions occurs:

- The `format` string fails to match the data in the input string

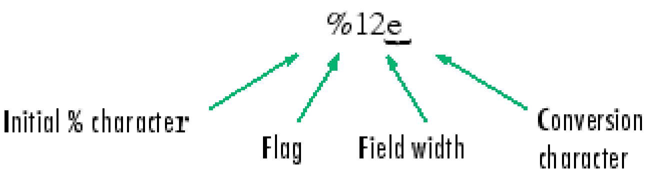
- The amount of data specified by `size` is read
- The end of the string is reached

`[A, count, errmsg, nextindex] = sscanf(...)` reads data from the MATLAB string (character array) `s`, converts it according to the specified `format` string, and returns it in matrix `A`. `count` is an optional output argument that returns the number of values successfully read. `errmsg` is an optional output argument that returns an error message string if an error occurred or an empty string if an error did not occur. `nextindex` is an optional output argument specifying one more than the number of characters scanned in `s`.

Remarks

When MATLAB reads a specified string, it attempts to match the data in the input string to the format string. If a match occurs, the data is written into the output matrix. If a partial match occurs, only the matching data is written to the matrix, and the read operation stops.

The `format` string consists of ordinary characters and/or conversion specifications. Conversion specifications indicate the type of data to be matched and involve the character `%`, optional width fields, and conversion characters, organized as shown below:



Add one or more of these characters between the `%` and the conversion character.

An asterisk (*)	Skip over the matched value and do not store it in the output matrix
A digit string	Maximum field width
A letter	The size of the receiving object; for example, `h` for short, as in `%hd` for a short integer, or `l` for long, as in `%ld` for a long integer or `%lg` for a double floating-point number

Valid conversion characters are as shown.

`%c`	Sequence of characters; number specified by field width
`%d`	Base 10 integers
`%e, %f, %g`	Floating-point numbers
`%i`	Defaults to signed base 10 integers. Data starting with `0` is read as base 8. Data starting with `0x` or `0X` is read as base 16.
`%o`	Signed octal integer returned as unsigned
`%s`	A series of non-white-space characters
`%u`	Unsigned decimal
`%x`	Signed hexadecimal integer returned as unsigned
`[...]`	Sequence of characters (`scanlist`)

Format specifiers `%e`, `%f`, and `%g` accept the text `'inf'`, `'-inf'`, `'nan'`, and `'-nan'`. This text is not case sensitive. The `sscanf` function converts these to the numeric representation of `Inf`, `-Inf`, `NaN`, and `-NaN`.

Use `%c` to read space characters, or `%s` to skip all white space.

For more information about format strings, refer to the `scanf()` and `fscanf()` routines in a C language reference manual.

Output Characteristics: Only Numeric Values Read

Format characters that cause `sscanf` to read numbers from the input string are `%d`, `%e`, `%f`, `%g`, `%i`, `%o`, `%u`, and `%x`. When `sscanf` reads only numbers from the input string, the elements of the output matrix `A` are numbers.

When there is no `size` argument or the `size` argument is `inf`, `sscanf` reads to the end of the input string. The output matrix is a column vector with one element for each number read from the input.

When the `size` argument is a scalar `n`, `sscanf` reads at most `n` numbers from the input string. The output matrix is a column vector with one element for each number read from the input.

When the `size` argument is a matrix `[m,n]`, `sscanf` reads at most `(m*n)` numbers from the input string. The output matrix contains at most `m` rows and `n` columns. `sscanf` fills the output matrix in column order, using as many columns as it needs to contain all the numbers read from the input. Any unfilled elements in the final column contain zeros.

Output Characteristics: Only Character Values Read

The format characters that cause `sscanf` to read characters and strings from the input string are `%c` and `%s`. When `sscanf` reads only characters and strings from the input string, the elements of the output matrix `A` are characters. When `sscanf` reads a string from the input, the output matrix includes one element for each character in the string.

When there is no `size` argument or the `size` argument is `inf`, `sscanf` reads to the end of the input string. The output matrix is a row vector with one element for each character read from the input.

When the `size` argument is a scalar `n`, `sscanf` reads at most `n` character or string values from the input string. The output matrix is a row vector with one element for each character read from the input. When string values are read from the input, the output matrix can contain more than `n` columns.

When the `size` argument is a matrix `[m,n]`, `sscanf` reads at most `(m*n)` character or string values from the input string. The output matrix contains at most m rows. sscanf fills the output matrix in column order, using as many columns as it needs to contain all the characters read from the input. When string values are read from the input, the output matrix can contain more than n columns. Any unfilled elements in the final column contain char(0).

Output Characteristics: Both Numeric and Character Values Read

When sscanf reads a combination of numbers and either characters or strings from the input string, the elements of the output matrix A are numbers. This is true even when a format specifier such as '%*d %s' tells MATLAB to ignore numbers in the input string and output only characters or strings. When sscanf reads a string from the input, the output matrix includes one element for each character in the string. All characters are converted to their numeric equivalents in the output matrix.

When there is no size argument or the size argument is inf, sscanf reads to the end of the input string. The output matrix is a column vector with one element for each character read from the input.

When the size argument is a scalar n, sscanf reads at most n number, character, or string values from the input string. The output matrix contains at most n rows. sscanf fills the output matrix in column order, using as many columns as it needs to represent all the numbers and characters read from the input. When string values are read from the input, the output matrix can contain more than one column. Any unfilled elements in the final column contain zeros.

When the size argument is a matrix [m,n], sscanf reads at most (m*n) number, character, or string values from the input string. The output matrix contains at most m rows. sscanf fills the output matrix in column order, using as many columns as it needs to represent all the numbers and characters read from the input. When string values are read from the input, the output matrix can contain more than n columns. Any unfilled elements in the final column contain zeros.

Note This section applies only when `sscanf` actually reads a combination of numbers and either characters or strings from the input string. Even if the format string has both format characters that would result in numbers (such as `%d`) and format characters that would result in characters or strings (such as `%s`), `sscanf` might actually read only numbers or only characters or strings. If `sscanf` reads only numbers, see "Output Characteristics: Only Numeric Values Read" on page 2-3269. If `sscanf` reads only characters or strings, see "Output Characteristics: Only Character Values Read" on page 2-3269.

Examples

Example 1

The statements

```
s = '2.7183  3.1416';
A = sscanf(s,'%f')
```

create a two-element vector containing poor approximations to `e` and `pi`.

Example 2

When using the `%i` conversion specifier, `sscanf` reads data starting with `0` as base 8 and returns the converted value as signed:

```
sscanf('-010', '%i')
ans =
    -8
```

When using `%o`, on the other hand, `sscanf` returns the converted value as unsigned:

```
sscanf('-010', '%o')
ans =
  4.2950e+009
```

Example 3

Create character array `A` representing both character and numeric data:

```
A = ['abc 46 6 ghi'; 'def 7 89 jkl']
A =
   abc 46 6 ghi
   def 7 89 jkl
```

Read A into 2-by-N matrix B, ignoring the character data. As stated in the Description section, sscanf reads the characters in A in column order, filling matrix B in column order:

```
B = sscanf(A, '%*s %d %d %*s', [2, inf])
B =
   476
   869
```

If you want sscanf to return the numeric data in B in the same order as in A, you can use this technique:

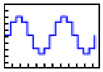
```
for k = 1:2
   C(k,:) = sscanf(A(k, :)', '%*s %d %d %*s', [1, inf]);
end

C
C =
    46     6
     7    89
```

See Also

eval, sprintf, textread

Purpose

Stairstep graph



GUI Alternatives

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

Syntax

```
stairs(Y)
stairs(X,Y)
stairs(...,LineSpec)
stairs(...,'PropertyName',propertyvalue)
stairs(axes_handle,...)
h = stairs(...)
[xb,yb] = stairs(Y,...)
hlines = stairs('v6',...)
```

Description

Stairstep graphs are useful for drawing time-history graphs of digitally sampled data.

`stairs(Y)` draws a stairstep graph of the elements of `Y`, drawing one line per column for matrices. The axes `ColorOrder` property determines the color of the lines.

When `Y` is a vector, the *x*-axis scale ranges from `1` to `length(Y)`. When `Y` is a matrix, the *x*-axis scale ranges from `1` to the number of rows in `Y`.

`stairs(X,Y)` plots the elements in `Y` at the locations specified in `X`.

`X` must be the same size as `Y` or, if `Y` is a matrix, `X` can be a row or a column vector such that

```
length(X) = size(Y,1)
```

`stairs(...,LineSpec)` specifies a line style, marker symbol, and color for the graph. (See `LineSpec` for more information.)

`stairs(...,'PropertyName',propertyvalue)` creates the stairstep graph, applying the specified property settings. See `Stairseries` properties for a description of properties.

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

`h = stairs(...)` returns the handles of the stairseries objects created (one per matrix column).

`[xb,yb] = stairs(Y,...)` does not draw graphs, but returns vectors `xb` and `yb` such that `plot(xb,yb)` plots the stairstep graph.

Backward-Compatible Version

`hlines = stairs('v6',...)` returns the handles of line objects instead of stairseries objects for compatibility with MATLAB 6.5 and earlier.

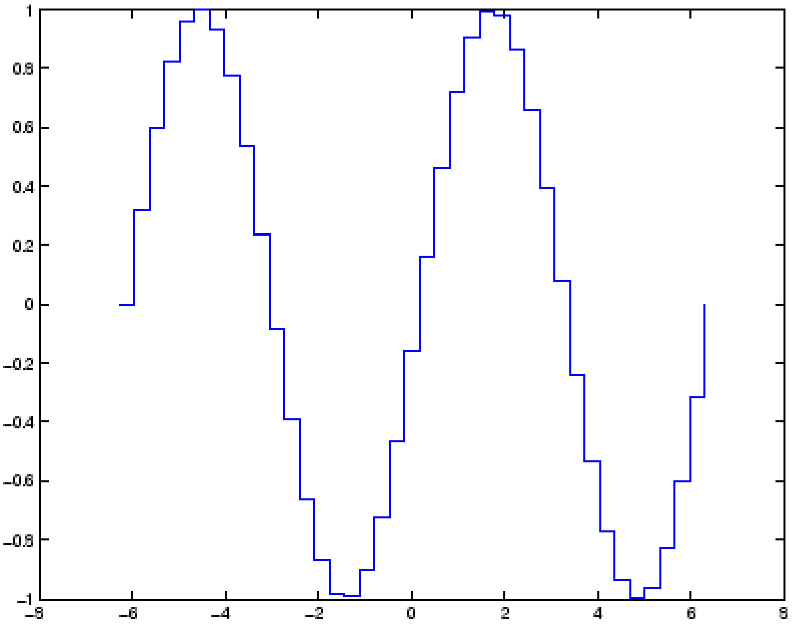
Note The `v6` option enables users of Version 7.x of MATLAB to create FIG-files that previous versions can open. It is obsolete and will be removed in a future version of MATLAB.

See Plot Objects and Backward Compatibility for more information.

Examples

Create a stairstep plot of a sine wave.

```
x = linspace(-2*pi,2*pi,40);
stairs(x,sin(x))
```



See Also

`bar`, `hist`, `stem`

"Discrete Data Plots" on page 1-93 for related functions

`Stairseries Properties` for property descriptions

Stairseries Properties

Purpose

Define stairseries properties

Modifying Properties

You can set and query graphics object properties using the `set` and `get` commands or the Property Editor (`propertyeditor`).

Note that you cannot define default property values for stairseries objects.

See Plot Objects for information on stairseries objects.

Stairseries Property Descriptions

This section provides a description of properties. Curly braces {} enclose default values.

`Annotation`

`hg.Annotation` object Read Only

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

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

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

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

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

Setting the IconDisplayStyle Property

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

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

Using the IconDisplayStyle Property

See "Controlling Legends" for more information and examples.

`BeingDeleted`

`on | {off}` Read Only

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

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

`BusyAction`
`cancel | {queue}`

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

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

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

`ButtonDownFcn`
string or function handle

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

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

This property can be

- A string that is a valid MATLAB expression
- The name of an M-file

- A function handle

  Set this property to a function handle that references the callback. The expressions execute in the MATLAB workspace.

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

The expression executes in the MATLAB workspace.

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

`Children`
array of graphics object handles

Children of this object. The handle of a patch object that is the child of this object (whether visible or not).

Note that if a child object's `HandleVisibility` property is set to `callback` or `off`, its handle does not show up in this object's `Children` property unless you set the root `ShowHiddenHandles` property to `on`:

```
set(0,'ShowHiddenHandles','on')
```

`Clipping`
`{on} | off`

Clipping mode. MATLAB clips graphs to the axes plot box by default. If you set `Clipping` to `off`, portions of graphs can be displayed outside the axes plot box. This can occur if you create a plot object, set `hold` to `on`, freeze axis scaling (`axis manual`), and then create a larger plot object.

`Color`
ColorSpec

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

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

`CreateFcn`
string or function handle

Callback routine executed during object creation. This property defines a callback that executes when MATLAB creates an object. You must specify the callback during the creation of the object. For example,

```
area(y,'CreateFcn',@CallbackFcn)
```

where `@CallbackFcn` is a function handle that references the callback function.

MATLAB executes this routine after setting all other object properties. Setting this property on an existing object has no effect.

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

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

`DeleteFcn`
string or function handle

Callback executed during object deletion. A callback that executes when this object is deleted (e.g., this might happen when you issue a `delete` command on the object, its parent axes, or the figure containing it). MATLAB executes the callback before destroying the object's properties so the callback routine can query these values.

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

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

See the `BeingDeleted` property for related information.

`DisplayName`

string (default is empty string)

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

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

See "Controlling Legends" for more examples.

`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.

`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 four edge handles and four corner handles. When `SelectionHighlight` is `off`, MATLAB does not draw the handles except when in plot edit mode and objects are selected manually.

`Tag`

string

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

For example, you might create an areaseries object and set the `Tag` property.

```
t = area(Y,'Tag','area1')
```

When you want to access objects of a given type, you can use `findobj` to find the object's handle. The following statement changes the `FaceColor` property of the object whose `Tag` is `area1`.

```
set(findobj('Tag','area1'),'FaceColor','red')
```

`Type`

string (read only)

Type of graphics object. This property contains a string that identifies the class of the graphics object. For stairseries objects, `Type` is '`hggroup`'. The following statement finds all the hggroup objects in the current axes object.

```
t = findobj(gca,'Type','hggroup');
```

`UIContextMenu`
handle of a uicontextmenu object

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

`UserData`
array

User-specified data. This property can be any data you want to associate with this object (including cell arrays and structures). The object does not set values for this property, but you can access it using the `set` and `get` functions.

`Visible`
`{on} | off`

Visibility of this object and its children. By default, a new object's visibility is `on`. This means all children of the object are visible unless the child object's `Visible` property is set to `off`. Setting an object's `Visible` property to `off` prevents the object from being displayed. However, the object still exists and you can set and query its properties.

`XData`
array

X-axis location of stairs. The `stairs` function uses `XData` to label the *x*-axis. `XData` can be either a matrix equal in size to `YData` or a vector equal in length to the number of rows in `YData`. That is, `length(XData) == size(YData,1)`.

If you do not specify `XData` (i.e., the input argument `x`), the `stairs` function uses the indices of `YData` to create the stairstep graph. See the `XDataMode` property for related information.

`XDataMode`

{auto} | manual

Use automatic or user-specified x-axis values. If you specify `XData` (by setting the `XData` property or specifying the `x` input argument), MATLAB sets this property to `manual` and uses the specified values to label the *x*-axis.

If you set `XDataMode` to `auto` after having specified `XData`, MATLAB resets the *x*-axis ticks to `1:size(YData,1)` or to the column indices of the `ZData`, overwriting any previous values for `XData`.

`XDataSource`

string (MATLAB variable)

Link `XData` to MATLAB variable. Set this property to a MATLAB variable that is evaluated in the base workspace to generate the `XData`.

MATLAB reevaluates this property only when you set it. Therefore, a change to workspace variables appearing in an expression does not change `XData`.

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

See the `refreshdata` reference page for more information.

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

`YData`
scalar, vector, or matrix

Stairs plot data. `YData` contains the data plotted in the stairstep graph. Each value in `YData` is represented by a marker in the stairstep graph. If `YData` is a matrix, the `stairs` function creates a line for each column in the matrix.

The input argument `y` in the `stairs` function calling syntax assigns values to `YData`.

`YDataSource`
string (MATLAB variable)

Link `YData` to MATLAB variable. Set this property to a MATLAB variable that is evaluated in the base workspace to generate the `YData`.

MATLAB reevaluates this property only when you set it. Therefore, a change to workspace variables appearing in an expression does not change `YData`.

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

See the `refreshdata` reference page for more information.

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

Purpose

Start timer(s) running

Syntax

```
start(obj)
```

Description

`start(obj)` starts the timer running, represented by the timer object, `obj`. If `obj` is an array of timer objects, `start` starts all the timers. Use the `timer` function to create a timer object.

`start` sets the `Running` property of the timer object, `obj`, to `'on'`, initiates `TimerFcn` callbacks, and executes the `StartFcn` callback.

The timer stops running if one of the following conditions apply:

- The first `TimerFcn` callback completes, if `ExecutionMode` is `'singleShot'`.
- The number of `TimerFcn` callbacks specified in `TasksToExecute` have been executed.
- The `stop(obj)` command is issued.
- An error occurred while executing a `TimerFcn` callback.

See Also

`timer`, `stop`

Purpose

Start timer(s) running at specified time

Syntax

```
startat(obj,time)
startat(obj,S)
startat(obj,S,pivotyear)
startat(obj,Y,M,D)
startat(obj,[Y,M,D])
startat(obj,Y,M,D,H,MI,S)
startat(obj,[Y,M,D,H,MI,S])
```

Description

`startat(obj,time)` starts the timer running, represented by the timer object `obj`, at the time specified by the serial date number `time`. If `obj` is an array of timer objects, `startat` starts all the timers running at the specified time. Use the `timer` function to create the timer object.

`startat` sets the `Running` property of the timer object, `obj`, to `'on'`, initiates `TimerFcn` callbacks, and executes the `StartFcn` callback.

The serial date number, `time`, indicates the number of days that have elapsed since 1-Jan-0000 (starting at 1). See `datenum` for additional information about serial date numbers.

`startat(obj,S)` starts the timer running at the time specified by the date string `S`. The date string must use date format 0, 1, 2, 6, 13, 14, 15, 16, or 23, as defined by the `datestr` function. Date strings with two-character years are interpreted to be within the 100 years centered on the current year.

`startat(obj,S,pivotyear)` uses the specified pivot year as the starting year of the 100-year range in which a two-character year resides. The default pivot year is the current year minus 50 years.

`startat(obj,Y,M,D)` `startat(obj,[Y,M,D])` start the timer at the year (`Y`), month (`M`), and day (`D`) specified. `Y`, `M`, and `D` must be arrays of the same size (or they can be a scalar).

`startat(obj,Y,M,D,H,MI,S)` `startat(obj,[Y,M,D,H,MI,S])` start the timer at the year (`Y`), month (`M`), day (`D`), hour (`H`), minute (`MI`), and second (`S`) specified. `Y`, `M`, `D`, `H`, `MI`, and `S` must be arrays of the same size (or they can be a scalar). Values outside the normal range of each array are automatically carried to the next unit (for example, month values greater than 12 are carried to years). Month values less than 1 are set to be 1; all other units can wrap and have valid negative values.

The timer stops running if one of the following conditions apply:

- The number of `TimerFcn` callbacks specified in `TasksToExecute` have been executed.
- The `stop(obj)` command is issued.
- An error occurred while executing a `TimerFcn` callback.

Examples

This example uses a timer object to execute a function at a specified time.

```
t1=timer('TimerFcn','disp(''it is 10 o''''clock'')');
startat(t1,'10:00:00');
```

This example uses a timer to display a message when an hour has elapsed.

```
t2=timer('TimerFcn','disp(''It has been an hour now.'')');
startat(t2,now+1/24);
```

See Also

`datenum`, `datestr`, `now`, `timer`, `start`, `stop`

startup

Purpose Startup M-file for user-defined options

Syntax `startup`

Description `startup` automatically executes the master M-file `matlabrc.m` and, if it exists, `startup.m`, when the MATLAB program starts. On multiuser or networked systems, `matlabrc.m` is reserved for use by the system manager. The file `matlabrc.m` invokes the file `startup.m` if it exists on the search path MATLAB uses. You can create a `startup.m` file in your own startup directory for MATLAB. The file can include physical constants, defaults for Handle Graphics properties, engineering conversion factors, or anything else you want predefined in your workspace.

Algorithm At startup, MATLAB only runs `matlabrc.m`. However, `matlabrc.m` contains the statements

```
if exist('startup')==2
    startup
end
```

that run `startup.m`. You can extend this process to create additional startup M-files, if needed.

See Also `finish`, `matlabrc`, `matlabroot`, `path`, `quit`, `userpath`

See Startup Options and Preferences in the MATLAB Desktop Tools and Development Environment documentation.

Purpose

Standard deviation

Syntax

```
s = std(X)
s = std(X,flag)
s = std(X,flag,dim)
```

Definition

There are two common textbook definitions for the standard deviation s of a data vector X.

$$(1)\quad s = \left(\frac{1}{n-1}\sum_{i=1}^{n}(x_i-\bar{x})^2\right)^{\frac{1}{2}}$$

$$(2)\quad s = \left(\frac{1}{n}\sum_{i=1}^{n}(x_i-\bar{x})^2\right)^{\frac{1}{2}}$$

where

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n}x_i$$

and n is the number of elements in the sample. The two forms of the equation differ only in $n-1$ versus n in the divisor.

Description

`s = std(X)`, where X is a vector, returns the standard deviation using (1) above. The result s is the square root of an unbiased estimator of the variance of the population from which X is drawn, as long as X consists of independent, identically distributed samples.

If X is a matrix, `std(X)` returns a row vector containing the standard deviation of the elements of each column of X. If X is a multidimensional array, `std(X)` is the standard deviation of the elements along the first nonsingleton dimension of X.

`s = std(X,flag)` for `flag = 0`, is the same as `std(X)`. For `flag = 1`, `std(X,1)` returns the standard deviation using (2) above, producing the second moment of the set of values about their mean.

`s = std(X,flag,dim)` computes the standard deviations along the dimension of `X` specified by scalar `dim`. Set `flag` to `0` to normalize `Y` by n-1; set `flag` to `1` to normalize by n.

Examples

For matrix `X`

```
X =
     1     5     9
    7    15    22
s = std(X,0,1)
s =
    4.2426    7.0711   9.1924
s = std(X,0,2)
s =
    4.000
    7.5056
```

See Also

`corrcoef`, `cov`, `mean`, `median`, `var`

Purpose

Standard deviation of `timeseries` data

Syntax

```
ts_std = std(ts)
ts_std = std(ts,'PropertyName1',PropertyValue1,...)
```

Description

`ts_std = std(ts)` returns the standard deviation of the time-series data. When `ts.Data` is a vector, ts_std is the standard deviation of `ts.Data` values. When `ts.Data` is a matrix, ts_std is the standard deviation of each column of `ts.Data` (when `IsTimeFirst` is `true` and the first dimension of `ts` is aligned with time). For the N-dimensional `ts.Data` array, `std` always operates along the first nonsingleton dimension of `ts.Data`.

`ts_std = std(ts,'PropertyName1',PropertyValue1,...)` specifies the following optional input arguments:

- `'MissingData'` property has two possible values, `'remove'` (default) or `'interpolate'`, indicating how to treat missing data during the calculation.
- `'Quality'` values are specified by a vector of integers, indicating which quality codes represent missing samples (for vector data) or missing observations (for data arrays with two or more dimensions).
- `'Weighting'` property has two possible values, `'none'` (default) or `'time'`.
  When you specify `'time'`, larger time values correspond to larger weights.

Examples

1 Load a 24-by-3 data array.

```
load count.dat
```

2 Create a `timeseries` object with 24 time values.

```
count_ts = timeseries(count,1:24,'Name','CountPerSecond')
```

3 Calculate the standard deviation of each data column for this `timeseries` object.

```
std(count_ts)

ans =

   25.3703   41.4057   68.0281
```

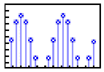
The standard deviation is calculated independently for each data column in the `timeseries` object.

See Also

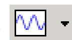
`iqr (timeseries)`, `mean (timeseries)`, `median (timeseries)`, `var (timeseries)`, `timeseries`

Purpose

Plot discrete sequence data



GUI Alternatives

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

Syntax

```
stem(Y)
stem(X,Y)
stem(...,'fill')
stem(...,LineSpec)
stem(axes_handle,...)
h = stem(...)
hlines = stem('v6',...)
```

Description

A two-dimensional stem plot displays data as lines extending from a baseline along the x-axis. A circle (the default) or other marker whose y-position represents the data value terminates each stem.

`stem(Y)` plots the data sequence `Y` as stems that extend from equally spaced and automatically generated values along the x-axis. When `Y` is a matrix, `stem` plots all elements in a row against the same x value.

`stem(X,Y)` plots `X` versus the columns of `Y`. `X` and `Y` must be vectors or matrices of the same size. Additionally, `X` can be a row or a column vector and `Y` a matrix with `length(X)` rows.

`stem(...,'fill')` specifies whether to color the circle at the end of the stem.

`stem(...,LineSpec)` specifies the line style, marker symbol, and color for the stem and top marker (the baseline is not affected). See `LineSpec` for more information.

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

`h = stem(...)` returns a vector of stemseries object handles in `h`, one handle per column of data in `Y`.

Backward-Compatible Version

`hlines = stem('v6',...)` returns the handles of line objects instead of stemseries objects for compatibility with MATLAB 6.5 and earlier.

`hlines` contains the handles to three `line` graphics objects:

- `hlines(1)` — The marker symbol at the top of each stem
- `hlines(2)` — The stem line
- `hlines(3)` — The baseline handle

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

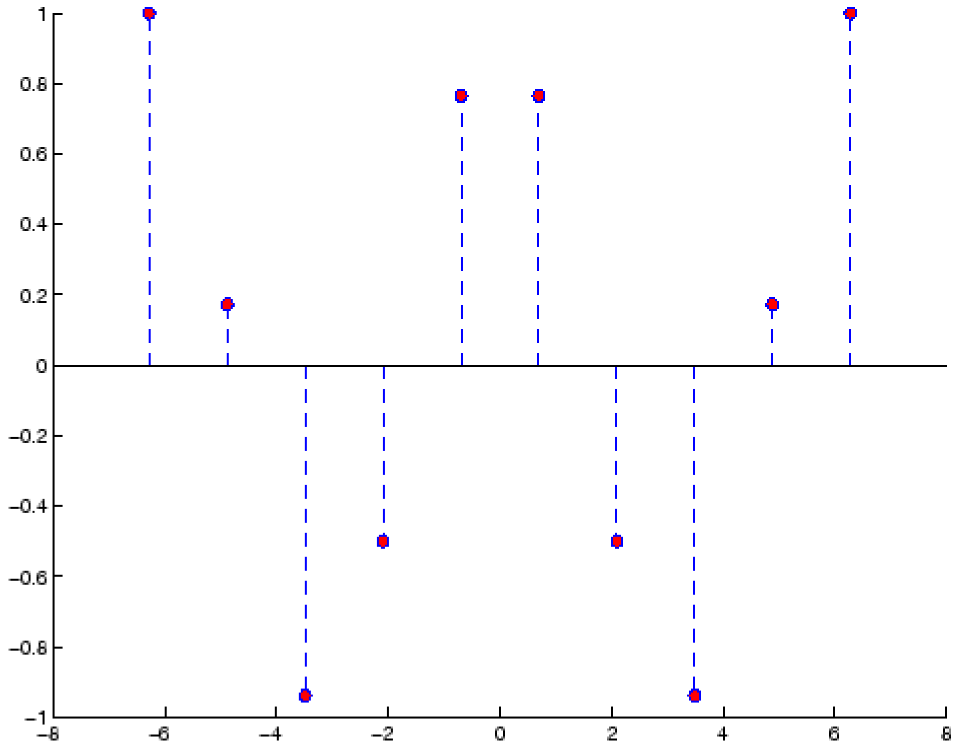
See Plot Objects and Backward Compatibility for more information.

Examples

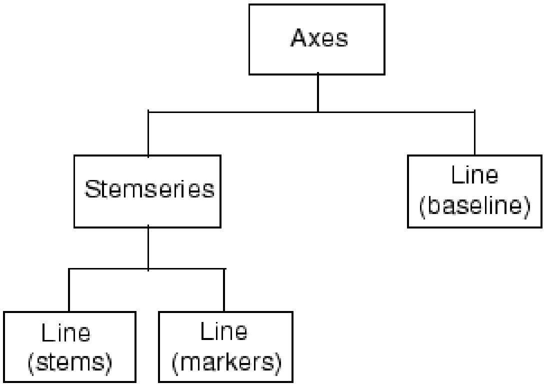
Single Series of Data

This example creates a stem plot representing the cosine of 10 values linearly spaced between 0 and 2π. Note that the line style of the baseline is set by first getting its handle from the stemseries object's `BaseLine` property.

```
t = linspace(-2*pi,2*pi,10);
h = stem(t,cos(t),'fill','--');
set(get(h,'BaseLine'),'LineStyle',':')
set(h,'MarkerFaceColor','red')
```



The following diagram illustrates the parent-child relationship in the previous stem plot. Note that the stemseries object contains two line objects used to draw the stem lines and the end markers. The baseline is a separate line object.



If you do not want the baseline to show, you can remove it with the following command:

```
delete(get(stem_handle,'Baseline'))
```

where `stem_handle` is the handle for the stemseries object. You can use similar code to change the color or style of the baseline, specifying any line property and value, for example,

```
set(get(stem_handle,'Baseline'),'LineWidth',3)
```

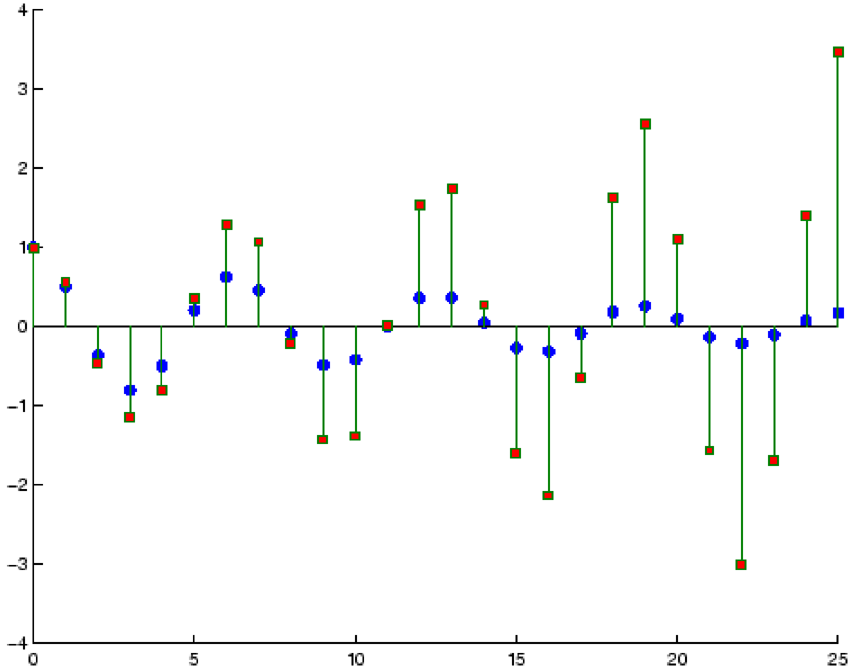
Two Series of Data on One Graph

The following example creates a stem plot from a two-column matrix. In this case, the `stem` function creates two stemseries objects, one of each column of data. Both objects' handles are returned in the output argument `h`.

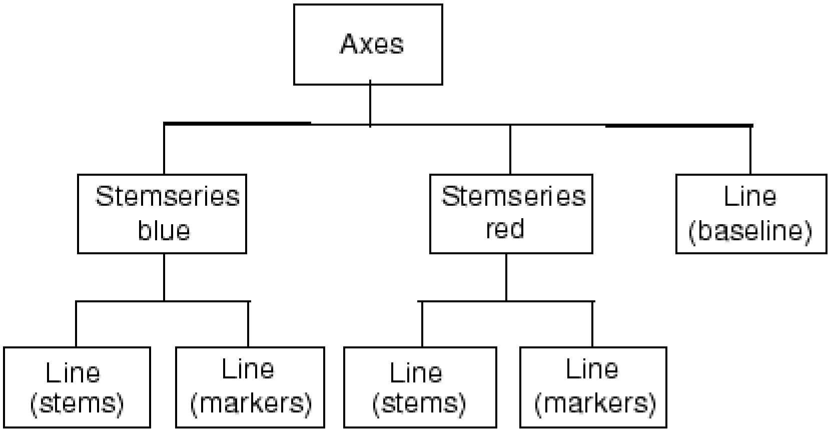
- `h(1)` is the handle to the stemseries object plotting the expression `exp(-.07*x).*cos(x)`.
- `h(2)` is the handle to the stemseries object plotting the expression `exp(.05*x).*cos(x)`.

```
x = 0:25;
y = [exp(-.07*x).*cos(x);exp(.05*x).*cos(x)]';
h = stem(x,y);
```

```
set(h(1),'MarkerFaceColor','blue')
set(h(2),'MarkerFaceColor','red','Marker','square')
```



The following diagram illustrates the parent-child relationship in the previous stem plot. Note that each column in the input matrix y results in the creation of a stemseries object, which contains two line objects (one for the stems and one for the markers). The baseline is shared by both stemseries objects.



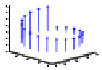
See Also

`bar`, `plot`, `stairs`

`Stemseries` properties for property descriptions

Purpose

Plot 3-D discrete sequence data



GUI Alternatives

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

Syntax

```
stem3(Z)
stem3(X,Y,Z)
stem3(...,'fill')
stem3(...,LineSpec)
h = stem3(...)
hlines = stem3('v6',...)
```

Description

Three-dimensional stem plots display lines extending from the *x*-*y* plane. A circle (the default) or other marker symbol whose *z*-position represents the data value terminates each stem.

`stem3(Z)` plots the data sequence `Z` as stems that extend from the *x*-*y* plane. *x* and *y* are generated automatically. When `Z` is a row vector, `stem3` plots all elements at equally spaced *x* values against the same *y* value. When `Z` is a column vector, `stem3` plots all elements at equally spaced *y* values against the same *x* value.

`stem3(X,Y,Z)` plots the data sequence `Z` at values specified by `X` and `Y`. `X`, `Y`, and `Z` must all be vectors or matrices of the same size.

`stem3(...,'fill')` specifies whether to color the interior of the circle at the end of the stem.

`stem3(...,LineSpec)` specifies the line style, marker symbol, and color for the stems. See `LineSpec` for more information.

`h = stem3(...)` returns handles to stemseries graphics objects.

Backward-Compatible Version

`hlines = stem3('v6',...)` returns the handles of line objects instead of stemseries objects for compatibility with MATLAB 6.5 and earlier.

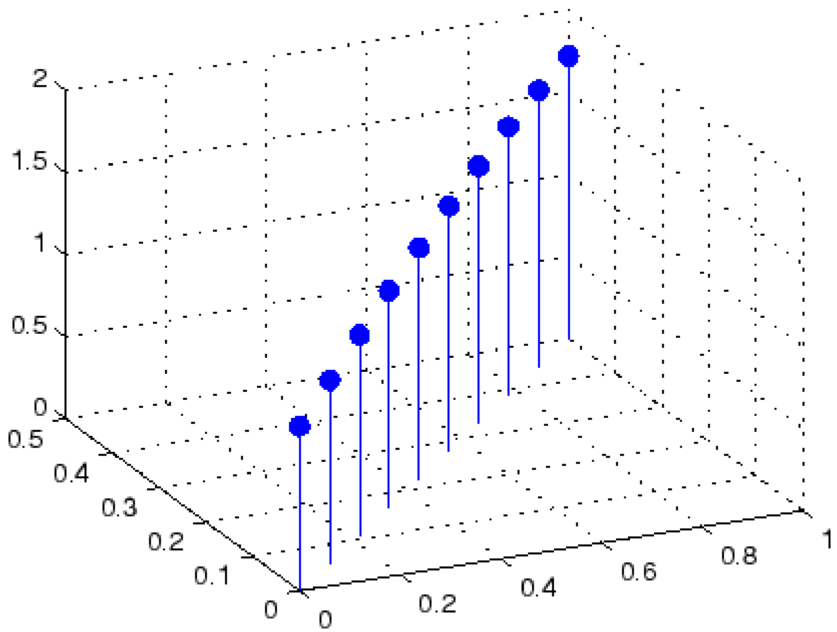
Note The `v6` option enables users of Version 7.x of MATLAB to create FIG-files that previous versions can open. It is obsolete and will be removed in a future version of MATLAB.

See Plot Objects and Backward Compatibility for more information.

Examples

Create a three-dimensional stem plot to visualize a function of two variables.

```
X = linspace(0,1,10);
Y = X./2;
Z = sin(X) + cos(Y);
stem3(X,Y,Z,'fill')
view(-25,30)
```



See Also

`bar`, `plot`, `stairs`, `stem`

"Discrete Data Plots" on page 1-93 for related functions

`Stemseries Properties` for descriptions of properties

Three-Dimensional Stem Plots for more examples

Purpose

Define stemseries properties

Modifying Properties

You can set and query graphics object properties using the `set` and `get` commands or with the property editor (`propertyeditor`).

Note that you cannot define default properties for stemseries objects.

See Plot Objects for information on stemseries objects.

Stemseries Property Descriptions

This section provides a description of properties. Curly braces { } enclose default values.

`Annotation`

`hg.Annotation` object Read Only

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

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

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

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

Setting the IconDisplayStyle Property

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

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

Using the IconDisplayStyle Property

See "Controlling Legends" for more information and examples.

`BaseLine`

handle of baseline

Handle of the baseline object. This property contains the handle of the line object used as the baseline. You can set the properties of this line using its handle. For example, the following statements create a stem plot, obtain the handle of the baseline from the stemseries object, and then set line properties that make the baseline a dashed, red line.

```
stem_handle = stem(randn(10,1));
baseline_handle = get(stem_handle,'BaseLine');
set(baseline_handle,'LineStyle','--','Color','red')
```

`BaseValue`

y-axis value

Y-axis value where baseline is drawn. You can specify the value along the *y*-axis at which the MATLAB software draws the baseline.

`BeingDeleted`

`on | {off}` Read Only

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 stem lines. A three-element RGB vector or one of the MATLAB predefined names, specifying the line color. See the `ColorSpec` reference page for more information on specifying color.

For example, the following statement would produce a stem plot with red lines.

```
h = stem(randn(10,1),'Color','r');
```

`CreateFcn`

string or function handle

Callback routine executed during object creation. This property defines a callback that executes when MATLAB creates an object. You must specify the callback during the creation of the object. For example,

```
area(y,'CreateFcn',@CallbackFcn)
```

where `@CallbackFcn` is a function handle that references the callback function.

MATLAB executes this routine after setting all other object properties. Setting this property on an existing object has no effect.

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

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

`DeleteFcn`
string or function handle

Callback executed during object deletion. A callback that executes when this object is deleted (e.g., this might happen when you issue a `delete` command on the object, its parent axes, or the figure containing it). MATLAB executes the callback before destroying the object's properties so the callback routine can query these values.

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

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

See the `BeingDeleted` property for related information.

`DisplayName`
string (default is empty string)

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

- If you specify string arguments with the `legend` function, `DisplayName` is set to this stemseries object's corresponding string and that string is used for the legend.
- If `DisplayName` is empty, legend creates a string of the form, `['data' n]`, where *n* is the number assigned to the object

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.

`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)

Marker Specifier	Description
h	Six-pointed star (hexagram)
none	No marker (default)

MarkerEdgeColor
ColorSpec | none | {auto}

Marker edge color. The color of the marker or the edge color for filled markers (circle, square, diamond, pentagram, hexagram, and the four triangles). ColorSpec defines the color to use. none specifies no color, which makes nonfilled markers invisible. auto sets MarkerEdgeColor to the same color as the Color property.

MarkerFaceColor
ColorSpec | {none} | auto

Marker face color. The fill color for markers that are closed shapes (circle, square, diamond, pentagram, hexagram, and the four triangles). ColorSpec defines the color to use. none makes the interior of the marker transparent, allowing the background to show through. auto sets the fill color to the axes color, or to the figure color if the axes Color property is set to none (which is the factory default for axes objects).

MarkerSize
size in points

Marker size. A scalar specifying the size of the marker in points. The default value for MarkerSize is 6 points (1 point = 1/72 inch). Note that MATLAB draws the point marker (specified by the '.' symbol) at one-third the specified size.

Parent
handle of parent axes, hggroup, or hgtransform

Parent of this object. This property contains the handle of the object's parent. The parent is normally the axes, 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.

For example, you might create a stemseries object and set the `Tag` property:

```
t = stem(Y,'Tag','stem1')
```

When you want to access the stemseries object, you can use `findobj` to find the stemseries object's handle. The following statement changes the `MarkerFaceColor` property of the object whose `Tag` is `stem1`.

```
set(findobj('Tag','stem1'),'MarkerFaceColor','red')
```

`Type`
string (read only)

Type of graphics object. This property contains a string that identifies the class of the graphics object. For stemseries objects, `Type` is `'hggroup'`. The following statement finds all the hggroup objects in the current axes object.

```
t = findobj(gca,'Type','hggroup');
```

`UIContextMenu`
handle of a uicontextmenu object

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

`UserData`
array

User-specified data. This property can be any data you want to associate with this object (including cell arrays and structures). The object does not set values for this property, but you can access it using the `set` and `get` functions.

`Visible`
`{on} | off`

Visibility of this object and its children. By default, a new object's visibility is `on`. This means all children of the object are visible unless the child object's `Visible` property is set to `off`. Setting an object's `Visible` property to `off` prevents the object from being displayed. However, the object still exists and you can set and query its properties.

`XData`
array

X-axis location of stems. The stem function draws an individual stem at each *x*-axis location in the `XData` array. `XData` can be either a matrix equal in size to `YData` or a vector equal in length to the number of rows in `YData`. That is, `length(XData) == size(YData,1)`. `XData` does not need to be monotonically increasing.

If you do not specify `XData` (i.e., the input argument `x`), the stem function uses the indices of `YData` to create the stem plot. See the `XDataMode` property for related information.

`XDataMode`
{auto} | manual

Use automatic or user-specified x-axis values. If you specify `XData` (by setting the `XData` property or specifying the `x` input argument), MATLAB sets this property to `manual` and uses the specified values to label the *x*-axis.

If you set `XDataMode` to `auto` after having specified `XData`, MATLAB resets the *x*-axis ticks to `1:size(YData,1)` or to the column indices of the `ZData`, overwriting any previous values for `XData`.

`XDataSource`
string (MATLAB variable)

Link `XData` *to MATLAB variable.* Set this property to a MATLAB variable that is evaluated in the base workspace to generate the `XData`.

MATLAB reevaluates this property only when you set it. Therefore, a change to workspace variables appearing in an expression does not change `XData`.

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

See the `refreshdata` reference page for more information.

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

`YData`

scalar, vector, or matrix

Stem plot data. `YData` contains the data plotted as stems. Each value in `YData` is represented by a marker in the stem plot. If `YData` is a matrix, MATLAB creates a series of stems for each column in the matrix.

The input argument `y` in the `stem` function calling syntax assigns values to `YData`.

`YDataSource`

string (MATLAB variable)

Link `YData` *to MATLAB variable*. Set this property to a MATLAB variable that is evaluated in the base workspace to generate the `YData`.

MATLAB reevaluates this property only when you set it. Therefore, a change to workspace variables appearing in an expression does not change `YData`.

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

See the `refreshdata` reference page for more information.

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

`ZData`

vector of coordinates

Z-coordinates. A data defining the stems for 3-D stem graphs. `XData` and `YData` (if specified) must be the same size.

`ZDataSource`

string (MATLAB variable)

Link `ZData` *to MATLAB variable*. Set this property to a MATLAB variable that is evaluated in the base workspace to generate the `ZData`.

MATLAB reevaluates this property only when you set it. Therefore, a change to workspace variables appearing in an expression does not change `ZData`.

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

See the `refreshdata` reference page for more information.

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

Purpose

Stop timer(s)

Syntax

```
stop(obj)
```

Description

`stop(obj)` stops the timer, represented by the timer object, `obj`. If obj is an array of timer objects, the `stop` function stops them all. Use the `timer` function to create a timer object.

The `stop` function sets the `Running` property of the timer object, `obj`, to `'off'`, halts further `TimerFcn` callbacks, and executes the `StopFcn` callback.

See Also

`timer`, `start`

Purpose

Stop asynchronous read and write operations

Syntax

```
stopasync(obj)
```

Description

`stopasync(obj)` stops any asynchronous read or write operation that is in progress for the serial port object, `obj`.

Remarks

You can write data asynchronously using the `fprintf` or `fwrite` function. You can read data asynchronously using the `readasync` function, or by configuring the `ReadAsyncMode` property to `continuous`. In-progress asynchronous operations are indicated by the `TransferStatus` property.

If `obj` is an array of serial port objects and one of the objects cannot be stopped, the remaining objects in the array are stopped and a warning is returned. After an object stops:

- Its `TransferStatus` property is configured to `idle`.
- Its `ReadAsyncMode` property is configured to `manual`.
- The data in its output buffer is flushed.

Data in the input buffer is not flushed. You can return this data to the MATLAB workspace using any of the synchronous read functions. If you execute the `readasync` function, or configure the `ReadAsyncMode` property to `continuous`, then the new data is appended to the existing data in the input buffer.

See Also

Functions

`fprintf`, `fwrite`, `readasync`

Properties

`ReadAsyncMode`, `TransferStatus`

Purpose

Convert string to double-precision value

Syntax

```
X = str2double('str')
X = str2double(C)
```

Description

`X = str2double('str')` converts the string `str`, which should be an ASCII character representation of a real or complex scalar value, to the MATLAB double-precision representation. The string can contain digits, a comma (thousands separator), a decimal point, a leading `+` or `-` sign, an `e` preceding a power of 10 scale factor, and an `i` for a complex unit.

If `str` does not represent a valid scalar value, `str2double` returns `NaN`.

`X = str2double(C)` converts the strings in the cell array of strings `C` to double precision. The matrix `X` returned will be the same size as `C`.

Examples

Here are some valid `str2double` conversions.

```
str2double('123.45e7')
str2double('123 + 45i')
str2double('3.14159')
str2double('2.7i - 3.14')
str2double({'2.71' '3.1415'})
str2double('1,200.34')
```

See Also

`char`, `hex2num`, `num2str`, `str2num`

Purpose

Construct function handle from function name string

Syntax

```
str2func('str')
```

Description

`str2func('str')` constructs a function handle `fhandle` for the function named in the string `'str'`.

You can create a function handle using either the `@function` syntax or the `str2func` command. You can create an array of function handles from strings by creating the handles individually with `str2func`, and then storing these handles in a cell array.

Remarks

Nested functions are not accessible to `str2func`. To construct a function handle for a nested function, you must use the function handle constructor, `@`.

Examples

Example 1

To convert the string, `'sin'`, into a handle for that function, type

```
fh = str2func('sin')
fh =
    @sin
```

Example 2

If you pass a function name string in a variable, the function that receives the variable can convert the function name to a function handle using `str2func`. The example below passes the variable, `funcname`, to function `makeHandle`, which then creates a function handle. Here is the function M-file:

```
function fh = makeHandle(funcname)
fh = str2func(funcname);
```

This is the code that calls `makdHandle` to construct the function handle:

```
makeHandle('sin')
ans =
```

```
@sin
```

Example 3

To call `str2func` on a cell array of strings, use the `cellfun` function. This returns a cell array of function handles:

```
fh_array = cellfun(@str2func, {'sin' 'cos' 'tan'}, ...
                   'UniformOutput', false);

fh_array{2}(5)
ans =
   0.2837
```

Example 4

In the following example, the `myminbnd` function expects to receive either a function handle or string in the first argument. If you pass a string, `myminbnd` constructs a function handle from it using `str2func`, and then uses that handle in a call to `fminbnd`:

```
function myminbnd(fhandle, lower, upper)
if ischar(fhandle)
   disp 'converting function string to function handle ...'
   fhandle = str2func(fhandle);
end
fminbnd(fhandle, lower, upper)
```

Whether you call `myminbnd` with a function handle or function name string, the function can handle the argument appropriately:

```
myminbnd('humps', 0.3, 1)
converting function string to function handle ...
ans =
    0.6370
```

See Also

`function_handle`, `func2str`, `functions`

str2mat

Purpose

Form blank-padded character matrix from strings

Syntax

`S = str2mat(T1, T2, T3, ...)`

Description

`S = str2mat(T1, T2, T3, ...)` forms the matrix `S` containing the text strings `T1, T2, T3, ...` as rows. The function automatically pads each string with blanks in order to form a valid matrix. Each text parameter, `Ti`, can itself be a string matrix. This allows the creation of arbitrarily large string matrices. Empty strings are significant.

Note This routine will become obsolete in a future version. Use `char` instead.

Remarks

`str2mat` differs from `strvcat` in that empty strings produce blank rows in the output. In `strvcat`, empty strings are ignored.

Examples

```
x = str2mat('36842', '39751', '38453', '90307');

whos x
  Name      Size         Bytes  Class

  x         4x5             40  char array

x(2,3)

ans =

    7
```

See Also

`char`, `strvcat`

Purpose

Convert string to number

Syntax

```
x = str2num('str')
[x, status] = str2num('str')
```

Description

Note `str2num` uses the `eval` function to convert the input argument. Side effects can occur if the string contains calls to functions. Using `str2double` can avoid some of these side effects.

`x = str2num('str')` converts the string `str`, which is an ASCII character representation of a numeric value, to numeric representation. `str2num` also converts string matrices to numeric matrices. If the input string does not represent a valid number or matrix, `str2num(str)` returns the empty matrix in `x`.

The input string can contain one or more numbers separated by spaces, commas, or semicolons, such as '`5`', '`10,11,12`', or '`5,10;15,20`'. In addition to numerical values and delimiters, the input string can also include a decimal point, leading + or - signs, the letter `e` or `d` preceding a power of 10 scale factor, or the letter `i` or `j` indicating a complex or imaginary number.

The following table shows several examples of valid inputs to `str2num`:

String Input	Numeric Output	Output Class
`'500'`	500	1-by-1 scalar `double`
`'500 250 125 67'`	500, 250, 125, 67	1-by-4 row vector of `double`
`'500; 250; 125; 62.5'`	500.0000 250.0000 125.0000 62.5000	4-by-1 column vector of `double`

String Input	Numeric Output	Output Class
'1 23 6 21; 53:56'	1 23 6 21 53 54 55 56	2-by-5 matrix of double
'12e-3 5.9e-3'	0.0120 0.0059	vector of double
'uint16(500)'	500	16–bit unsigned integer

If the input string does not represent a valid number or matrix, str2num(str) returns the empty matrix in x.

[x, status] = str2num('str') returns the status of the conversion in logical status, where status equals logical 1 (true) if the conversion succeeds, and logical 0 (false) otherwise.

Space characters can be significant. For instance, str2num('1+2i') and str2num('1 + 2i') produce x = 1+2i, while str2num('1 +2i') produces x = [1 2i]. You can avoid these problems by using the str2double function.

Examples

Input a character string that contains a single number. The output is a scalar double:

```
A = str2num('500')
A =
   500

class(A)
ans =
   double
```

Repeat this operation, but this time using an unsigned 16–bit integer:

```
A = str2num('uint16(500)')
A =
    500

class(A)
```

```
ans =
   uint16
```

Try three different ways of specifying a row vector. Each returns the same answer:

```
str2num('2 4 6 8')              % Separate with spaces.
ans =
     2     4     6     8

str2num('2,4,6,8')              % Separate with commas.
ans =
     2     4     6     8

str2num('[2 4 6 8]')            % Enclose in brackets.
ans =
     2     4     6     8
```

Note that the first two of these commands do not need the MATLAB square bracket operator to create a matrix. The `str2num` function inserts the brackets for you if they are needed.

Use a column vector this time:

```
str2num('2; 4; 6; 8')
ans =
     2
     4
     6
     8
```

And now a 2-by-2 matrix:

```
str2num('2 4; 6 8')
ans =
     2     4
     6     8
```

See Also `num2str`, `str2double`, `hex2num`, `sscanf`, `sparse`, `char`, special characters

Purpose Concatenate strings horizontally

Syntax

```
t = strcat(s1, s2, s3, ...)
```

Description `t = strcat(s1, s2, s3, ...)` horizontally concatenates corresponding rows of the character arrays `s1`, `s2`, `s3`, etc. All input arrays must have the same number of rows (or any can be a single string). When the inputs are all character arrays, the output is also a character array.

When any of the inputs is a cell array of strings, `strcat` returns a cell array of strings formed by concatenating corresponding elements of `s1`, `s2`, etc. The inputs must all have the same size (or any can be a scalar). Any of the inputs can also be character arrays.

`strcat` ignores trailing ASCII white space characters and omits all such characters from the output. White space characters in ASCII are space, newline, carriage return, tab, vertical tab, or form-feed characters, all of which return a `true` response from the MATLAB `isspace` function. Use the concatenation syntax `[s1 s2 s3 ...]` to preserve trailing spaces. `strcat` does not ignore inputs that are cell arrays of strings.

Remarks `strcat` and matrix operation are different for strings that contain trailing spaces:

```
a = 'hello '
b = 'goodbye'
strcat(a, b)
ans =
hellogoodbye
[a b]
ans =
hello goodbye
```

Examples Given two 1-by-2 cell arrays `a` and `b`,

```
a =           b =
    'abcde'    'fghi'         'jkl'    'mn'
```

the command `t = strcat(a,b)` yields

```
t =
    'abcdejkl'    'fghimn'
```

Given the 1-by-1 cell array `c = {`Q'}`, the command `t = strcat(a,b,c)` yields

```
t =
    'abcdejklQ'    'fghimnQ'
```

See Also

`strvcat`, `cat`, `vertcat`, `horzcat`, `cellstr`, `special character []`

Purpose

Compare strings

Syntax

```
TF = strcmp('str1', 'str2')
TF = strcmp('str', C)
TF = strcmp(C1, C2)
```

Each of these syntaxes applies to both `strcmp` and `strcmpi`. The `strcmp` function is case sensitive in matching strings, while `strcmpi` is not.

Description

Although the following descriptions show only `strcmp`, they apply to `strcmpi` as well. The two functions are the same except that `strcmpi` compares strings without sensitivity to letter case:

`TF = strcmp('str1', 'str2')` compares the strings `str1` and `str2` and returns logical 1 (`true`) if they are identical, and returns logical 0 (`false`) otherwise. `str1` and `str2` can be character arrays of any dimension, but `strcmp` does not return `true` unless the sizes of both arrays are equal, and the contents of the two arrays are the same.

`TF = strcmp('str', C)` compares string `str` to the each element of cell array `C`, where `str` is a character vector (or a 1-by-1 cell array) and `C` is a cell array of strings. The function returns `TF`, a logical array that is the same size as `C` and contains logical 1 (`true`) for those elements of `C` that are a match, and logical 0 (`false`) for those elements that are not. The order of the first two input arguments is not important.

`TF = strcmp(C1, C2)` compares each element of `C1` to the same element in `C2`, where `C1` and `C2` are equal-size cell arrays of strings. Input `C1` or `C2` can also be a character array with the right number of rows. The function returns `TF`, a logical array that is the same size as `C1` and `C2`, and contains logical 1 (`true`) for those elements of `C1` and `C2` that are a match, and logical 0 (`false`) for those elements that are not.

Remarks

These functions are intended for comparison of character data. When used to compare numeric data, they return logical `0`.

Any leading and trailing blanks in either of the strings are explicitly included in the comparison.

The value returned by strcmp and strcmpi is not the same as the C language convention.

strcmp and strcmpi support international character sets.

Examples

Example 1

Perform a simple comparison of two strings:

```
strcmp('Yes', 'No')
ans =
     0
strcmp('Yes', 'Yes')
ans =
     1
```

Example 2

Create 3 cell arrays of strings:

```
A = {'MATLAB','SIMULINK';                          ...
     'Toolboxes', 'The MathWorks'};

B = {'Handle Graphics', 'Real Time Workshop';   ...
     'Toolboxes', 'The MathWorks'};

C = {'handle graphics', 'Signal Processing';   ...
     '  Toolboxes', 'The MATHWORKS'};
```

Compare cell arrays A and B with sensitivity to case:

```
strcmp(A, B)
ans =
     0     0
     1     1
```

Compare cell arrays B and C without sensitivity to case. Note that 'Toolboxes' doesn't match because of the leading space characters in C{2,1} that do not appear in B{2,1}:

```
strcmpi(B, C)
ans =
     1     0
     0     1
```

Example 3

Compare a string vector to a cell array of strings, a string vector to a string array, and a string array to a cell array of strings. Start by creating a cell array of strings (`cellArr`), a string array containing the same strings plus space characters for padding s(`strArr`), and a string vector containing one of the strings plus padding (`strVec`):

```
cellArr = { ...
   'There are 10 kinds of people in the world,'; ...
   'those who understand binary math,'; ...
   'and those who don''t.'};

strArr = char(cellArr);
strVec = strArr(2,:)
strVec =
    those who understand binary math,
```

Remove the space padding from the string vector and compare it to the cell array. The MATLAB software compares the string with each row of the cell array, finding a match on the second row:

```
strcmp(deblank(strVec), cellArr)
ans =
     0
     1
     0
```

Compare the string vector with the string array. Unlike the case above, MATLAB does not compare the string vector with each row of the string array. It compares the entire contents of one against the entire contents of the other:

```
strcmp(strVec, strArr)
```

```
ans =
     0
```

Lastly, compare each row of the three-row string array against the same rows of the cell array. MATLAB finds them all to be equivalent. Note that in this case you do not have to remove the space padding from the string array:

```
strcmp(strArr, cellArr)
ans =
     1
     1
     1
```

See Also

`strncmp`, `strncmpi`, `strmatch`, `strfind`, `findstr`, `regexp`, `regexpi`, `regexprep`, `regexptranslate`

Purpose

Compute 2-D streamline data

Syntax

```
XY = stream2(x,y,u,v,startx,starty)
XY = stream2(u,v,startx,starty)
XY = stream2(...,options)
```

Description

`XY = stream2(x,y,u,v,startx,starty)` computes streamlines from vector data `u` and `v`. The arrays `x` and `y` define the coordinates for `u` and `v` and must be monotonic and 2-D plaid (such as the data produced by `meshgrid`). `startx` and `starty` define the starting positions of the streamlines. The section "Specifying Starting Points for Stream Plots" provides more information on defining starting points.

The returned value `XY` contains a cell array of vertex arrays.

`XY = stream2(u,v,startx,starty)` assumes the arrays `x` and `y` are defined as `[x,y] = meshgrid(1:n,1:m)` where `[m,n] = size(u)`.

`XY = stream2(...,options)` specifies the options used when creating the streamlines. Define `options` as a one- or two-element vector containing the step size or the step size and the maximum number of vertices in a streamline:

```
[stepsize]
```

or

```
[stepsize, max_number_vertices]
```

If you do not specify a value, MATLAB software uses the default:

- Step size = 0.1 (one tenth of a cell)
- Maximum number of vertices = 10000

Use the `streamline` command to plot the data returned by `stream2`.

Examples

This example draws 2-D streamlines from data representing air currents over regions of North America.

```
load wind
[sx,sy] = meshgrid(80,20:10:50);
streamline(stream2(x(:,:,5),y(:,:,5),u(:,:,5),v(:,:,5),sx,sy));
```

See Also

`coneplot`, `stream3`, `streamline`

"Volume Visualization" on page 1-106 for related functions

Specifying Starting Points for Stream Plots for related information

Purpose

Compute 3-D streamline data

Syntax

```
XYZ = stream3(X,Y,Z,U,V,W,startx,starty,startz)
XYZ = stream3(U,V,W,startx,starty,startz)
XYZ = stream3(...,options)
```

Description

`XYZ = stream3(X,Y,Z,U,V,W,startx,starty,startz)` computes streamlines from vector data `U`, `V`, `W`. The arrays `X`, `Y`, `Z` define the coordinates for `U`, `V`, `W` and must be monotonic and 3-D plaid (such as the data produced by `meshgrid`). `startx`, `starty`, and `startz` define the starting positions of the streamlines. The section "Specifying Starting Points for Stream Plots" provides more information on defining starting points.

The returned value `XYZ` contains a cell array of vertex arrays.

`XYZ = stream3(U,V,W,startx,starty,startz)` assumes the arrays `X`, `Y`, and `Z` are defined as `[X,Y,Z] = meshgrid(1:N,1:M,1:P)` where `[M,N,P] = size(U)`.

`XYZ = stream3(...,options)` specifies the options used when creating the streamlines. Define `options` as a one- or two-element vector containing the step size or the step size and the maximum number of vertices in a streamline:

```
[stepsize]
```

or

```
[stepsize, max_number_vertices]
```

If you do not specify values, MATLAB software uses the default:

- Step size = 0.1 (one tenth of a cell)
- Maximum number of vertices = 10000

Use the `streamline` command to plot the data returned by `stream3`.

Examples

This example draws 3-D streamlines from data representing air currents over regions of North America.

```
load wind
[sx sy sz] = meshgrid(80,20:10:50,0:5:15);
streamline(stream3(x,y,z,u,v,w,sx,sy,sz))
view(3)
```

See Also

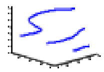
`coneplot`, `stream2`, `streamline`

"Volume Visualization" on page 1-106 for related functions

Specifying Starting Points for Stream Plots for related information

Purpose

Plot streamlines from 2-D or 3-D vector data



GUI Alternatives

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

Syntax

```
streamline(X,Y,Z,U,V,W,startx,starty,startz)
streamline(U,V,W,startx,starty,startz)
streamline(XYZ)
streamline(X,Y,U,V,startx,starty)
streamline(U,V,startx,starty)
streamline(XY)
streamline(...,options)
streamline(axes_handle,...)
h = streamline(...)
```

Description

`streamline(X,Y,Z,U,V,W,startx,starty,startz)` draws streamlines from 3-D vector data `U`, `V`, `W`. The arrays `X`, `Y`, `Z` define the coordinates for `U`, `V`, `W` and must be monotonic and 3-D plaid (such as the data produced by `meshgrid`). `startx`, `starty`, `startz` define the starting positions of the streamlines. The section Specifying Starting Points for Stream Plots provides more information on defining starting points.

`streamline(U,V,W,startx,starty,startz)` assumes the arrays `X`, `Y`, and `Z` are defined as `[X,Y,Z] = meshgrid(1:N,1:M,1:P)`, where `[M,N,P] = size(U)`.

`streamline(XYZ)` assumes `XYZ` is a precomputed cell array of vertex arrays (as produced by `stream3`).

`streamline(X,Y,U,V,startx,starty)` draws streamlines from 2-D vector data `U`, `V`. The arrays `X`, `Y` define the coordinates for `U`, `V` and must be monotonic and 2-D plaid (such as the data produced by `meshgrid`). `startx` and `starty` define the starting positions of the streamlines. The output argument `h` contains a vector of line handles, one handle for each streamline.

`streamline(U,V,startx,starty)` assumes the arrays `X` and `Y` are defined as `[X,Y] = meshgrid(1:N,1:M)`, where `[M,N] = size(U)`.

`streamline(XY)` assumes `XY` is a precomputed cell array of vertex arrays (as produced by `stream2`).

`streamline(...,options)` specifies the options used when creating the streamlines. Define `options` as a one- or two-element vector containing the step size or the step size and the maximum number of vertices in a streamline:

```
[stepsize]
```

or

```
[stepsize, max_number_vertices]
```

If you do not specify values, MATLAB uses the default:

- Step size = 0.1 (one tenth of a cell)
- Maximum number of vertices = 1000

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

`h = streamline(...)` returns a vector of line handles, one handle for each streamline.

Examples

This example draws streamlines from data representing air currents over a region of North America. Loading the `wind` data set creates the variables `x`, `y`, `z`, `u`, `v`, and `w` in the MATLAB workspace.

The plane of streamlines indicates the flow of air from the west to the east (the *x*-direction) beginning at `x = 80` (which is close to the minimum value of the x coordinates). The *y*- and *z*-coordinate starting points are multivalued and approximately span the range of these coordinates. `meshgrid` generates the starting positions of the streamlines.

```
load wind
[sx,sy,sz] = meshgrid(80,20:10:50,0:5:15);
h = streamline(x,y,z,u,v,w,sx,sy,sz);
set(h,'Color','red')
view(3)
```

See Also

`coneplot`, `stream2`, `stream3`, `streamparticles`

"Volume Visualization" on page 1-106 for related functions

Specifying Starting Points for Stream Plots for related information

Stream Line Plots of Vector Data for another example

streamparticles

Purpose

Plot stream particles

GUI Alternatives

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

Syntax

```
streamparticles(vertices)
streamparticles(vertices,n)
streamparticles(...,'PropertyName',PropertyValue,...)
streamparticles(line_handle,...)
h = streamparticles(...)
```

Description

`streamparticles(vertices)` draws stream particles of a vector field. Stream particles are usually represented by markers and can show the position and velocity of a streamline. `vertices` is a cell array of 2-D or 3-D vertices (as if produced by `stream2` or `stream3`).

`streamparticles(vertices,n)` uses `n` to determine how many stream particles to draw. The `ParticleAlignment` property controls how `n` is interpreted.

- If `ParticleAlignment` is set to `off` (the default) and `n` is greater than `1`, approximately `n` particles are drawn evenly spaced over the streamline vertices.

  If `n` is less than or equal to `1`, `n` is interpreted as a fraction of the original stream vertices; for example, if `n` is `0.2`, approximately 20% of the vertices are used.

  `n` determines the upper bound for the number of particles drawn. The actual number of particles can deviate from `n` by as much as a factor of 2.

- If `ParticleAlignment` is `on`, `n` determines the number of particles on the streamline having the most vertices and sets the spacing on the other streamlines to this value. The default value is `n = 1`.

`streamparticles(...,'PropertyName',PropertyValue,...)` controls the stream particles using named properties and specified values. Any unspecified properties have default values. MATLAB ignores the case of property names.

Stream Particle Properties

`Animate` — Stream particle motion [nonnegative integer]

The number of times to animate the stream particles. The default is `0`, which does not animate. `Inf` animates until you enter **Ctrl+C**.

`FrameRate` — Animation frames per second [nonnegative integer]

This property specifies the number of frames per second for the animation. `Inf`, the default, draws the animation as fast as possible. Note that the speed of the animation might be limited by the speed of the computer. In such cases, the value of `FrameRate` cannot necessarily be achieved.

`ParticleAlignment` — Align particles with streamlines [`on | {off}`]

Set this property to `on` to draw particles at the beginning of each streamline. This property controls how `streamparticles` interprets the argument `n` (number of stream particles).

Stream particles are line objects. In addition to stream particle properties, you can specify any `line` object property, such as `Marker` and `EraseMode`. `streamparticles` sets the following line properties when called.

Line Property	Value Set by streamparticles
`EraseMode`	`xor`
`LineStyle`	`none`
`Marker`	`o`

Line Property	Value Set by streamparticles
MarkerEdgeColor	none
MarkerFaceColor	red

You can override any of these properties by specifying a property name and value as arguments to `streamparticles`. For example, this statement uses RGB values to set the `MarkerFaceColor` to medium gray:

```
streamparticles(vertices,'MarkerFaceColor',[.5 .5 .5])
```

`streamparticles(line_handle,...)` uses the line object identified by `line_handle` to draw the stream particles.

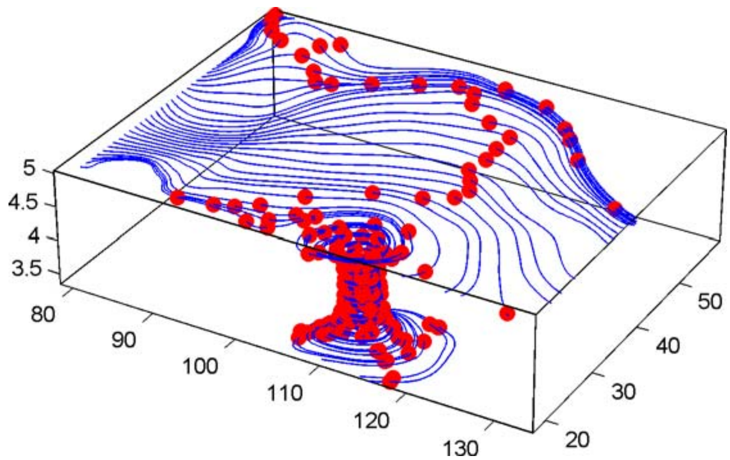
`h = streamparticles(...)` returns a vector of handles to the line objects it creates.

Examples

This example combines streamlines with stream particle animation. The `interpstreamspeed` function determines the vertices along the streamlines where stream particles will be drawn during the animation, thereby controlling the speed of the animation. Setting the axes `DrawMode` property to `fast` provides faster rendering.

```
load wind
[sx sy sz] = meshgrid(80,20:1:55,5);
verts = stream3(x,y,z,u,v,w,sx,sy,sz);
sl = streamline(verts);
iverts = interpstreamspeed(x,y,z,u,v,w,verts,.025);
axis tight; view(30,30); daspect([1 1 .125])
camproj perspective; camva(8)
set(gca,'DrawMode','fast')
box on
streamparticles(iverts,35,'animate',10,'ParticleAlignment','on')
```

The following picture is a static view of the animation.



This example uses the streamlines in the `z = 5` plane to animate the flow along these lines with `streamparticles`.

```
load wind
daspect([1 1 1]); view(2)
[verts averts] = streamslice(x,y,z,u,v,w,[],[],[5]);
sl = streamline([verts averts]);
axis tight off;
set(sl,'Visible','off')
iverts = interpstreamspeed(x,y,z,u,v,w,verts,.05);
set(gca,'DrawMode','fast','Position',[0 0 1 1],'ZLim',[4.9 5.1])
set(gcf,'Color','black')
streamparticles(iverts, 200, ...
    'Animate',100,'FrameRate',40, ...
    'MarkerSize',10,'MarkerFaceColor','yellow')
```

See Also

`interpstreamspeed`, `stream3`, `streamline`

"Volume Visualization" on page 1-106 for related functions

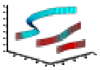
Creating Stream Particle Animations for more details

Specifying Starting Points for Stream Plots for related information

streamribbon

Purpose

3-D stream ribbon plot from vector volume data



GUI Alternatives

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

Syntax

```
streamribbon(X,Y,Z,U,V,W,startx,starty,startz)
streamribbon(U,V,W,startx,starty,startz)
streamribbon(vertices,X,Y,Z,cav,speed)
streamribbon(vertices,cav,speed)
streamribbon(vertices,twistangle)
streamribbon(...,width)
streamribbon(axes_handle,...)
h = streamribbon(...)
```

Description

`streamribbon(X,Y,Z,U,V,W,startx,starty,startz)` draws stream ribbons from vector volume data `U`, `V`, `W`. The arrays `X`, `Y`, `Z` define the coordinates for `U`, `V`, `W` and must be monotonic and 3-D plaid (as if produced by `meshgrid`). `startx`, `starty`, and `startz` define the starting positions of the stream ribbons at the center of the ribbons. The section Specifying Starting Points for Stream Plots provides more information on defining starting points.

The twist of the ribbons is proportional to the curl of the vector field. The width of the ribbons is calculated automatically.

Generally, you should set the `DataAspectRatio` (`daspect`) before calling `streamribbon`.

`streamribbon(U,V,W,startx,starty,startz)` assumes `X`, `Y`, and `Z` are determined by the expression

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

where `[m,n,p] = size(U)`.

`streamribbon(vertices,X,Y,Z,cav,speed)` assumes precomputed streamline vertices, curl angular velocity, and flow speed. `vertices` is a cell array of streamline vertices (as produced by `stream3`). `X`, `Y`, `Z`, `cav`, and `speed` are 3-D arrays.

`streamribbon(vertices,cav,speed)` assumes `X`, `Y`, and `Z` are determined by the expression

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

where `[m,n,p] = size(cav)`.

`streamribbon(vertices,twistangle)` uses the cell array of vectors `twistangle` for the twist of the ribbons (in radians). The size of each corresponding element of `vertices` and `twistangle` must be equal.

`streamribbon(...,width)` sets the width of the ribbons to `width`.

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

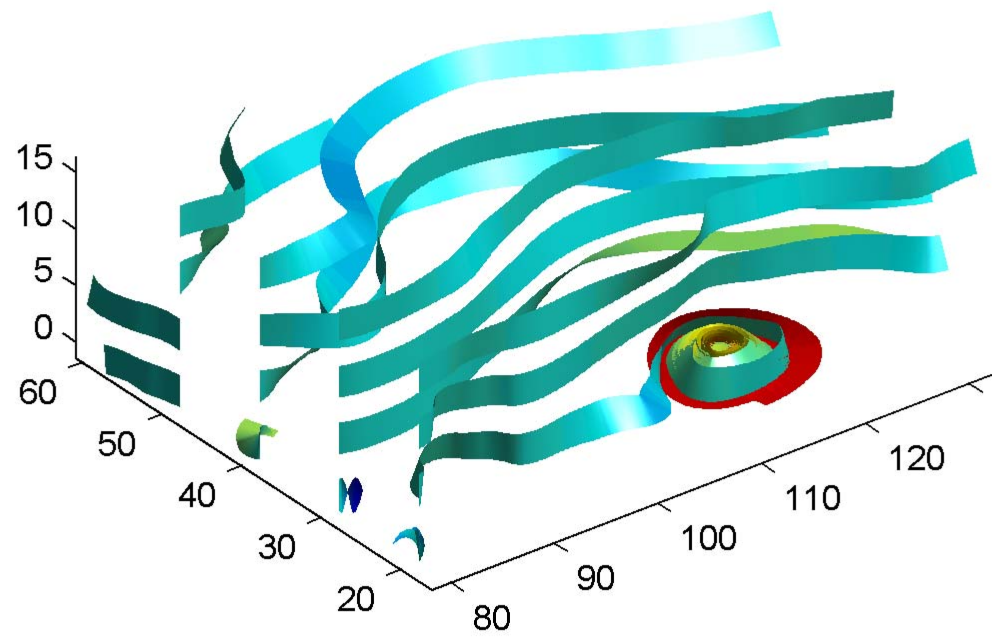
`h = streamribbon(...)` returns a vector of handles (one per start point) to `surface` objects.

Examples

This example uses stream ribbons to indicate the flow in the `wind` data set. Inputs include the coordinates, vector field components, and starting location for the stream ribbons.

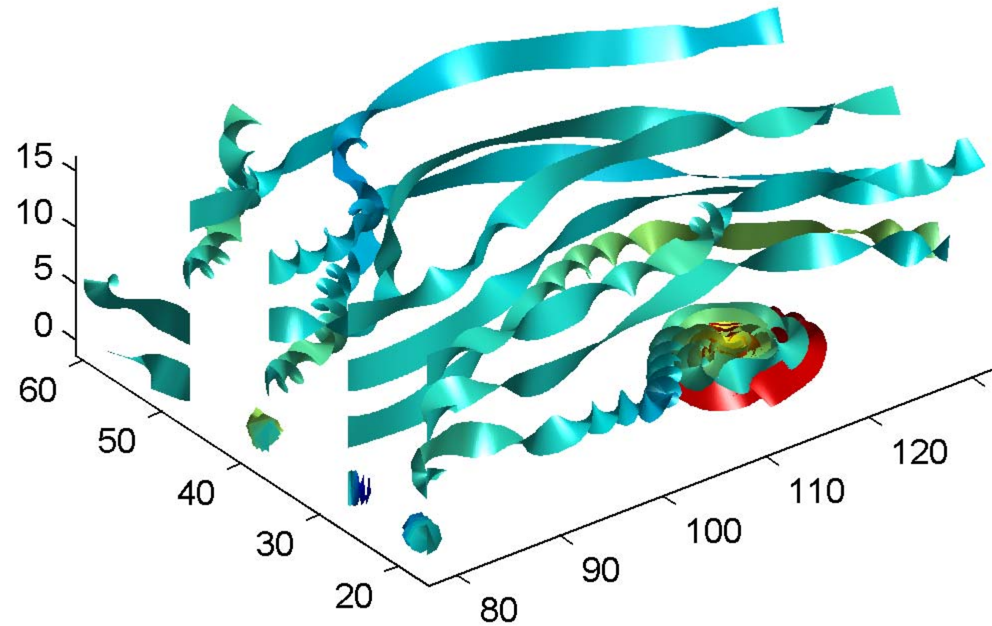
```
load wind
[sx sy sz] = meshgrid(80,20:10:50,0:5:15);
daspect([1 1 1])
streamribbon(x,y,z,u,v,w,sx,sy,sz);
%-----Define viewing and lighting
axis tight
shading interp;
view(3);
```

```
camlight; lighting gouraud
```



This example uses precalculated vertex data (`stream3`), curl average velocity (`curl`), and speed $\sqrt{u^2 + v^2 + w^2}$. Using precalculated data enables you to use values other than those calculated from the single data source. In this case, the speed is reduced by a factor of 10 compared to the previous example.

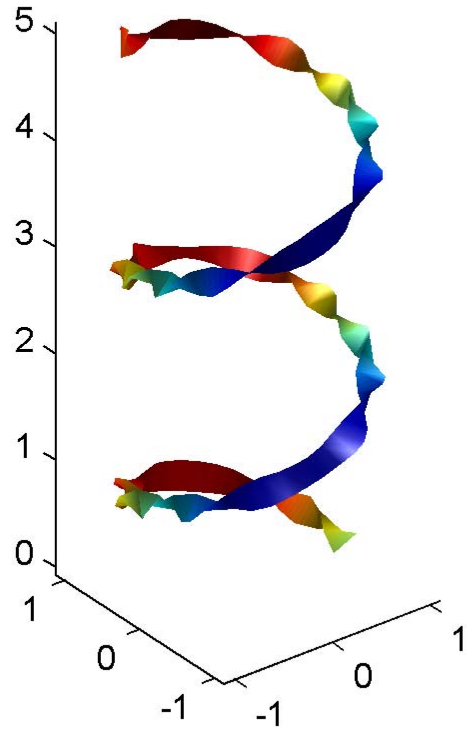
```
load wind
[sx sy sz] = meshgrid(80,20:10:50,0:5:15);
daspect([1 1 1])
verts = stream3(x,y,z,u,v,w,sx,sy,sz);
cav = curl(x,y,z,u,v,w);
spd = sqrt(u.^2 + v.^2 + w.^2).*.1;
streamribbon(verts,x,y,z,cav,spd);
%-----Define viewing and lighting
axis tight
shading interp
view(3)
camlight; lighting gouraud
```



This example specifies a twist angle for the stream ribbon.

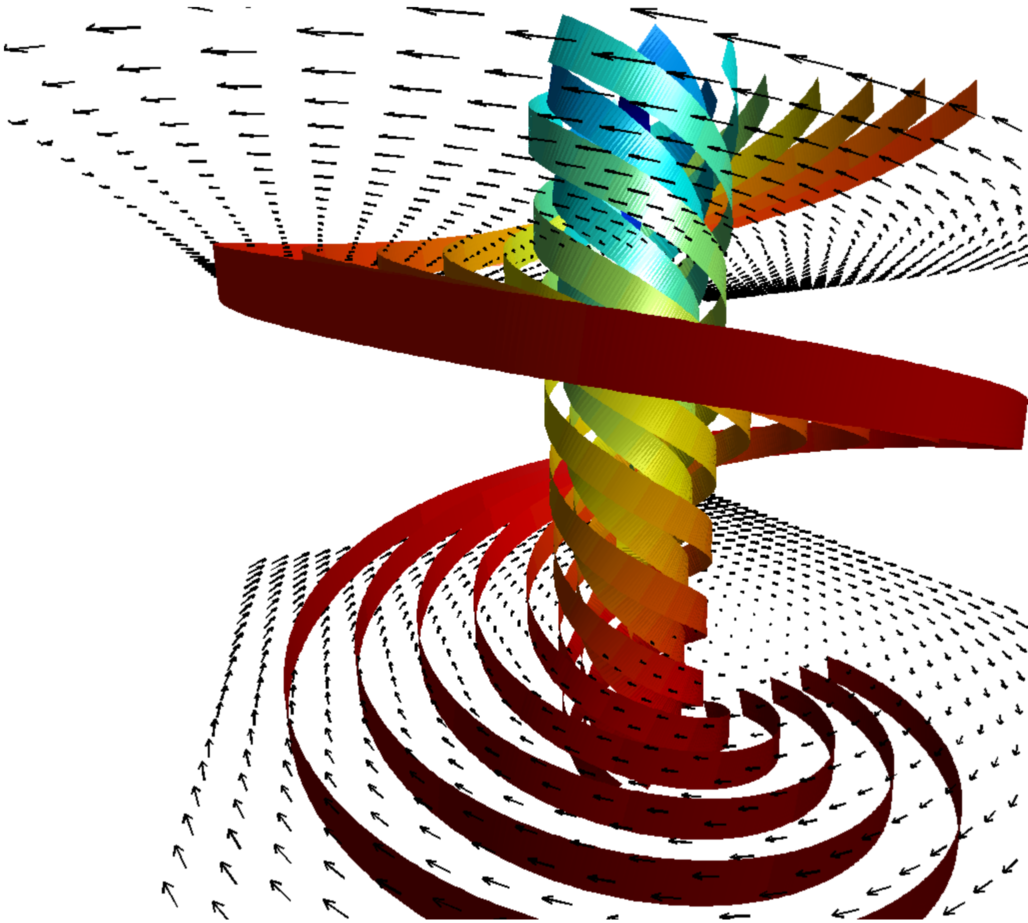
```
t = 0:.15:15;
verts = {[cos(t)' sin(t)' (t/3)']};
twistangle = {cos(t)'};
daspect([1 1 1])
streamribbon(verts,twistangle);
%-----Define viewing and lighting
```

```
axis tight
shading interp;
view(3);
camlight; lighting gouraud
```



This example combines cone plots (`coneplot`) and stream ribbon plots in one graph.

```
%-----Define 3-D arrays x, y, z, u, v, w
xmin = -7; xmax = 7;
ymin = -7; ymax = 7;
zmin = -7; zmax = 7;
x = linspace(xmin,xmax,30);
y = linspace(ymin,ymax,20);
z = linspace(zmin,zmax,20);
[x y z] = meshgrid(x,y,z);
u = y; v = -x; w = 0*x+1;
daspect([1 1 1]);
[cx cy cz] = meshgrid(linspace(xmin,xmax,30),...
 linspace(ymin,ymax,30),[-3 4]);
h = coneplot(x,y,z,u,v,w,cx,cy,cz,'quiver');
set(h,'color','k');
%-----Plot two sets of streamribbons
[sx sy sz] = meshgrid([-1 0 1],[-1 0 1],-6);
streamribbon(x,y,z,u,v,w,sx,sy,sz);
[sx sy sz] = meshgrid([1:6],[0],-6);
streamribbon(x,y,z,u,v,w,sx,sy,sz);
%-----Define viewing and lighting
shading interp
view(-30,10) ; axis off tight
camproj perspective; camva(66); camlookat;
camdolly(0,0,.5,'fixtarget')
camlight
```



See Also

`curl`, `streamtube`, `streamline`, `stream3`

“Volume Visualization” on page 1-106 for related functions

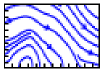
Displaying Curl with Stream Ribbons for another example

Specifying Starting Points for Stream Plots for related information

streamslice

Purpose

Plot streamlines in slice planes



GUI Alternatives

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

Syntax

```
streamslice(X,Y,Z,U,V,W,startx,starty,startz)
streamslice(U,V,W,startx,starty,startz)
streamslice(X,Y,U,V)
streamslice(U,V)
streamslice(...,density)
streamslice(...,'arrowsmode')
streamslice(...,'method')
streamslice(axes_handle,...)
h = streamslice(...)
[vertices arrowvertices] = streamslice(...)
```

Description

`streamslice(X,Y,Z,U,V,W,startx,starty,startz)` draws well-spaced streamlines (with direction arrows) from vector data `U`, `V`, `W` in axis aligned *x*-, *y*-, *z*-planes starting at the points in the vectors `startx`, `starty`, `startz`. (The section Specifying Starting Points for Stream Plots provides more information on defining starting points.) The arrays `X`, `Y`, `Z` define the coordinates for `U`, `V`, `W` and must be monotonic and 3-D plaid (as if produced by `meshgrid`). `U`, `V`, `W` must be m-by-n-by-p volume arrays.

Do not assume that the flow is parallel to the slice plane. For example, in a stream slice at a constant `z`, the `z` component of the vector field `W` is ignored when you are calculating the streamlines for that plane.

Stream slices are useful for determining where to start streamlines, stream tubes, and stream ribbons. It is good practice is to set the axes DataAspectRatio to [1 1 1] when using streamslice.

streamslice(U,V,W,startx,starty,startz) assumes X, Y, and Z are determined by the expression

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

where [m,n,p] = size(U).

streamslice(X,Y,U,V) draws well-spaced streamlines (with direction arrows) from vector volume data U, V. The arrays X, Y define the coordinates for U, V and must be monotonic and 2-D plaid (as if produced by meshgrid).

streamslice(U,V) assumes X, Y, and Z are determined by the expression

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

where [m,n,p] = size(U).

streamslice(...,density) modifies the automatic spacing of the streamlines. density must be greater than 0. The default value is 1; higher values produce more streamlines on each plane. For example, 2 produces approximately twice as many streamlines, while 0.5 produces approximately half as many.

streamslice(...,'*arrowsmode*') determines if direction arrows are present or not. arrowmode can be

- arrows — Draw direction arrows on the streamlines (default).
- noarrows — Do not draw direction arrows.

streamslice(...,'*method*') specifies the interpolation method to use. method can be

- linear — Linear interpolation (default)

- `cubic` — Cubic interpolation
- `nearest` — Nearest-neighbor interpolation

See `interp3` for more information on interpolation methods.

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

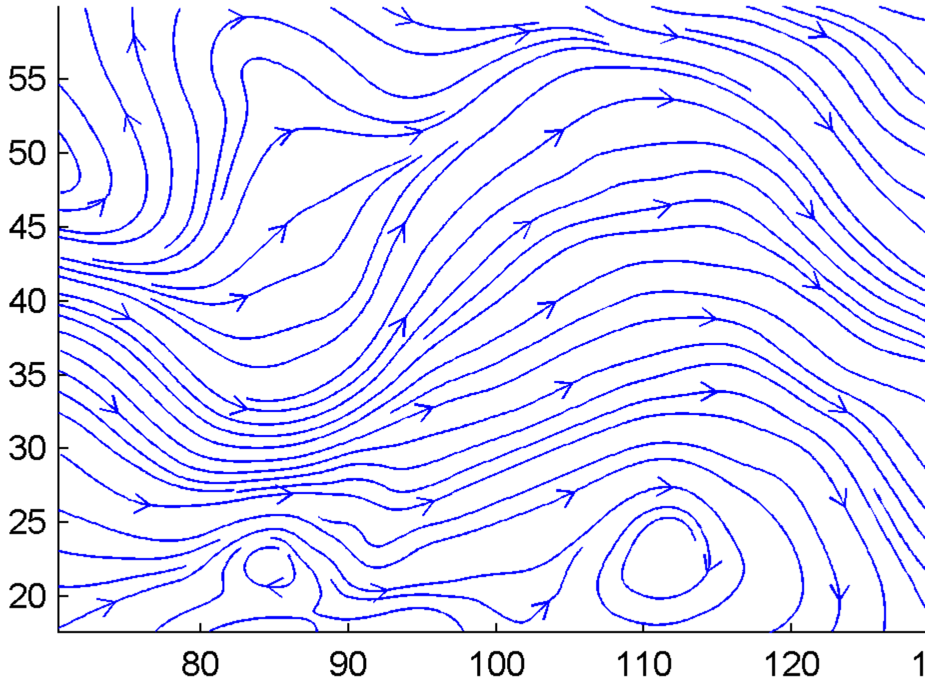
`h = streamslice(...)` returns a vector of handles to the line objects created.

`[vertices arrowvertices] = streamslice(...)` returns two cell arrays of vertices for drawing the streamlines and the arrows. You can pass these values to any of the streamline drawing functions (`streamline`, `streamribbon`, `streamtube`).

Examples

This example creates a stream slice in the `wind` data set at `z = 5`.

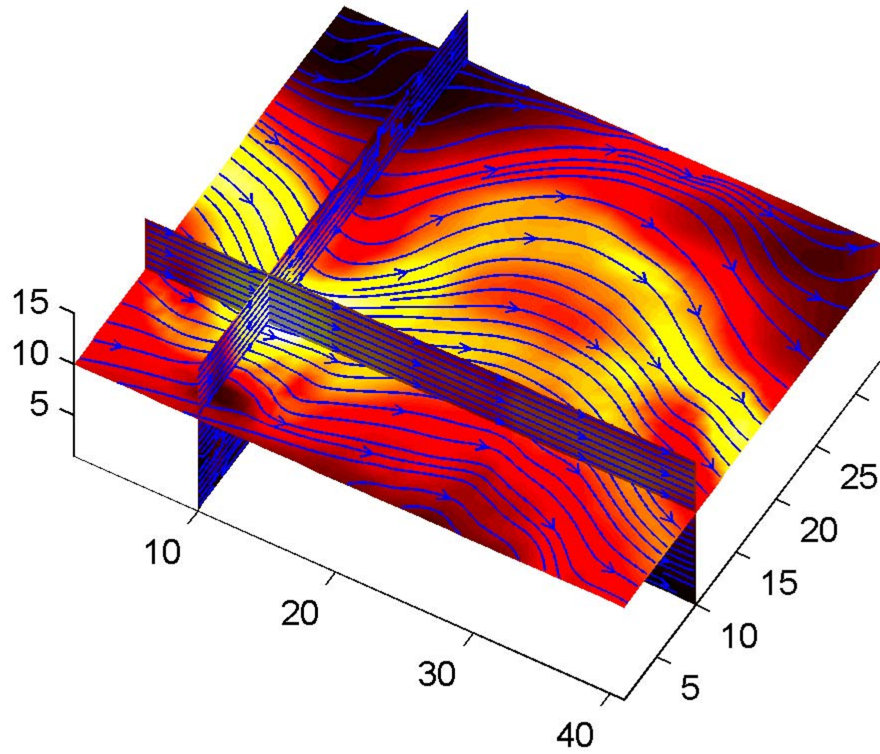
```
load wind
daspect([1 1 1])
streamslice(x,y,z,u,v,w,[],[],[5])
axis tight
```



This example uses `streamslice` to calculate vertex data for the streamlines and the direction arrows. This data is then used by `streamline` to plot the lines and arrows. Slice planes illustrating with color the wind speed $\sqrt{u^2 + v^2 + w^2}$ are drawn by `slice` in the same planes.

```
load wind
```

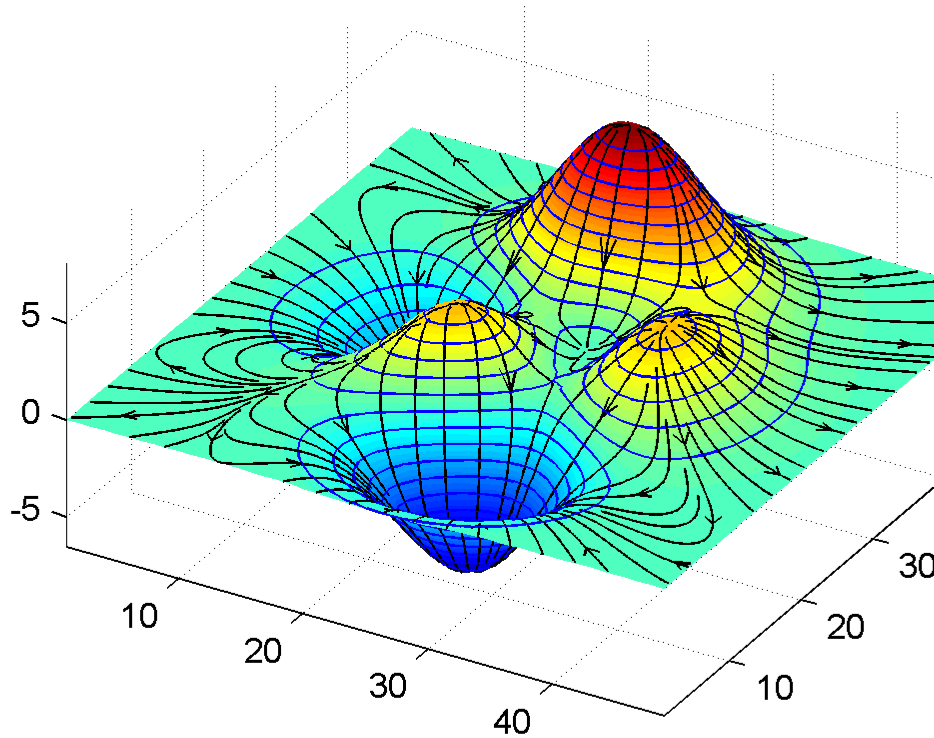
```
daspect([1 1 1])
[verts averts] = streamslice(u,v,w,10,10,10);
streamline([verts averts])
spd = sqrt(u.^2 + v.^2 + w.^2);
hold on;
slice(spd,10,10,10);
colormap(hot)
shading interp
view(30,50); axis(volumebounds(spd));
camlight; material([.5 1 0])
```



This example superimposes contour lines on a surface and then uses `streamslice` to draw lines that indicate the gradient of the surface. `interp2` is used to find the points for the lines that lie on the surface.

```
z = peaks;
surf(z)
shading interp
hold on
```

```
[c ch] = contour3(z,20); set(ch,'edgecolor','b')
[u v] = gradient(z);
h = streamslice(-u,-v);
set(h,'color','k')
for i=1:length(h);
 zi = interp2(z,get(h(i),'xdata'),get(h(i),'ydata'));
 set(h(i),'zdata',zi);
end
view(30,50); axis tight
```



See Also

`contourslice`, `slice`, `streamline`, `volumebounds`

"Volume Visualization" on page 1-106 for related functions

Specifying Starting Points for Stream Plots for related information

streamtube

Purpose

Create 3-D stream tube plot

GUI Alternatives

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

Syntax

```
streamtube(X,Y,Z,U,V,W,startx,starty,startz)
streamtube(U,V,W,startx,starty,startz)
streamtube(vertices,X,Y,Z,divergence)
streamtube(vertices,divergence)
streamtube(vertices,width)
streamtube(vertices)
streamtube(...,[scale n])
streamtube(axes_handle,...)
h = streamtube(...z)
```

Description

`streamtube(X,Y,Z,U,V,W,startx,starty,startz)` draws stream tubes from vector volume data `U`, `V`, `W`. The arrays `X`, `Y`, `Z` define the coordinates for `U`, `V`, `W` and must be monotonic and 3-D plaid (as if produced by `meshgrid`). `startx`, `starty`, and `startz` define the starting positions of the streamlines at the center of the tubes. The section Specifying Starting Points for Stream Plots provides more information on defining starting points.

The width of the tubes is proportional to the normalized divergence of the vector field.

Generally, you should set the `DataAspectRatio` (`daspect`) before calling `streamtube`.

`streamtube(U,V,W,startx,starty,startz)` assumes `X`, `Y`, and `Z` are determined by the expression

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

where [m,n,p] = size(U).

streamtube(vertices,X,Y,Z,divergence) assumes precomputed streamline vertices and divergence. vertices is a cell array of streamline vertices (as produced by stream3). X, Y, Z, and divergence are 3-D arrays.

streamtube(vertices,divergence) assumes X, Y, and Z are determined by the expression

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

where [m,n,p] = size(divergence).

streamtube(vertices,width) specifies the width of the tubes in the cell array of vectors, width. The size of each corresponding element of vertices and width must be equal. width can also be a scalar, specifying a single value for the width of all stream tubes.

streamtube(vertices) selects the width automatically.

streamtube(...,[scale n]) scales the width of the tubes by scale. The default is scale = 1. When the stream tubes are created, using start points or divergence, specifying scale = 0 suppresses automatic scaling. n is the number of points along the circumference of the tube. The default is n = 20.

streamtube(axes_handle,...) plots into the axes object with the handle axes_handle instead of into the current axes object (gca).

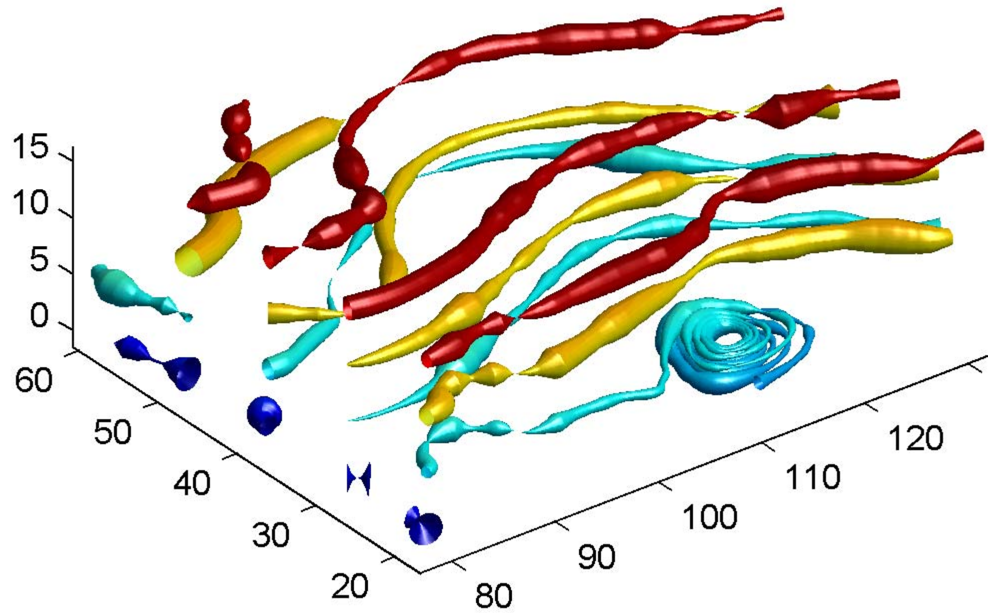
h = streamtube(...z) returns a vector of handles (one per start point) to surface objects used to draw the stream tubes.

Examples

This example uses stream tubes to indicate the flow in the wind data set. Inputs include the coordinates, vector field components, and starting location for the stream tubes.

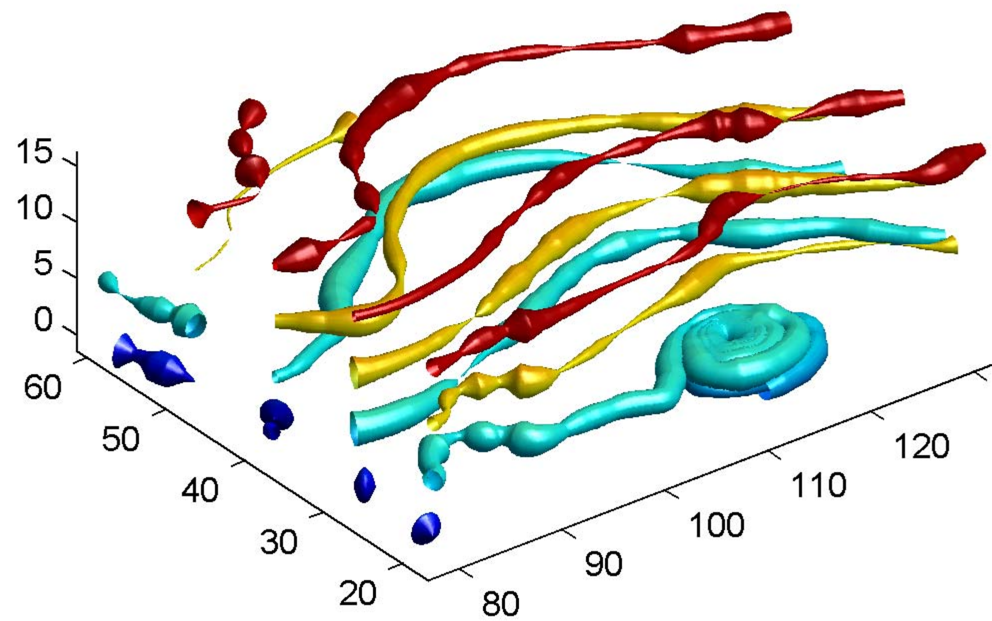
```
load wind
[sx sy sz] = meshgrid(80,20:10:50,0:5:15);
```

```
daspect([1 1 1])
streamtube(x,y,z,u,v,w,sx,sy,sz);
%-----Define viewing and lighting
view(3)
axis tight
shading interp;
camlight; lighting gouraud
```



This example uses precalculated vertex data (`stream3`) and divergence (`divergence`).

```
load wind
[sx sy sz] = meshgrid(80,20:10:50,0:5:15);
daspect([1 1 1])
verts = stream3(x,y,z,u,v,w,sx,sy,sz);
div = divergence(x,y,z,u,v,w);
streamtube(verts,x,y,z,-div);
%-----Define viewing and lighting
view(3)
axis tight
shading interp
camlight; lighting gouraud
```



See Also

divergence, streamribbon, streamline, stream3

"Volume Visualization" on page 1-106 for related functions

Displaying Divergence with Stream Tubes for another example

Specifying Starting Points for Stream Plots for related information

Purpose

Find one string within another

Syntax

```
k = strfind(str, pattern)
k = strfind(cellstr, pattern)
```

Description

`k = strfind(str, pattern)` searches the string `str` for occurrences of a shorter string, `pattern`, and returns the starting index of each such occurrence in the double array `k`. If `pattern` is not found in `str`, or if `pattern` is longer than `str`, then `strfind` returns the empty array `[]`.

`k = strfind(cellstr, pattern)` searches each string in cell array of strings `cellstr` for occurrences of a shorter string, `pattern`, and returns the starting index of each such occurrence in cell array `k`. If `pattern` is not found in a string or if `pattern` is longer then all strings in the cell array, then `strfind` returns the empty array `[]`, for that string in the cell array.

The search performed by `strfind` is case sensitive. Any leading and trailing blanks in `pattern` or in the strings being searched are explicitly included in the comparison.

Examples

Use `strfind` to find a two-letter pattern in string `S`:

```
S = 'Find the starting indices of the pattern string';
strfind(S, 'in')
ans =
     2    15    19    45

strfind(S, 'In')
ans =
     []

strfind(S, ' ')
ans =
     5     9    18    26    29    33    41
```

Use `strfind` on a cell array of strings:

```
cstr = {'How much wood would a woodchuck chuck';
        'if a woodchuck could chuck wood?'};

idx = strfind(cstr, 'wood');

idx{:,:}
ans =
    10    23
ans =
     6    28
```

This means that `'wood'` occurs at indices 10 and 23 in the first string and at indices 6 and 28 in the second.

See Also

`findstr`, `strmatch`, `strtok`, `strcmp`, `strncmp`, `strcmpi`, `strncmpi`, `regexp`, `regexpi`, `regexprep`

Purpose

String handling

Syntax

```
S = 'Any Characters'
S = [S1 S2 ...]
S = strcat(S1, S2, ...)
```

Description

`S = 'Any Characters'` creates a character array, or string. The string is actually a vector whose components are the numeric codes for the characters (the first 127 codes are ASCII). The actual characters displayed depend on the character encoding scheme for a given font. The length of `S` is the number of characters. A quotation within the string is indicated by two quotes.

`S = [S1 S2 ...]` concatenates character arrays `S1`, `S2`, etc. into a new character array, `S`.

`S = strcat(S1, S2, ...)` concatenates `S1`, `S2`, etc., which can be character arrays or "Cell Arrays of Strings". When the inputs are all character arrays, the output is also a character array. When any of the inputs is a cell array of strings, `strcat` returns a cell array of strings.

Trailing spaces in `strcat` character array inputs are ignored and do not appear in the output. This is not true for `strcat` inputs that are cell arrays of strings. Use the `S = [S1 S2 ...]` concatenation syntax, shown above, to preserve trailing spaces.

`S = char(X)` can be used to convert an array that contains positive integers representing numeric codes into a MATLAB character array.

`X = double(S)` converts the string to its equivalent double-precision numeric codes.

A collection of strings can be created in either of the following two ways:

- As the rows of a character array via `strvcat`
- As a cell array of strings via the curly braces

You can convert between character array and cell array of strings using `char` and `cellstr`. Most string functions support both types.

`ischar(S)` tells if `S` is a string variable. `iscellstr(S)` tells if `S` is a cell array of strings.

Examples

Create a simple string that includes a single quote.

```
msg = 'You''re right!'

msg =
You're right!
```

Create the string `name` using two methods of concatenation.

```
name = ['Thomas' ' R. ' 'Lee']
name = strcat('Thomas',' R.',' Lee')
```

Create a vertical array of strings.

```
C = strvcat('Hello','Yes','No','Goodbye')

C =
Hello
Yes
No
Goodbye
```

Create a cell array of strings.

```
S = {'Hello' 'Yes' 'No' 'Goodbye'}

S =
    'Hello'    'Yes'    'No'    'Goodbye'
```

See Also

`char`, `isstrprop`, `cellstr`, `ischar`, `isletter`, `isspace`, `iscellstr`, `strvcat`, `sprintf`, `sscanf`, `text`, `input`

Purpose

Justify character array

Syntax

```
T = strjust(S)
T = strjust(S, 'right')
T = strjust(S, 'left')
T = strjust(S, 'center')
```

Description

`T = strjust(S)` or `T = strjust(S, 'right')` returns a right-justified version of the character array `S`.

`T = strjust(S, 'left')` returns a left-justified version of `S`.

`T = strjust(S, 'center')` returns a center-justified version of `S`.

See Also

`deblank`, `strtrim`

strmatch

Purpose

Find possible matches for string

Syntax

```
x = strmatch(str, strarray)
x = strmatch(str, strarray, 'exact')
```

Description

`x = strmatch(str, strarray)` looks through the rows of the character array or cell array of strings `strarray` to find strings that begin with the text contained in `str`, and returns the matching row indices. Any trailing space characters in `str` or `strarray` are ignored when matching. `strmatch` is fastest when `strarray` is a character array.

`x = strmatch(str, strarray, 'exact')` compares `str` with each row of `strarray`, looking for an exact match of the entire strings. Any trailing space characters in `str` or `strarray` are ignored when matching.

Examples

The statement

```
x = strmatch('max', strvcat('max', 'minimax', 'maximum'))
```

returns `x = [1; 3]` since rows 1 and 3 begin with `'max'`. The statement

```
x = strmatch('max', strvcat('max', 'minimax', 'maximum'),'exact')
```

returns `x = 1`, since only row 1 matches `'max'` exactly.

See Also

`strcmp`, `strcmpi`, `strncmp`, `strncmpi`, `strfind`, `findstr`, `strvcat`, `regexp`, `regexpi`, `regexprep`

Purpose

Compare first `n` characters of strings

Syntax

```
TF = strncmp('str1', 'str2', n)
TF = strncmp('str', C, n)
TF = strncmp(C1, C2, n)
```

Each of these syntaxes applies to both `strncmp` and `strncmpi`. The `strncmp` function is case sensitive in matching strings, while `strncmpi` is not.

Description

Although the following descriptions show only `strncmp`, they apply to `strncmpi` as well. The two functions are the same except that `strncmpi` compares strings without sensitivity to letter case:

`TF = strncmp('str1', 'str2', n)` compares the first `n` characters of strings `str1` and `str2` and returns logical 1 (`true`) if they are identical, and returns logical 0 (`false`) otherwise. `str1` and `str2` can be character arrays of any dimension, but `strncmp` does not return `true` unless the sizes of both arrays are equal, and the contents of the two arrays are the same.

`TF = strncmp('str', C, n)` compares the first `n` characters of `str` to the first `n` characters of each element of cell array `C`, where `str` is a character vector (or a 1-by-1 cell array), and `C` is a cell array of strings. The function returns `TF`, a logical array that is the same size as `C` and contains logical 1 (`true`) for those elements of `C` that are a match, and logical 0 (`false`) for those elements that are not. The order of the first two input arguments is not important.

`TF = strncmp(C1, C2, n)` compares each element of `C1` to the same element in `C2`, where `C1` and `C2` are equal-size cell arrays of strings. Input `C1` or `C2` can also be a character array with the right number of rows. The function attempts to match only the first `n` characters of each string. The function returns `TF`, a logical array that is the same size as `C1` and `C2`, and contains logical 1 (`true`) for those elements of `C1` and `C2` that are a match, and logical 0 (`false`) for those elements that are not.

Remarks

These functions are intended for comparison of character data. When used to compare numeric data, they return logical `0`.

Any leading and trailing blanks in either of the strings are explicitly included in the comparison.

The value returned by `strncmp` and `strncmpi` is not the same as the C language convention.

`strncmp` and `strncmpi` support international character sets.

Examples

Example 1

From a list of 10 MATLAB functions, find those that apply to using a camera:

```
function_list = {'calendar' 'case' 'camdolly' 'circshift' ...
                 'caxis' 'camtarget' 'cast' 'camorbit' ...
                 'callib' 'cart2sph'};

strncmp(function_list, 'cam', 3)
ans =
    0    0    1    0    0    1    0    1    0    0

function_list{strncmp(function_list, 'cam', 3)}
ans =
   camdolly
ans =
   camtarget
ans =
   camorbit
```

Example 2

Create two 5-by-10 string arrays `str1` and `str2` that are equal except for the element at row 4, column 3. Using linear indexing, this is element 14:

```
str1 = ['AAAAAAAAAA'; 'BBBBBBBBBB'; 'CCCCCCCCCC'; ...
        'DDDDDDDDDD'; 'EEEEEEEEEE']
```

```
str1 =
    AAAAAAAAAA
    BBBBBBBBBB
    CCCCCCCCCC
    DDDDDDDDDD
    EEEEEEEEEE

str2 = str1;
str2(4,3) = '-'
str2 =
    AAAAAAAAAA
    BBBBBBBBBB
    CCCCCCCCCC
    DD-DDDDDDD
    EEEEEEEEEE
```

Because MATLAB compares the arrays in linear order (that is, column by column rather than row by row), `strncmp` finds only the first 13 elements to be the same:

```
str1   A B C D E A B C D E A B C D E
str2   A B C D E A B C D E A B C - E
                                 |
                              element 14

strncmp(str1, str2, 13)
ans =
     1

strncmp(str1, str2, 14)
ans =
     0
```

See Also

`strcmp`, `strcmpi`, `strmatch`, `strfind`, `findstr`, `regexp`, `regexpi`, `regexprep`, `regexptranslate`

strread

Purpose

Read formatted data from string

Note The textscan function is intended as a replacement for both strread and textread.

Syntax

```
A = strread('str')
[A, B, ...] = strread('str')
[A, B, ...] = strread('str', 'format')
[A, B, ...] = strread('str', 'format', N)
[A, B, ...] = strread('str', 'format', N, param, value, ...)
```

Description

A = strread('str') reads numeric data from input string str into a 1-by-N vector A, where N equals the number of whitespace-separated numbers in str. Use this form only with strings containing numeric data. See "Example 1" on page 2-3390 below.

[A, B, ...] = strread('str') reads numeric data from the string input str into scalar output variables A, B, and so on. The number of output variables must equal the number of whitespace-separated numbers in str. Use this form only with strings containing numeric data. See "Example 2" on page 2-3390 below.

[A, B, ...] = strread('str', 'format') reads data from str into variables A, B, and so on using the specified format. The number of output variables A, B, etc. must be equal to the number of format specifiers (e.g., %s or %d) in the format argument. You can read all of the data in str to a single output variable as long as you use only one format specifier in the command. See "Example 4" on page 2-3391 and "Example 5" on page 2-3391 below.

The table Formats for strread on page 2-3387 lists the valid format specifiers. More information on using formats is available under "Formats" on page 2-3389 in the Remarks section below.

[A, B, ...] = strread('str', 'format', N) reads data from str reusing the format string N times, where N is an integer greater than zero. If N is -1, strread reads the entire string. When str contains only numeric data, you can set `format` to the empty string (`''`). See "Example 3" on page 2-3391 below.

`[A, B, ...] = strread('str', 'format', N, param, value, ...)` customizes `strread` using `param/value` pairs, as listed in the table Parameters and Values for strread on page 2-3388 below. When `str` contains only numeric data, you can set `format` to the empty string (`''`). The `N` argument is optional and may be omitted entirely. See "Example 7" on page 2-3392 below.

Formats for strread

Format	Action	Output
Literals (ordinary characters)	Ignore the matching characters. For example, in a string that has `Dept` followed by a number (for department number), to skip the `Dept` and read only the number, use `'Dept'` in the `format` string.	None
`%d`	Read a signed integer value.	Double array
`%u`	Read an integer value.	Double array
`%f`	Read a floating-point value.	Double array
`%s`	Read a white-space separated string.	Cell array of strings
`%q`	Read a double quoted string, ignoring the quotes.	Cell array of strings
`%c`	Read characters, including white space.	Character array
`%[...]`	Read the longest string containing characters specified in the brackets.	Cell array of strings

Formats for strread (Continued)

Format	Action	Output
%[^...]	Read the longest nonempty string containing characters that are not specified in the brackets.	Cell array of strings
%*...	Ignore the characters following *. See "Example 8" on page 2-3392 below.	No output
%w...	Read field width specified by w. The %f format supports %w.pf, where w is the field width and p is the precision.	

Parameters and Values for strread

param	value	Action
whitespace	* where * can be	Treats vector of characters, *, as white space. Default is \b\r\n\t.
	b	Backspace
	f	Form feed
	n	New line
	r	Carriage return
	t	Horizontal tab
	\\	Backslash
	\'' or ''	Single quotation mark
	%%	Percent sign

Parameters and Values for strread (Continued)

param	value	Action
delimiter	Delimiter character	Specifies delimiter character. Default is one or more whitespace characters.
expchars	Exponent characters	Default is eEdD.
bufsize	Positive integer	Specifies the maximum string length, in bytes. Default is 4095.
commentstyle	matlab	Ignores characters after %.
commentstyle	shell	Ignores characters after #.
commentstyle	c	Ignores characters between /* and */.
commentstyle	c++	Ignores characters after //.

Remarks

Delimiters

If your data uses a character other than a space as a delimiter, you must use the strread parameter 'delimiter' to specify the delimiter. For example, if the string str used a semicolon as a delimiter, you would use this command:

```
[names, types, x, y, answer] = strread(str,'%s %s %f ...
    %d %s','delimiter',';')
```

Formats

The format string determines the number and types of return arguments. The number of return arguments must match the number of conversion specifiers in the format string.

The strread function continues reading str until the entire string is read. If there are fewer format specifiers than there are entities in str, strread reapplies the format specifiers, starting over at the beginning. See "Example 5" on page 2-3391 below.

The format string supports a subset of the conversion specifiers and conventions of the C language fscanf routine. White-space characters in the format string are ignored.

Preserving White-Space

If you want to preserve leading and trailing spaces in a string, use the whitespace parameter as shown here:

```
str = '   An  example      of preserving     spaces      ';

strread(str, '%s', 'whitespace', '')
ans =
    '   An  example      of preserving     spaces      '
```

Examples

Example 1

Read numeric data into a 1-by-5 vector:

```
a = strread('0.41 8.24 3.57 6.24 9.27')
a =
    0.4100    8.2400    3.5700    6.2400    9.2700
```

Example 2

Read numeric data into separate scalar variables:

```
[a b c d e] = strread('0.41 8.24 3.57 6.24 9.27')
a =
    0.4100
b =
    8.2400
c =
    3.5700
d =
    6.2400
e =
    9.2700
```

Example 3

Read the only first three numbers in the string, also formatting as floating point:

```
a = strread('0.41 8.24 3.57 6.24 9.27', '%4.2f', 3)

a =
    0.4100
    8.2400
    3.5700
```

Example 4

Truncate the data to one decimal digit by specifying format `%3.1f`. The second specifier, `%*1d`, tells `strread` not to read in the remaining decimal digit:

```
a = strread('0.41 8.24 3.57 6.24 9.27', '%3.1f %*1d')

a =
    0.4000
    8.2000
    3.5000
    6.2000
    9.2000
```

Example 5

Read six numbers into two variables, reusing the format specifiers:

```
[a b] = strread('0.41 8.24 3.57 6.24 9.27 3.29', '%f %f')

a =
    0.4100
    3.5700
    9.2700
b =
    8.2400
    6.2400
```

```
     3.2900
```

Example 6

Read string and numeric data to two output variables. Ignore commas in the input string:

```
str = 'Section 4, Page 7, Line 26';

[name value] = strread(str, '%s %d,')
name =
    'Section'
    'Page'
    'Line'
value =
     4
     7
    26
```

Example 7

Read the string used in the last example, but this time delimiting with commas instead of spaces:

```
str = 'Section 4, Page 7, Line 26';

[a b c] = strread(str, '%s %s %s', 'delimiter', ',')
a =
    'Section 4'
b =
    'Page 7'
c =
    'Line 26'
```

Example 8

Read selected portions of the input string:

```
str = '<table border=5 width="100%" cellspacing=0>';

[border width space] = strread(str, ...
```

```
    '%*s%*s %c %*s "%4s" %*s %c', 'delimiter', '= ')
border =
     5
width =
    '100%'
space =
     0
```

Example 9

Read the string into two vectors, restricting the `Answer` values to `T` and `F`. Also note that two delimiters (comma and space) are used here:

```
str = 'Answer_1: T, Answer_2: F, Answer_3: F';

[a b] = strread(str, '%s %[TF]', 'delimiter', ', ')
a =
    'Answer_1:'
    'Answer_2:'
    'Answer_3:'
b =
    'T'
    'F'
    'F'
```

See Also

`textscan`, `textread`, `sscanf`

Purpose

Find and replace substring

Syntax

```
str = strrep(str1, str2, str3)
```

Description

`str = strrep(str1, str2, str3)` replaces all occurrences of the string `str2` within string `str1` with the string `str3`.

`strrep(str1, str2, str3)`, when any of `str1`, `str2`, or `str3` is a cell array of strings, returns a cell array the same size as `str1`, `str2`, and `str3` obtained by performing a `strrep` using corresponding elements of the inputs. The inputs must all be the same size (or any can be a scalar cell). Any one of the strings can also be a character array with the right number of rows.

Examples

```
s1 = 'This is a good example.';
str = strrep(s1, 'good', 'great')
str =
This is a great example.
A =
    'MATLAB'       'SIMULINK'
    'Toolboxes'    'The MathWorks'
B =
    'Handle Graphics'    'Real Time Workshop'
    'Toolboxes'          'The MathWorks'
C =
    'Signal Processing'    'Image Processing'
    'MATLAB'               'SIMULINK'
strrep(A, B, C)
ans =
    'MATLAB' 'SIMULINK'
    'MATLAB' 'SIMULINK'
```

See Also

`strfind`

Purpose Selected parts of string

Syntax

```
token = strtok('str')
token = strtok('str', delimiter)
[token, remain] = strtok('str', ...)
```

Description

`token = strtok('str')` returns in `token` that part of the input string `str` that precedes the first white-space character (the default delimiter). Parsing of the string begins at the first nondelimiting (i.e., nonwhite-space) character and continues to the right until the MATLAB software either locates a delimiter or reaches the end of the string. If no delimiters are found in the body of the input string, then the entire string (excluding any leading delimiting characters) is returned.

White-space characters include space (ASCII 32), tab (ASCII 9), and carriage return (ASCII 13).

If `str` is a cell array of strings, `token` is a cell array of tokens.

`token = strtok('str', delimiter)` is the same as the above syntax except that you can specify one or more nondefault delimiters in the character vector, `delimiter`. Ignoring any leading delimiters, MATLAB returns in `token` that part of the input string that precedes one of the characters from the given `delimiter` vector.

`[token, remain] = strtok('str', ...)` returns in `remain` a substring of the input string that begins immediately after the `token` substring and ends with the last character in `str`. If no delimiters are found in the body of the input string, then the entire string (excluding any leading delimiting characters) is returned in `token`, and `remain` is an empty string (`''`).

If `str` is a cell array of strings, `token` is a cell array of tokens and `remain` is a character array.

Examples

Example 1

This example uses the default white-space delimiter:

```
s = '  This is a simple example.';
```

```
[token, remain] = strtok(s)
token =
   This
remain =
   is a simple example.
```

Example 2

Take a string of HTML code and break it down into segments delimited by the < and > characters. Write a `while` loop to parse the string and print each segment:

```
s = sprintf('%s%s%s%s', ...
'<ul class=continued><li class=continued>', ...
'<pre><a name="13474"></a>token = strtok', ...
'(''str'', delimiter)<a name="13475"></a>', ...
'token = strtok(''str'')');

remain = s;

while true
   [str, remain] = strtok(remain, '<>');
   if isempty(str),  break;  end
   disp(sprintf('%s', str))
   end
```

Here is the output:

```
ul class=continued
li class=continued
pre
a name="13474"
/a
token = strtok('str', delimiter)
a name="13475"
/a
token = strtok('str')
```

Example 3

Using `strtok` on a cell array of strings returns a cell array of strings in `token` and a character array in `remain`:

```
s = {'all in good time'; ...
     'my dog has fleas'; ...
     'leave no stone unturned'};

remain = s;

for k = 1:4
   [token, remain] = strtok(remain);
   token
   end
```

Here is the output:

```
token =
    'all'
    'my'
    'leave'
token =
    'in'
    'dog'
    'no'
token =
    'good'
    'has'
    'stone'
token =
    'time'
    'fleas'
    'unturned'
```

See Also

`findstr`, `strmatch`

strtrim

Purpose

Remove leading and trailing white space from string

Syntax

```
S = strtrim(str)
C = strtrim(cstr)
```

Description

`S = strtrim(str)` returns a copy of string `str` with all leading and trailing white-space characters removed. A white-space character is one for which the `isspace` function returns logical `1` (`true`).

`C = strtrim(cstr)` returns a copy of the cell array of strings `cstr` with all leading and trailing white-space characters removed from each string in the cell array.

Examples

Remove the leading white-space characters (spaces and tabs) from `str`:

```
str = sprintf('  \t   Remove    leading white-space')
str =
        Remove    leading white-space

str = strtrim(str)
str =
Remove    leading white-space
```

Remove leading and trailing white-space from the cell array of strings:

```
cstr = {'     Trim leading white-space';
        'Trim trailing white-space     '};

cstr = strtrim(cstr)
cstr =
    'Trim leading white-space'
    'Trim trailing white-space'
```

See Also

`isspace`, `cellstr`, `deblank`, `strjust`

Purpose

Create structure array

Syntax

```
s = struct('field1', values1, 'field2', values2, ...)
s = struct('field1', {}, 'field2', {}, ...)
s = struct
s = struct([])
s = struct(obj)
```

Description

`s = struct('field1', values1, 'field2', values2, ...)` creates a structure array with the specified fields and values. Each value input (`values1`, `values2`, etc.), can either be a cell array or a scalar value. Those that are cell arrays must all have the same dimensions.

The size of the resulting structure is the same size as the value cell arrays, or 1-by-1 if none of the values is a cell array. Elements of the `value` array inputs are placed into corresponding structure array elements.

Note If any of the `values` fields is an empty cell array `{}`, the MATLAB software creates an empty structure array in which all fields are also empty.

Structure field names must begin with a letter, and are case-sensitive. The rest of the name may contain letters, numerals, and underscore characters. Use the `namelengthmax` function to determine the maximum length of a field name.

`s = struct('field1', {}, 'field2', {}, ...)` creates an empty structure with fields `field1`, `field2`, `...`

`s = struct` creates a 1-by-1 structure with no fields.

`s = struct([])` creates an empty structure with no fields.

`s = struct(obj)` creates a structure `s` that is identical to the underlying structure in the input object `obj`. MATLAB does not convert obj, but rather creates s as a new structure. This structure does not retain the class information in obj.

Remarks

Two Ways to Access Fields

The most common way to access the data in a structure is by specifying the name of the field that you want to reference. Another means of accessing structure data is to use dynamic field names. These names express the field as a variable expression that MATLAB evaluates at run-time.

Fields That Are Cell Arrays

To create fields that contain cell arrays, place the cell arrays within a value cell array. For instance, to create a 1-by-1 structure, type

```
s = struct('strings',{{'hello','yes'}},'lengths',[5 3])
s =
   strings: {'hello'  'yes'}
   lengths: [5 3]
```

Specifying Cell Versus Noncell Values

When using the syntax

```
s = struct('field1', values1, 'field2', values2, ...)
```

the values inputs can be cell arrays or scalar values. For those values that are specified as a cell array, MATLAB assigns each element of values{m,n,...} to the corresponding field in each element of structure s:

```
s(m,n,...).fieldN = valuesN{m,n,...}
```

For those values that are scalar, MATLAB assigns that single value to the corresponding field for all elements of structure s:

```
s(m,n,...).fieldN = valuesN
```

See Example 3, below.

Examples

Example 1

The command

```
s = struct('type', {'big','little'}, 'color', {'red'}, ...
    'x', {3 4})
```

produces a structure array s:

```
s =
1x2 struct array with fields:
    type
    color
    x
```

The value arrays have been distributed among the fields of s:

```
s(1)
ans =
       type: 'big'
     color: 'red'
         x: 3
s(2)
ans =
       type: 'little'
     color: 'red'
         x: 4
```

Example 2

Similarly, the command

```
a.b = struct('z', {});
```

produces an empty structure a.b with field z.

```
a.b
ans =
      0x0 struct array with fields:
          z
```

Example 3

This example initializes one field `f1` using a cell array, and the other `f2` using a scalar value:

```
s = struct('f1', {1 3; 2 4}, 'f2', 25)
s =
2x2 struct array with fields:
    f1
    f2
```

Field `f1` in each element of `s` is assigned the corresponding value from the cell array `{1 3; 2 4}`:

```
s.f1
ans =
     1
ans =
     2
ans =
     3
ans =
     4
```

Field `f2` for all elements of `s` is assigned one common value because the `values` input for this field was specified as a scalar:

```
s.f2
ans =
    25
ans =
    25
ans =
    25
ans =
    25
```

See Also

`isstruct`, `fieldnames`, `isfield`, `orderfields`, `getfield`, `setfield`, `rmfield`, `substruct`, `deal`, `cell2struct`, `struct2cell`, `namelengthmax`, dynamic field names

struct2cell

Purpose

Convert structure to cell array

Syntax

```
c = struct2cell(s)
```

Description

`c = struct2cell(s)` converts the `m`-by-`n` structure `s` (with `p` fields) into a `p`-by-`m`-by-`n` cell array `c`.

If structure `s` is multidimensional, cell array `c` has size `[p size(s)]`.

Examples

The commands

```
clear s, s.category = 'tree';
s.height = 37.4; s.name = 'birch';
```

create the structure

```
s =
    category: 'tree'
      height: 37.4000
        name: 'birch'
```

Converting the structure to a cell array,

```
c = struct2cell(s)

c =
    'tree'
    [37.4000]
    'birch'
```

See Also

`cell2struct`, `cell`, `iscell`, `struct`, `isstruct`, `fieldnames`, "Using Dynamic Field Names"

Purpose

Apply function to each field of scalar structure

Syntax

```
A = structfun(fun, S)
[A, B, ...] = structfun(fun, S)
[A, ...] = structfun(fun, S, 'param1', value1, ...)
```

Description

`A = structfun(fun, S)` applies the function specified by `fun` to each field of scalar structure `S`, and returns the results in array `A`. `fun` is a function handle to a function that takes one input argument and returns a scalar value. Return value `A` is a column vector that has one element for each field in input structure `S`. The Nth element of `A` is the result of applying `fun` to the Nth field of `S`, and the order of the fields is the same as that returned by a call to `fieldnames`. (`A` is returned as one or more scalar structures when the `UniformOutput` option is set to `false`. See the table below.))

`fun` must return values of the same class each time it is called. If `fun` is a handle to an overloaded function, then `structfun` follows MATLAB dispatching rules in calling the function.

`[A, B, ...]  = structfun(fun, S)` returns arrays `A`, `B`, `...`, each array corresponding to one of the output arguments of `fun`. `structfun` calls `fun` each time with as many outputs as there are in the call to `structfun`. `fun` can return output arguments having different classes, but the class of each output must be the same each time `fun` is called.

`[A, ...]  = structfun(fun, S, 'param1', value1, ...)` enables you to specify optional parameter name/parameter value pairs. Parameters are

Parameter	Value
'UniformOutput'	Logical value indicating whether or not the outputs of `fun` can be returned without encapsulation in a structure. The default value is `true`. If equal to logical 1 (`true`), `fun` must return scalar values that can be concatenated into an array. The outputs can be any of the following types: numeric, logical, char, struct, or cell. If equal to logical 0 (`false`), `structfun` returns a scalar structure or multiple scalar structures having fields that are the same as the fields of the input structure `S`. The values in the output structure fields are the results of calling `fun` on the corresponding values in the input structure `B`. In this case, the outputs can be of any data type.

'ErrorHandler'	Function handle specifying the function MATLAB is to call if the call to `fun` fails. MATLAB calls the error handling function with the following input arguments:
	
	• A structure, with the fields `'identifier'`, `'message'`, and `'index'`, respectively containing the identifier of the error that occurred, the text of the error message, and the number of the field (in the same order as returned by field names) at which the error occurred.
	• The input argument at which the call to the function failed.
	
	The error handling function should either rethrow an error or return the same number of outputs as `fun`. These outputs are then returned as the outputs of `structfun`. If `'UniformOutput'` is `true`, the outputs of the error handler must also be scalars of the same type as the outputs of `fun`.
	
	For example,
	
	`function [A, B] = errorFunc(S, ...`
	`    varargin)`
	`warning(S.identifier, S.message);`
	`A = NaN; B = NaN;`

Examples

To create shortened weekday names from the full names, for example: Create a structure with strings in several fields:

```
s.f1 = 'Sunday';
s.f2 = 'Monday';
s.f3 = 'Tuesday';
s.f4 = 'Wednesday';
s.f5 = 'Thursday';
s.f6 = 'Friday';
s.f7 = 'Saturday';

shortNames = structfun(@(x) ( x(1:3) ), s, ...
                        'UniformOutput', false);
```

See Also

`cellfun`, `arrayfun`, `function_handle`, `cell2mat`, `spfun`

Purpose

Concatenate strings vertically

Syntax

```
S = strvcat(t1, t2, t3, ...)
S = strvcat(c)
```

Description

`S = strvcat(t1, t2, t3, ...)` forms the character array `S` containing the text strings (or string matrices) `t1,t2,t3,...` as rows. Spaces are appended to each string as necessary to form a valid matrix. Empty arguments are ignored.

`S = strvcat(c)` when `c` is a cell array of strings, passes each element of `c` as an input to `strvcat`. Empty strings in the input are ignored.

Remarks

If each text parameter, `ti`, is itself a character array, `strvcat` appends them vertically to create arbitrarily large string matrices.

Examples

The command `strvcat('Hello','Yes')` is the same as `['Hello';'Yes ']`, except that `strvcat` performs the padding automatically.

```
t1 = 'first'; t2 = 'string'; t3 = 'matrix'; t4 = 'second';

S1 = strvcat(t1, t2, t3)       S2 = strvcat(t4, t2, t3)

S1 =                           S2 =

first                          second
string                         string
matrix                         matrix

S3 = strvcat(S1, S2)

S3 =
first
string
matrix
second
string
```

```
matrix
```

See Also

strcat, cat, vertcat, horzcat, int2str, mat2str, num2str, strings, special character []

sub2ind

Purpose

Single index from subscripts

Syntax

```
IND = sub2ind(siz,I,J)
IND = sub2ind(siz,I1,I2,...,In)
```

Description

The `sub2ind` command determines the equivalent single index corresponding to a set of subscript values.

`IND = sub2ind(siz,I,J)` returns the linear index equivalent to the row and column subscripts `I` and `J` for a matrix of size `siz`. `siz` is a vector with `ndim(A)` elements (in this case, 2), where `siz(1)` is the number of rows and `siz(2)` is the number of columns.

`IND = sub2ind(siz,I1,I2,...,In)` returns the linear index equivalent to the `n` subscripts `I1,I2,...,In` for an array of size `siz`. `siz` is an `n`-element vector that specifies the size of each array dimension.

Examples

Create a 3-by-4-by-2 array, `A`.

```
A = [17 24 1 8; 2 22 7 14; 4 6 13 20];
A(:,:,2) = A - 10

A(:,:,1) =

    17    24     1     8
     2    22     7    14
     4     6    13    20


A(:,:,2) =

     7    14    -9    -2
    -8    12    -3     4
    -6    -4     3    10
```

The value at row 2, column 1, page 2 of the array is -8.

```
A(2,1,2)
```

```
ans =

    -8
```

To convert `A(2,1,2)` into its equivalent single subscript, use `sub2ind`.

```
sub2ind(size(A),2,1,2)

ans =

    14
```

You can now access the same location in `A` using the single subscripting method.

```
A(14)

ans =

    -8
```

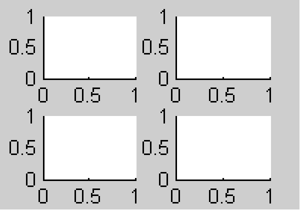
See Also

`ind2sub`, `find`, `size`

subplot

Purpose

Create axes in tiled positions



GUI Alternatives

To add subplots to a figure, click one of the *New Subplot* icons in the Figure Palette, and slide right to select an arrangement of subplots. For details, see Plotting Tools — Interactive Plotting in the MATLAB Graphics documentation.

Syntax

```
h = subplot(m,n,p) or subplot(mnp)
subplot(m,n,p,'replace')
subplot(m,n,P)
subplot(h)
subplot('Position',[left bottom width height])
subplot(..., prop1, value1, prop2, value2, ...)
h = subplot(...)
subplot(m,n,p,'v6')
```

Description

`subplot` divides the current figure into rectangular panes that are numbered rowwise. Each pane contains an axes object. Subsequent plots are output to the current pane.

`h = subplot(m,n,p) or subplot(mnp)` breaks the figure window into an `m`-by-`n` matrix of small axes, selects the `p`th axes object for the current plot, and returns the axes handle. The axes are counted along the top row of the figure window, then the second row, etc. For example,

```
subplot(2,1,1), plot(income)
subplot(2,1,2), plot(outgo)
```

plots income on the top half of the window and outgo on the bottom half. If the `CurrentAxes` is nested in a uipanel, the panel is used as the parent for the subplot instead of the current figure. The new axes object becomes the current axes.

`subplot(m,n,p,'replace')` If the specified axes object already exists, delete it and create a new axes.

`subplot(m,n,P)`, where `P` is a vector, specifies an axes position that covers all the subplot positions listed in `P`, including those spanned by `P`. For example, `subplot(2,3,[2 5])` creates one axes spanning positions 2 and 5 only (because there are no intervening locations in the grid), while `subplot(2,3,[2 6])` creates one axes spanning positions 2, 3, 5, and 6.

`subplot(h)` makes the axes object with handle `h` current for subsequent plotting commands.

`subplot('Position',[left bottom width height])` creates an axes at the position specified by a four-element vector. `left`, `bottom`, `width`, and `height` are in normalized coordinates in the range from 0.0 to 1.0.

`subplot(..., prop1, value1, prop2, value2, ...)` sets the specified property-value pairs on the subplot axis. To add the subplot to a specific figure pass the figure handle as the value for the `Parent` property. You cannot specify both a `Parent` and a `Position`; that is, `subplot('Position',[left bottom width height], 'Parent',h)` is not a valid syntax.

`h = subplot(...)` returns the handle to the new axes object.

Backward-Compatible Version

`subplot(m,n,p,'v6')` places the axes so that the plot boxes are aligned, but does not prevent the labels and ticks from overlapping. Saved subplots created with the `v6` option are compatible with MATLAB 6.5 and earlier versions.

Use the `subplot 'v6'` option and save the figure with the `'v6'` option when you want to be able to load a FIG-file containing subplots into MATLAB Version 6.5 or earlier.

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

See Plot Objects and Backward Compatibility for more information.

Remarks

If a subplot specification causes a new axis to overlap a existing axis, the existing axis is deleted - unless the position of the new and existing axis are identical. For example, the statement `subplot(1,2,1)` deletes all existing axes overlapping the left side of the figure window and creates a new axis on that side—unless there is an axes there with a position that exactly matches the position of the new axes (and `'replace'` was not specified), in which case all other overlapping axes will be deleted and the matching axes will become the current axes.

You can add subplots to GUIs as well as to figures. For information about creating subplots in a GUIDE-generated GUI, see "Creating Subplots" in the MATLAB Creating Graphical User Interfaces documentation.

If a `subplot` specification causes a new axes object to overlap any existing axes, `subplot` deletes the existing axes object and uicontrol objects. However, if the `subplot` specification exactly matches the position of an existing axes object, the matching axes object is not deleted and it becomes the current axes.

`subplot(1,1,1)` or `clf` deletes all axes objects and returns to the default `subplot(1,1,1)` configuration.

You can omit the parentheses and specify `subplot` as

```
subplot mnp
```

where `m` refers to the row, `n` refers to the column, and `p` specifies the pane.

Be aware when creating subplots from scripts that the `Position` property of subplots is not finalized until either

- A `drawnow` command is issued.
- MATLAB returns to await a user command.

That is, the value obtained for subplot `i` by the command

```
get(h(i),'position')
```

will not be correct until the script refreshes the plot or exits.

Special Case: subplot(111)

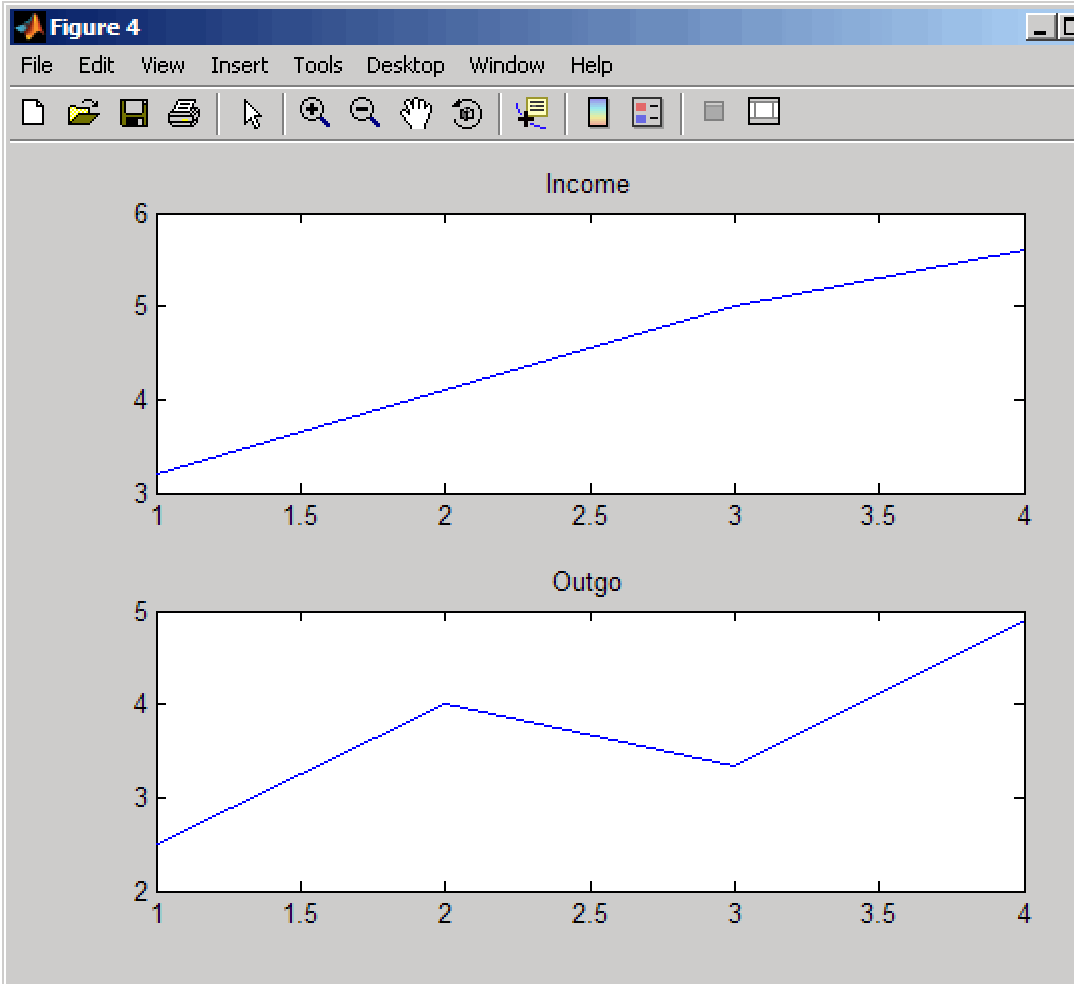
The command `subplot(111)` is not identical in behavior to `subplot(1,1,1)` and exists only for compatibility with previous releases. This syntax does not immediately create an axes object, but instead sets up the figure so that the next graphics command executes a `clf reset` (deleting all figure children) and creates a new axes object in the default position. This syntax does not return a handle, so it is an error to specify a return argument. (MATLAB implements this behavior by setting the figure's `NextPlot` property to `replace`.)

Examples

Upper and Lower Subplots with Titles

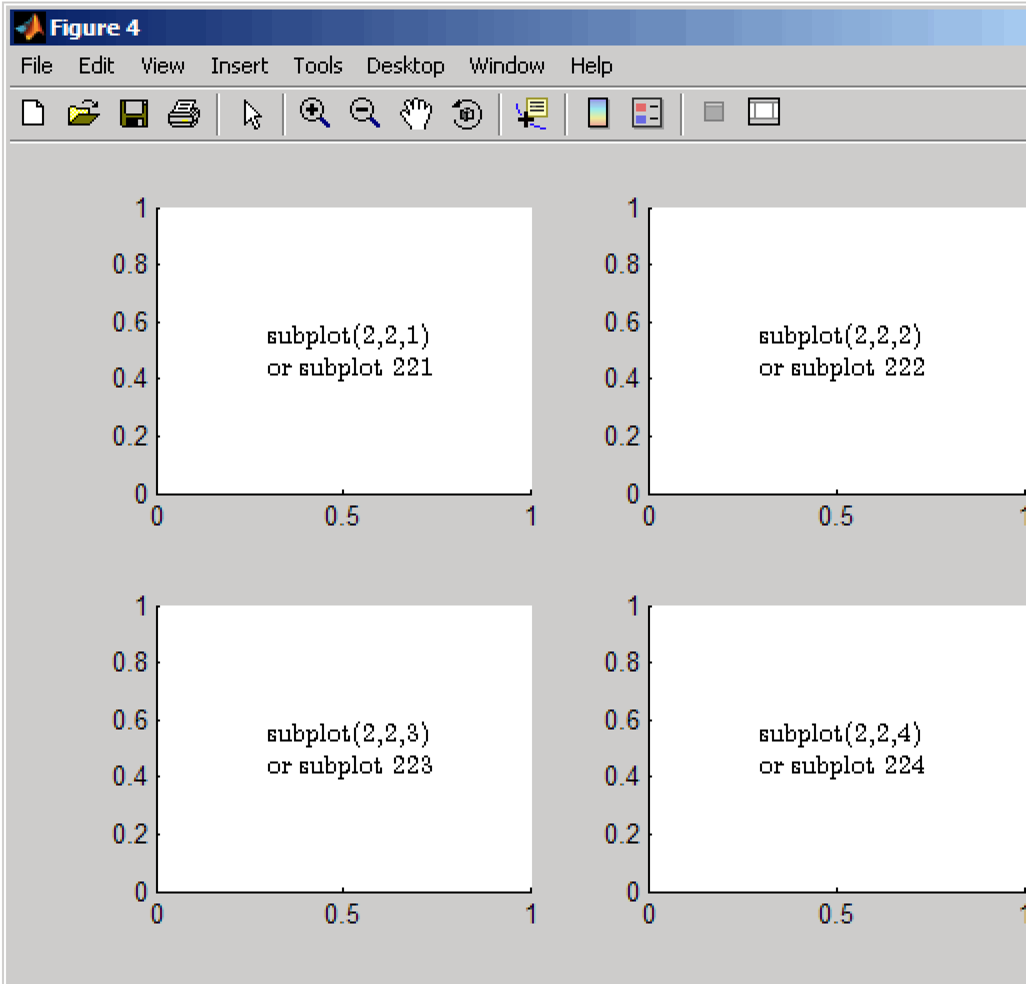
To plot `income` in the top half of a figure and `outgo` in the bottom half,

```
income = [3.2 4.1 5.0 5.6];
outgo = [2.5 4.0 3.35 4.9];
subplot(2,1,1); plot(income)
title('Income')
subplot(2,1,2); plot(outgo)
title('Outgo')
```



Subplots in Quadrants

The following illustration shows four subplot regions and indicates the command used to create each.

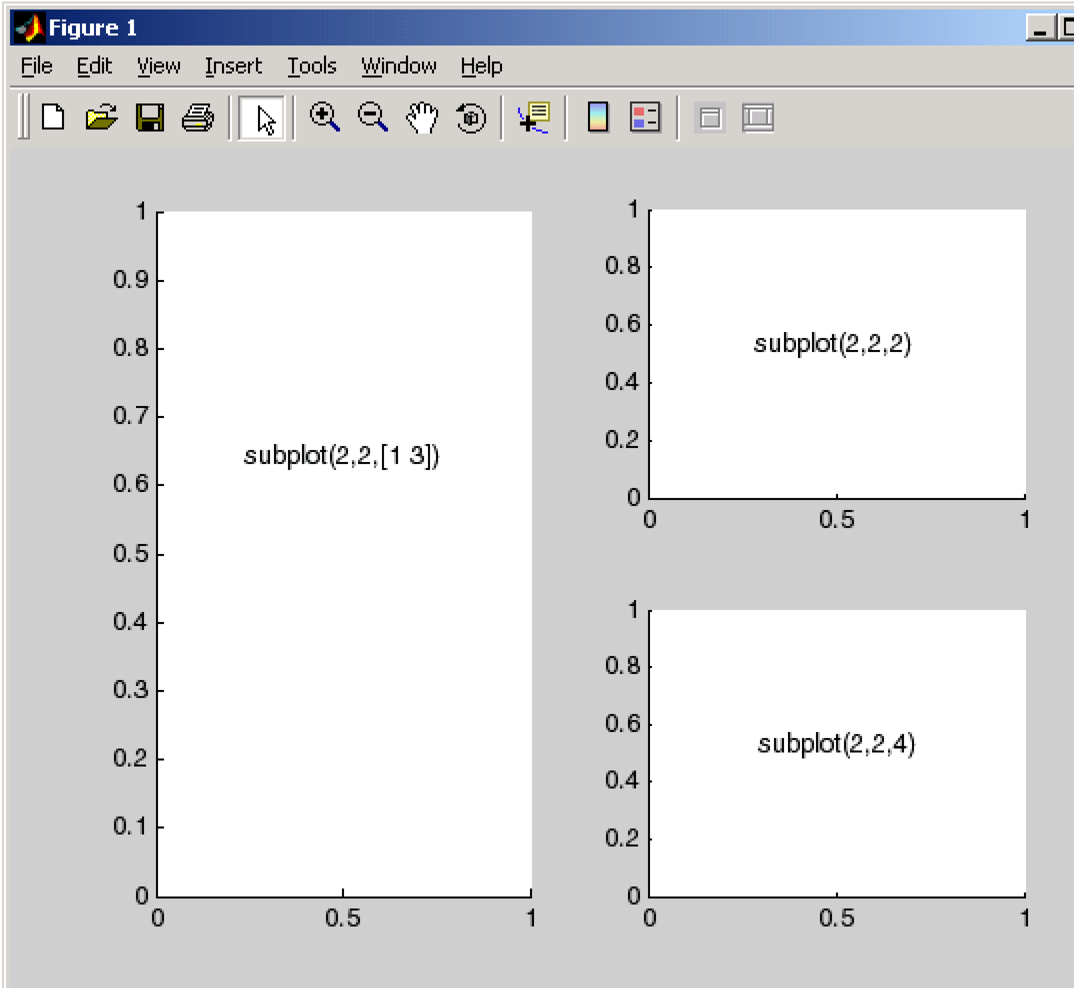


Assymetrical Subplots

The following combinations produce asymmetrical arrangements of subplots.

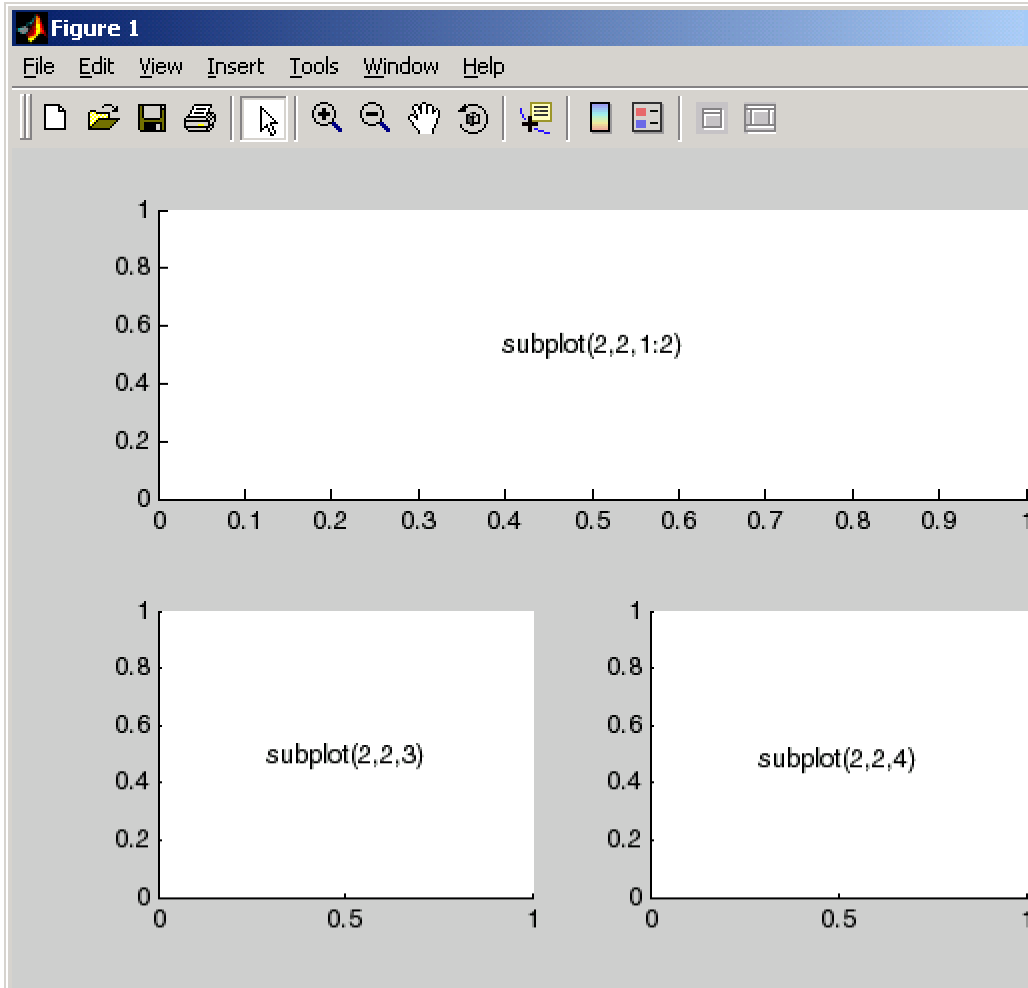
```
subplot(2,2,[1 3])
```

```
subplot(2,2,2)
subplot(2,2,4)
```



You can also use the colon operator to specify multiple locations if they are in sequence.

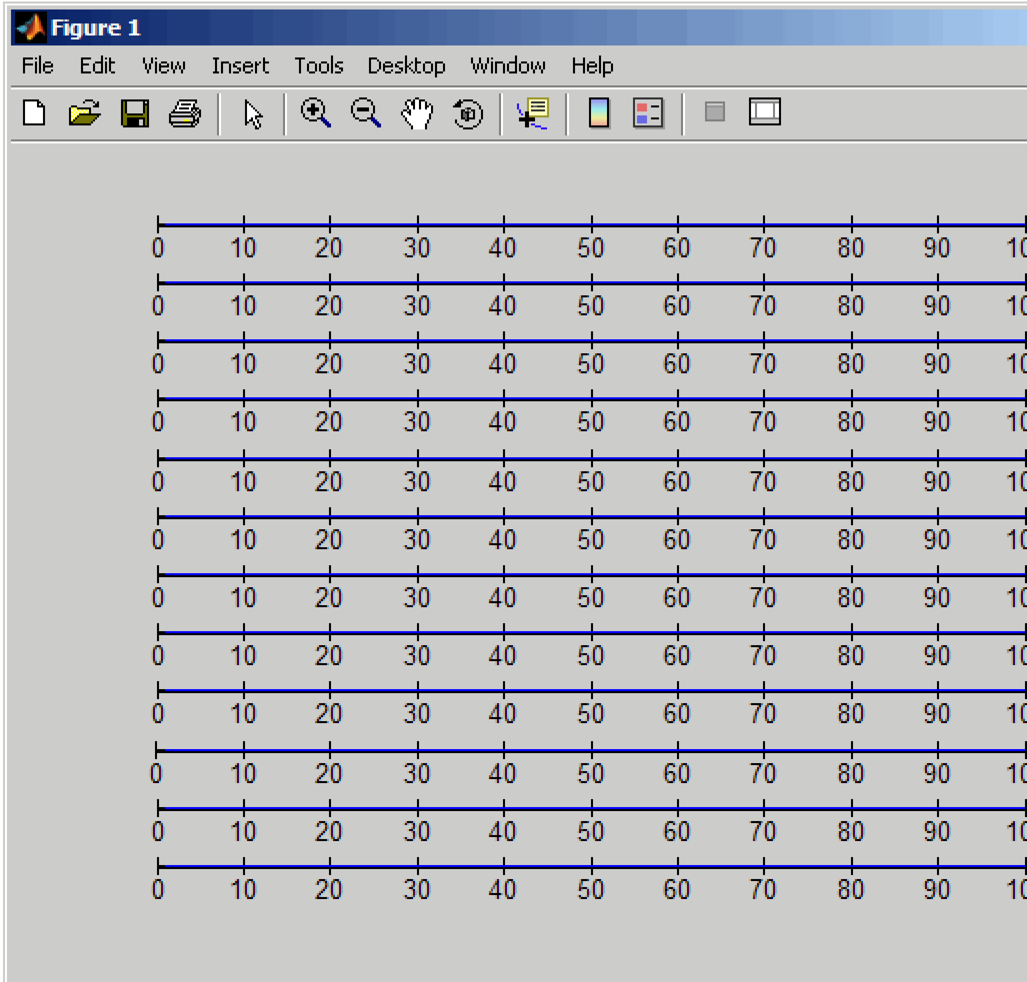
```
subplot(2,2,1:2)
subplot(2,2,3)
subplot(2,2,4)
```



Suppressing Axis Ticks

When you create many subplots in a figure, the axes tickmarks, which are shown by default, can either be obliterated or can cause axes to collapse, as the following code demonstrates:

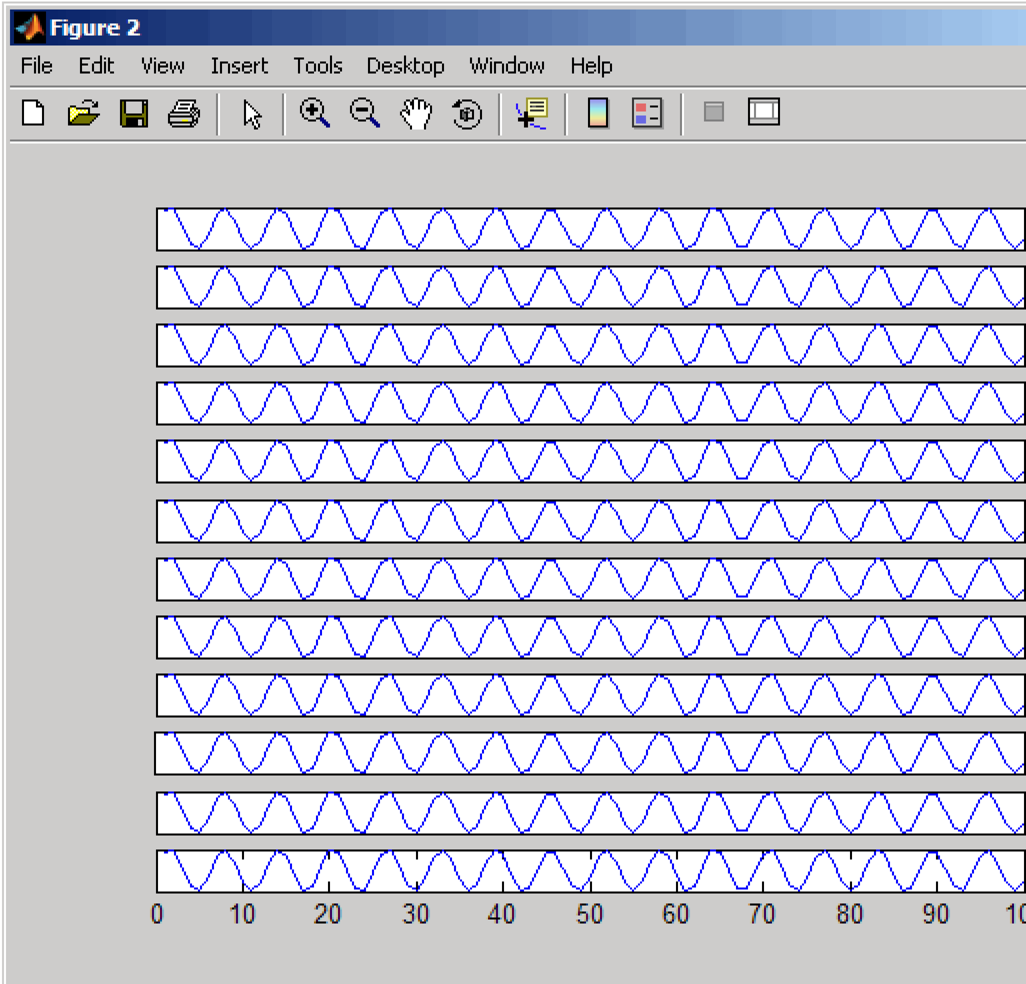
```
figure
for i=1:12
    subplot(12,1,i)
    plot (sin(1:100)*10^(i-1))
end
```



One way to get around this issue is to enlarge the figure to create enough space to properly display the tick labels.

Another approach is to eliminate the clutter by suppressing xticks and yticks for subplots as data are plotted into them. You can then label a single axes if the subplots are stacked, as follows:

```
figure
for i=1:12
    subplot(12,1,i)
    plot (sin(1:100)*10^(i-1))
    set(gca,'xtick',[],'ytick',[])
end
% Reset the bottom subplot to have xticks
set(gca,'xtickMode', 'auto')
```



See Also

`axes`, `cla`, `clf`, `figure`, `gca`

"Basic Plots and Graphs" on page 1-90 for more information

"Creating Subplots" in the MATLAB Creating Graphical User Interfaces documentation describes adding subplots to GUIs.

Purpose

Subscripted assignment for objects

Syntax

```
A = subsasgn(A, S, B)
```

Description

`A = subsasgn(A, S, B)` is called for the syntax `A(i)=B`, `A{i}=B`, or `A.i=B` when `A` is an object. `S` is a structure array with the fields

- `type`: A string containing `'()'`, `'{}'`, or `'.'`, where `'()'` specifies integer subscripts, `'{}'` specifies cell array subscripts, and `'.'` specifies subscripted structure fields.
- `subs`: A cell array or string containing the actual subscripts.

Remarks

`subsasgn` is designed to be used by the MATLAB interpreter to handle indexed assignments to objects. Calling `subsasgn` directly as a function is not recommended. If you do use `subsasgn` in this way, it conforms to the formal MATLAB dispatching rules and can yield unexpected results.

In the assignment `A(J,K,...) = B(M,N,...)`, subscripts `J`, `K`, `M`, `N`, etc. may be scalar, vector, or array, provided that all of the following are true:

- The number of subscripts specified for `B`, excluding trailing subscripts equal to 1, does not exceed `ndims(B)`.
- The number of nonscalar subscripts specified for `A` equals the number of nonscalar subscripts specified for `B`. For example, `A(5, 1:4, 1, 2) = B(5:8)` is valid because both sides of the equation use one nonscalar subscript.
- The order and length of all nonscalar subscripts specified for `A` matches the order and length of nonscalar subscripts specified for `B`. For example, `A(1:4, 3, 3:9) = B(5:8, 1:7)` is valid because both sides of the equation (ignoring the one scalar subscript `3`) use a 4-element subscript followed by a 7-element subscript.

See the Remarks section of the `numel` reference page for information concerning the use of `numel` with regards to the overloaded `subsasgn` function.

If `A` is an array of one of the fundamental MATLAB data types, then assigning a value to `A` with indexed assignment calls the builtin MATLAB `subsasgn` method. It does not call any `subsasgn` method that you may have overloaded for that data type. For example, if `A` is an array of type `double`, and there is an `@double/subsasgn` method on your MATLAB path, the statement `A(I) = B` does not call this method, but calls the MATLAB builtin `subsasgn` method instead.

Examples

The syntax `A(1:2,:)=B` calls `A=subsasgn(A,S,B)` where `S` is a 1-by-1 structure with `S.type='()'` and `S.subs = {1:2,':'}`. A colon used as a subscript is passed as the string `':'`.

The syntax `A{1:2}=B` calls `A=subsasgn(A,S,B)` where `S.type='{}'`.

The syntax `A.field=B` calls `subsasgn(A,S,B)` where `S.type='.'` and `S.subs='field'`.

These simple calls are combined in a straightforward way for more complicated subscripting expressions. In such cases `length(S)` is the number of subscripting levels. For instance, `A(1,2).name(3:5)=B` calls `A=subsasgn(A,S,B)` where `S` is a 3-by-1 structure array with the following values:

`S(1).type='()'`	`S(2).type='.'`	`S(3).type='()'`
`S(1).subs={1,2}`	`S(2).subs='name'`	`S(3).subs={3:5}`

See Also

`subsref`, `substruct`

See for more information about overloaded methods and `subsasgn`.

Purpose Subscripted indexing for objects

Syntax

```
ind = subsindex(A)
```

Description

`ind = subsindex(A)` is called for the syntax `'X(A)'` when `A` is an object. `subsindex` must return the value of the object as a zero-based integer index. (`ind` must contain integer values in the range `0` to `prod(size(X))-1`.) `subsindex` is called by the default `subsref` and `subsasgn` functions, and you can call it if you overload these functions.

See Also `subsasgn`, `subsref`

subspace

Purpose Angle between two subspaces

Syntax

```
theta = subspace(A,B)
```

Description `theta = subspace(A,B)` finds the angle between two subspaces specified by the columns of `A` and `B`. If `A` and `B` are column vectors of unit length, this is the same as `acos(A'*B)`.

Remarks If the angle between the two subspaces is small, the two spaces are nearly linearly dependent. In a physical experiment described by some observations `A`, and a second realization of the experiment described by `B`, `subspace(A,B)` gives a measure of the amount of new information afforded by the second experiment not associated with statistical errors of fluctuations.

Examples Consider two subspaces of a Hadamard matrix, whose columns are orthogonal.

```
H = hadamard(8);
A = H(:,2:4);
B = H(:,5:8);
```

Note that matrices `A` and `B` are different sizes — `A` has three columns and `B` four. It is not necessary that two subspaces be the same size in order to find the angle between them. Geometrically, this is the angle between two hyperplanes embedded in a higher dimensional space.

```
theta = subspace(A,B)
theta =
    1.5708
```

That `A` and `B` are orthogonal is shown by the fact that `theta` is equal to $\pi/2$.

```
theta - pi/2
ans =
     0
```

Purpose

Subscripted reference for objects

Syntax

```
B = subsref(A, S)
```

Description

`B = subsref(A, S)` is called for the syntax `A(i)`, `A{i}`, or `A.i` when `A` is an object. `S` is a structure array with the fields

- `type`: A string containing `'()'`, `'{}'`, or `'.'`, where `'()'` specifies integer subscripts, `'{}'` specifies cell array subscripts, and `'.'` specifies subscripted structure fields.
- `subs`: A cell array or string containing the actual subscripts.

Remarks

`subsref` is designed to be used by the MATLAB interpreter to handle indexed references to objects. Calling `subsref` directly as a function is not recommended. If you do use `subsref` in this way, it conforms to the formal MATLAB dispatching rules and can yield unexpected results.

See the Remarks section of the `numel` reference page for information concerning the use of `numel` with regards to the overloaded `subsref` function.

If `A` is an array of one of the fundamental MATLAB data types, then referencing a value of `A` using an indexed reference calls the builtin MATLAB `subsref` method. It does not call any `subsref` method that you may have overloaded for that data type. For example, if `A` is an array of type `double`, and there is an `@double/subsref` method on your MATLAB path, the statement `B = A(I)` does not call this method, but calls the MATLAB builtin `subsref` method instead.

Examples

The syntax `A(1:2,:)` calls `subsref(A,S)` where `S` is a 1-by-1 structure with `S.type='()'` and `S.subs={1:2,':'}`. A colon used as a subscript is passed as the string `':'`.

The syntax `A{1:2}` calls `subsref(A,S)` where `S.type='{}'` and `S.subs={1:2}`.

The syntax `A.field` calls `subsref(A,S)` where `S.type='.'` and `S.subs='field'`.

These simple calls are combined in a straightforward way for more complicated subscripting expressions. In such cases `length(S)` is the number of subscripting levels. For instance, `A(1,2).name(3:5)` calls `subsref(A,S)` where `S` is a 3-by-1 structure array with the following values:

`S(1).type='()'`	`S(2).type='.'`	`S(3).type='()'`
`S(1).subs={1,2}`	`S(2).subs='name'`	`S(3).subs={3:5}`

See Also

`subsasgn`, `substruct`

See for more information about overloaded methods and `subsref`.

Purpose

Create structure argument for `subsasgn` or `subsref`

Syntax

```
S = substruct(type1, subs1, type2, subs2, ...)
```

Description

`S = substruct(type1, subs1, type2, subs2, ...)` creates a structure with the fields required by an overloaded `subsref` or `subsasgn` method. Each `type` string must be one of `'.'`, `'()'`, or `'{}'`. The corresponding `subs` argument must be either a field name (for the `'.'` type) or a cell array containing the index vectors (for the `'()'` or `'{}'` types).

The output `S` is a structure array containing the fields

- `type`: one of `'.'`, `'()'`, or `'{}'`
- `subs`: subscript values (field name or cell array of index vectors)

Examples

To call `subsref` with parameters equivalent to the syntax

```
B = A(3,5).field
```

you can use

```
S = substruct('()', {3,5}, '.', 'field');
B = subsref(A, S);
```

The structure created by `substruct` in this example contains the following:

```
S(1)

ans =

    type: '()'
    subs: {[3]  [5]}

S(2)
```

```
ans =

    type: '.'
    subs: 'field'
```

See Also

subsasgn, subsref

Purpose

Extract subset of volume data set

Syntax

```
[Nx,Ny,Nz,Nv] = subvolume(X,Y,Z,V,limits)
[Nx,Ny,Nz,Nv] = subvolume(V,limits)
Nv = subvolume(...)
```

Description

`[Nx,Ny,Nz,Nv] = subvolume(X,Y,Z,V,limits)` extracts a subset of the volume data set `V` using the specified axis-aligned `limits`. `limits = [xmin,xmax,ymin, ymax,zmin,zmax]` (Any `NaN`s in the limits indicate that the volume should not be cropped along that axis.)

The arrays `X`, `Y`, and `Z` define the coordinates for the volume `V`. The subvolume is returned in `NV` and the coordinates of the subvolume are given in `NX`, `NY`, and `NZ`.

`[Nx,Ny,Nz,Nv] = subvolume(V,limits)` assumes the arrays `X`, `Y`, and `Z` are defined as

```
[X,Y,Z] = meshgrid(1:N,1:M,1:P)
```

where `[M,N,P] = size(V)`.

`Nv = subvolume(...)` returns only the subvolume.

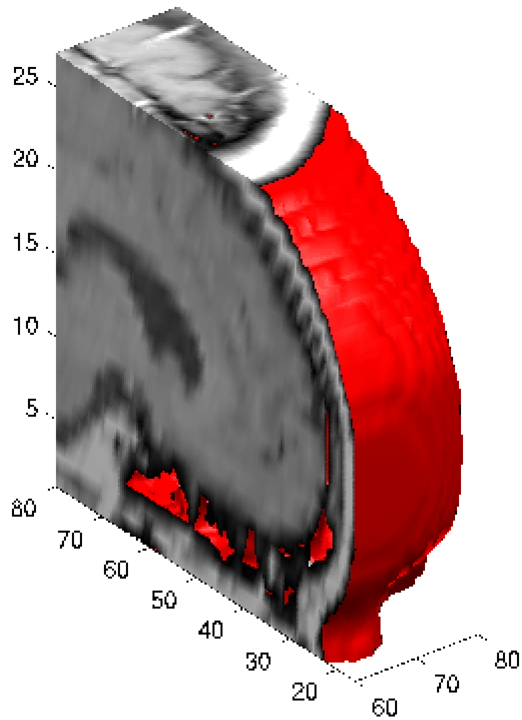
Examples

This example uses a data set that is a collection of MRI slices of a human skull. The data is processed in a variety of ways:

- The 4-D array is squeezed (`squeeze`) into three dimensions and then a subset of the data is extracted (`subvolume`).
- The outline of the skull is an isosurface generated as a patch (`p1`) whose vertex normals are recalculated to improve the appearance when lighting is applied (`patch`, `isosurface`, `isonormals`).
- A second patch (`p2`) with interpolated face color draws the end caps (`FaceColor`, `isocaps`).
- The view of the object is set (`view`, `axis`, `daspect`).

- A 100-element grayscale colormap provides coloring for the end caps (colormap).
- Adding lights to the right and left of the camera illuminates the object (camlight, lighting).

```
load mri
D = squeeze(D);
[x,y,z,D] = subvolume(D,[60,80,nan,80,nan,nan]);
p1 = patch(isosurface(x,y,z,D, 5),...
     'FaceColor','red','EdgeColor','none');
isonormals(x,y,z,D,p1);
p2 = patch(isocaps(x,y,z,D, 5),...
     'FaceColor','interp','EdgeColor','none');
view(3); axis tight; daspect([1,1,.4])
colormap(gray(100))
camlight right; camlight left; lighting gouraud
```



See Also

isocaps, isonormals, isosurface, reducepatch, reducevolume, smooth3

"Volume Visualization" on page 1-106 for related functions

Purpose Sum of array elements

Syntax

```
B = sum(A)
B = sum(A,dim)
B = sum(..., 'double')
B = sum(..., dim,'double')
B = sum(..., 'native')
B = sum(..., dim,'native')
```

Description

`B = sum(A)` returns sums along different dimensions of an array.

If `A` is a vector, `sum(A)` returns the sum of the elements.

If `A` is a matrix, `sum(A)` treats the columns of `A` as vectors, returning a row vector of the sums of each column.

If `A` is a multidimensional array, `sum(A)` treats the values along the first non-singleton dimension as vectors, returning an array of row vectors.

`B = sum(A,dim)` sums along the dimension of `A` specified by scalar `dim`. The `dim` input is an integer value from 1 to `N`, where `N` is the number of dimensions in `A`. Set `dim` to 1 to compute the sum of each column, 2 to sum rows, etc.

`B = sum(..., 'double')` and `B = sum(..., dim,'double')` performs additions in double-precision and return an answer of type `double`, even if `A` has data type `single` or an integer data type. This is the default for integer data types.

`B = sum(..., 'native')` and `B = sum(..., dim,'native')` performs additions in the native data type of `A` and return an answer of the same data type. This is the default for `single` and `double`.

Remarks

`sum(diag(X))` is the `trace` of `X`.

Examples

The magic square of order 3 is

```
M = magic(3)
M =
```

```
      8     1     6
      3     5     7
      4     9     2
```

This is called a magic square because the sums of the elements in each column are the same.

```
sum(M) =
      15     15     15
```

as are the sums of the elements in each row, obtained either by transposing or using the`dim` argument.

- Transposing

  ```
  sum(M') =
        15     15     15
  ```

- Using the `dim` argument

  ```
  sum(M,1)

  ans =

       15     15     15
  ```

Nondouble Data Type Support

This section describes the support of sum for data types other than `double`.

Data Type single

You can apply `sum` to an array of type `single` and MATLAB software returns an answer of type `single`. For example,

```
sum(single([2 5 8]))

ans =

      15
```

```
class(ans)

ans =

single
```

Integer Data Types

When you apply `sum` to any of the following integer data types, MATLAB software returns an answer of type double:

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

For example,

```
sum(single([2 5 8]});
class(ans)

ans =

single
```

If you want MATLAB to perform additions on an integer data type in the same integer type as the input, use the syntax

```
sum(int8([2 5 8], 'native');
class(ans)

ans =

int8
```

See Also

`accumarray`, `cumsum`, `diff`, `isfloat`, `prod`

Purpose

Sum of `timeseries` data

Syntax

```
ts_sm = sum(ts)
ts_sm = sum(ts,'PropertyName1',PropertyValue1,...)
```

Description

`ts_sm = sum(ts)` returns the sum of the time-series data. When `ts.Data` is a vector, ts_sm is the sum of `ts.Data` values. When `ts.Data` is a matrix, ts_sm is a row vector containing the sum of each column of `ts.Data` (when `IsTimeFirst` is `true` and the first dimension of `ts` is aligned with time). For the N-dimensional `ts.Data` array, `sum` always operates along the first nonsingleton dimension of `ts.Data`.

`ts_sm = sum(ts,'PropertyName1',PropertyValue1,...)` specifies the following optional input arguments:

- `'MissingData'` property has two possible values, `'remove'` (default) or `'interpolate'`, indicating how to treat missing data during the calculation.
- `'Quality'` values are specified by a vector of integers, indicating which quality codes represent missing samples (for vector data) or missing observations (for data arrays with two or more dimensions).
- `'Weighting'` property has two possible values, `'none'` (default) or `'time'`.
  When you specify `'time'`, larger time values correspond to larger weights.

Examples

1. Load a 24-by-3 data array.

   ```
   load count.dat
   ```

2. Create a `timeseries` object with 24 time values.

   ```
   count_ts = timeseries(count,1:24,'Name','CountPerSecond')
   ```

3. Calculate the sum of each data column for this `timeseries` object.

   ```
   sum(count_ts)
   ```

```
ans =

        768        1117        1574
```

The sum is calculated independently for each data column in the `timeseries` object.

See Also

`iqr (timeseries)`, `mean (timeseries)`, `median (timeseries)`, `std (timeseries)`, `var (timeseries)`, `timeseries`

Purpose

Establish superior class relationship

Syntax

```
superiorto('class1', 'class2', ...)
```

Description

The `superiorto` function establishes a precedence that determines which object method is called.

Note You can use this function only from a constructor that calls the `class` function to create an object, which was the only way to create MATLAB classes prior to MATLAB Version 7.6.

See *Object-Oriented Programming* for information on the creating MATLAB classes.

`superiorto('class1', 'class2', ...)` invoked within a class constructor method, establishes that class as having precedence over the classes in the function argument list for purposes of function dispatching (i.e., which method or function is called in any given situation).

Remarks

Suppose `a` is an object of class `'class_a'`, `b` is an object of class `'class_b'` and `c` is an object of class `'class_c'`. Also suppose the constructor method for `class_c.m` contains the statement `superiorto('class_a')`. Then, either of the following two statements:

```
e = fun(a,c);
e = fun(c,a);
```

invokes `class_c/fun`.

If a function is called with two objects having an unspecified relationship, the two objects are considered to have equal precedence, and the left-most object's method is called. So `fun(b,c)` calls `class_b/fun`, while `fun(c,b)` calls `class_c/fun`.

See Also

`inferiorto`

support

Purpose

Open MathWorks Technical Support Web page

Syntax

```
support
```

Description

`support` opens the MathWorks Technical Support Web page, `http://www.mathworks.com/support`, in the MATLAB Web browser.

This Web page contains resources including

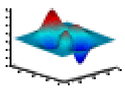
- A search engine, including an option for solutions to common problems
- Information about installation and licensing
- A patch archive for bug fixes you can download
- Other useful resources

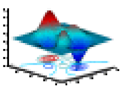
See Also

`doc`, `web`

Purpose

3-D shaded surface plot





GUI Alternatives

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

Syntax

```
surf(Z)
surf(Z,C)
surf(X,Y,Z)
surf(X,Y,Z,C)
surf(...,'PropertyName',PropertyValue)
surf(axes_handles,...)
surfc(...)
h = surf(...)
hsurface = surf('v6',...)
hsurface = surfc('v6',...)
```

Description

Use `surf` and `surfc` to view mathematical functions over a rectangular region. `surf` and `surfc` create colored parametric surfaces specified by `X`, `Y`, and `Z`, with color specified by `Z` or `C`.

`surf(Z)` creates a a three-dimensional shaded surface from the *z* components in matrix `Z`, using `x = 1:n` and `y = 1:m`, where `[m,n] = size(Z)`. The height, `Z`, is a single-valued function defined over a geometrically rectangular grid. `Z` specifies the color data as well as surface height, so color is proportional to surface height.

`surf(Z,C)` plots the height of `Z`, a single-valued function defined over a geometrically rectangular grid, and uses matrix C, assumed to be the same size as Z, to color the surface.

`surf(X,Y,Z)` creates a shaded surface using `Z` for the color data as well as surface height. `X` and `Y` are vectors or matrices defining the `x` and `y` components of a surface. If `X` and `Y` are vectors, `length(X) = n` and `length(Y) = m`, where `[m,n] = size(Z)`. In this case, the vertices of the surface faces are *(X(j), Y(i), Z(i,j))* triples. To create X and Y matrices for arbitrary domains, use the `meshgrid` function.

`surf(X,Y,Z,C)` creates a shaded surface, with color defined by `C`. MATLAB performs a linear transformation on this data to obtain colors from the current colormap.

`surf(...,'PropertyName',PropertyValue)` specifies surface `properties` along with the data.

`surf(axes_handles,...)` and surfc(axes_handles,...) plot into the axes with handle `axes_handle` instead of the current axes (`gca`).

`surfc(...)` draws a contour plot beneath the surface.

`h = surf(...)` and h = surfc(...) return a handle to a surfaceplot graphics object.

Backward-Compatible Version

`hsurface = surf('v6',...)` and `hsurface = surfc('v6',...)` return the handles of surface objects instead of surfaceplot objects for compatibility with MATLAB 6.5 and earlier.

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

See Plot Objects and Backward Compatibility for more information.

Remarks

`surf` and `surfc` do not accept complex inputs.

Algorithm

Abstractly, a parametric surface is parameterized by two independent variables, `i` and `j`, which vary continuously over a rectangle; for example, $1 \le i \le m$ and $1 \le j \le n$. The three functions `x(i,j)`, `y(i,j)`, and `z(i,j)` specify the surface. When `i` and `j` are integer values, they define a rectangular grid with integer grid points. The functions `x(i,j)`, `y(i,j)`, and `z(i,j)` become three `m`-by-`n` matrices, `X`, `Y`, and `Z`. Surface color is a fourth function, `c(i,j)`, denoted by matrix `C`.

Each point in the rectangular grid can be thought of as connected to its four nearest neighbors.

```
        i-1,j
          |
i,j-1 - i,j - i,j+1
          |
        i+1,j
```

This underlying rectangular grid induces four-sided patches on the surface. To express this another way, `[X(:) Y(:) Z(:)]` returns a list of triples specifying points in 3-space. Each interior point is connected to the four neighbors inherited from the matrix indexing. Points on the edge of the surface have three neighbors; the four points at the corners of the grid have only two neighbors. This defines a mesh of quadrilaterals or a *quad-mesh*.

Surface color can be specified in two different ways: at the vertices or at the centers of each patch. In this general setting, the surface need not be a single-valued function of `x` and `y`. Moreover, the four-sided surface patches need not be planar. For example, you can have surfaces defined in polar, cylindrical, and spherical coordinate systems.

The `shading` function sets the shading. If the shading is `interp`, `C` must be the same size as `X`, `Y`, and `Z`; it specifies the colors at the vertices. The color within a surface patch is a bilinear function of the local coordinates. If the shading is `faceted` (the default) or `flat`, `C(i,j)` specifies the constant color in the surface patch:

```
  (i,j)    -    (i,j+1)
    |    C(i,j)   |
 (i+1,j)   -   (i+1,j+1)
```

In this case, C can be the same size as X, Y, and Z and its last row and column are ignored. Alternatively, its row and column dimensions can be one less than those of X, Y, and Z.

The surf and surfc functions specify the viewpoint using view(3).

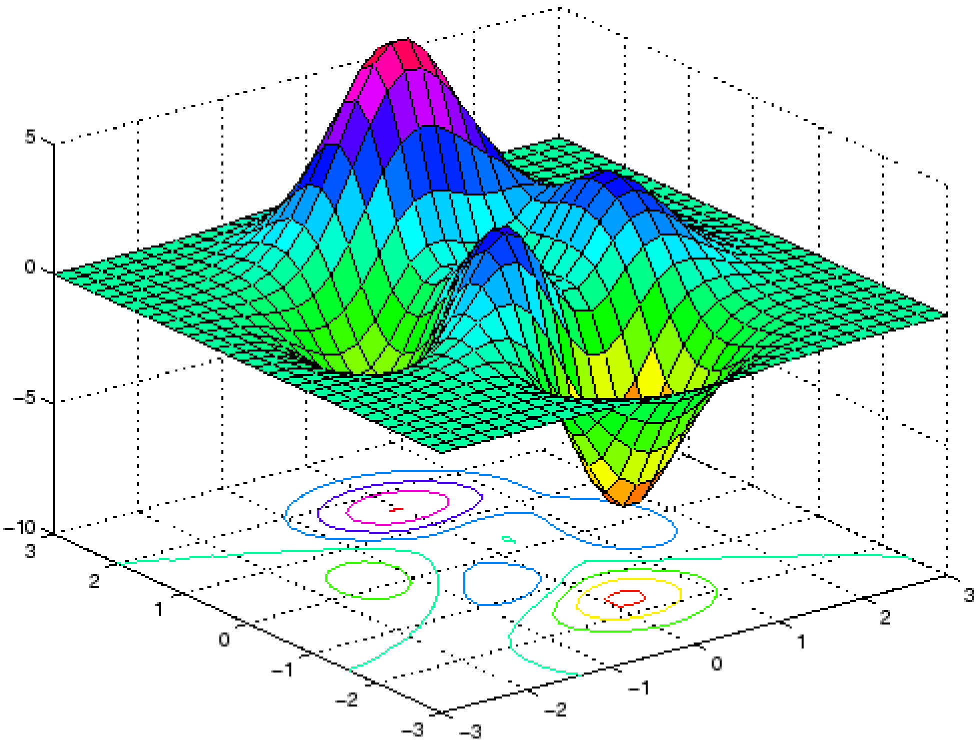
The range of X, Y, and Z or the current setting of the axes XLimMode, YLimMode, and ZLimMode properties (also set by the axis function) determines the axis labels.

The range of C or the current setting of the axes CLim and CLimMode properties (also set by the caxis function) determines the color scaling. The scaled color values are used as indices into the current colormap.

Examples

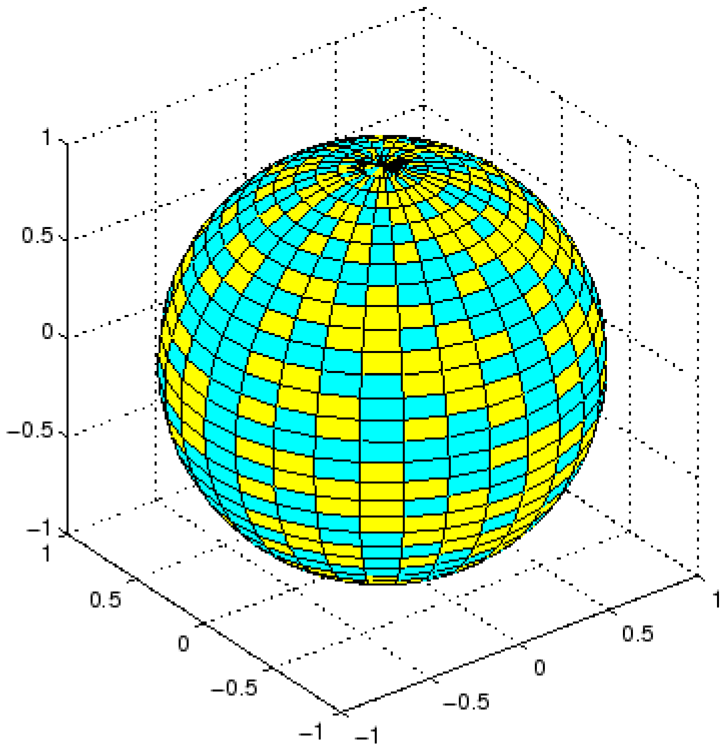
Display a surfaceplot and contour plot of the peaks surface.

```
[X,Y,Z] = peaks(30);
surfc(X,Y,Z)
colormap hsv
axis([-3 3 -3 3 -10 5])
```



Color a sphere with the pattern of +1s and -1s in a Hadamard matrix.

```
k = 5;
n = 2^k-1;
[x,y,z] = sphere(n);
c = hadamard(2^k);
surf(x,y,z,c);
colormap([1  1  0; 0  1  1])
axis equal
```



See Also

`axis`, `caxis`, `colormap`, `contour`, `delaunay`, `imagesc`, `mesh`, `meshgrid`, `pcolor`, `shading`, `trisurf`, `view`

Properties for surfaceplot graphics objects

"Surface and Mesh Creation" on page 1-101 for related functions

"Creating Mesh and Surface Plots" in the Getting Started with MATLAB documentation for background and examples.

Representing a Matrix as a Surface in the MATLAB 3-D Visualization documentation for further examples

Coloring Mesh and Surface Plots for information about how to control the coloring of surfaces

Purpose

Convert surface data to patch data

Syntax

```
fvc = surf2patch(Z)
fvc = surf2patch(Z,C)
fvc = surf2patch(X,Y,Z)
fvc = surf2patch(X,Y,Z,C)
fvc = surf2patch(...,'triangles')
[f,v,c] = surf2patch(...)
```

Description

`fvc = surf2patch(h)`

converts the geometry and color data from the `surface` object identified by the handle `h` into patch format and returns the face, vertex, and color data in the struct `fvc`. You can pass this struct directly to the `patch` command.

`fvc = surf2patch(Z)` calculates the patch data from the surface's `ZData` matrix `Z`.

`fvc = surf2patch(Z,C)` calculates the patch data from the surface's `ZData` and `CData` matrices `Z` and `C`.

`fvc = surf2patch(X,Y,Z)` calculates the patch data from the surface's `XData`, `YData`, and `ZData` matrices `X`, `Y`, and `Z`.

`fvc = surf2patch(X,Y,Z,C)` calculates the patch data from the surface's `XData`, `YData`, `ZData`, and `CData` matrices `X`, `Y`, `Z`, and `C`.

`fvc = surf2patch(...,'triangles')` creates triangular faces instead of the quadrilaterals that compose surfaces.

`[f,v,c] = surf2patch(...)` returns the face, vertex, and color data in the three arrays `f`, `v`, and `c` instead of a struct.

Examples

The first example uses the `sphere` command to generate the `XData`, `YData`, and `ZData` of a surface, which is then converted to a patch. Note that the `ZData` (`z`) is passed to `surf2patch` as both the third and fourth arguments — the third argument is the `ZData` and the fourth argument is taken as the `CData`. This is because the `patch` command does not automatically use the *z*-coordinate data for the color data, as does the `surface` command.

Also, because `patch` is a low-level command, you must set the `view` to 3-D and `shading` to `faceted` to produce the same results produced by the `surf` command.

```
[x y z] = sphere;
patch(surf2patch(x,y,z,z));
shading faceted; view(3)
```

In the second example `surf2patch` calculates face, vertex, and color data from a surface whose handle has been passed as an argument.

```
s = surf(peaks);
pause
patch(surf2patch(s));
delete(s)
shading faceted; view(3)
```

See Also

`patch`, `reducepatch`, `shrinkfaces`, `surface`, `surf`

"Volume Visualization" on page 1-106 for related functions

Purpose

Create surface object

Syntax

```
surface(Z)
surface(Z,C)
surface(X,Y,Z)
surface(X,Y,Z,C)
surface(x,y,Z)
surface(...'PropertyName',PropertyValue,...)
h = surface(...)
```

Description

`surface` is the low-level function for creating surface graphics objects. Surfaces are plots of matrix data created using the row and column indices of each element as the *x*- and *y*-coordinates and the value of each element as the *z*-coordinate.

`surface(Z)` plots the surface specified by the matrix `Z`. Here, `Z` is a single-valued function, defined over a geometrically rectangular grid.

`surface(Z,C)` plots the surface specified by `Z` and colors it according to the data in `C` (see "Examples").

`surface(X,Y,Z)` uses `C = Z`, so color is proportional to surface height above the *x*-*y* plane.

`surface(X,Y,Z,C)` plots the parametric surface specified by `X`, `Y`, and `Z`, with color specified by `C`.

`surface(x,y,Z)`, surface(x,y,Z,C) replaces the first two matrix arguments with vectors and must have `length(x) = n` and `length(y) = m` where `[m,n] = size(Z)`. In this case, the vertices of the surface facets are the triples `(x(j),y(i),Z(i,j))`. Note that `x` corresponds to the columns of `Z` and `y` corresponds to the rows of `Z`. For a complete discussion of parametric surfaces, see the `surf` function.

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

`h = surface(...)` returns a handle to the created surface object.

Remarks

surface does not respect the settings of the figure and axes NextPlot properties. It simply adds the surface object to the current axes.

If you do not specify separate color data (C), MATLAB uses the matrix (Z) to determine the coloring of the surface. In this case, color is proportional to values of Z. You can specify a separate matrix to color the surface independently of the data defining the area of the surface.

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

surface provides convenience forms that allow you to omit the property name for the XData, YData, ZData, and CData properties. For example,

```
surface('XData',X,'YData',Y,'ZData',Z,'CData',C)
```

is equivalent to

```
surface(X,Y,Z,C)
```

When you specify only a single matrix input argument,

```
surface(Z)
```

MATLAB assigns the data properties as if you specified

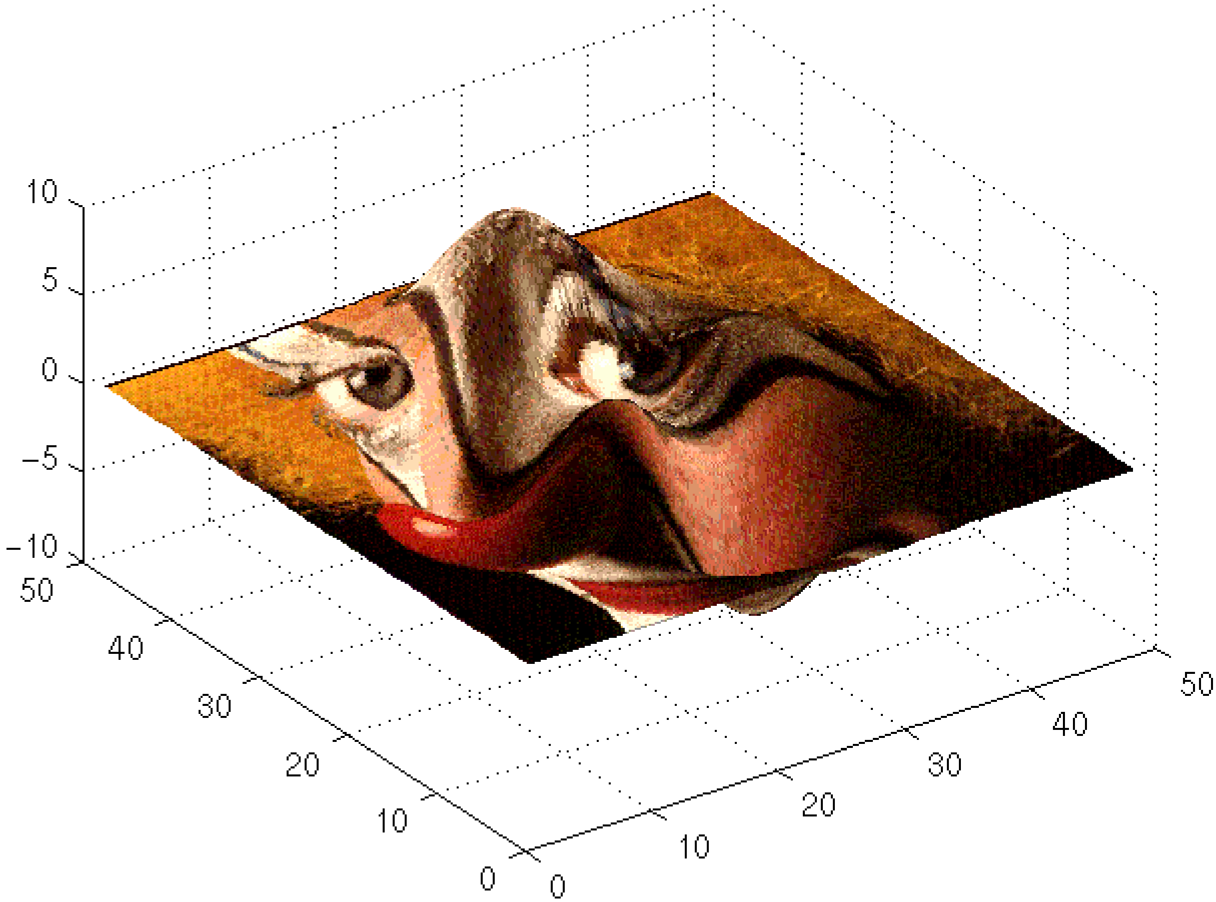
```
surface('XData',[1:size(Z,2)],...
    'YData',[1:size(Z,1)],...
    'ZData',Z,...
    'CData',Z)
```

The axis, caxis, colormap, hold, shading, and view commands set graphics properties that affect surfaces. You can also set and query surface property values after creating them using the set and get commands.

Example

This example creates a surface using the peaks M-file to generate the data, and colors it using the clown image. The ZData is a 49-by-49 element matrix, while the CData is a 200-by-320 matrix. You must set the surface's FaceColor to texturemap to use ZData and CData of different dimensions.

```
load clown
surface(peaks,flipud(X),...
   'FaceColor','texturemap',...
   'EdgeColor','none',...
   'CDataMapping','direct')
colormap(map)
view(-35,45)
```



Note the use of the `surface(Z,C)` convenience form combined with property name/property value pairs.

Since the clown data (`X`) is typically viewed with the `image` command, which MATLAB normally displays with `'ij'` axis numbering and `direct CDataMapping`, this example reverses the data in the vertical direction using `flipud` and sets the `CDataMapping` property to `direct`.

Setting Default Properties

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

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

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

See Also

`ColorSpec`, `patch`, `pcolor`, `surf`

Representing a Matrix as a Surface for examples

"Surface and Mesh Creation" on page 1-101 and "Object Creation" on page 1-98 for related functions

`Surface Properties` for property descriptions

Surface Properties

Purpose

Surface properties

Modifying Properties

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

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

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

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

Surface Property Descriptions

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

`AlphaData`
m-by-n matrix of `double` or `uint8`

The transparency data. A matrix of non-NaN values specifying the transparency of each face or vertex of the object. The `AlphaData` can be of class double or uint8.

MATLAB software determines the transparency in one of three ways:

- Using the elements of `AlphaData` as transparency values (`AlphaDataMapping` set to `none`)
- Using the elements of `AlphaData` as indices into the current alphamap (`AlphaDataMapping` set to `direct`)
- Scaling the elements of `AlphaData` to range between the minimum and maximum values of the axes `ALim` property (`AlphaDataMapping` set to `scaled`, the default)

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

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

- `none` — The transparency values of `AlphaData` are between 0 and 1 or are clamped to this range (the default).
- `scaled` — Transform the `AlphaData` to span the portion of the alphamap indicated by the axes `ALim` property, linearly mapping data values to alpha values.
- `direct` — use the `AlphaData` as indices directly into the alphamap. When not scaled, the data are usually integer values ranging from `1` to `length(alphamap)`. MATLAB maps values less than `1` to the first alpha value in the alphamap, and values greater than `length(alphamap)` to the last alpha value in the alphamap. Values with a decimal portion are fixed to the nearest lower integer. If `AlphaData` is an array of `uint8` integers, then the indexing begins at `0` (i.e., MATLAB maps a value of `0` to the first alpha value in the alphamap).

`AmbientStrength`
scalar >= 0 and <= 1

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

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

Annotation
hg.Annotation object Read Only

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

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

Once you have obtained the hg.LegendEntry object, you can set its IconDisplayStyle property to control whether the surface object is displayed in a figure legend:

IconDisplayStyle Value	Purpose
on	Represent this surface object in a legend (default)
off	Do not include this surface object in a legend
children	Same as on because surface objects do not have children

Setting the IconDisplayStyle property

These commands set the IconDisplayStyle of a graphics object with handle hobj to off:

```
hAnnotation = get(hobj,'Annotation');
hLegendEntry = get(hAnnotation','LegendInformation');
set(hLegendEntry,'IconDisplayStyle','off')
```

Using the IconDisplayStyle property

See "Controlling Legends" for more information and examples.

`BackFaceLighting`

`unlit | lit | reverselit`

Face lighting control. This property determines how faces are lit when their vertex normals point away from the camera.

- `unlit` — Face is not lit.
- `lit` — Face is lit in normal way.
- `reverselit` — Face is lit as if the vertex pointed towards the camera.

This property is useful for discriminating between the internal and external surfaces of an object. See "Back Face Lighting" for an example.

`BeingDeleted`

`on | {off}` Read Only

This object is being deleted. The `BeingDeleted` property provides a mechanism that you can use to determine if objects are in the process of being deleted. MATLAB sets the `BeingDeleted` property to `on` when the object's delete function callback is called (see the `DeleteFcn` property). It remains set to `on` while the delete function executes, after which the object no longer exists.

For example, an object's delete function might call other functions that act on a number of different objects. These functions may not need to perform actions on objects that are going to be deleted, and therefore, can check the object's `BeingDeleted` property before acting.

`BusyAction`

`cancel | {queue}`

Callback routine interruption. The `BusyAction` property enables you to control how MATLAB handles events that potentially interrupt executing callback routines. If there is a callback routine executing, callback routines invoked subsequently always attempt to interrupt it. If the Interruptible property of the object whose callback is executing is set to on (the default), then interruption occurs at the next point where the event queue is processed. If the Interruptible property is off, the BusyAction property (of the object owning the executing callback) determines how MATLAB handles the event. The choices are

- cancel — Discard the event that attempted to execute a second callback routine.
- queue — Queue the event that attempted to execute a second callback routine until the current callback finishes.

ButtonDownFcn

function handle, cell array containing function handle and additional arguments, or string (not recommended)

Button press callback function. A callback function that executes whenever you press a mouse button while the pointer is over the surface object.

See the figure's SelectionType property to determine if modifier keys were also pressed.

Set this property to a function handle that references the callback. The function must define at least two input arguments (handle of object associated with the button down event and an event structure, which is empty for this property). For example, the following function takes different action depending on what type of selection was made:

```
function button_down(src,evnt)
% src - the object that is the source of the event
% evnt - empty for this property
   sel_typ = get(gcbf,'SelectionType')
   switch sel_typ
      case 'normal'
```

```
            disp('User clicked left-mouse button')
            set(src,'Selected','on')
         case 'extend'
            disp('User did a shift-click')
            set(src,'Selected','on')
         case 'alt'
            disp('User did a control-click')
            set(src,'Selected','on')
            set(src,'SelectionHighlight','off')
      end
   end
```

Suppose `h` is the handle of a surface object and that the `button_down` function is on your MATLAB path. The following statement assigns the function above to the `ButtonDownFcn`:

```
set(h,'ButtonDownFcn',@button_down)
```

See "Function Handle Callbacks" for information on how to use function handles to define the callback function.

`CData`

matrix (of type `double`)

Vertex colors. A matrix containing values that specify the color at every point in `ZData`.

Mapping CData to a Colormap

You can specify color as indexed values or true color. Indexed color data specifies a single value for each vertex. These values are either scaled to map linearly into the current colormap (see `caxis`) or interpreted directly as indices into the colormap, depending on the setting of the `CDataMapping` property.

CData as True Color

True color defines an RGB value for each vertex. If the coordinate data (XData, for example) are contained in *m*-by-*n* matrices, then CData must be an *m*-by-*n*-3 array. The first page contains the red components, the second the green components, and the third the blue components of the colors.

Texturemapping the Surface FaceColor

If you set the FaceColor property to texturemap, CData does not need to be the same size as ZData, but must be of type double or uint8. In this case, MATLAB maps CData to conform to the surface defined by ZData.

CDataMapping
{scaled} | direct

Direct or scaled color mapping. This property determines how MATLAB interprets indexed color data used to color the surface. (If you use true color specification for CData, this property has no effect.)

- scaled — Transform the color data to span the portion of the colormap indicated by the axes CLim property, linearly mapping data values to colors. See the caxis reference page for more information on this mapping.
- direct — Use the color data as indices directly into the colormap. The color data should then be integer values ranging from 1 to length(colormap). MATLAB maps values less than 1 to the first color in the colormap, and values greater than length(colormap) to the last color in the colormap. Values with a decimal portion are fixed to the nearest lower integer.

Children
matrix of handles

Always the empty matrix; surface objects have no children.

`Clipping`
`{on} | off`

Clipping to axes rectangle. When `Clipping` is `on`, MATLAB does not display any portion of the surface that is outside the axes rectangle.

`CreateFcn`
function handle, cell array containing function handle and additional arguments, or string (not recommended)

Callback function executed during object creation. This property defines a callback function that executes when MATLAB creates a surface object. You must define this property as a default value for surfaces or set the `CreateFcn` property during object creation.

For example, the following statement creates a surface (assuming `x`, `y`, `z`, and `c` are defined), and executes the function referenced by the function handle `@myCreateFcn`.

```
surface(x,y,z,c,'CreateFcn',@myCreateFcn)
```

MATLAB executes this routine after setting all surface properties. Setting this property on an existing surface object has no effect.

The handle of the object whose `CreateFcn` is being executed is passed by MATLAB as the first argument to the callback function and is also accessible through the root `CallbackObject` property, which you can query using `gcbo`.

See "Function Handle Callbacks" for information on how to use function handles to define the callback function.

`DeleteFcn`
function handle, cell array containing function handle and additional arguments, or string (not recommended)

Delete surface callback function. A callback function that executes when you delete the surface object (e.g., when you issue a `delete` command or clear the axes `cla` or figure `clf`). For example, the following function displays object property data before the object is deleted.

```
function delete_fcn(src,evnt)
% src - the object that is the source of the event
% evnt - empty for this property
   obj_tp = get(src,'Type');
   disp([obj_tp, ' object deleted'])
   disp('Its user data is:')
   disp(get(src,'UserData'))
end
```

MATLAB executes the function before deleting the object's properties so these values are available to the callback function. The function must define at least two input arguments (handle of object being deleted and an event structure, which is empty for this property)

The handle of the object whose `DeleteFcn` is being executed is passed by MATLAB as the first argument to the callback function and is also accessible through the root `CallbackObject` property, which you can query using `gcbo`.

See "Function Handle Callbacks" for information on how to use function handles to define the callback function.

`DiffuseStrength`

scalar >= 0 and <= 1

Intensity of diffuse light. This property sets the intensity of the diffuse component of the light falling on the surface. Diffuse light comes from light objects in the axes.

You can also set the intensity of the ambient and specular components of the light on the surface object. See the `AmbientStrength` and `SpecularStrength` properties.

`DisplayName`
string (default is empty string)

String used by legend for this surface object. The `legend` function uses the string defined by the `DisplayName` property to label this surface object in the legend.

- If you specify string arguments with the `legend` function, `DisplayName` is set to this surface object's corresponding string and that string is used for the legend.
- If `DisplayName` is empty, legend creates a string of the form, `['data' n]`, where *n* is the number assigned to the object based on its location in the list of legend entries. However, `legend` does not set `DisplayName` to this string.
- If you edit the string directly in an existing legend, `DisplayName` is set to the edited string.
- If you specify a string for the `DisplayName` property and create the legend using the figure toolbar, then MATLAB uses the string defined by `DisplayName`.
- To add programmatically a legend that uses the `DisplayName` string, call `legend` with the `toggle` or `show` option.

See "Controlling Legends" for more examples.

`EdgeAlpha`
`{scalar = 1} | flat | interp`

Transparency of the surface edges. This property can be any of the following:

- `scalar` — A single non-Nan scalar value between `0` and `1` that controls the transparency of all the edges of the object.

1 (the default) means fully opaque and 0 means completely transparent.

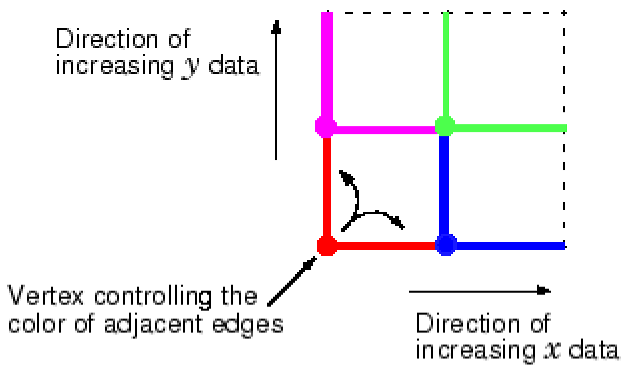
- flat — The alpha data (AlphaData) value for the first vertex of the face determines the transparency of the edges.
- interp — Linear interpolation of the alpha data (AlphaData) values at each vertex determines the transparency of the edge.

Note that you must specify AlphaData as a matrix equal in size to ZData to use flat or interp EdgeAlpha.

EdgeColor
{ColorSpec} | none | flat | interp

Color of the surface edge. This property determines how MATLAB colors the edges of the individual faces that make up the surface:

- ColorSpec — A three-element RGB vector or one of the MATLAB predefined names, specifying a single color for edges. The default EdgeColor is black. See ColorSpec for more information on specifying color.
- none — Edges are not drawn.
- flat — The CData value of the first vertex for a face determines the color of each edge.



- `interp` — Linear interpolation of the `CData` values at the face vertices determines the edge color.

`EdgeLighting`
`{none} | flat | gouraud | phong`

Algorithm used for lighting calculations. This property selects the algorithm used to calculate the effect of `light` objects on surface edges. Choices are

- `none` — Lights do not affect the edges of this object.
- `flat` — The effect of light objects is uniform across each edge of the surface.
- `gouraud` — The effect of light objects is calculated at the vertices and then linearly interpolated across the edge lines.
- `phong` — The effect of light objects is determined by interpolating the vertex normals across each edge line and calculating the reflectance at each pixel. Phong lighting generally produces better results than Gouraud lighting, but takes longer to render.

`EraseMode`
`{normal} | none | xor | background`

Erase mode. This property controls the technique MATLAB uses to draw and erase surface objects. Alternative erase modes are useful for creating animated sequences, where control of the way individual objects are redrawn is necessary to improve performance and obtain the desired effect.

- `normal` — Redraw the affected region of the display, performing the three-dimensional analysis necessary to ensure that all objects are rendered correctly. This mode produces the most accurate picture, but is the slowest. The other modes are faster, but do not perform a complete redraw and are therefore less accurate.

- `none` — Do not erase the surface when it is moved or destroyed. While the object is still visible on the screen after erasing with `EraseMode none`, you cannot print it because MATLAB stores no information about its former location.
- `xor` — Draw and erase the surface by performing an exclusive OR (XOR) with each pixel index of the screen behind it. Erasing the surface does not damage the color of the objects behind it. However, surface color depends on the color of the screen behind it and is correctly colored only when over the axes background `Color`, or the figure background `Color` if the axes `Color` is set to `none`.
- `background` — Erase the surface by drawing it in the axes background `Color`, or the figure background `Color` if the axes `Color` is set to `none`. This damages objects that are behind the erased object, but surface objects are always properly colored.

  Printing with Nonnormal Erase Modes

MATLAB always prints figures as if the `EraseMode` of all objects is `normal`. This means graphics objects created with `EraseMode` set to `none`, `xor`, or `background` can look different on screen than on paper. On screen, MATLAB may mathematically combine layers of colors (e.g., performing an XOR of a pixel color with that of the pixel behind it) and ignore three-dimensional sorting to obtain greater rendering speed. However, these techniques are not applied to the printed output.

You can use the MATLAB `getframe` command or other screen capture application to create an image of a figure containing nonnormal mode objects.

`FaceAlpha`

`{scalar = 1} | flat | interp | texturemap`

Transparency of the surface faces. This property can be any of the following:

- `scalar` — A single non-NaN scalar value between `0` and `1` that controls the transparency of all the faces of the object. `1` (the default) means fully opaque and `0` means completely transparent (invisible).
- `flat` — The values of the alpha data (`AlphaData`) determine the transparency for each face. The alpha data at the first vertex determine the transparency of the entire face.
- `interp` — Bilinear interpolation of the alpha data (`AlphaData`) at each vertex determines the transparency of each face.
- `texturemap` — Use transparency for the texture map.

Note that you must specify `AlphaData` as a matrix equal in size to `ZData` to use `flat` or `interp` `FaceAlpha`.

`FaceColor`
`ColorSpec | none | {flat} | interp | texturemap`

Color of the surface face. This property can be any of the following:

- `ColorSpec` — A three-element RGB vector or one of the MATLAB predefined names, specifying a single color for faces. See `ColorSpec` for more information on specifying color.
- `none` — Do not draw faces. Note that edges are drawn independently of faces.
- `flat` — The values of `CData` determine the color for each face of the surface. The color data at the first vertex determine the color of the entire face.
- `interp` — Bilinear interpolation of the values at each vertex (the `CData`) determines the coloring of each face.
- `texturemap` — Texture map the `CData` to the surface. MATLAB transforms the color data so that it conforms to the surface. (See the texture mapping example.)

`FaceLighting`
`{none} | flat | gouraud | phong`

Algorithm used for lighting calculations. This property selects the algorithm used to calculate the effect of `light` objects on the surface. Choices are

- `none` — Lights do not affect the faces of this object.
- `flat` — The effect of light objects is uniform across the faces of the surface. Select this choice to view faceted objects.
- `gouraud` — The effect of light objects is calculated at the vertices and then linearly interpolated across the faces. Select this choice to view curved surfaces.
- `phong` — The effect of light objects is determined by interpolating the vertex normals across each face and calculating the reflectance at each pixel. Select this choice to view curved surfaces. Phong lighting generally produces better results than Gouraud lighting, but takes longer to render.

`HandleVisibility`

`{on} | callback | off`

Control access to object's handle by command-line users and GUIs. This property determines when an object's handle is visible in its parent's list of children. This property is useful for preventing command-line users from accidentally drawing into or deleting a figure that contains only user interface devices (such as a dialog box).

Handles are always visible when `HandleVisibility` is `on`.

Setting `HandleVisibility` to `callback` causes handles to be visible from within callback routines or functions invoked by callback routines, but not from within functions invoked from the command line. This provides a means to protect GUIs from command-line users, while allowing callback routines to have complete access to object handles.

Setting `HandleVisibility` to `off` makes handles invisible at all times. This might be necessary when a callback routine invokes a function that could potentially damage the GUI (such as evaluating a user-typed string), and so temporarily hides its own handles during the execution of that function.

When a handle is not visible in its parent's list of children, it cannot be returned by functions that obtain handles by searching the object hierarchy or querying handle properties. This includes `get`, `findobj`, `gca`, `gcf`, `gco`, `newplot`, `cla`, `clf`, and `close`.

When a handle's visibility is restricted using `callback` or `off`, the object's handle does not appear in its parent's `Children` property, figures do not appear in the root's `CurrentFigure` property, objects do not appear in the root's `CallbackObject` property or in the figure's `CurrentObject` property, and axes do not appear in their parent's `CurrentAxes` property.

You can set the root `ShowHiddenHandles` property to `on` to make all handles visible, regardless of their `HandleVisibility` settings (this does not affect the values of the `HandleVisibility` properties).

Handles that are hidden are still valid. If you know an object's handle, you can set and get its properties, and pass it to any function that operates on handles.

`HitTest`

`{on} | off`

Selectable by mouse click. `HitTest` determines if the surface can become the current object (as returned by the `gco` command and the figure `CurrentObject` property) as a result of a mouse click on the surface. If `HitTest` is `off`, clicking on the surface selects the object below it (which may be the axes containing it).

`Interruptible`

`{on} | off`

Callback routine interruption mode. The `Interruptible` property controls whether a surface callback routine can be interrupted by subsequently invoked callback routines. Only callback routines defined for the `ButtonDownFcn` are affected by the `Interruptible` property. MATLAB checks for events that can interrupt a callback routine only when it encounters a `drawnow`, `figure`, `getframe`, or `pause` command in the routine. See the `BusyAction` property for related information.

`LineStyle`

`{-} | -- | : | -. | none`

Edge line type. This property determines the line style used to draw surface edges. The available line styles are shown in this table.

Symbol	Line Style
	Solid line (default)
	Dashed line
`:`	Dotted line
`.`	Dash-dot line
`none`	No line

`LineWidth`

scalar

Edge line width. The width of the lines in points used to draw surface edges. The default width is 0.5 points (1 point = 1/72 inch).

`Marker`

marker symbol (see table)

Marker symbol. The `Marker` property specifies symbols that are displayed at vertices. You can set values for the `Marker` property independently from the `LineStyle` property.

You can specify these markers.

Marker Specifier	Description
+	Plus sign
o	Circle
*	Asterisk
.	Point
x	Cross
s	Square
d	Diamond
^	Upward-pointing triangle
v	Downward-pointing triangle
>	Right-pointing triangle
<	Left-pointing triangle
p	Five-pointed star (pentagram)
h	Six-pointed star (hexagram)
none	No marker (default)

MarkerEdgeColor

none | {auto} | flat | ColorSpec

Marker edge color. The color of the marker or the edge color for filled markers (circle, square, diamond, pentagram, hexagram, and the four triangles).

- none specifies no color, which makes nonfilled markers invisible.
- auto uses the same color as the EdgeColor property.
- flat uses the CData value of the vertex to determine the color of the maker edge.

- `ColorSpec` defines a single color to use for the edge (see `ColorSpec` for more information).

`MarkerFaceColor`
: `{none} | auto | flat | ColorSpec`

Marker face color. The fill color for markers that are closed shapes (circle, square, diamond, pentagram, hexagram, and the four triangles).

- `none` makes the interior of the marker transparent, allowing the background to show through.
- `auto` uses the axes `Color` for the marker face color.
- `flat` uses the `CData` value of the vertex to determine the color of the face.
- `ColorSpec` defines a single color to use for all markers on the surface (see `ColorSpec` for more information).

`MarkerSize`
: size in points

Marker size. A scalar specifying the marker size, in points. The default value for `MarkerSize` is 6 points (1 point = 1/72 inch). Note that MATLAB draws the point marker at 1/3 the specified marker size.

`MeshStyle`
: `{both} | row | column`

Row and column lines. This property specifies whether to draw all edge lines or just row or column edge lines.

- `both` draws edges for both rows and columns.
- `row` draws row edges only.
- `column` draws column edges only.

`NormalMode`
`{auto} | manual`

MATLAB generated or user-specified normal vectors. When this property is `auto`, MATLAB calculates vertex normals based on the coordinate data. If you specify your own vertex normals, MATLAB sets this property to `manual` and does not generate its own data. See also the `VertexNormals` property.

`Parent`
handle of axes, hggroup, or hgtransform

Parent of surface object. This property contains the handle of the surface object's parent. The parent of a surface object is the axes, hggroup, or hgtransform object that contains it.

See "Objects That Can Contain Other Objects" for more information on parenting graphics objects.

`Selected`
`on | {off}`

Is object selected? When this property is `on`, MATLAB displays a dashed bounding box around the surface if the `SelectionHighlight` property is also `on`. You can, for example, define the `ButtonDownFcn` to set this property, allowing users to select the object with the mouse.

`SelectionHighlight`
`{on} | off`

Objects are highlighted when selected. When the `Selected` property is `on`, MATLAB indicates the selected state by drawing a dashed bounding box around the surface. When `SelectionHighlight` is `off`, MATLAB does not draw the handles.

`SpecularColorReflectance`
scalar in the range 0 to 1

Color of specularly reflected light. When this property is 0, the color of the specularly reflected light depends on both the color of the object from which it reflects and the color of the light source. When set to 1, the color of the specularly reflected light depends only on the color or the light source (i.e., the light object `Color` property). The proportions vary linearly for values in between.

`SpecularExponent`
scalar >= 1

Harshness of specular reflection. This property controls the size of the specular spot. Most materials have exponents in the range of 5 to 20.

`SpecularStrength`
scalar >= 0 and <= 1

Intensity of specular light. This property sets the intensity of the specular component of the light falling on the surface. Specular light comes from light objects in the axes.

You can also set the intensity of the ambient and diffuse components of the light on the surface object. See the `AmbientStrength` and `DiffuseStrength` properties. Also see the `material` function.

`Tag`
string

User-specified object label. The `Tag` property provides a means to identify graphics objects with a user-specified label. This is particularly useful when you are constructing interactive graphics programs that would otherwise need to define object handles as global variables or pass them as arguments between callback routines. You can define `Tag` as any string.

`Type`
string (read only)

Class of the graphics object. The class of the graphics object. For surface objects, `Type` is always the string `'surface'`.

`UIContextMenu`
handle of a uicontextmenu object

Associate a context menu with the surface. Assign this property the handle of a uicontextmenu object created in the same figure as the surface. Use the `uicontextmenu` function to create the context menu. MATLAB displays the context menu whenever you right-click over the surface.

`UserData`
matrix

User-specified data. Any matrix you want to associate with the surface object. MATLAB does not use this data, but you can access it using the `set` and `get` commands.

`VertexNormals`
vector or matrix

Surface normal vectors. This property contains the vertex normals for the surface. MATLAB generates this data to perform lighting calculations. You can supply your own vertex normal data, even if it does not match the coordinate data. This can be useful to produce interesting lighting effects.

`Visible`
`{on} | off`

Surface object visibility. By default, all surfaces are visible. When set to `off`, the surface is not visible, but still exists, and you can query and set its properties.

`XData`
vector or matrix

X-coordinates. The *x*-position of the surface points. If you specify a row vector, `surface` replicates the row internally until it has the same number of columns as `ZData`.

`YData`
vector or matrix

Y-coordinates. The *y*-position of the surface points. If you specify a row vector, `surface` replicates the row internally until it has the same number of rows as `ZData`.

`ZData`
matrix

Z-coordinates. The *z*-position of the surfaceplot data points. See the Description section for more information.

Purpose

Define surfaceplot properties

Modifying Properties

You can set and query graphics object properties in two ways:

- The Property Editor is an interactive tool that enables you to see and change object property values.
- The `set` and `get` commands enable you to set and query the values of properties.

Note that you cannot define default properties for surfaceplot objects.

See Plot Objects for information on surfaceplot objects.

Surfaceplot Property Descriptions

This section lists property names along with the types of values each accepts. Curly braces { } enclose default values.

`AlphaData`

m-by-n matrix of `double` or `uint8`

The transparency data. A matrix of non-NaN values specifying the transparency of each face or vertex of the object. The `AlphaData` can be of class double or uint8.

MATLAB software determines the transparency in one of three ways:

- Using the elements of `AlphaData` as transparency values (`AlphaDataMapping` set to `none`)
- Using the elements of `AlphaData` as indices into the current alphamap (`AlphaDataMapping` set to `direct`)
- Scaling the elements of `AlphaData` to range between the minimum and maximum values of the axes `ALim` property (`AlphaDataMapping` set to `scaled`, the default)

`AlphaDataMapping`

`{none} | direct| scaled`

Transparency mapping method. This property determines how MATLAB interprets indexed alpha data. It can be any of the following:

- `none` — The transparency values of `AlphaData` are between 0 and 1 or are clamped to this range (the default).
- `scaled` — Transform the `AlphaData` to span the portion of the alphamap indicated by the axes `ALim` property, linearly mapping data values to alpha values.
- `direct` — Use the `AlphaData` as indices directly into the alphamap. When not scaled, the data are usually integer values ranging from `1` to `length(alphamap)`. MATLAB maps values less than `1` to the first alpha value in the alphamap, and values greater than `length(alphamap)` to the last alpha value in the alphamap. Values with a decimal portion are fixed to the nearest, lower integer. If `AlphaData` is an array of `uint8` integers, then the indexing begins at `0` (i.e., MATLAB maps a value of `0` to the first alpha value in the alphamap).

`AmbientStrength`
scalar >= 0 and <= 1

Strength of ambient light. This property sets the strength of the ambient light, which is a nondirectional light source that illuminates the entire scene. You must have at least one visible light object in the axes for the ambient light to be visible. The axes `AmbientLightColor` property sets the color of the ambient light, which is therefore the same on all objects in the axes.

You can also set the strength of the diffuse and specular contribution of `light` objects. See the surfaceplot `DiffuseStrength` and `SpecularStrength` properties.

`Annotation`
`hg.Annotation` object Read Only

Control the display of surfaceplot objects in legends. The `Annotation` property enables you to specify whether this surfaceplot object is represented in a figure legend.

Querying the `Annotation` property returns the handle of an `hg.Annotation` object. The `hg.Annotation` object has a property called `LegendInformation`, which contains an `hg.LegendEntry` object.

Once you have obtained the `hg.LegendEntry` object, you can set its `IconDisplayStyle` property to control whether the surfaceplot object is displayed in a figure legend:

IconDisplayStyle Value	Purpose
`on`	Represent this surfaceplot object in a legend (default)
`off`	Do not include this surfaceplot object in a legend
`children`	Same as `on` because surfaceplot objects do not have children

Setting the `IconDisplayStyle` property

These commands set the `IconDisplayStyle` of a graphics object with handle `hobj` to `off`:

```
hAnnotation = get(hobj,'Annotation');
hLegendEntry = get(hAnnotation','LegendInformation');
set(hLegendEntry,'IconDisplayStyle','off')
```

Using the `IconDisplayStyle` property

See "Controlling Legends" for more information and examples.

`BackFaceLighting`
`unlit | lit | reverselit`

Face lighting control. This property determines how faces are lit when their vertex normals point away from the camera.

- `unlit` — Face is not lit.
- `lit` — Face is lit in normal way.
- `reverselit` — Face is lit as if the vertex pointed towards the camera.

This property is useful for discriminating between the internal and external surfaces of an object. See Back Face Lighting for an example.

`BeingDeleted`
`on | {off}` Read Only

This object is being deleted. The `BeingDeleted` property provides a mechanism that you can use to determine if objects are in the process of being deleted. MATLAB sets the `BeingDeleted` property to `on` when the object's delete function callback is called (see the `DeleteFcn` property). It remains set to `on` while the delete function executes, after which the object no longer exists.

For example, an object's delete function might call other functions that act on a number of different objects. These functions might not need to perform actions on objects if the objects are going to be deleted, and therefore, can check the object's `BeingDeleted` property before acting.

`BusyAction`
`cancel | {queue}`

Callback routine interruption. The `BusyAction` property enables you to control how MATLAB handles events that potentially interrupt executing callbacks. If there is a callback function executing, callbacks invoked subsequently always attempt to interrupt it.

If the `Interruptible` property of the object whose callback is executing is set to `on` (the default), then interruption occurs at the next point where the event queue is processed. If the `Interruptible` property is `off`, the `BusyAction` property (of the object owning the executing callback) determines how MATLAB handles the event. The choices are

- `cancel` — Discard the event that attempted to execute a second callback routine.
- `queue` — Queue the event that attempted to execute a second callback routine until the current callback finishes.

`ButtonDownFcn`

`cancel | {queue}`

Callback routine interruption. The `BusyAction` property enables you to control how MATLAB handles events that potentially interrupt executing callbacks. If there is a callback function executing, callbacks invoked subsequently always attempt to interrupt it.

If the `Interruptible` property of the object whose callback is executing is set to `on` (the default), then interruption occurs at the next point where the event queue is processed. If the `Interruptible` property is `off`, the `BusyAction` property (of the object owning the executing callback) determines how MATLAB handles the event. The choices are

- `cancel` — Discard the event that attempted to execute a second callback routine.
- `queue` — Queue the event that attempted to execute a second callback routine until the current callback finishes.

`CData`

matrix

Vertex colors. A matrix containing values that specify the color at every point in `ZData`. If you set the `FaceColor` property to `texturemap`, `CData` does not need to be the same size as `ZData`. In this case, MATLAB maps `CData` to conform to the surfaceplot defined by `ZData`.

You can specify color as indexed values or true color. Indexed color data specifies a single value for each vertex. These values are either scaled to map linearly into the current colormap (see `caxis`) or interpreted directly as indices into the colormap, depending on the setting of the `CDataMapping` property. Note that any non-texture data passed as an input argument must be of type double.

True color defines an RGB value for each vertex. If the coordinate data (`XData`, for example) are contained in *m*-by-*n* matrices, then `CData` must be an *m*-by-*n*-by-3 array. The first page contains the red components, the second the green components, and the third the blue components of the colors.

`CDataMapping`

`{scaled} | direct`

Direct or scaled color mapping. This property determines how MATLAB interprets indexed color data used to color the surfaceplot. (If you use true color specification for `CData`, this property has no effect.)

- `scaled` — Transform the color data to span the portion of the colormap indicated by the axes `CLim` property, linearly mapping data values to colors. See the `caxis` reference page for more information on this mapping.
- `direct` — Use the color data as indices directly into the colormap. The color data should then be integer values ranging

from 1 to `length(colormap)`. MATLAB maps values less than 1 to the first color in the colormap, and values greater than `length(colormap)` to the last color in the colormap. Values with a decimal portion are fixed to the nearest lower integer.

`CDataMode`

{auto} | manual

Use automatic or user-specified color data values. If you specify `CData`, MATLAB sets this property to `manual` and uses the `CData` values to color the surfaceplot.

If you set `CDataMode` to `auto` after having specified `CData`, MATLAB resets the color data of the surfaceplot to that defined by `ZData`, overwriting any previous values for `CData`.

`CDataSource`

string (MATLAB variable)

Link CData to MATLAB variable. Set this property to a MATLAB variable that is evaluated in the base workspace to generate the `CData`.

MATLAB reevaluates this property only when you set it. Therefore, a change to workspace variables appearing in an expression does not change `CData`.

You can use the `refreshdata` function to force an update of the object's data. `refreshdata` also enables you to specify that the data source variable be evaluated in the workspace of a function from which you call `refreshdata`.

See the `refreshdata` reference page for more information.

Note If you change one data source property to return data of a different dimension, you might cause the function to generate a warning and not render the graph until you have changed all data source properties to appropriate values.

`Children`

matrix of handles

Always the empty matrix; surfaceplot objects have no children.

`Clipping`

`{on} | off`

Clipping to axes rectangle. When `Clipping` is `on`, MATLAB does not display any portion of the surfaceplot that is outside the axes rectangle.

`CreateFcn`

string or function handle

Callback routine executed during object creation. This property defines a callback that executes when MATLAB creates an object. You must specify the callback during the creation of the object. For example,

```
area(y,'CreateFcn',@CallbackFcn)
```

where `@CallbackFcn` is a function handle that references the callback function.

MATLAB executes this routine after setting all other object properties. Setting this property on an existing object has no effect.

The handle of the object whose `CreateFcn` is being executed is accessible only through the root `CallbackObject` property, which you can query using `gcbo`.

See "Function Handle Callbacks" for information on how to use function handles to define the callback function.

`DeleteFcn`
string or function handle

Callback executed during object deletion. A callback that executes when this object is deleted (e.g., this might happen when you issue a `delete` command on the object, its parent axes, or the figure containing it). MATLAB executes the callback before destroying the object's properties so the callback routine can query these values.

The handle of the object whose `DeleteFcn` is being executed is accessible only through the root `CallbackObject` property, which can be queried using `gcbo`.

See "Function Handle Callbacks" for information on how to use function handles to define the callback function.

See the `BeingDeleted` property for related information.

`DiffuseStrength`
scalar >= 0 and <= 1

Intensity of diffuse light. This property sets the intensity of the diffuse component of the light falling on the surface. Diffuse light comes from light objects in the axes.

You can also set the intensity of the ambient and specular components of the light on the object. See the `AmbientStrength` and `SpecularStrength` properties.

DisplayName

string (default is empty string)

String used by legend for this surfaceplot object. The legend function uses the string defined by the DisplayName property to label this surfaceplot object in the legend.

- If you specify string arguments with the legend function, DisplayName is set to this surfaceplot object's corresponding string and that string is used for the legend.
- If DisplayName is empty, legend creates a string of the form, ['data' *n*], where *n* is the number assigned to the object based on its location in the list of legend entries. However, legend does not set DisplayName to this string.
- If you edit the string directly in an existing legend, DisplayName is set to the edited string.
- If you specify a string for the DisplayName property and create the legend using the figure toolbar, then MATLAB uses the string defined by DisplayName.
- To add programmatically a legend that uses the DisplayName string, call legend with the toggle or show option.

See "Controlling Legends" for more examples.

EdgeAlpha

{scalar = 1} | flat | interp

Transparency of the patch and surface edges. This property can be any of the following:

- scalar — A single non-Nan scalar value between 0 and 1 that controls the transparency of all the edges of the object. 1 (the default) means fully opaque and 0 means completely transparent.
- flat — The alpha data (AlphaData) value for the first vertex of the face determines the transparency of the edges.

- `interp` — Linear interpolation of the alpha data (`AlphaData`) values at each vertex determines the transparency of the edge.

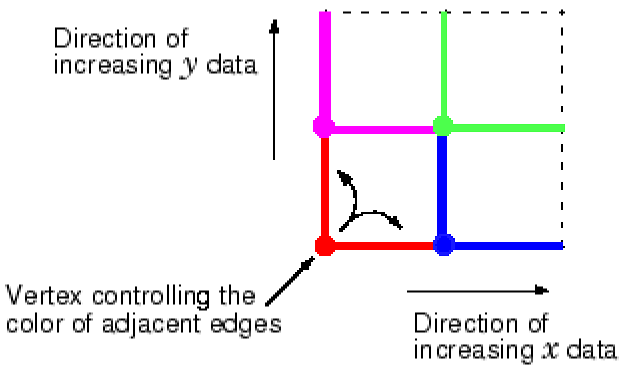
Note that you must specify `AlphaData` as a matrix equal in size to `ZData` to use `flat` or `interp` `EdgeAlpha`.

`EdgeColor`

`{ColorSpec} | none | flat | interp`

Color of the surfaceplot edge. This property determines how MATLAB colors the edges of the individual faces that make up the surface:

- `ColorSpec` — A three-element RGB vector or one of the MATLAB predefined names, specifying a single color for edges. The default `EdgeColor` is black. See `ColorSpec` for more information on specifying color.
- `none` — Edges are not drawn.
- `flat` — The `CData` value of the first vertex for a face determines the color of each edge.



- `interp` — Linear interpolation of the `CData` values at the face vertices determines the edge color.

`EdgeLighting`
`{none} | flat | gouraud | phong`

Algorithm used for lighting calculations. This property selects the algorithm used to calculate the effect of light objects on surfaceplot edges. Choices are

- `none` — Lights do not affect the edges of this object.
- `flat` — The effect of light objects is uniform across each edge of the surface.
- `gouraud` — The effect of light objects is calculated at the vertices and then linearly interpolated across the edge lines.
- `phong` — The effect of light objects is determined by interpolating the vertex normals across each edge line and calculating the reflectance at each pixel. Phong lighting generally produces better results than Gouraud lighting, but takes longer to render.

`EraseMode`
`{normal} | none | xor | background`

Erase mode. This property controls the technique MATLAB uses to draw and erase objects and their children. Alternative erase modes are useful for creating animated sequences, where control of the way individual objects are redrawn is necessary to improve performance and obtain the desired effect.

- `normal` — Redraw the affected region of the display, performing the three-dimensional analysis necessary to ensure that all objects are rendered correctly. This mode produces the most accurate picture, but is the slowest. The other modes are faster, but do not perform a complete redraw and are therefore less accurate.
- `none` — Do not erase objects when they are moved or destroyed. While the objects are still visible on the screen after erasing

with `EraseMode` `none`, you cannot print these objects because MATLAB stores no information about their former locations.

- `xor` — Draw and erase the object by performing an exclusive OR (XOR) with each pixel index of the screen behind it. Erasing the object does not damage the color of the objects behind it. However, the color of the erased object depends on the color of the screen behind it and it is correctly colored only when it is over the axes background color (or the figure background color if the axes `Color` property is set to `none`). That is, it isn't erased correctly if there are objects behind it.
- `background` — Erase the graphics objects by redrawing them in the axes background color, (or the figure background color if the axes `Color` property is set to `none`). This damages other graphics objects that are behind the erased object, but the erased object is always properly colored.

Printing with Nonnormal Erase Modes

MATLAB always prints figures as if the `EraseMode` of all objects is `normal`. This means graphics objects created with `EraseMode` set to `none`, `xor`, or `background` can look different on screen than on paper. On screen, MATLAB can mathematically combine layers of colors (e.g., performing an XOR on a pixel color with that of the pixel behind it) and ignore three-dimensional sorting to obtain greater rendering speed. However, these techniques are not applied to the printed output.

Set the axes background color with the axes `Color` property. Set the figure background color with the figure `Color` property.

You can use the MATLAB `getframe` command or other screen capture applications to create an image of a figure containing nonnormal mode objects.

`FaceAlpha`

`{scalar = 1} | flat | interp | texturemap`

Transparency of the surfaceplot faces. This property can be any of the following:

- `scalar` — A single non-NaN scalar value between `0` and `1` that controls the transparency of all the faces of the object. `1` (the default) means fully opaque and `0` means completely transparent (invisible).
- `flat` — The values of the alpha data (`AlphaData`) determine the transparency for each face. The alpha data at the first vertex determine the transparency of the entire face.
- `interp` — Bilinear interpolation of the alpha data (`AlphaData`) at each vertex determines the transparency of each face.
- `texturemap` — Use transparency for the texture map.

Note that you must specify `AlphaData` as a matrix equal in size to `ZData` to use `flat` or `interp` `FaceAlpha`.

`FaceColor`
`ColorSpec | none | {flat} | interp`

Color of the surfaceplot face. This property can be any of the following:

- `ColorSpec` — A three-element RGB vector or one of the MATLAB predefined names, specifying a single color for faces. See `ColorSpec` for more information on specifying color.
- `none` — Do not draw faces. Note that edges are drawn independently of faces.
- `flat` — The values of `CData` determine the color for each face of the surface. The color data at the first vertex determine the color of the entire face.
- `interp` — Bilinear interpolation of the values at each vertex (the `CData`) determines the coloring of each face.

- `texturemap` — Texture map the `Cdata` to the surface. MATLAB transforms the color data so that it conforms to the surface. (See the texture mapping example for `surface`.)

`FaceLighting`
`{none} | flat | gouraud | phong`

Algorithm used for lighting calculations. This property selects the algorithm used to calculate the effect of light objects on the surface. Choices are

- `none` — Lights do not affect the faces of this object.
- `flat` — The effect of light objects is uniform across the faces of the surface. Select this choice to view faceted objects.
- `gouraud` — The effect of light objects is calculated at the vertices and then linearly interpolated across the faces. Select this choice to view curved surfaces.
- `phong` — The effect of light objects is determined by interpolating the vertex normals across each face and calculating the reflectance at each pixel. Select this choice to view curved surfaces. Phong lighting generally produces better results than Gouraud lighting, but takes longer to render.

`HandleVisibility`
`{on} | callback | off`

Control access to object's handle by command-line users and GUIs. This property determines when an object's handle is visible in its parent's list of children. `HandleVisibility` is useful for preventing command-line users from accidentally accessing objects that you need to protect for some reason.

- `on` — Handles are always visible when `HandleVisibility` is `on`.
- `callback` — Setting `HandleVisibility` to `callback` causes handles to be visible from within callback routines or functions invoked by callback routines, but not from within functions invoked from the command line. This provides a means to

protect GUIs from command-line users, while allowing callback routines to have access to object handles.

- off — Setting HandleVisibility to off makes handles invisible at all times. This might be necessary when a callback invokes a function that might potentially damage the GUI (such as evaluating a user-typed string) and so temporarily hides its own handles during the execution of that function.

Functions Affected by Handle Visibility

When a handle is not visible in its parent's list of children, it cannot be returned by functions that obtain handles by searching the object hierarchy or querying handle properties. This includes get, findobj, gca, gcf, gco, newplot, cla, clf, and close.

Properties Affected by Handle Visibility

When a handle's visibility is restricted using callback or off, the object's handle does not appear in its parent's Children property, figures do not appear in the root's CurrentFigure property, objects do not appear in the root's CallbackObject property or in the figure's CurrentObject property, and axes do not appear in their parent's CurrentAxes property.

Overriding Handle Visibility

You can set the root ShowHiddenHandles property to on to make all handles visible regardless of their HandleVisibility settings (this does not affect the values of the HandleVisibility properties). See also findall.

Handle Validity

Handles that are hidden are still valid. If you know an object's handle, you can set and get its properties and pass it to any function that operates on handles.

Note If you change one data source property to a variable that contains data of a different dimension, you might cause the function to generate a warning and not render the graph until you have changed all data source properties to appropriate values.

`HitTest`
    `{on} | off`

Selectable by mouse click. `HitTest` determines whether this object can become the current object (as returned by the `gco` command and the figure `CurrentObject` property) as a result of a mouse click on the objects that compose the area graph. If `HitTest` is `off`, clicking this object selects the object below it (which is usually the axes containing it).

`Interruptible`
    `{on} | off`

Callback routine interruption mode. The `Interruptible` property controls whether an object's callback can be interrupted by callbacks invoked subsequently.

Only callbacks defined for the `ButtonDownFcn` property are affected by the `Interruptible` property. MATLAB checks for events that can interrupt a callback only when it encounters a `drawnow`, `figure`, `getframe`, or `pause` command in the routine. See the `BusyAction` property for related information.

Setting `Interruptible` to `on` allows any graphics object's callback to interrupt callback routines originating from a bar property. Note that MATLAB does not save the state of variables or the display (e.g., the handle returned by the `gca` or `gcf` command) when an interruption occurs.

`LineStyle`
    `{-} | — | : | -. | none`

Line style. This property specifies the line style of the object. Available line styles are shown in the following table.

Specifier String	Line Style
`-`	Solid line (default)
`--`	Dashed line
`:`	Dotted line
`-.`	Dash-dot line
`none`	No line

You can use `LineStyle` `none` when you want to place a marker at each point but do not want the points connected with a line (see the `Marker` property).

`LineWidth`
scalar

The width of linear objects and edges of filled areas. Specify this value in points (1 point = $^1/_{72}$ inch). The default `LineWidth` is 0.5 points.

`Marker`
character (see table)

Marker symbol. The `Marker` property specifies the type of markers that are displayed at plot vertices. You can set values for the `Marker` property independently from the `LineStyle` property. Supported markers include those shown in the following table.

Marker Specifier	Description
`+`	Plus sign
`o`	Circle

Marker Specifier	Description
*	Asterisk
.	Point
x	Cross
s	Square
d	Diamond
^	Upward-pointing triangle
v	Downward-pointing triangle
>	Right-pointing triangle
<	Left-pointing triangle
p	Five-pointed star (pentagram)
h	Six-pointed star (hexagram)
none	No marker (default)

`MarkerEdgeColor`
`none | {auto} | flat | ColorSpec`

Marker edge color. The color of the marker or the edge color for filled markers (circle, square, diamond, pentagram, hexagram, and the four triangles).

- `none` specifies no color, which makes nonfilled markers invisible.
- `auto` uses the same color as the `EdgeColor` property.
- `flat` uses the `CData` value of the vertex to determine the color of the maker edge.
- `ColorSpec` defines a single color to use for the edge (see `ColorSpec` for more information).

`MarkerFaceColor`
`{none} | auto | flat | ColorSpec`

Marker face color. The fill color for markers that are closed shapes (circle, square, diamond, pentagram, hexagram, and the four triangles).

- `none` makes the interior of the marker transparent, allowing the background to show through.
- `auto` uses the axes `Color` for the marker face color.
- `flat` uses the `CData` value of the vertex to determine the color of the face.
- `ColorSpec` defines a single color to use for all markers on the surfaceplot (see `ColorSpec` for more information).

`MarkerSize`
size in points

Marker size. A scalar specifying the size of the marker in points. The default value for `MarkerSize` is 6 points (1 point = 1/72 inch). Note that MATLAB draws the point marker (specified by the `'.'` symbol) at one-third the specified size.

`MeshStyle`
`{both} | row | column`

Row and column lines. This property specifies whether to draw all edge lines or just row or column edge lines.

- `both` draws edges for both rows and columns.
- `row` draws row edges only.
- `column` draws column edges only.

`NormalMode`
`{auto} | manual`

MATLAB generated or user-specified normal vectors. When this property is `auto`, MATLAB calculates vertex normals based on the coordinate data. If you specify your own vertex normals, MATLAB sets this property to `manual` and does not generate its own data. See also the `VertexNormals` property.

`Parent`
handle of parent axes, hggroup, or hgtransform

Parent of this object. This property contains the handle of the object's parent. The parent is normally the axes, hggroup, or hgtransform object that contains the object.

See "Objects That Can Contain Other Objects" for more information on parenting graphics objects.

`Selected`
`on | {off}`

Is object selected? When you set this property to `on`, MATLAB displays selection "handles" at the corners and midpoints if the `SelectionHighlight` property is also `on` (the default). You can, for example, define the `ButtonDownFcn` callback to set this property to `on`, thereby indicating that this particular object is selected. This property is also set to `on` when an object is manually selected in plot edit mode.

`SelectionHighlight`
`{on} | off`

Objects are highlighted when selected. When the `Selected` property is `on`, MATLAB indicates the selected state by drawing four edge handles and four corner handles. When `SelectionHighlight` is `off`, MATLAB does not draw the handles except when in plot edit mode and objects are selected manually.

`SpecularColorReflectance`
scalar in the range 0 to 1

Color of specularly reflected light. When this property is 0, the color of the specularly reflected light depends on both the color of the object from which it reflects and the color of the light source.

When set to 1, the color of the specularly reflected light depends only on the color or the light source (i.e., the light object `Color` property). The proportions vary linearly for values in between.

`SpecularExponent`
scalar >= 1

Harshness of specular reflection. This property controls the size of the specular spot. Most materials have exponents in the range of 5 to 20.

`SpecularStrength`
scalar >= 0 and <= 1

Intensity of specular light. This property sets the intensity of the specular component of the light falling on the surface. Specular light comes from light objects in the axes.

You can also set the intensity of the ambient and diffuse components of the light on the surfaceplot object. See the `AmbientStrength` and `DiffuseStrength` properties. Also see the `material` function.

`Tag`
string

User-specified object label. The `Tag` property provides a means to identify graphics objects with a user-specified label. This is particularly useful when you are constructing interactive graphics programs that would otherwise need to define object handles as global variables or pass them as arguments between callbacks. You can define `Tag` as any string.

For example, you might create an areaseries object and set the `Tag` property.

```
t = area(Y,'Tag','area1')
```

When you want to access objects of a given type, you can use `findobj` to find the object's handle. The following statement changes the `FaceColor` property of the object whose `Tag` is `area1`.

```
set(findobj('Tag','area1'),'FaceColor','red')
```

`Type`
string (read only)

Class of the graphics object. The class of the graphics object. For surfaceplot objects, `Type` is always the string `'surface'`.

`UIContextMenu`
handle of a uicontextmenu object

Associate a context menu with this object. Assign this property the handle of a uicontextmenu object created in the object's parent figure. Use the `uicontextmenu` function to create the context menu. MATLAB displays the context menu whenever you right-click over the object.

`UserData`
array

User-specified data. This property can be any data you want to associate with this object (including cell arrays and structures). The object does not set values for this property, but you can access it using the `set` and `get` functions.

`VertexNormals`
vector or matrix

Surfaceplot normal vectors. This property contains the vertex normals for the surfaceplot. MATLAB generates this data to perform lighting calculations. You can supply your own vertex normal data, even if it does not match the coordinate data. This can be useful to produce interesting lighting effects.

`Visible`
`{on} | off`

Visibility of this object and its children. By default, a new object's visibility is `on`. This means all children of the object are visible unless the child object's `Visible` property is set to `off`. Setting an object's `Visible` property to `off` prevents the object from being displayed. However, the object still exists and you can set and query its properties.

`XData`
vector or matrix

X-coordinates. The *x*-position of the surfaceplot data points. If you specify a row vector, MATLAB replicates the row internally until it has the same number of columns as `ZData`.

`XDataMode`
{auto} | manual

Use automatic or user-specified x-axis values. If you specify `XData` (by setting the `XData` property or specifying the `x` input argument), MATLAB sets this property to `manual` and uses the specified values to label the *x*-axis.

If you set `XDataMode` to `auto` after having specified `XData`, MATLAB resets the *x*-axis ticks to `1:size(YData,1)` or to the column indices of the `ZData`, overwriting any previous values for `XData`.

`XDataSource`
string (MATLAB variable)

Link `XData` to MATLAB variable. Set this property to a MATLAB variable that is evaluated in the base workspace to generate the `XData`.

MATLAB reevaluates this property only when you set it. Therefore, a change to workspace variables appearing in an expression does not change `XData`.

You can use the `refreshdata` function to force an update of the object's data. `refreshdata` also enables you to specify that the data source variable be evaluated in the workspace of a function from which you call `refreshdata`.

See the `refreshdata` reference page for more information.

Note If you change one data source property to a variable that contains data of a different dimension, you might cause the function to generate a warning and not render the graph until you have changed all data source properties to appropriate values.

`YData`

vector or matrix

Y-coordinates. The *y*-position of the surfaceplot data points. If you specify a row vector, MATLAB replicates the row internally until it has the same number of rows as `ZData`.

`YDataMode`

{auto} | manual

Use automatic or user-specified x-axis values. If you specify `XData`, MATLAB sets this property to `manual`.

If you set `YDataMode` to `auto` after having specified `YData`, MATLAB resets the *y*-axis ticks and *y*-tick labels to the row indices of the `ZData`, overwriting any previous values for `YData`.

`YDataSource`

string (MATLAB variable)

Link `YData` *to MATLAB variable.* Set this property to a MATLAB variable that is evaluated in the base workspace to generate the `YData`.

MATLAB reevaluates this property only when you set it. Therefore, a change to workspace variables appearing in an expression does not change `YData`.

You can use the `refreshdata` function to force an update of the object's data. `refreshdata` also enables you to specify that the data source variable be evaluated in the workspace of a function from which you call `refreshdata`.

See the `refreshdata` reference page for more information.

Note If you change one data source property to a variable that contains data of a different dimension, you might cause the function to generate a warning and not render the graph until you have changed all data source properties to appropriate values.

`ZData`

matrix

Z-coordinates. The *z*-position of the surfaceplot data points. See the Description section for more information.

`ZDataSource`

string (MATLAB variable)

Link `ZData` *to MATLAB variable.* Set this property to a MATLAB variable that is evaluated in the base workspace to generate the `ZData`.

MATLAB reevaluates this property only when you set it. Therefore, a change to workspace variables appearing in an expression does not change `ZData`.

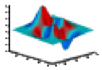
You can use the `refreshdata` function to force an update of the object's data. `refreshdata` also enables you to specify that the data source variable be evaluated in the workspace of a function from which you call `refreshdata`.

See the `refreshdata` reference page for more information.

Note If you change one data source property to a variable that contains data of a different dimension, you might cause the function to generate a warning and not render the graph until you have changed all data source properties to appropriate values.

Purpose

Surface plot with colormap-based lighting



GUI Alternatives

To graph selected variables, use the Plot Selector in the Workspace Browser, or use the Figure Palette Plot Catalog. Manipulate graphs in *plot edit* mode with the Property Editor. For details, see Plotting Tools — Interactive Plotting in the MATLAB Graphics documentation and Creating Graphics from the Workspace Browser in the MATLAB Desktop Tools documentation.

Syntax

```
surfl(Z)
surfl(...,'light')
surfl(...,s)
surfl(X,Y,Z,s,k)
h = surfl(...)
```

Description

The `surfl` function displays a shaded surface based on a combination of ambient, diffuse, and specular lighting models.

`surfl(Z)` and surfl(X,Y,Z) create three-dimensional shaded surfaces using the default direction for the light source and the default lighting coefficients for the shading model. `X`, `Y`, and `Z` are vectors or matrices that define the x, y, and z components of a surface.

`surfl(...,'light')` produces a colored, lighted surface using a MATLAB light object. This produces results different from the default lighting method, `surfl(...,'cdata')`, which changes the color data for the surface to be the reflectance of the surface.

`surfl(...,s)` specifies the direction of the light source. `s` is a two- or three-element vector that specifies the direction from a surface to a light source. `s = [sx sy sz]` or `s = [azimuth elevation]`. The default `s` is 45° counterclockwise from the current view direction.

`surfl(X,Y,Z,s,k)` specifies the reflectance constant. `k` is a four-element vector defining the relative contributions of ambient light, diffuse reflection, specular reflection, and the specular shine coefficient. k = [ka kd ks shine] and defaults to [.55,.6,.4,10].

h = surfl(...) returns a handle to a surface graphics object.

Remarks

surfl does not accept complex inputs.

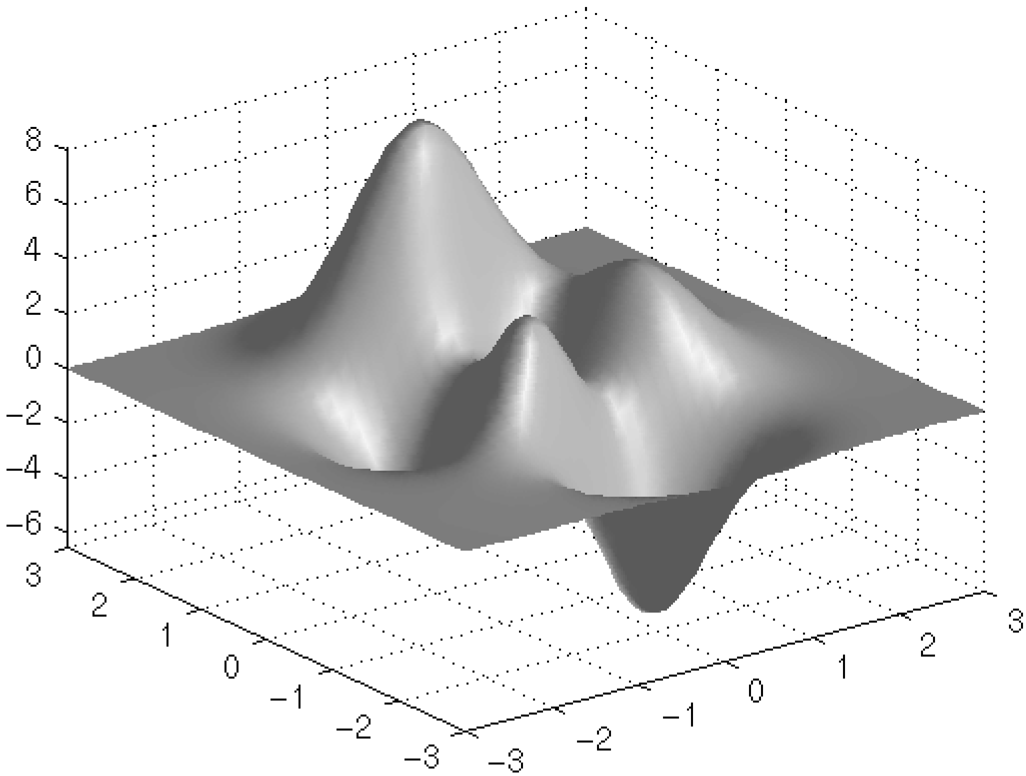
For smoother color transitions, use colormaps that have linear intensity variations (e.g., gray, copper, bone, pink).

The ordering of points in the X, Y, and Z matrices defines the inside and outside of parametric surfaces. If you want the opposite side of the surface to reflect the light source, use surfl(X',Y',Z'). Because of the way surface normal vectors are computed, surfl requires matrices that are at least 3-by-3.

Examples

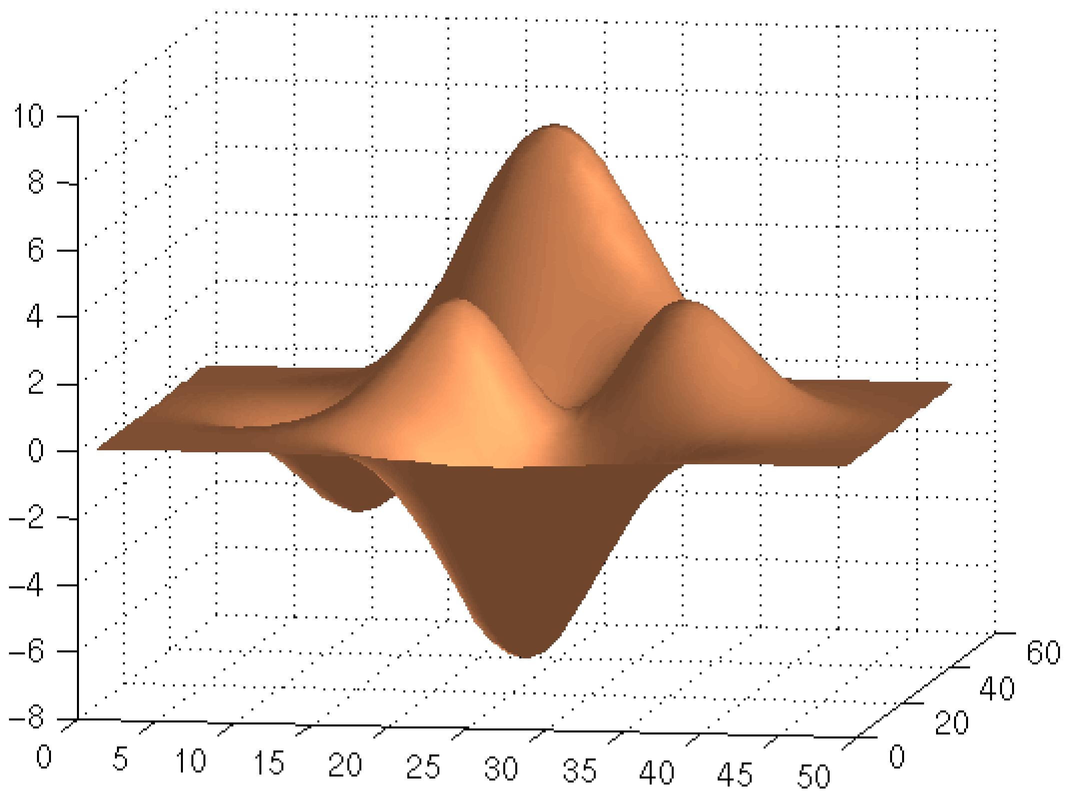
View peaks using colormap-based lighting.

```
[x,y] = meshgrid(-3:1/8:3);
z = peaks(x,y);
surfl(x,y,z);
shading interp
colormap(gray);
axis([-3  3  -3  3  -8  8])
```



To plot a lighted surface from a view direction other than the default,

```
view([10 10])
grid on
hold on
surfl(peaks)
shading interp
colormap copper
hold off
```



See Also

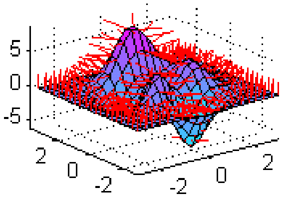
`colormap`, `shading`, `light`

"Surface and Mesh Creation" on page 1-101 for functions related to surfaces

"Lighting" on page 1-105 for functions related to lighting

Purpose

Compute and display 3-D surface normals



Syntax

```
surfnorm(Z)
surfnorm(X,Y,Z)
[Nx,Ny,Nz] = surfnorm(...)
```

Description

The `surfnorm` function computes surface normals for the surface defined by `X`, `Y`, and `Z`. The surface normals are unnormalized and valid at each vertex. Normals are not shown for surface elements that face away from the viewer.

`surfnorm(Z)` and `surfnorm(X,Y,Z)` plot a surface and its surface normals. `Z` is a matrix that defines the *z* component of the surface. `X` and `Y` are vectors or matrices that define the *x* and *y* components of the surface.

`[Nx,Ny,Nz] = surfnorm(...)` returns the components of the three-dimensional surface normals for the surface.

Remarks

`surfnorm` does not accept complex inputs.

The direction of the normals is reversed by calling `surfnorm` with transposed arguments:

```
surfnorm(X',Y',Z')
```

`surfl` uses `surfnorm` to compute surface normals when calculating the reflectance of a surface.

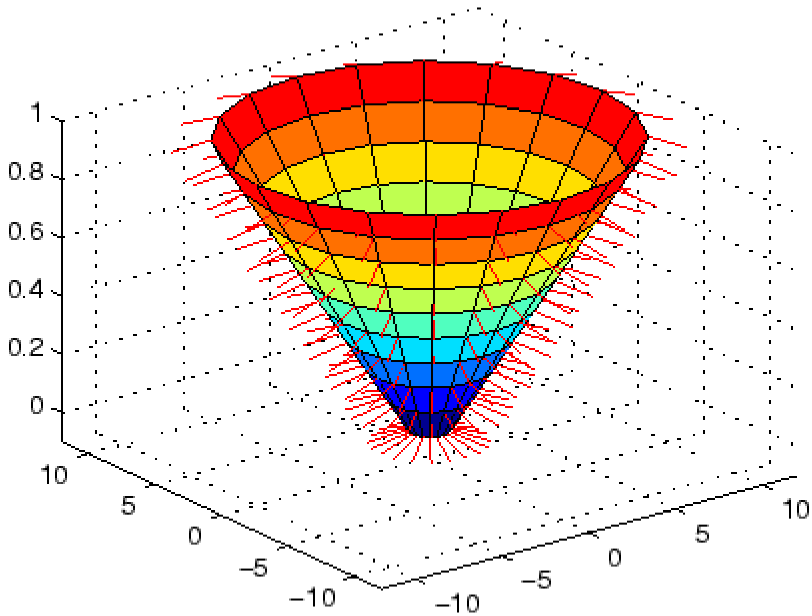
Algorithm

The surface normals are based on a bicubic fit of the data in X, Y, and Z. For each vertex, diagonal vectors are computed and crossed to form the normal.

Examples

Plot the normal vectors for a truncated cone.

```
[x,y,z] = cylinder(1:10);
surfnorm(x,y,z)
axis([-12 12 -12 12 -0.1 1])
```



See Also

surf, quiver3

“Colormaps” on page 1-103 for related functions

Purpose

Singular value decomposition

Syntax

```
s = svd(X)
[U,S,V] = svd(X)
[U,S,V] = svd(X,0)
[U,S,V] = svd(X,'econ')
```

Description

The `svd` command computes the matrix singular value decomposition.

`s = svd(X)` returns a vector of singular values.

`[U,S,V] = svd(X)` produces a diagonal matrix `S` of the same dimension as `X`, with nonnegative diagonal elements in decreasing order, and unitary matrices `U` and `V` so that `X = U*S*V'`.

`[U,S,V] = svd(X,0)` produces the "economy size" decomposition. If `X` is m-by-n with m > n, then `svd` computes only the first `n` columns of `U` and `S` is n-by-n.

`[U,S,V] = svd(X,'econ')` also produces the "economy size" decomposition. If `X` is m-by-n with m >= n, it is equivalent to `svd(X,0)`. For m < n, only the first m columns of `V` are computed and `S` is m-by-m.

Examples

For the matrix

```
X =
     1     2
     3     4
     5     6
     7     8
```

the statement

```
[U,S,V] = svd(X)
```

produces

```
U =
   -0.1525   -0.8226   -0.3945   -0.3800
```

```
    -0.3499   -0.4214    0.2428    0.8007
    -0.5474   -0.0201    0.6979   -0.4614
    -0.7448    0.3812   -0.5462    0.0407

S =
     14.2691         0
           0    0.6268
           0         0
           0         0

V =
    -0.6414    0.7672
    -0.7672   -0.6414
```

The economy size decomposition generated by

```
[U,S,V] = svd(X,0)
```

produces

```
U =
    -0.1525   -0.8226
    -0.3499   -0.4214
    -0.5474   -0.0201
    -0.7448    0.3812
S =
    14.2691         0
          0    0.6268
V =
    -0.6414    0.7672
    -0.7672   -0.6414
```

Algorithm

`svd` uses the LAPACK routines listed in the following table to compute the singular value decomposition.

	Real	Complex
X double	DGESVD	ZGESVD
X single	SGESVD	CGESVD

Diagnostics

If the limit of 75 QR step iterations is exhausted while seeking a singular value, this message appears:

```
Solution will not converge.
```

References

[1] Anderson, E., Z. Bai, C. Bischof, S. Blackford, J. Demmel, J. Dongarra, J. Du Croz, A. Greenbaum, S. Hammarling, A. McKenney, and D. Sorensen, *LAPACK User's Guide* (`http://www.netlib.org/lapack/lug/lapack_lug.html`), Third Edition, SIAM, Philadelphia, 1999.

Purpose

Find singular values and vectors

Syntax

```
s = svds(A)
s = svds(A,k)
s = svds(A,k,sigma)
s = svds(A,k,'L')
s = svds(A,k,sigma,options)
[U,S,V] = svds(A,...)
[U,S,V,flag] = svds(A,...)
```

Description

`s = svds(A)` computes the six largest singular values and associated singular vectors of matrix `A`. If `A` is `m`-by-`n`, `svds(A)` manipulates eigenvalues and vectors returned by `eigs(B)`, where `B = [sparse(m,m) A; A' sparse(n,n)]`, to find a few singular values and vectors of `A`. The positive eigenvalues of the symmetric matrix `B` are the same as the singular values of `A`.

`s = svds(A,k)` computes the `k` largest singular values and associated singular vectors of matrix `A`.

`s = svds(A,k,sigma)` computes the `k` singular values closest to the scalar shift sigma. For example, `s = svds(A,k,0)` computes the `k` smallest singular values and associated singular vectors.

`s = svds(A,k,'L')` computes the `k` largest singular values (the default).

`s = svds(A,k,sigma,options)` sets some parameters (see `eigs`):

Option Structure Fields and Descriptions

Field name	Parameter	Default
`options.tol`	Convergence tolerance: `norm(AV-US,1)<=tol*norm(A,1)`	`1e-10`
`options.maxit`	Maximum number of iterations	`300`
`options.disp`	Number of values displayed each iteration	`0`

[U,S,V] = svds(A,...) returns three output arguments, and if A is m-by-n:

- U is m-by-k with orthonormal columns
- S is k-by-k diagonal
- V is n-by-k with orthonormal columns
- U*S*V' is the closest rank k approximation to A

[U,S,V,flag] = svds(A,...) returns a convergence flag. If eigs converged then norn(A*V-U*S,1) <= tol*norm(A,1) and flag is 0. If eigs did not converge, then flag is 1.

Note svds is best used to find a few singular values of a large, sparse matrix. To find all the singular values of such a matrix, svd(full(A)) will usually perform better than svds(A,min(size(A))).

Algorithm

svds(A,k) uses eigs to find the k largest magnitude eigenvalues and corresponding eigenvectors of B = [0 A; A' 0].

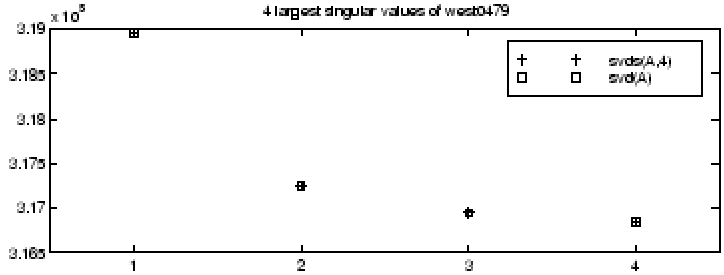
svds(A,k,0) uses eigs to find the 2k smallest magnitude eigenvalues and corresponding eigenvectors of B = [0 A; A' 0], and then selects the k positive eigenvalues and their eigenvectors.

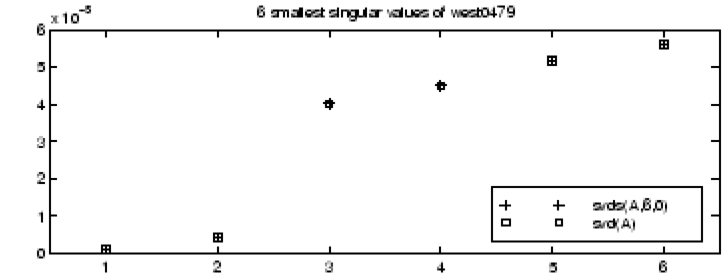
Example

west0479 is a real 479-by-479 sparse matrix. svd calculates all 479 singular values. svds picks out the largest and smallest singular values.

```
load west0479
s = svd(full(west0479))
sl = svds(west0479,4)
ss = svds(west0479,6,0)
```

These plots show some of the singular values of west0479 as computed by svd and svds.





The largest singular value of `west0479` can be computed a few different ways:

```
svds(west0479,1) =
 3.189517598808622e+05
max(svd(full(west0479))) =
 3.18951759880862e+05
norm(full(west0479)) =
 3.189517598808623e+05
```

and estimated:

```
normest(west0479) =
 3.189385666549991e+05
```

See Also

`svd`, `eigs`

Purpose

Swap byte ordering

Syntax

`Y = swapbytes(X)`

Description

`Y = swapbytes(X)` reverses the byte ordering of each element in array `X`, converting little-endian values to big-endian (and vice versa). The input array must contain all full, noncomplex, numeric elements.

Examples

Example 1

Reverse the byte order for a scalar 32-bit value, changing hexadecimal `12345678` to `78563412`:

```
A = uint32(hex2dec('12345678'));

B = dec2hex(swapbytes(A))
B =
    78563412
```

Example 2

Reverse the byte order for each element of a 1-by-4 matrix:

```
X = uint16([0 1 128 65535])
X =
      0      1    128  65535

Y = swapbytes(X);
Y =
      0    256  32768  65535
```

Examining the output in hexadecimal notation shows the byte swapping:

```
format hex

X, Y
X =
   0000   0001   0080   ffff
```

```
Y =
   0000   0100   8000   ffff
```

Example 3

Create a three-dimensional array A of 16-bit integers and then swap the bytes of each element:

```
format hex

A = uint16(magic(3) * 150);
A(:,:,2) = A * 40;

A
A(:,:,1) =
   04b0   0096   0384
   01c2   02ee   041a
   0258   0546   012c
A(:,:,2) =
   bb80   1770   8ca0
   4650   7530   a410
   5dc0   d2f0   2ee0

swapbytes(A)
ans(:,:,1) =
   b004   9600   8403
   c201   ee02   1a04
   5802   4605   2c01
ans(:,:,2) =
   80bb   7017   a08c
   5046   3075   10a4
   c05d   f0d2   e02e
```

See Also

typecast

Purpose

Switch among several cases, based on expression

Syntax

```
switch switch_expr
 case case_expr
    statement, ..., statement
  case {case_expr1, case_expr2, case_expr3, ...}
    statement, ..., statement
  otherwise
    statement, ..., statement
end
```

Discussion

The `switch` statement syntax is a means of conditionally executing code. In particular, `switch` executes one set of statements selected from an arbitrary number of alternatives. Each alternative is called a *`case`*, and consists of

- The `case` statement
- One or more case expressions
- One or more statements

In its basic syntax, `switch` executes the statements associated with the first case where *`switch_expr`* == *`case_expr`*. When the case expression is a cell array (as in the second case above), the *`case_expr`* matches if any of the elements of the cell array matches the switch expression. If no case expression matches the switch expression, then control passes to the `otherwise` case (if it exists). After the case is executed, program execution resumes with the statement after the `end`.

The *`switch_expr`* can be a scalar or a string. A scalar *`switch_expr`* matches a *`case_expr`* if *`switch_expr==case_expr`*. A string *`switch_expr`* matches a *`case_expr`* if `strcmp(`*`switch_expr,case_expr`*`)` returns logical `1` (`true`).

Note for C Programmers Unlike the C language `switch` construct, the MATLAB `switch` does not "fall through." That is, `switch` executes only the first matching case; subsequent matching `cases` do not execute. Therefore, `break` statements are not used.

Examples

To execute a certain block of code based on what the string, `method`, is set to,

```
method = 'Bilinear';

switch lower(method)
   case {'linear','bilinear'}
      disp('Method is linear')
   case 'cubic'
      disp('Method is cubic')
   case 'nearest'
      disp('Method is nearest')
   otherwise
      disp('Unknown method.')
end

Method is linear
```

See Also

`case`, `otherwise`, `end`, `if`, `else`, `elseif`, `while`

symamd

Purpose Symmetric approximate minimum degree permutation

Syntax

```
p = symamd(S)
p = symamd(S,knobs)
[p,stats] = symamd(...)
```

Description

`p = symamd(S)` for a symmetric positive definite matrix `S`, returns the permutation vector `p` such that `S(p,p)` tends to have a sparser Cholesky factor than `S`. To find the ordering for `S`, `symamd` constructs a matrix `M` such that `spones(M'*M) = spones (S)`, and then computes `p = colamd(M)`. The `symamd` function may also work well for symmetric indefinite matrices.

`S` must be square; only the strictly lower triangular part is referenced.

`p = symamd(S,knobs)` where `knobs` is a scalar. If `S` is `n`-by-`n`, rows and columns with more than `knobs*n` entries are removed prior to ordering, and ordered last in the output permutation `p`. If the `knobs` parameter is not present, then `knobs = spparms('wh_frac')`.

`[p,stats] = symamd(...)` produces the optional vector `stats` that provides data about the ordering and the validity of the matrix `S`.

`stats(1)`	Number of dense or empty rows ignored by `symamd`
`stats(2)`	Number of dense or empty columns ignored by `symamd`
`stats(3)`	Number of garbage collections performed on the internal data structure used by `symamd` (roughly of size `8.4*nnz(tril(S,-1)) + 9n` 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 `symamd`. For this reason, `symamd` verifies that `S` is valid:

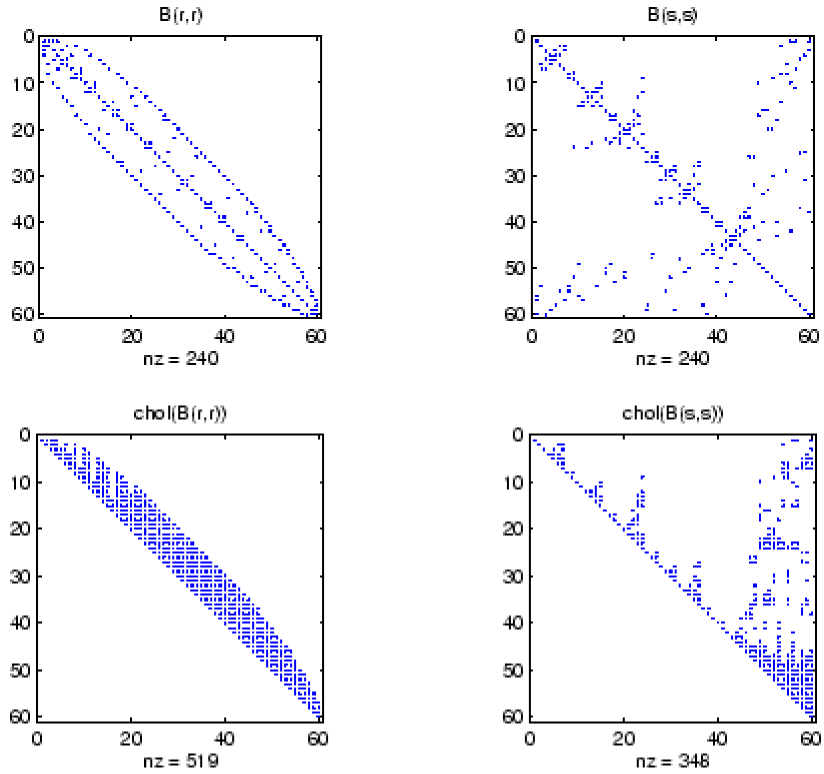
- If a row index appears two or more times in the same column, `symamd` ignores the duplicate entries, continues processing, and provides information about the duplicate entries in `stats(4:7)`.
- If row indices in a column are out of order, `symamd` sorts each column of its internal copy of the matrix `S` (but does not repair the input matrix `S`), continues processing, and provides information about the out-of-order entries in `stats(4:7)`.
- If `S` is invalid in any other way, `symamd` cannot continue. It prints an error message, and returns no output arguments (`p` or `stats`).

The ordering is followed by a symmetric elimination tree post-ordering.

Examples

Here is a comparison of reverse Cuthill-McKee and minimum degree on the Bucky ball example mentioned in the `symrcm` reference page.

```
B = bucky+4*speye(60);
r = symrcm(B);
p = symamd(B);
R = B(r,r);
S = B(p,p);
subplot(2,2,1), spy(R,4), title('B(r,r)')
subplot(2,2,2), spy(S,4), title('B(s,s)')
subplot(2,2,3), spy(chol(R),4), title('chol(B(r,r))')
subplot(2,2,4), spy(chol(S),4), title('chol(B(s,s))')
```



Even though this is a very small problem, the behavior of both orderings is typical. RCM produces a matrix with a narrow bandwidth which fills in almost completely during the Cholesky factorization. Minimum degree produces a structure with large blocks of contiguous zeros which do not fill in during the factorization. Consequently, the minimum degree ordering requires less time and storage for the factorization.

See Also

`colamd`, `colperm`, `spparms`, `symrcm`, `amd`

References

The authors of the code for `symamd` are Stefan I. Larimore and Timothy A. Davis (`davis@cise.ufl.edu`), University of Florida. The algorithm was developed in collaboration with John Gilbert, Xerox PARC, and Esmond Ng, Oak Ridge National Laboratory. Sparse Matrix Algorithms Research at the University of Florida: `http://www.cise.ufl.edu/research/sparse/`

symbfact

Purpose

Symbolic factorization analysis

Syntax

```
count = symbfact(A)
count = symbfact(A,'sym')
count = symbfact(A,'col')
count = symbfact(A,'row')
count = symbfact(A,'lo')
[count,h,parent,post,R] = symbfact(...)
[count,h,parent,post,L] = symbfact(A,type,'lower')
```

Description

`count = symbfact(A)` returns the vector of row counts of `R=chol(A'*A)`. `symbfact` should be much faster than `chol(A)`.

`count = symbfact(A,'sym')` is the same as `count = symbfact(A)`.

`count = symbfact(A,'col')` returns row counts of `R=chol(A'*A)` (without forming it explicitly).

`count = symbfact(A,'row')` returns row counts of `R=chol(A*A')`.

`count = symbfact(A,'lo')` is the same as `count = symbfact(A)` and uses `tril(A)`.

`[count,h,parent,post,R] = symbfact(...)` has several optional return values.

The flop count for a subsequent Cholesky factorization is `sum(count.^2)`

Return Value	Description
`h`	Height of the elimination tree
`parent`	The elimination tree itself
`post`	Postordering of the elimination tree
`R`	0-1 matrix having the structure of `chol(A)` for the symmetric case, `chol(A'*A)` for the `'col'` case, or `chol(A*A')` for the `'row'` case.

`symbfact(A)` and `symbfact(A,'sym')` use the upper triangular part of `A (triu(A))` and assume the lower triangular part is the transpose of the upper triangular part. `symbfact(A,'lo')` uses `tril(A)` instead.

`[count,h,parent,post,L] = symbfact(A,type,'lower')` where `type` is one of `'sym'`,`'col'`, `'row'`, or`'lo'` returns a lower triangular symbolic factor `L=R'`. This form is quicker and requires less memory.

See Also

`chol`, `etree`, `treelayout`

Purpose

Symmetric LQ method

Syntax

```
x = symmlq(A,b)
symmlq(A,b,tol)
symmlq(A,b,tol,maxit)
symmlq(A,b,tol,maxit,M)
symmlq(A,b,tol,maxit,M1,M2)
symmlq(A,b,tol,maxit,M1,M2,x0)
[x,flag] = symmlq(A,b,...)
[x,flag,relres] = symmlq(A,b,...)
[x,flag,relres,iter] = symmlq(A,b,...)
[x,flag,relres,iter,resvec] = symmlq(A,b,...)
[x,flag,relres,iter,resvec,resveccg] = symmlq(A,b,...)
```

Description

`x = symmlq(A,b)` attempts to solve the system of linear equations `A*x=b` for `x`. The `n`-by-`n` coefficient matrix `A` must be symmetric but need not be positive definite. It should also be large and sparse. The column vector `b` must have length `n`. `A` can be a function handle `afun` such that `afun(x)` returns `A*x`. See "Function Handles" in the MATLAB Programming documentation for more information.

"Parametrizing Functions", in the MATLAB Mathematics documentation, explains how to provide additional parameters to the function `afun`, as well as the preconditioner function `mfun` described below, if necessary.

If `symmlq` converges, a message to that effect is displayed. If `symmlq` fails to converge after the maximum number of iterations or halts for any reason, a warning message is printed displaying the relative residual `norm(b-A*x)/norm(b)` and the iteration number at which the method stopped or failed.

`symmlq(A,b,tol)` specifies the tolerance of the method. If `tol` is `[]`, then `symmlq` uses the default, `1e-6`.

`symmlq(A,b,tol,maxit)` specifies the maximum number of iterations. If `maxit` is `[]`, then `symmlq` uses the default, `min(n,20)`.

symmlq(A,b,tol,maxit,M) and symmlq(A,b,tol,maxit,M1,M2) use the symmetric positive definite preconditioner M or M = M1*M2 and effectively solve the system inv(sqrt(M))*A*inv(sqrt(M))*y = inv(sqrt(M))*b for y and then return x = in(sqrt(M))*y. If M is [] then symmlq applies no preconditioner. M can be a function handle mfun such that mfun(x) returns M\x.

symmlq(A,b,tol,maxit,M1,M2,x0) specifies the initial guess. If x0 is [], then symmlq uses the default, an all-zero vector.

[x,flag] = symmlq(A,b,...) also returns a convergence flag.

Flag	Convergence
0	symmlq converged to the desired tolerance tol within maxit iterations.
1	symmlq iterated maxit times but did not converge.
2	Preconditioner M was ill-conditioned.
3	symmlq stagnated. (Two consecutive iterates were the same.)
4	One of the scalar quantities calculated during symmlq became too small or too large to continue computing.
5	Preconditioner M was not symmetric positive definite.

Whenever flag is not 0, the solution x returned is that with minimal norm residual computed over all the iterations. No messages are displayed if the flag output is specified.

[x,flag,relres] = symmlq(A,b,...) also returns the relative residual norm(b-A*x)/norm(b). If flag is 0, relres <= tol.

[x,flag,relres,iter] = symmlq(A,b,...) also returns the iteration number at which x was computed, where 0 <= iter <= maxit.

[x,flag,relres,iter,resvec] = symmlq(A,b,...) also returns a vector of estimates of the symmlq residual norms at each iteration, including norm(b-A*x0).

[x,flag,relres,iter,resvec,resveccg] = symmlq(A,b,...) also returns a vector of estimates of the conjugate gradients residual norms at each iteration.

Examples

Example 1

```
n = 100;
on = ones(n,1);
A = spdiags([-2*on 4*on -2*on],-1:1,n,n);
b = sum(A,2);
tol = 1e-10;
maxit = 50; M1 = spdiags(4*on,0,n,n);

x = symmlq(A,b,tol,maxit,M1);
symmlq converged at iteration 49 to a solution with relative
residual 4.3e-015
```

Example 2

This example replaces the matrix A in Example 1 with a handle to a matrix-vector product function afun. The example is contained in an M-file run_symmlq that

- Calls symmlq with the function handle @afun as its first argument.
- Contains afun as a nested function, so that all variables in run_symmlq are available to afun.

The following shows the code for run_symmlq:

```
function x1 = run_symmlq
n = 100;
on = ones(n,1);
A = spdiags([-2*on 4*on -on],-1:1,n,n);
b = sum(A,2);
tol = 1e-8;
maxit = 15;
M1 = spdiags([on/(-2) on],-1:0,n,n);
M2 = spdiags([4*on -on],0:1,n,n);
```

```
x1 = symmlq(@afun,b,tol,maxit,M1);

       function y = afun(x)
          y = 4 * x;
          y(2:n) = y(2:n) - 2 * x(1:n-1);
          y(1:n-1) = y(1:n-1) - 2 * x(2:n);
       end
end
```

When you enter

```
x1=run_symmlq;
```

MATLAB software displays the message

```
symmlq converged at iteration 49 to a solution with relative
residual 4.3e-015
```

Example 3

Use a symmetric indefinite matrix that fails with pcg.

```
A = diag([20:-1:1,-1:-1:-20]);
b = sum(A,2);      % The true solution is the vector of all ones.
x = pcg(A,b);      % Errors out at the first iteration.
pcg stopped at iteration 1 without converging to the desired
tolerance 1e-006 because a scalar quantity became too small or
too large to continue computing.
The iterate returned (number 0) has relative residual 1
```

However, symmlq can handle the indefinite matrix A.

```
x = symmlq(A,b,1e-6,40);
symmlq converged at iteration 39 to a solution with relative
residual 1.3e-007
```

See Also

bicg, bicgstab, cgs, lsqr, gmres, minres, pcg, qmr

function_handle (@), mldivide (\)

References

[1] Barrett, R., M. Berry, T. F. Chan, et al., *Templates for the Solution of Linear Systems: Building Blocks for Iterative Methods*, SIAM, Philadelphia, 1994.

[2] Paige, C. C. and M. A. Saunders, "Solution of Sparse Indefinite Systems of Linear Equations." *SIAM J. Numer. Anal.*, Vol.12, 1975, pp. 617-629.

Purpose

Sparse reverse Cuthill-McKee ordering

Syntax

```
r = symrcm(S)
```

Description

`r = symrcm(S)` returns the symmetric reverse Cuthill-McKee ordering of `S`. This is a permutation `r` such that `S(r,r)` tends to have its nonzero elements closer to the diagonal. This is a good preordering for LU or Cholesky factorization of matrices that come from long, skinny problems. The ordering works for both symmetric and nonsymmetric `S`.

For a real, symmetric sparse matrix, `S`, the eigenvalues of `S(r,r)` are the same as those of `S`, but `eig(S(r,r))` probably takes less time to compute than `eig(S)`.

Algorithm

The algorithm first finds a pseudoperipheral vertex of the graph of the matrix. It then generates a level structure by breadth-first search and orders the vertices by decreasing distance from the pseudoperipheral vertex. The implementation is based closely on the SPARSPAK implementation described by George and Liu.

Examples

The statement

```
B = bucky;
```

uses an M-file in the `demos` toolbox to generate the adjacency graph of a truncated icosahedron. This is better known as a soccer ball, a Buckminster Fuller geodesic dome (hence the name `bucky`), or, more recently, as a 60-atom carbon molecule. There are 60 vertices. The vertices have been ordered by numbering half of them from one hemisphere, pentagon by pentagon; then reflecting into the other hemisphere and gluing the two halves together. With this numbering, the matrix does not have a particularly narrow bandwidth, as the first spy plot shows

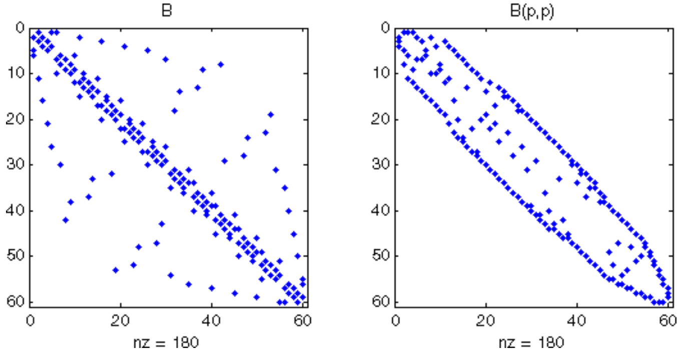
```
subplot(1,2,1), spy(B), title('B')
```

The reverse Cuthill-McKee ordering is obtained with

```
p = symrcm(B);
R = B(p,p);
```

The spy plot shows a much narrower bandwidth.

```
subplot(1,2,2), spy(R), title('B(p,p)')
```



This example is continued in the reference pages for symamd.

The bandwidth can also be computed with

```
[i,j] = find(B);
bw = max(i-j) + 1;
```

The bandwidths of B and R are 35 and 12, respectively.

See Also

colamd, colperm, symamd

References

[1] George, Alan and Joseph Liu, *Computer Solution of Large Sparse Positive Definite Systems*, Prentice-Hall, 1981.

[2] Gilbert, John R., Cleve Moler, and Robert Schreiber, "Sparse Matrices in MATLAB: Design and Implementation," *SIAM Journal on Matrix Analysis*, 1992. A slightly expanded version is also available as a technical report from the Xerox Palo Alto Research Center.

Purpose Determine symbolic variables in expression

Syntax

```
symvar 'expr'
s = symvar('expr')
```

Description `symvar 'expr'` searches the expression, `expr`, for identifiers other than `i`, `j`, `pi`, `inf`, `nan`, `eps`, and common functions. `symvar` displays those variables that it finds or, if no such variable exists, displays an empty cell array, `{}`.

`s = symvar('expr')` returns the variables in a cell array of strings, `s`. If no such variable exists, `s` is an empty cell array.

Examples `symvar` finds variables `beta1` and `x`, but skips `pi` and the `cos` function.

```
symvar 'cos(pi*x - beta1)'

ans =

    'beta1'
    'x'
```

See Also `findstr`

synchronize

Purpose

Synchronize and resample two `timeseries` objects using common time vector

Syntax

```
[ts1 ts2] = synchronize(ts1,ts2,'SynchronizeMethod')
```

Description

`[ts1 ts2] = synchronize(ts1,ts2,'SynchronizeMethod')` creates two new `timeseries` objects by synchronizing ts1 and ts2 using a common time vector. The string `'SynchronizeMethod'` defines the method for synchronizing the `timeseries` and can be one of the following:

- `'Union'` — Resample `timeseries` objects using a time vector that is a union of the time vectors of ts1 and `ts2` on the time range where the two time vectors overlap.
- `'Intersection'` — Resample `timeseries` objects on a time vector that is the intersection of the time vectors of ts1 and ts2.
- `'Uniform'` — Requires an additional argument as follows:

  ```
  [ts1 ts2] = synchronize(ts1,ts2,'Uniform','Interval',value)
  ```

  This method resamples time series on a uniform time vector, where value specifies the time interval between the two samples. The uniform time vector is the overlap of the time vectors of ts1 and ts2. The interval units are assumed to be the smaller units of ts1 and ts2.

You can specify additional arguments by using property-value pairs:

- `'InterpMethod'`: Forces the specified interpolation method (over the default method) for this synchronize operation. Can be either a string, `'linear'` or `'zoh'`, or a `tsdata.interpolation` object that contains a user-defined interpolation method.
- `'QualityCode'`: Integer (between -128 and 127) used as the quality code for both time series after the synchronization.

- 'KeepOriginalTimes': Logical value (true or false) indicating whether the new time series should keep the original time values. For example,

```
ts1 = timeseries([1 2],[datestr(now); datestr(now+1)]);
ts2 = timeseries([1 2],[datestr(now-1); datestr(now)]);
```

  Note that ts1.timeinfo.StartDate is one day after ts2.timeinfo.StartDate. If you use

```
 [ts1 ts2] = synchronize(ts1,ts2,'union');
```

  the ts1.timeinfo.StartDate is changed to match ts2.TimeInfo.StartDate and ts1.Time changes to 1.

  But if you use

```
[ts1 ts2] =
synchronize(ts1,ts2,'union','KeepOriginalTimes',true);
```

  ts1.timeinfo.StartDate is unchanged and ts1.Time is still 0.

- 'tolerance': Real number used as the tolerance for differentiating two time values when comparing the ts1 and ts2 time vectors. The default tolerance is 1e-10. For example, when the sixth time value in ts1 is 5+(1e-12) and the sixth time value in ts2 is 5-(1e-13), both values are treated as 5 by default. To differentiate those two times, you can set 'tolerance' to a smaller value such as 1e-15, for example.

See Also

timeseries

syntax

Purpose

Two ways to call MATLAB functions

Description

You can call MATLAB functions using either *command syntax* or *function syntax*, as described below.

Command Syntax

A function call in this syntax consists of the function name followed by one or more arguments separated by spaces:

```
functionname arg1 arg2 ... argn
```

Command syntax does not allow you to obtain any values that might be returned by the function. Attempting to assign output from the function to a variable using command syntax generates an error. Use function syntax instead.

Examples of command syntax:

```
save mydata.mat x y z
import java.awt.Button java.lang.String
```

Arguments are treated as string literals. See the examples below, under "Argument Passing" on page 2-3539.

Function Syntax

A function call in this syntax consists of the function name followed by one or more arguments separated by commas and enclosed in parentheses:

```
functionname(arg1, arg2, ..., argn)
```

You can assign the output of the function to one or more output values. When assigning to more than one output variable, separate the variables by commas or spaces and enclose them in square brackets ([]):

```
[out1,out2,...,outn] = functionname(arg1, arg2, ..., argn)
```

Examples of function syntax:

```
copyfile('srcfile', '..\mytests', 'writable')
[x1,x2,x3,x4] = deal(A{:})
```

Arguments are passed to the function by value. See the examples below, under "Argument Passing" on page 2-3539.

Argument Passing

When calling a function using command syntax, MATLAB passes the arguments as string literals. When using function syntax, arguments are passed by value.

In the following example, assign a value to `A` and then call `disp` on the variable to display the value passed. Calling `disp` with command syntax passes the variable name, `'A'`:

```
A = pi;
disp A
   A
```

while function syntax passes the value assigned to `A`:

```
A = pi;
disp(A)
   3.1416
```

The next example passes two strings to `strcmp` for comparison. Calling the function with command syntax compares the variable names, `'str1'` and `'str2'`:

```
str1 = 'one';    str2 = 'one';
strcmp str1 str2
ans =
     0       (unequal)
```

while function syntax compares the values assigned to the variables, `'one'` and `'one'`:

```
str1 = 'one';    str2 = 'one';
strcmp(str1, str2)
```

```
ans =
     1        (equal)
```

Passing Strings

When using the function syntax to pass a string literal to a function, you must enclose the string in single quotes, ('string'). For example, to create a new directory called myapptests, use

```
mkdir('myapptests')
```

On the other hand, variables that contain strings do not need to be enclosed in quotes:

```
dirname = 'myapptests';
mkdir(dirname)
```

See Also

mlint

Purpose Execute operating system command and return result

Syntax

```
system('command')
[status, result] = system('command')
```

Description

`system('command')` calls upon the operating system to run `command`, for example `dir` or `ls` or a UNIX[26] shell script, and directs the output to the MATLAB software. If `command` runs successfully, `ans` is `0`. If `command` fails or does not exist on your operating system, `ans` is a nonzero value and an explanatory message appears.

`[status, result] = system('command')` calls upon the operating system to run `command`, and directs the output to MATLAB. If `command` runs successfully, `status` is `0` and `result` contains the output from `command`. If `command` fails or does not exist on your operating system, `status` is a nonzero value and `result` contains an explanatory message.

Note Running `system` on a MicrosoftWindows platform with a `command` that relies on the current directory fails when the current directory is specified using a UNC pathname because DOS does not support UNC pathnames. When this happens, MATLAB returns the error:

```
???  Error using ==> system DOS commands may not be
executed when the current directory is a UNC pathname.
```

To work around this limitation, change the directory to a mapped drive prior to running `system` or a function that calls `system`.

Examples

On a Windows system, display the current directory by accessing the operating system.

```
[status currdir] = system('cd')
status =
    0
currdir =
    D:\work\matlab\test
```

See Also

`!` (bang), `computer`, `dos`, `perl`, `unix`, `winopen`

26. UNIX is a registered trademark of The Open Group in the United States and other countries.

"Running External Programs" in the MATLAB Desktop Tools and Development Environment documentation

Purpose

Tangent of argument in radians

Syntax

```
Y = tan(X)
```

Description

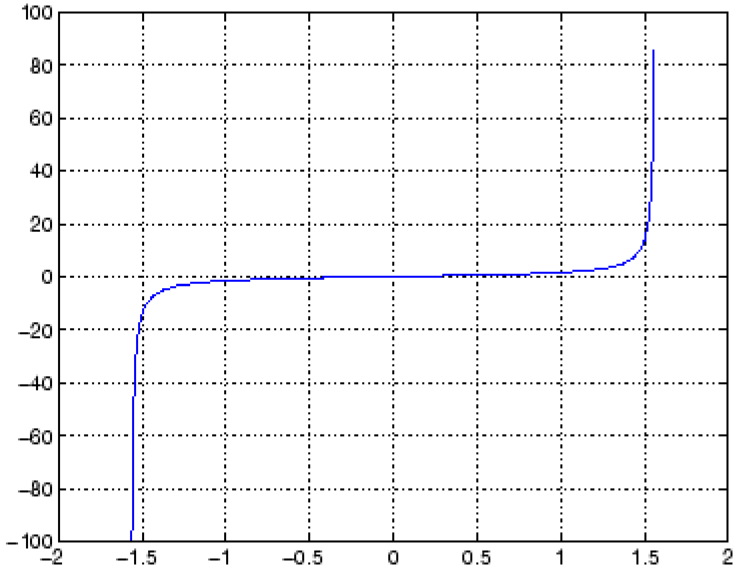
The `tan` function operates element-wise on arrays. The function's domains and ranges include complex values. All angles are in radians.

`Y = tan(X)` returns the circular tangent of each element of `X`.

Examples

Graph the tangent function over the domain $-\pi/2 < x < \pi/2$.

```
x = (-pi/2)+0.01:0.01:(pi/2)-0.01;
plot(x,tan(x)), grid on
```



The expression `tan(pi/2)` does not evaluate as infinite but as the reciprocal of the floating point accuracy `eps` since `pi` is only a floating-point approximation to the exact value of π.

Definition

The tangent can be defined as

$$\tan(z) = \frac{\sin(z)}{\cos(z)}$$

Algorithm

`tan` uses FDLIBM, which was developed at SunSoft, a Sun Microsystems, Inc. business, by Kwok C. Ng, and others. For information about FDLIBM, see `http://www.netlib.org`.

See Also

`tand`, `tanh`, `atan`, `atan2`, `atand`, `atanh`

tand

Purpose Tangent of argument in degrees

Syntax

```
Y = tand(X)
```

Description `Y = tand(X)` is the tangent of the elements of `X`, expressed in degrees. For odd integers `n`, `tand(n*90)` is infinite, whereas `tan(n*pi/2)` is large but finite, reflecting the accuracy of the floating point value of `pi`.

See Also `tan`, `tanh`, `atan`, `atan2`, `atand`, `atanh`

Purpose Hyperbolic tangent

Syntax

```
Y = tanh(X)
```

Description

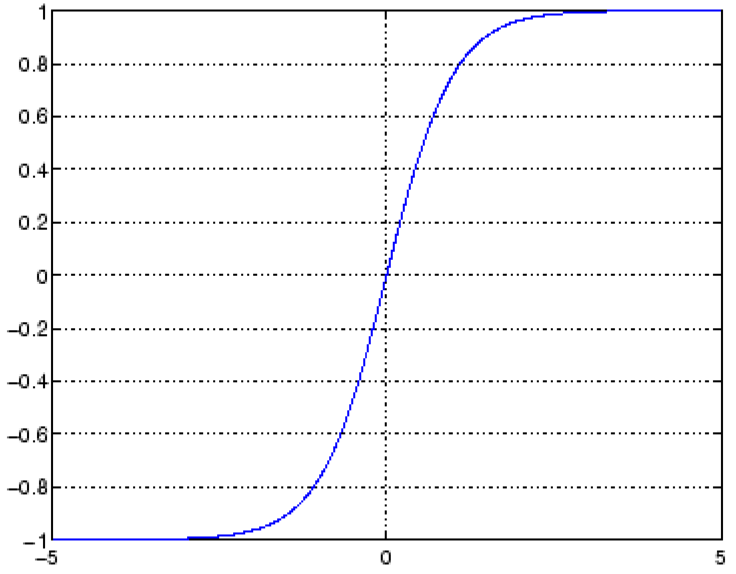
The `tanh` function operates element-wise on arrays. The function's domains and ranges include complex values. All angles are in radians.

`Y = tanh(X)` returns the hyperbolic tangent of each element of `X`.

Examples

Graph the hyperbolic tangent function over the domain $-5 \le x \le 5$.

```
x = -5:0.01:5;
plot(x,tanh(x)), grid on
```



Definition

The hyperbolic tangent can be defined as

$$\tanh(z) = \frac{\sinh(z)}{\cosh(z)}$$

Algorithm

tanh uses FDLIBM, which was developed at SunSoft, a Sun Microsystems, Inc. business, by Kwok C. Ng, and others. For information about FDLIBM, see http://www.netlib.org.

See Also

atan, atan2, tan

Purpose

Compress files into tar file

Syntax

```
tar(tarfilename,files)
tar(tarfilename,files,rootdir)
entrynames = tar(...)
```

Description

`tar(tarfilename,files)` creates a tar file named `tarfilename` from the list of files and directories specified in `files`. Relative paths are stored in the tar file, but absolute paths are not. Directories recursively include all of their content.

`tarfilename` is a string specifying the name of the tar file. MATLAB appends the `.tar` extension if `tarfilename` has no extentsion. The `tarfilename` extension can end in `.tgz` or `.gz`. In this case, `tarfilename` is gzipped.

`files` is a string or cell array of strings containing the list of files or directories included in `tarfilename`. Individual files that are on the MATLAB path can be specified as partial path names. Otherwise an individual file can be specified relative to the current directory or with an absolute path.

Directories must be specified relative to the current directory or with absolute paths. On UNIX[27] systems, directories can also start with `~/` or `~username/`, which expands to the current user's home directory or the specified user's home directory, respectively. The wildcard character `*` can be used when specifying files or directories, except when relying on the MATLAB path to resolve a file name or partial path name.

`tar(tarfilename,files,rootdir)` allows the path for `files` to be specified relative to `rootdir` rather than the current directory.

`entrynames = tar(...)` returns a string cell array of the names of the files contained in `tarfilename`. If `files` contains a relative path, `entrynames` also contains the relative path.

Example

Tar all files in the current directory to the file `backup.tgz`.

```
tar('backup.tgz','.');
```

See Also

`gzip`, `gunzip`, `untar`, `unzip`, `zip`

27. UNIX is a registered trademark of The Open Group in the United States and other countries.

Purpose Name of system's temporary directory

Syntax

```
tmp_dir = tempdir
```

Description

`tmp_dir = tempdir` returns the name of the system's temporary directory, if one exists. This function does not create a new directory.

See "Opening Temporary Files and Directories" for more information.

See Also `tempname`

tempname

Purpose Unique name for temporary file

Syntax

```
tmp_nam = tempname
```

Description `tmp_nam = tempname` returns a unique string, `tmp_nam`, suitable for use as a temporary filename.

Note The filename that `tempname` generates is not guaranteed to be unique; however, it is likely to be so.

See "Opening Temporary Files and Directories" for more information.

See Also `tempdir`

Purpose

Tetrahedron mesh plot

Syntax

```
tetramesh(T,X,c)
tetramesh(T,X)
h = tetramesh(...)
tetramesh(...,'param','value','param','value'...)
```

Description

`tetramesh(T,X,c)` displays the tetrahedrons defined in the `m`-by-4 matrix `T` as mesh. `T` is usually the output of `delaunayn`. A row of `T` contains indices into `X` of the vertices of a tetrahedron. `X` is an `n`-by-3 matrix, representing `n` points in 3 dimension. The tetrahedron colors are defined by the vector `C`, which is used as indices into the current colormap.

Note If `T` is the output of `delaunay3`, then `X` is the concatenation of the `delaunay3` input arguments `x`, `y`, `z` interpreted as column vectors, i.e., `X = [x(:)  y(:)  z(:)]`.

`tetramesh(T,X)` uses `C = 1:m` as the color for the `m` tetrahedrons. Each tetrahedron has a different color (modulo the number of colors available in the current colormap).

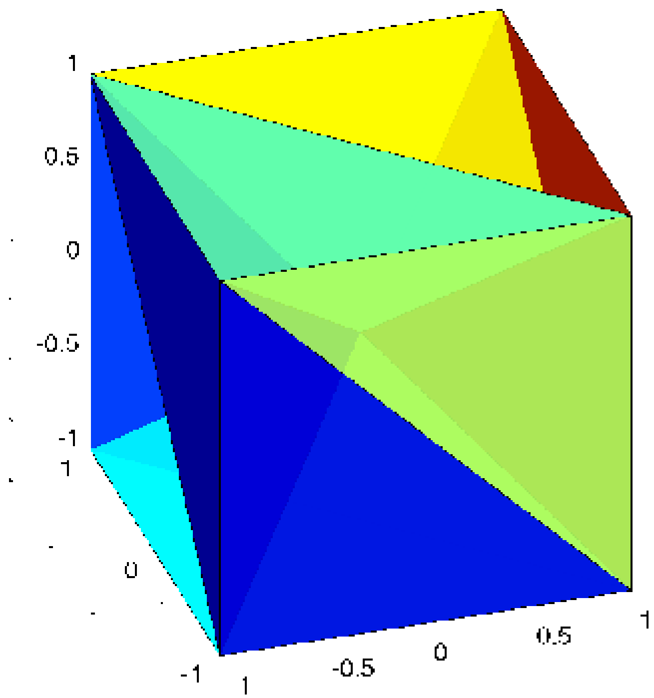
`h = tetramesh(...)` returns a vector of tetrahedron handles. Each element of `h` is a handle to the set of patches forming one tetrahedron. You can use these handles to view a particular tetrahedron by turning the patch `'Visible'` property `'on'` or `'off'`.

`tetramesh(...,'param','value','param','value'...)` allows additional patch property name/property value pairs to be used when displaying the tetrahedrons. For example, the default transparency parameter is set to `0.9`. You can overwrite this value by using the property name/property value pair `('FaceAlpha',value)` where `value` is a number between `0` and `1`. See `Patch Properties` for information about the available properties.

Examples

Generate a 3-dimensional Delaunay tessellation, then use `tetramesh` to visualize the tetrahedrons that form the corresponding simplex.

```
d = [-1 1];
[x,y,z] = meshgrid(d,d,d);  % A cube
x = [x(:);0];
y = [y(:);0];
z = [z(:);0];
% [x,y,z] are corners of a cube plus the center.
X = [x(:) y(:) z(:)];
Tes = delaunayn(X)

Tes =
     9     1     5     6
     3     9     1     5
     2     9     1     6
     2     3     9     4
     2     3     9     1
     7     9     5     6
     7     3     9     5
     8     7     9     6
     8     2     9     6
     8     2     9     4
     8     3     9     4
     8     7     3     9
tetramesh(Tes,X);camorbit(20,0)
```



See Also delaunayn, patch, Patch Properties, trimesh, trisurf

texlable

Purpose Produce TeX format from character string

Syntax

```
texlabel(f)
texlabel(f,'literal')
```

Description `texlabel(f)` converts the MATLAB expression `f` into the TeX equivalent for use in text strings. It processes Greek variable names (e.g., lambda, delta, etc.) into a string that is displayed as actual Greek letters.

`texlabel(f,'literal')` prints Greek variable names as literals.

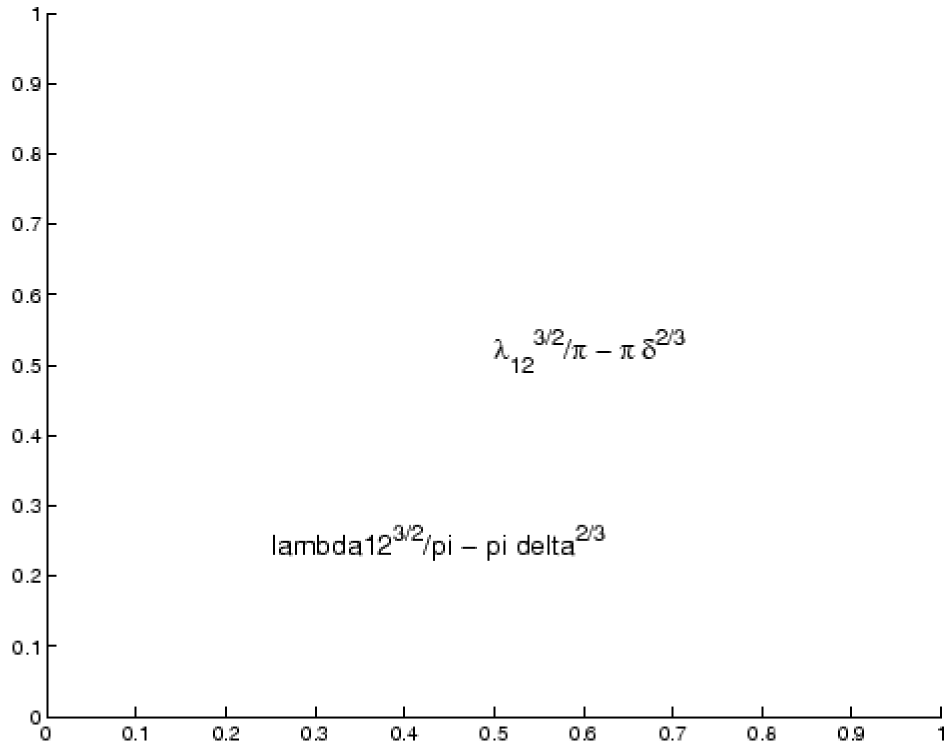
If the string is too long to fit into a figure window, then the center of the expression is replaced with a tilde ellipsis (~~~).

Examples You can use `texlabel` as an argument to the `title`, `xlabel`, `ylabel`, `zlabel`, and `text` commands. For example,

```
title(texlabel('sin(sqrt(x^2 + y^2))/sqrt(x^2 + y^2)'))
```

By default, `texlabel` translates Greek variable names to the equivalent Greek letter. You can select literal interpretation by including the `literal` argument. For example, compare these two commands.

```
text(.5,.5,...
     texlabel('lambda12^(3/2)/pi - pi*delta^(2/3)'))
text(.25,.25,...
     texlabel('lambda12^(3/2)/pi - pi*delta^(2/3)','literal'))
```



See Also

`text`, `title`, `xlabel`, `ylabel`, `zlabel`, the text `String` property

“Annotating Plots” on page 1-91 for related functions

Purpose

Create text object in current axes

Syntax

```
text(x,y,'string')
text(x,y,z,'string')
text(x,y,z,'string','PropertyName',PropertyValue....)
text('PropertyName',PropertyValue....)
h = text(...)
```

Description

`text` is the low-level function for creating text graphics objects. Use `text` to place character strings at specified locations.

`text(x,y,'string')` adds the string in quotes to the location specified by the point `(x,y)` `x` and `y` must be numbers of class `double`.

`text(x,y,z,'string')` adds the string in 3-D coordinates. `x`, `y` and `z` must be numbers of class `double`.

`text(x,y,z,'string','`*`PropertyName`*`',PropertyValue....)` adds the string in quotes to the location defined by the coordinates and uses the values for the specified text properties. See the text property list section at the end of this page for a list of text properties.

`text('`*`PropertyName`*`',PropertyValue....)` omits the coordinates entirely and specifies all properties using property name/property value pairs.

`h = text(...)` returns a column vector of handles to text objects, one handle per object. All forms of the `text` function optionally return this output argument.

See the `String` property for a list of symbols, including Greek letters.

Remarks

Position Text Within the Axes

The default text units are the units used to plot data in the graph. Specify the text location coordinates (the `x`, `y`, and `z` arguments) in the data units of the current graph (see “Examples” on page 2-3560. You can use other units to position the text by setting the text `Units` property to `normalized` or one of the nonrelative units (`pixels`, `inches`, `centimeters`, `points`).

Note that the Axes Units property controls the positioning of the Axes within the figure and is not related to the axes data units used for graphing.

The `Extent`, `VerticalAlignment`, and `HorizontalAlignment` properties control the positioning of the character string with regard to the text location point.

If the coordinates are vectors, `text` writes the string at all locations defined by the list of points. If the character string is an array the same length as `x`, `y`, and `z`, `text` writes the corresponding row of the string array at each point specified.

Multiline Text

When specifying strings for multiple text objects, the string can be

- A cell array of strings
- A padded string matrix

Each element of the specified string array creates a different text object.

When specifying the string for a single text object, cell arrays of strings and padded string matrices result in a text object with a multiline string, while vertical slash characters are not interpreted as separators and result in a single line string containing vertical slashes.

Behavior of the Text Function

`text` is a low-level function that accepts property name/property value pairs as input arguments. However, the convenience form,

```
text(x,y,z,'string')
```

is equivalent to

```
text('Position',[x,y,z],'String','string')
```

You can specify other properties only as property name/property value pairs. See the text property list at the end of this page for a description of each property. You can specify properties as property name/property value pairs, structure arrays, and cell arrays (see the `set` and `get` reference pages for examples of how to specify these data types).

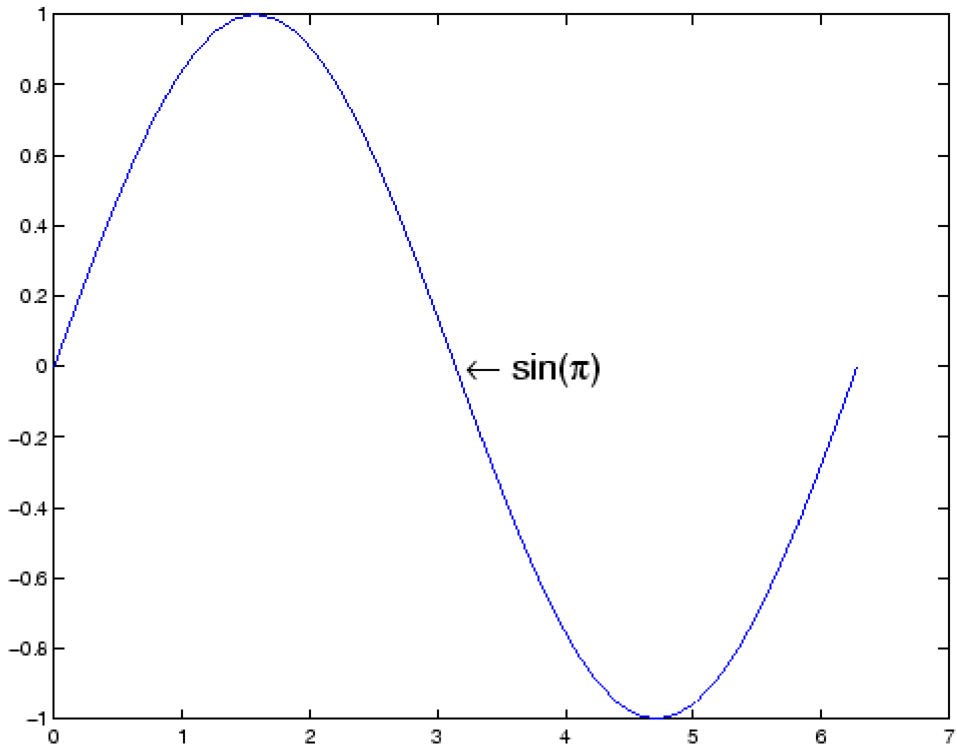
`text` does not respect the setting of the figure or axes `NextPlot` property. This allows you to add text objects to an existing axes without setting `hold` to `on`.

Examples

The statements

```
plot(0:pi/20:2*pi,sin(0:pi/20:2*pi))
text(pi,0,' \leftarrow sin(\pi)','FontSize',18)
```

annotate the point at `(pi,0)` with the string `sin(π)`



The statement

```
text(x,y,'\ite^{i\omega\tau} = cos(\omega\tau) + i sin(\omega\tau)')
```

uses embedded TeX sequences to produce

$$e^{i\omega\tau} = cos(\omega\tau) + i\ sin(\omega\tau)$$

Setting Default Properties

You can set default text properties on the axes, figure, and `root` `object`levels:

```
set(0,'DefaulttextProperty',PropertyValue...)
set(gcf,'DefaulttextProperty',PropertyValue...)
```

```
set(gca,'DefaulttextProperty',PropertyValue...)
```

Where *Property* is the name of the text property and PropertyValue is the value you are specifying. Use set and get to access text properties.

See Also

annotation, gtext, int2str, num2str, strings, title, xlabel, ylabel, zlabel

"Object Creation" on page 1-98 for related functions

Text Properties for property descriptions

Purpose

Text properties

Modifying Properties

You can set and query graphics object properties using the property editor or the `set` and `get` commands.

- The Property Editor is an interactive tool that enables you to see and change object property values.
- The `set` and `get` commands enable you to set and query the values of properties.

To change the default values of properties, see Setting Default Property Values.

See Core Objects for general information about this type of object.

Text Property Descriptions

This section lists property names along with the types of values each accepts. Curly braces { } enclose default values.

`Annotation`

`hg.Annotation` object Read Only

Control the display of text objects in legends. The `Annotation` property enables you to specify whether this text object is represented in a figure legend.

Querying the `Annotation` property returns the handle of an `hg.Annotation` object. The `hg.Annotation` object has a property called `LegendInformation`, which contains an `hg.LegendEntry` object.

Once you have obtained the `hg.LegendEntry` object, you can set its `IconDisplayStyle` property to control whether the text object is displayed in a figure legend:

IconDisplayStyle Value	Purpose
on	Represent this text object in a legend (default)
off	Do not include this text object in a legend
children	Same as on because text objects do not have children

Setting the IconDisplayStyle property

These commands set the IconDisplayStyle of a graphics object with handle hobj to off:

```
hAnnotation = get(hobj,'Annotation');
hLegendEntry = get(hAnnotation','LegendInformation');
set(hLegendEntry,'IconDisplayStyle','off')
```

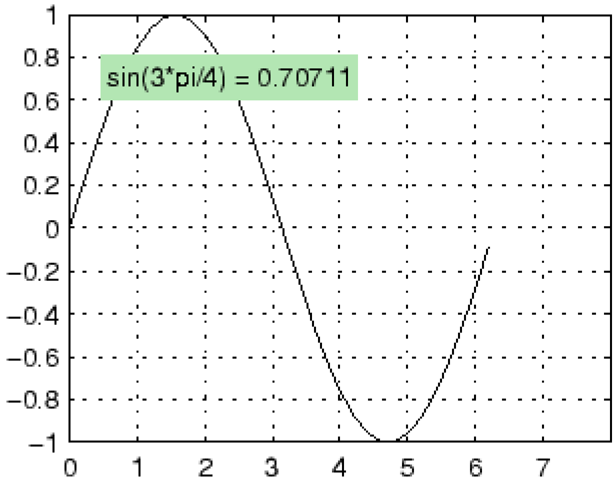
Using the IconDisplayStyle property

See “Controlling Legends” for more information and examples.

BackgroundColor
ColorSpec | {none}

Color of text extent rectangle. This property enables you to define a color for the rectangle that encloses the text Extent plus the text Margin. For example, the following code creates a text object that labels a plot and sets the background color to light green.

```
text(3*pi/4,sin(3*pi/4),...
 ['sin(3*pi/4) = ',num2str(sin(3*pi/4))],...
 'HorizontalAlignment','center',...
 'BackgroundColor',[.7 .9 .7]);
```



For additional features, see the following properties:

- `EdgeColor` — Color of the rectangle's edge (`none` by default).
- `LineStyle` — Style of the rectangle's edge line (first set `EdgeColor`)
- `LineWidth` — Width of the rectangle's edge line (first set `EdgeColor`)
- `Margin` — Increase the size of the rectangle by adding a margin to the existing text extent rectangle. This margin is added to the text extent rectangle to define the text background area that is enclosed by the `EdgeColor` rectangle. Note that the text extent does not change when you change the margin; only the rectangle displayed when you set the `EdgeColor` property and the area defined by the `BackgroundColor` change.

See also Drawing Text in a Box in the MATLAB Graphics documentation for an example using background color with contour labels.

`BeingDeleted`

`on | {off}` read only

This object is being deleted. The `BeingDeleted` property provides a mechanism that you can use to determine if objects are in the process of being deleted. MATLAB software sets the `BeingDeleted` property to `on` when the object's delete function callback is called (see the `DeleteFcn` property) It remains set to `on` while the delete function executes, after which the object no longer exists.

For example, an object's delete function might call other functions that act on a number of different objects. These functions may not need to perform actions on objects that are going to be deleted, and therefore can check the object's `BeingDeleted` property before acting.

`BusyAction`

`cancel | {queue}`

Callback routine interruption. The `BusyAction` property enables you to control how MATLAB handles events that potentially interrupt executing callback routines. If there is a callback routine executing, callback routines invoked subsequently always attempt to interrupt it. If the `Interruptible` property of the object whose callback is executing is set to `on` (the default), then interruption occurs at the next point where the event queue is processed. If the `Interruptible` property is set to `off`, the `BusyAction` property (of the object owning the executing callback) determines how MATLAB handles the event. The choices are

- `cancel` — Discard the event that attempted to execute a second callback routine.
- `queue` — Queue the event that attempted to execute a second callback routine until the current callback finishes.

`ButtonDownFcn`

function handle, cell array containing function handle and additional arguments, or string (not recommended)

Button press callback function. A callback function that executes whenever you press a mouse button while the pointer is over the text object.

See the figure's `SelectionType` property to determine if modifier keys were also pressed.

Set this property to a function handle that references the callback. The function must define at least two input arguments (handle of object associated with the button down event and an event structure, which is empty for this property). For example, the following function takes different action depending on what type of selection was made:

```
function button_down(src,evnt)
% src - the object that is the source of the event
% evnt - empty for this property
   sel_typ = get(gcbf,'SelectionType')
   switch sel_typ
      case 'normal'
         disp('User clicked left-mouse button')
         set(src,'Selected','on')
      case 'extend'
         disp('User did a shift-click')
         set(src,'Selected','on')
      case 'alt'
         disp('User did a control-click')
         set(src,'Selected','on')
         set(src,'SelectionHighlight','off')
   end
end
```

Suppose `h` is the handle of a text object and that the `button_down` function is on your MATLAB path. The following statement assigns the function above to the `ButtonDownFcn`:

```
set(h,'ButtonDownFcn',@button_down)
```

See "Function Handle Callbacks" for information on how to use function handles to define the callback function.

`Children`
matrix (read only)

The empty matrix; text objects have no children.

`Clipping`
`on | {off}`

Clipping mode. When `Clipping` is `on`, MATLAB does not display any portion of the text that is outside the axes.

`Color`
`ColorSpec`

Text color. A three-element RGB vector or one of the predefined names, specifying the text color. The default value for `Color` is white. See `ColorSpec` for more information on specifying color.

`CreateFcn`
function handle, cell array containing function handle and additional arguments, or string (not recommended)

Callback function executed during object creation. A callback function that executes when MATLAB creates a text object. You must define this property as a default value for text or in a call to the `text` function that creates a new text object. For example, the statement

```
set(0,'DefaultTextCreateFcn',@text_create)
```

defines a default value on the root level that sets the figure `Pointer` property to crosshairs whenever you create a text object. The callback function must be on your MATLAB path when you execute the above statement.

```
function text_create(src,evnt)
```

```
% src - the object that is the source of the event
% evnt - empty for this property
 set(gcbf,'Pointer','crosshair')
end
```

MATLAB executes this function after setting all text properties. Setting this property on an existing text object has no effect. The function must define at least two input arguments (handle of object created and an event structure, which is empty for this property).

The handle of the object whose `CreateFcn` is being executed is passed by MATLAB as the first argument to the callback function and is also accessible through the root `CallbackObject` property, which you can query using `gcbo`.

See "Function Handle Callbacks" for information on how to use function handles to define the callback function.

`DeleteFcn`

function handle, cell array containing function handle and additional arguments, or string (not recommended)

Delete text callback function. A callback function that executes when you delete the text object (e.g., when you issue a `delete` command or clear the axes `cla` or figure `clf`). For example, the following function displays object property data before the object is deleted.

```
function delete_fcn(src,evnt)
% src - the object that is the source of the event
% evnt - empty for this property
   obj_tp = get(src,'Type');
   disp([obj_tp, ' object deleted'])
   disp('Its user data is:')
   disp(get(src,'UserData'))
end
```

MATLAB executes the function before deleting the object's properties so these values are available to the callback function. The function must define at least two input arguments (handle of object being deleted and an event structure, which is empty for this property)

The handle of the object whose `DeleteFcn` is being executed is passed by MATLAB as the first argument to the callback function and is also accessible through the root `CallbackObject` property, which you can query using `gcbo`.

See Function Handle Callbacks for information on how to use function handles to define the callback function.

`DisplayName`

string (default is empty string)

String used by legend for this text object. The `legend` function uses the string defined by the `DisplayName` property to label this text object in the legend.

- If you specify string arguments with the `legend` function, `DisplayName` is set to this text object's corresponding string and that string is used for the legend.
- If `DisplayName` is empty, legend creates a string of the form, `['data' n]`, where *n* is the number assigned to the object based on its location in the list of legend entries. However, `legend` does not set `DisplayName` to this string.
- If you edit the string directly in an existing legend, `DisplayName` is set to the edited string.
- If you specify a string for the `DisplayName` property and create the legend using the figure toolbar, then MATLAB uses the string defined by `DisplayName`.
- To add programmatically a legend that uses the `DisplayName` string, call `legend` with the `toggle` or `show` option.

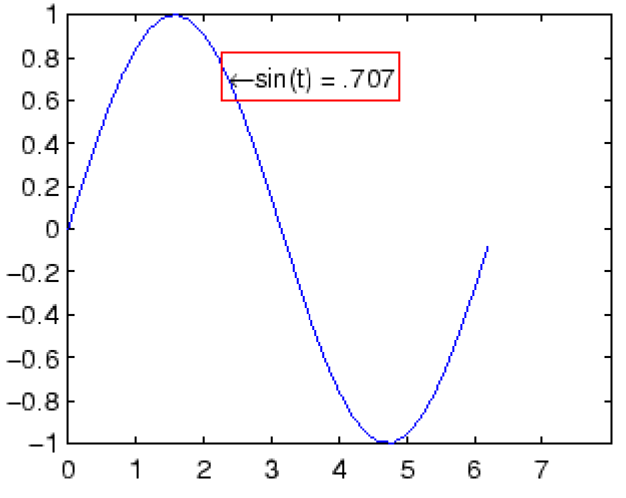
See "Controlling Legends" for more examples.

`EdgeColor`

`ColorSpec | {none}`

Color of edge drawn around text extent rectangle plus margin. This property enables you to specify the color of a box drawn around the text `Extent` plus the text `Margin`. For example, the following code draws a red rectangle around text that labels a plot.

```
text(3*pi/4,sin(3*pi/4),...
'\leftarrowsin(t) = .707',...
'EdgeColor','red');
```



For additional features, see the following properties:

- `BackgroundColor` — Color of the rectangle's interior (`none` by default)
- `LineStyle` — Style of the rectangle's edge line (first set `EdgeColor`)
- `LineWidth` — Width of the rectangle's edge line (first set `EdgeColor`)

- `Margin` — Increases the size of the rectangle by adding a margin to the area defined by the text extent rectangle. This margin is added to the text extent rectangle to define the text background area that is enclosed by the `EdgeColor` rectangle. Note that the text extent does not change when you change the margin; only the rectangle displayed when you set the `EdgeColor` property and the area defined by the `BackgroundColor` change.

`Editing`

`on | {off}`

Enable or disable editing mode. When this property is set to the default `off`, you cannot edit the text string interactively (i.e., you must change the `String` property to change the text). When this property is set to `on`, MATLAB places an insert cursor at the end of the text string and enables editing. To apply the new text string,

1. Press the **Esc** key.
2. Click in any figure window (including the current figure).
3. Reset the `Editing` property to `off.`

MATLAB then updates the `String` property to contain the new text and resets the `Editing` property to `off`. You must reset the `Editing` property to `on` to resume editing.

`EraseMode`

`{normal} | none | xor | background`

Erase mode. This property controls the technique MATLAB uses to draw and erase text objects. Alternative erase modes are useful for creating animated sequences where controlling the way individual objects are redrawn is necessary to improve performance and obtain the desired effect.

- `normal` — Redraw the affected region of the display, performing the three-dimensional analysis necessary to ensure that all objects are rendered correctly. This mode produces the most accurate picture, but is the slowest. The other modes are faster, but do not perform a complete redraw and are therefore less accurate.
- `none` — Do not erase the text when it is moved or destroyed. While the object is still visible on the screen after erasing with `EraseMode none`, you cannot print it because MATLAB stores no information about its former location.
- `xor` — Draw and erase the text by performing an exclusive OR (XOR) with each pixel index of the screen beneath it. When the text is erased, it does not damage the objects beneath it. However, when text is drawn in `xor` mode, its color depends on the color of the screen beneath it. It is correctly colored only when it is over axes background Color, or the figure background Color if the axes `Color` is set to `none`.
- `background` — Erase the text by drawing it in the axes background Color, or the figure background Color if the axes `Color` is set to `none`. This damages objects that are behind the erased text, but text is always properly colored.

  Printing with Nonnormal Erase Modes

MATLAB always prints figures as if the `EraseMode` of all objects is set to `normal`. This means graphics objects created with `EraseMode` set to `none`, `xor`, or `background` can look differently on screen than on paper. On screen, MATLAB may mathematically combine layers of colors (e.g., performing an XOR of a pixel color with that of the pixel behind it) and ignore three-dimensional sorting to obtain greater rendering speed. However, these techniques are not applied to the printed output.

You can use the MATLAB `getframe` command or other screen capture application to create an image of a figure containing nonnormal mode objects.

`Extent`

position rectangle (read only)

Position and size of text. A four-element read-only vector that defines the size and position of the text string

```
[left,bottom,width,height]
```

If the `Units` property is set to `data` (the default), `left` and `bottom` are the *x*- and *y*-coordinates of the lower left corner of the text `Extent`.

For all other values of `Units`, `left` and `bottom` are the distance from the lower left corner of the axes `position` rectangle to the lower left corner of the text `Extent`. `width` and `height` are the dimensions of the `Extent` rectangle. All measurements are in units specified by the `Units` property.

`FontAngle`
`{normal} | italic | oblique`

Character slant. MATLAB uses this property to select a font from those available on your particular system. Generally, setting this property to `italic` or `oblique` selects a slanted font.

`FontName`
A name, such as `Courier`, or the string `FixedWidth`

Font family. A string specifying the name of the font to use for the text object. To display and print properly, this must be a font that your system supports. The default font is Helvetica.

Specifying a Fixed-Width Font

If you want text to use a fixed-width font that looks good in any locale, you should set `FontName` to the string `FixedWidth`:

```
set(text_handle,'FontName','FixedWidth')
```

This eliminates the need to hard-code the name of a fixed-width font, which may not display text properly on systems that do not use ASCII character encoding (such as in Japan where multibyte character sets are used). A properly written MATLAB application that needs to use a fixed-width font should set `FontName` to `FixedWidth` (note that this string is case sensitive) and rely on `FixedWidthFontName` to be set correctly in the end user's environment.

End users can adapt a MATLAB application to different locales or personal environments by setting the root `FixedWidthFontName` property to the appropriate value for that locale from `startup.m`.

Note that setting the root `FixedWidthFontName` property causes an immediate update of the display to use the new font.

`FontSize`
size in `FontUnits`

Font size. A value specifying the font size to use for text in units determined by the `FontUnits` property. The default point size is 10 (1 point = 1/72 inch).

`FontWeight`
`light | {normal} | demi | bold`

Weight of text characters. MATLAB uses this property to select a font from those available on your particular system. Generally, setting this property to `bold` or `demi` causes MATLAB to use a bold font.

`FontUnits`
`{points} | normalized | inches |`
`centimeters | pixels`

Font size units. MATLAB uses this property to determine the units used by the `FontSize` property. Normalized units interpret `FontSize` as a fraction of the height of the parent axes. When you resize the axes, MATLAB modifies the screen `FontSize` accordingly. `pixels`, `inches`, `centimeters`, and `points` are absolute units (1 point = 1/72 inch).

Note that if you are setting both the FontSize and the FontUnits in one function call, you must set the FontUnits property first so that MATLAB can correctly interpret the specified FontSize.

HandleVisibility
`{on} | callback | off`

Control access to object's handle by command-line users and GUIs. This property determines when an object's handle is visible in its parent's list of children. HandleVisibility is useful for preventing command-line users from accidentally drawing into or deleting a figure that contains only user interface devices (such as a dialog box).

Handles are always visible when HandleVisibility is set to on.

Setting HandleVisibility to callback causes handles to be visible from within callback routines or functions invoked by callback routines, but not from within functions invoked from the command line. This provides a means to protect GUIs from command-line users, while allowing callback routines to have complete access to object handles.

Setting HandleVisibility to off makes handles invisible at all times. This may be necessary when a callback routine invokes a function that might potentially damage the GUI (such as evaluating a user-typed string), and so temporarily hides its own handles during the execution of that function.

When a handle is not visible in its parent's list of children, it cannot be returned by functions that obtain handles by searching the object hierarchy or querying handle properties. This includes get, findobj, gca, gcf, gco, newplot, cla, clf, and close.

When a handle's visibility is restricted using callback or off,

- The object's handle does not appear in its parent's Children property.

- Figures do not appear in the root's `CurrentFigure` property.
- Objects do not appear in the root's `CallbackObject` property or in the figure's `CurrentObject` property.
- Axes do not appear in their parent's `CurrentAxes` property.

You can set the root `ShowHiddenHandles` property to on to make all handles visible regardless of their `HandleVisibility` settings (this does not affect the values of the `HandleVisibility` properties).

Handles that are hidden are still valid. If you know an object's handle, you can set and get its properties, and pass it to any function that operates on handles.

`HitTest`

`{on} | off`

Selectable by mouse click. `HitTest` determines if the text can become the current object (as returned by the `gco` command and the figure `CurrentObject` property) as a result of a mouse click on the text. If `HitTest` is set to `off`, clicking the text selects the object below it (which is usually the axes containing it).

For example, suppose you define the button down function of an image (see the `ButtonDownFcn` property) to display text at the location you click with the mouse.

First define the callback routine.

```
function bd_function
pt = get(gca,'CurrentPoint');
text(pt(1,1),pt(1,2),pt(1,3),...
 '{\fontsize{20}\oplus} The spot to label',...
 'HitTest','off')
```

Now display an image, setting its `ButtonDownFcn` property to the callback routine.

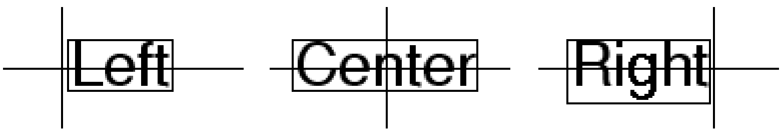
```
load earth
image(X,'ButtonDownFcn','bd_function'); colormap(map)
```

When you click the image, MATLAB displays the text string at that location. With `HitTest` set to `off`, existing text cannot intercept any subsequent button down events that occur over the text. This enables the image's button down function to execute.

`HorizontalAlignment`
`{left} | center | right`

Horizontal alignment of text. This property specifies the horizontal justification of the text string. It determines where MATLAB places the string with regard to the point specified by the `Position` property. The following picture illustrates the alignment options.

`HorizontalAlignment` viewed with the `VerticalAlignment` set to middle (the default).



See the `Extent` property for related information.

`Interpreter`
latex | `{tex} | none`

Interpret TEX instructions. This property controls whether MATLAB interprets certain characters in the `String` property as TEX instructions (default) or displays all characters literally. The options are:

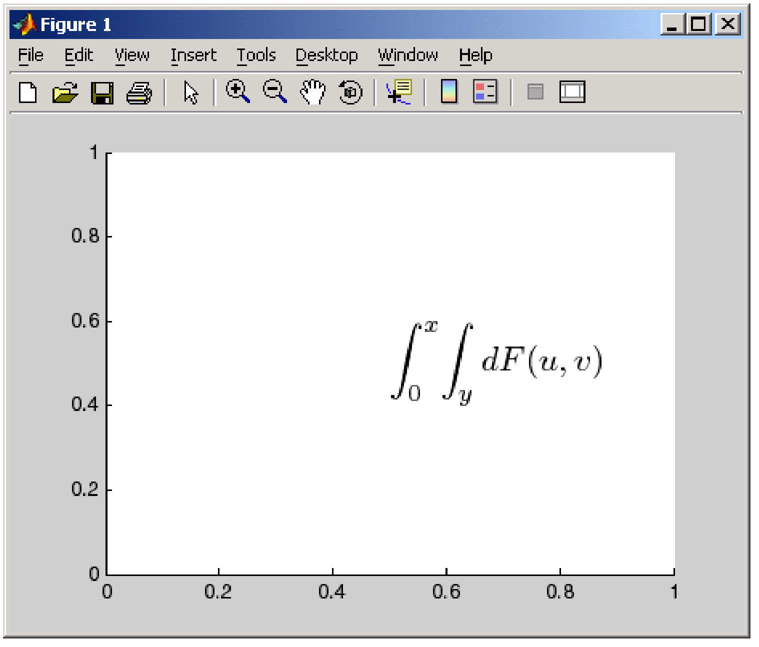
- `latex` — Supports the full LATEX markup language.
- `tex` — Supports a subset of plain TEX markup language. See the `String` property for a list of supported TEX instructions.

- none — Displays literal characters.

Latex Interpreter

To enable the LaTeX interpreter for text objects, set the Interpreter property to latex. For example, the following statement displays an equation in a figure at the point [.5 .5], and enlarges the font to 16 points.

```
text('Interpreter','latex',...
 'String','$$\int_0^x\!\int_y dF(u,v)$$',...
 'Position',[.5 .5],...
 'FontSize',16)
```



Information About Using TEX

The following references may be useful to people who are not familiar with TEX.

- Donald E. Knuth, *The TEXbook*, Addison Wesley, 1986.
- The TEX Users Group home page: http://www.tug.org

`Interruptible`
`{on} | off`

Callback routine interruption mode. The `Interruptible` property controls whether a text callback routine can be interrupted by subsequently invoked callback routines. Text objects have three properties that define callback routines: `ButtonDownFcn`, `CreateFcn`, and `DeleteFcn`. See the `BusyAction` property for information on how MATLAB executes callback routines.

`LineStyle`
`{-} | -- | : | -. | none`

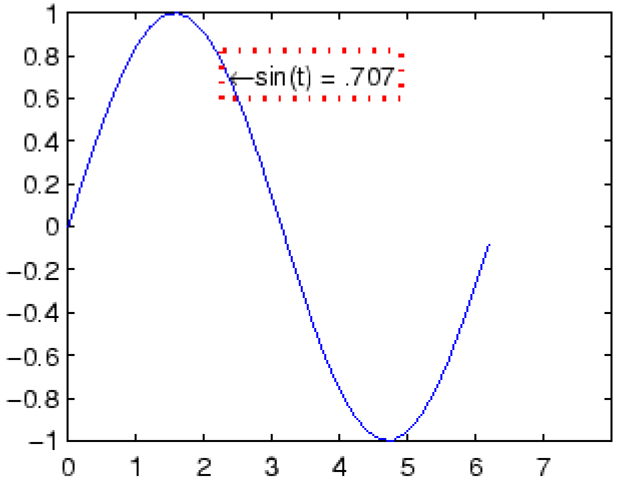
Edge line type. This property determines the line style used to draw the edges of the text `Extent`. The available line styles are shown in the following table.

Symbol	Line Style
-	Solid line (default)
–	Dashed line
:	Dotted line
-.	Dash-dot line
none	No line

For example, the following code draws a red rectangle with a dotted line style around text that labels a plot.

```
text(3*pi/4,sin(3*pi/4),...
     '\leftarrowsin(t) = .707',...
     'EdgeColor','red',...
     'LineWidth',2,...
```

```
'LineStyle',':');
```



For additional features, see the following properties:

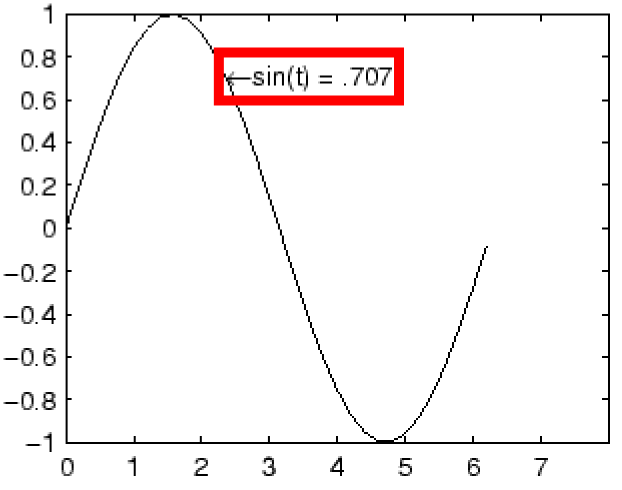
- `BackgroundColor` — Color of the rectangle's interior (`none` by default)
- `EdgeColor` — Color of the rectangle's edge (`none` by default)
- `LineWidth` — Width of the rectangle's edge line (first set `EdgeColor`)
- `Margin` — Increases the size of the rectangle by adding a margin to the existing text extent rectangle. This margin is added to the text extent rectangle to define the text background area that is enclosed by the `EdgeColor` rectangle. Note that the text extent does not change when you change the margin; only the rectangle displayed when you set the `EdgeColor` property and the area defined by the `BackgroundColor` change.

`LineWidth`

scalar (points)

Width of line used to draw text extent rectangle. When you set the text `EdgeColor` property to a color (the default is `none`), MATLAB displays a rectangle around the text `Extent`. Use the `LineWidth` property to specify the width of the rectangle edge. For example, the following code draws a red rectangle around text that labels a plot and specifies a line width of 3 points:

```
text(3*pi/4,sin(3*pi/4),...
'\leftarrowsin(t) = .707',...
'EdgeColor','red',...
'LineWidth',3);
```



For additional features, see the following properties:

- `BackgroundColor` — Color of the rectangle's interior (`none` by default)
- `EdgeColor` — Color of the rectangle's edge (`none` by default)
- `LineStyle` — Style of the rectangle's edge line (first set `EdgeColor`)
- `Margin` — Increases the size of the rectangle by adding a margin to the existing text extent rectangle. This margin is added to the text extent rectangle to define the text background area that is enclosed by the `EdgeColor` rectangle. Note that the text extent does not change when you change the margin; only the rectangle displayed

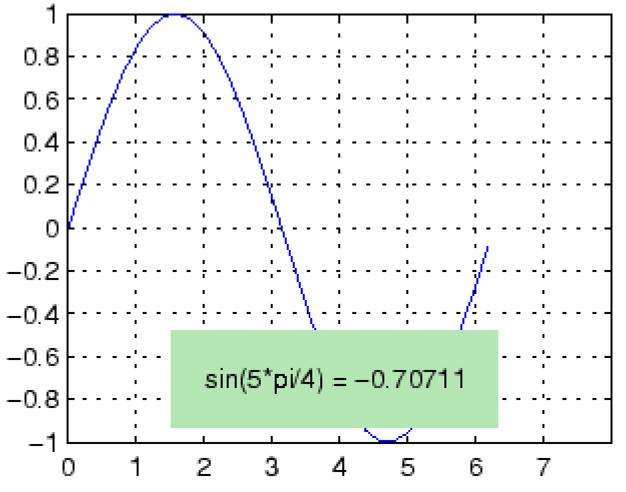
when you set the EdgeColor property and the area defined by the BackgroundColor change.

Margin

scalar (pixels)

Distance between the text extent and the rectangle edge. When you specify a color for the BackgroundColor or EdgeColor text properties, MATLAB draws a rectangle around the area defined by the text Extent plus the value specified by the Margin. For example, the following code displays a light green rectangle with a 10-pixel margin.

```
text(5*pi/4,sin(5*pi/4),...
 ['sin(5*pi/4) = ',num2str(sin(5*pi/4))],...
 'HorizontalAlignment','center',...
 'BackgroundColor',[.7 .9 .7],...
 'Margin',10);
```



For additional features, see the following properties:

- `BackgroundColor` — Color of the rectangle's interior (`none` by default)
- `EdgeColor` — Color of the rectangle's edge (`none` by default)
- `LineStyle` — Style of the rectangle's edge line (first set `EdgeColor`)
- `LineWidth` — Width of the rectangle's edge line (first set `EdgeColor`)

See how margin affects text extent properties

This example enables you to change the values of the `Margin` property and observe the effects on the `BackgroundColor` area and the `EdgeColor` rectangle.

Click to view in editor — This link opens the MATLAB editor with the following example.

Click to run example — Use your scroll wheel to vary the `Margin`.

`Parent`

handle of axes, hggroup, or hgtransform

Parent of text object. This property contains the handle of the text object's parent. The parent of a text object is the axes, hggroup, or hgtransform object that contains it.

See Objects That Can Contain Other Objects for more information on parenting graphics objects.

`Position`

`[x,y,[z]]`

Location of text. A two- or three-element vector, `[x y [z]]`, that specifies the location of the text in three dimensions. If you omit the `z` value, it defaults to 0. All measurements are in units specified by the `Units` property. Initial value is `[0 0 0]`.

`Rotation`

scalar (default = 0)

Text orientation. This property determines the orientation of the text string. Specify values of rotation in degrees (positive angles cause counterclockwise rotation).

`Selected`
`on | {off}`

Is object selected? When this property is set to `on`, MATLAB displays selection handles if the `SelectionHighlight` property is also set to `on`. You can, for example, define the `ButtonDownFcn` to set this property, allowing users to select the object with the mouse.

`SelectionHighlight`
`{on} | off`

Objects are highlighted when selected. When the `Selected` property is set to `on`, MATLAB indicates the selected state by drawing four edge handles and four corner handles. When `SelectionHighlight` is set to `off`, MATLAB does not draw the handles.

`String`
string

The text string. Specify this property as a quoted string for single-line strings, or as a cell array of strings, or a padded string matrix for multiline strings. MATLAB displays this string at the specified location. Vertical slash characters are not interpreted as line breaks in text strings, and are drawn as part of the text string. See Mathematical Symbols, Greek Letters, and TeX Characters for an example.

When the text `Interpreter` property is set to `Tex` (the default), you can use a subset of TeX commands embedded in the string to produce special characters such as Greek letters and mathematical symbols. The following table lists these characters and the character sequences used to define them.

Character Sequence	Symbol	Character Sequence	Symbol	Character Sequence	Symbol
\alpha	α	\upsilon	υ	\sim	~
\beta	β	\phi	Φ	\leq	≤
\gamma	γ	\chi	χ	\infty	∞
\delta	δ	\psi	ψ	\clubsuit	♣
\epsilon	ε	\omega	ω	\diamondsuit	♦
\zeta	ζ	\Gamma	Γ	\heartsuit	♥
\eta	η	\Delta	Δ	\spadesuit	♠
\theta	Θ	\Theta	Θ	\leftrightarrow	↔
\vartheta		\Lambda	Λ	\leftarrow	←
\iota	ι	\Xi	Ξ	\uparrow	↑
\kappa	κ	\Pi	Π	\rightarrow	→
\lambda	λ	\Sigma	Σ	\downarrow	↓
\mu	µ	\Upsilon		\circ	º
\nu	ν	\Phi	Φ	\pm	±
\xi	ξ	\Psi	Ψ	\geq	≥
\pi	π	\Omega	Ω	\propto	∝
\rho	ρ	\forall	∀	\partial	∂
\sigma	σ	\exists	∃	\bullet	•
\varsigma	ς	\ni	∍	\div	÷
\tau	τ	\cong	≅	\neq	≠
\equiv	≡	\approx	≈	\aleph	
\Im	ℑ	\Re	ℜ	\wp	℘

Character Sequence	Symbol	Character Sequence	Symbol	Character Sequence	Symbol
`\otimes`	⊗	`\oplus`	⊕	`\oslash`	∅
`\cap`	∩	`\cup`	∪	`\supseteq`	⊇
`\supset`	⊃	`\subseteq`	⊆	`\subset`	⊂
`\int`	∫	`\in`		`\o`	o
`\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:

- `\bf` — Bold font
- `\it` — Italic font
- `\sl` — Oblique font (rarely available)
- `\rm` — Normal font
- `\fontname{`*`fontname`*`}` — Specify the name of the font family to use.
- `\fontsize{`*`fontsize`*`}` — Specify the font size in `FontUnits`.
- `\color(`*`colorSpec`*`)` — Specify color for succeeding characters

Stream modifiers remain in effect until the end of the string or only within the context defined by braces { }.

Specifying Text Color in TeX Strings

Use the `\color` modifier to change the color of characters following it from the previous color (which is `black` by default). Syntax is:

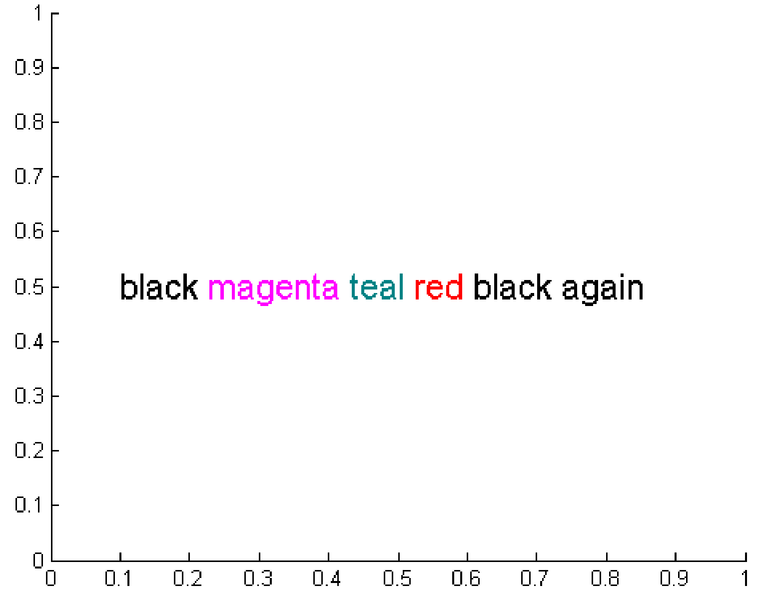
- `\color{colorname}` for the eight basic named colors (`red`, `green`, `yellow`, `magenta`, `blue`, `black`, `white`), and plus the four Simulink colors (`gray`, `darkGreen`, `orange`, and `lightBlue`)

  Note that short names (one-letter abbreviations) for colors are not supported by the `\color` modifier.

- `\color[rgb]{r g b}` to specify an RGB triplet with values between 0 and 1 as a cell array

For example,

```
text(.1,.5,['\fontsize{16}black {\color{magenta}magenta '...
'\color[rgb]{0 .5 .5}teal \color{red}red} black again'])
```



Specifying Subscript and Superscript Characters

The subscript character "_" and the superscript character "^" modify the character or substring defined in braces immediately following.

To print the special characters used to define the TeX strings when `Interpreter` is `Tex`, prefix them with the backslash "\" character: \\, \{, \} _, \^.

See the "Examples" on page 2-3560 in the `text` reference page for more information.

When `Interpreter` is set to `none`, no characters in the `String` are interpreted, and all are displayed when the text is drawn.

When `Interpreter` is set to `latex`, MATLAB provides a complete LaTeX interpreter for text objects. See the `Interpreter` property for more information.

`Tag`

string

User-specified object label. The `Tag` property provides a means to identify graphics objects with a user-specified label. This is particularly useful when you are constructing interactive graphics programs that would otherwise need to define object handles as global variables or pass them as arguments between callback routines. You can define `Tag` as any string.

`Type`

string (read only)

Class of graphics object. For text objects, `Type` is always the string `'text'`.

`Units`

`pixels | normalized | inches |`
`centimeters | points | {data}`

Units of measurement. This property specifies the units MATLAB uses to interpret the `Extent` and `Position` properties. All units are measured from the lower left corner of the axes plot box.

- `Normalized` units map the lower left corner of the rectangle defined by the axes to (0,0) and the upper right corner to (1.0,1.0).
- `pixels`, `inches`, `centimeters`, and `points` are absolute units (1 point = $^1/_{72}$ inch).
- `data` refers to the data units of the parent axes as determined by the data graphed (not the axes `Units` property, which controls the positioning of the within the figure window).

If you change the value of `Units`, it is good practice to return it to its default value after completing your computation so as not to affect other functions that assume `Units` is set to the default value.

`UserData`

matrix

User-specified data. Any data you want to associate with the text object. MATLAB does not use this data, but you can access it using `set` and `get`.

`UIContextMenu`

handle of a uicontextmenu object

Associate a context menu with the text. Assign this property the handle of a uicontextmenu object created in the same figure as the text. Use the `uicontextmenu` function to create the context menu. MATLAB displays the context menu whenever you right-click over the text.

`VerticalAlignment`

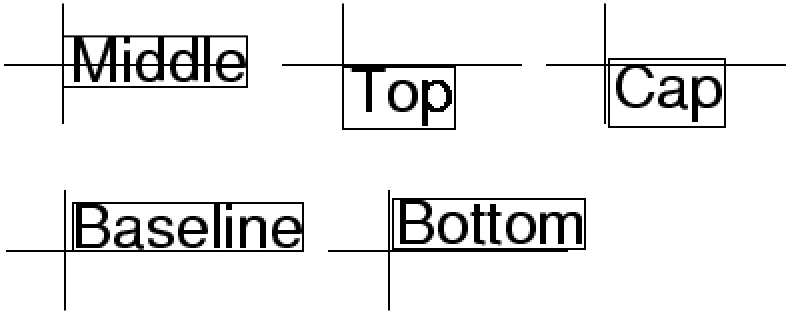
`top | cap | {middle} | baseline | bottom`

Vertical alignment of text. This property specifies the vertical justification of the text string. It determines where MATLAB places the string with regard to the value of the `Position` property. The possible values mean

- top — Place the top of the string' s `Extent` rectangle at the specified *y*-position.
- `cap` — Place the string so that the top of a capital letter is at the specified *y*-position.
- `middle` — Place the middle of the string at the specified *y*-position.
- `baseline` — Place font baseline at the specified *y*-position.
- `bottom` — Place the bottom of the string's `Extent` rectangle at the specified *y*-position.

The following picture illustrates the alignment options.

Text `VerticalAlignment` property viewed with the `HorizontalAlignment` property set to `left` (the default).



`Visible`

`{on} | off`

Text visibility. By default, all text is visible. When set to `off`, the text is not visible, but still exists, and you can query and set its properties.

Purpose

Read data from text file; write to multiple outputs

Note The `textscan` function is intended as a replacement for both `textread` and `strread`.

Graphical Interface

As an alternative to `textread`, use the Import Wizard. To activate the Import Wizard, select **Import Data** from the **File** menu.

Syntax

```
[A,B,C,...] = textread('filename','format')
[A,B,C,...] = textread('filename','format',N)
[...] = textread(...,'param','value',...)
```

Description

`[A,B,C,...] = textread('filename','format')` reads data from the file `'filename'` into the variables `A,B,C,` and so on, using the specified `format`, until the entire file is read. The `filename` and `format` inputs are strings, each enclosed in single quotes. `textread` is useful for reading text files with a known format. `textread` handles both fixed and free format files.

Note When reading large text files, reading from a specific point in a file, or reading file data into a cell array rather than multiple outputs, you might prefer to use the `textscan` function.

`textread` matches and converts groups of characters from the input. Each input field is defined as a string of non-white-space characters that extends to the next white-space or delimiter character, or to the maximum field width. Repeated delimiter characters are significant, while repeated white-space characters are treated as one.

The `format` string determines the number and types of return arguments. The number of return arguments is the number of items in the `format` string. The `format` string supports a subset of the conversion specifiers and conventions of the C language `fscanf` routine.

Values for the format string are listed in the table below. White-space characters in the format string are ignored.

format	Action	Output
Literals (ordinary characters)	Ignore the matching characters. For example, in a file that has Dept followed by a number (for department number), to skip the Dept and read only the number, use 'Dept' in the format string.	None
%d	Read a signed integer value.	Double array
%u	Read an integer value.	Double array
%f	Read a floating-point value.	Double array
%s	Read a white-space or delimiter-separated string.	Cell array of strings
%q	Read a double quoted string, ignoring the quotes.	Cell array of strings
%c	Read characters, including white space.	Character array
%[...]	Read the longest string containing characters specified in the brackets.	Cell array of strings
%[^...]	Read the longest nonempty string containing characters that are not specified in the brackets.	Cell array of strings
%*... instead of %	Ignore the matching characters specified by *.	No output
%w... instead of %	Read field width specified by w. The %f format supports %w.pf, where w is the field width and p is the precision.	

[A,B,C,...] = textread('filename','format',N) reads the data, reusing the format string N times, where N is an integer greater than zero. If N is smaller than zero, textread reads the entire file.

[...] = textread(...,'param','value',...) customizes textread using param/value pairs, as listed in the table below.

param	value	Action

	`' '`
	`\b`
	`\n`
	`\r`
	`\t`
		Space
		Backspace
		Newline
		Carriage return
		Horizontal tab

bufsize	Positive integer	Specifies the maximum string length, in bytes. Default is 4095.
commentstyle	matlab	Ignores characters after %.
commentstyle	shell	Ignores characters after #.
commentstyle	c	Ignores characters between /* and */.
commentstyle	c++	Ignores characters after //.
delimiter	One or more characters	Act as delimiters between elements. Default is none.
emptyvalue	Scalar double	Value given to empty cells when reading delimited files. Default is 0.
endofline	Single character or '\r\n'	Character that denotes the end of a line. Default is determined from file
expchars	Exponent characters	Default is eEdD.
headerlines	Positive integer	Ignores the specified number of lines at the beginning of the file.
whitespace	Any from the list below:	Treats vector of characters as white space. Default is ' \b\t'.

Note When textread reads a consecutive series of whitespace values, it treats them as one white space. When it reads a consecutive series of delimiter values, it treats each as a separate delimiter.

Remarks

If you want to preserve leading and trailing spaces in a string, use the `whitespace` parameter as shown here:

```
textread('myfile.txt', '%s', 'whitespace', '')
ans =
    '   An  example      of preserving    spaces       '
```

Examples

Example 1 — Read All Fields in Free Format File Using %

The first line of `mydata.dat` is

```
Sally    Level1 12.34 45 Yes
```

Read the first line of the file as a free format file using the `%` format.

```
[names, types, x, y, answer] = textread('mydata.dat', ...
'%s %s %f %d %s', 1)
```

returns

```
names =
    'Sally'
types =
    'Level1'
x =
  12.34000000000000
y =
    45
answer =
    'Yes'
```

Example 2 — Read as Fixed Format File, Ignoring the Floating Point Value

The first line of `mydata.dat` is

```
Sally    Level1 12.34 45 Yes
```

Read the first line of the file as a fixed format file, ignoring the floating-point value.

```
[names, types, y, answer] = textread('mydata.dat', ...
'%9c %5s %*f %2d %3s', 1)
```

returns

```
names =
Sally
types =
    'Level1'
y =
    45
answer =
    'Yes'
```

`%*f` in the `format` string causes `textread` to ignore the floating point value, in this case, `12.34`.

Example 3 — Read Using Literal to Ignore Matching Characters

The first line of `mydata.dat` is

```
Sally    Type1 12.34 45 Yes
```

Read the first line of the file, ignoring the characters `Type` in the second field.

```
[names, typenum, x, y, answer] = textread('mydata.dat', ...
'%s Type%d %f %d %s', 1)
```

returns

```
names =
    'Sally'
typenum =
    1
x =
  12.34000000000000
y =
    45
```

```
answer =
    'Yes'
```

`Type%d` in the `format` string causes the characters `Type` in the second field to be ignored, while the rest of the second field is read as a signed integer, in this case, `1`.

Example 4 — Specify Value to Fill Empty Cells

For files with empty cells, use the `emptyvalue` parameter. Suppose the file `data.csv` contains:

```
1,2,3,4,,6
7,8,9,,11,12
```

Read the file using `NaN` to fill any empty cells:

```
data = textread('data.csv', '', 'delimiter', ',', ...
                'emptyvalue', NaN);
```

Example 5 — Read M-File into a Cell Array of Strings

Read the file `fft.m` into cell array of strings.

```
file = textread('fft.m', '%s', 'delimiter', '\n', ...
                'whitespace', '');
```

See Also

`textscan`, `dlmread`, `csvread`, `strread`, `fscanf`

Purpose

Read formatted data from text file or string

Syntax

```
C = textscan(fid, 'format')
C = textscan(fid, 'format', N)
C = textscan(fid, 'format', param, value, ...)
C = textscan(fid, 'format', N, param, value, ...)
C = textscan(str, ...)
[C, position] = textscan(...)
```

Description

Note Before reading a file with `textscan`, you must open the file with the `fopen` function. `fopen` supplies the `fid` input required by `textscan`. When you are finished reading from the file, you should close the file by calling `fclose(fid)`.

`C = textscan(fid, 'format')` reads data from an open text file identified by file identifier `fid` into cell array `C`. The MATLAB software parses the data into fields and converts it according to the conversion specifiers in `format`. The `format` input is a string enclosed in single quotes. These conversion specifiers determine the type of each cell in the output cell array. The number of specifiers determines the number of cells in the cell array.

`C = textscan(fid, 'format', N)` reads data from the file, reusing the `format` conversion specifier `N` times, where `N` is a positive integer. You can resume reading from the file after `N` cycles by calling `textscan` again using the original `fid`.

`C = textscan(fid, 'format', param, value, ...)` reads data from the file using nondefault parameter settings specified by one or more pairs of `param` and `value` arguments. The section "User Configurable Options" on page 2-3608 lists all valid parameter strings, value descriptions, and defaults.

`C = textscan(fid, 'format', N, param, value, ...)` reads data from the file, reusing the `format` conversion specifier `N` times, and using nondefault parameter settings specified by pairs of `param` and `value` arguments.

`C = textscan(str, ...)` reads data from string `str` in exactly the same way as it does when reading from a file. You can use the `format`, `N`, and parameter/value arguments described above with this syntax. Unlike when reading from a file, if you call `textscan` more than once on the same string, it does not resume reading where the last call left off but instead reads from the beginning of the string each time.

`[C, position] = textscan(...)` returns the location of the file or string position as the second output argument. For a file, this is exactly equivalent to calling `ftell(fid)` after making the call to `textscan`. For a string, it indicates how many characters were read.

The Difference Between the textscan and textread Functions

The `textscan` function differs from `textread` in the following ways:

- The `textscan` function offers better performance than `textread`, making it a better choice when reading large files.
- With `textscan`, you can start reading at any point in the file. Once the file is open, (`textscan` requires that you open the file first), you can `fseek` to any position in the file and begin the scan at that point. The `textread` function requires that you start reading from the beginning of the file.
- Subsequent `textscan` operations start reading the file at the point where the last scan left off. The `textread` function always begins at the start of the file, regardless of any prior `textread` operations.
- `textscan` returns a single cell array regardless of how many fields you read. With `textscan`, you don't need to match the number of output arguments to the number of fields being read as you would with `textread`.
- `textscan` offers more choices in how the data being read is converted.
- `textscan` offers more user-configurable options.

Field Delimiters

The `textscan` function sees a text file as a collection of blocks. Each block consists of a number of internally consistent fields. Each field consists of a group of characters delimited by a field delimiter character. Fields can span a number of rows. Each row is delimited by an end-of-line (`EOL`) character sequence.

The default field delimiter is the white-space character, (i.e., any character that returns `true` from a call to the `isspace` function). You can set the delimiter to a different character by specifying a `'delimiter'` parameter in the `textscan` command (see "User Configurable Options" on page 2-3608). If a nondefault delimiter is specified, repeated delimiter characters are treated as separate delimiters. When using the default delimiter, repeated white-space characters are treated as a single delimiter.

The default end-of-line character sequence depends on which operating system you are using. You can change the end-of-line setting to a different character sequence by specifying an `'endofline'` parameter in the `textscan` command (see "User Configurable Options" on page 2-3608).

Conversion Specifiers

This table shows the conversion type specifiers supported by `textscan`.

Specifier	Description
`%n`	Read a number and convert to `double`.
`%d`	Read a number and convert to `int32`.
`%d8`	Read a number and convert to `int8`.
`%d16`	Read a number and convert to `int16`.
`%d32`	Read a number and convert to `int32`.
`%d64`	Read a number and convert to `int64`.
`%u`	Read a number and convert to `uint32`.

Specifier	Description
%u8	Read a number and convert to uint8.
%u16	Read a number and convert to uint16.
%u32	Read a number and convert to uint32.
%u64	Read a number and convert to uint64.
%f	Read a number and convert to double.
%f32	Read a number and convert to single.
%f64	Read a number and convert to double.
%s	Read a string.
%q	Read a (possibly double-quoted) string.
%c	Read one character, including white space.
%[...]	Read characters that match characters between the brackets. Stop reading at the first nonmatching character. Use %[]...] to include] in the set.
%[^...]	Read characters that do not match characters between the brackets. Stop reading at the first matching character. Use %[^]...] to exclude] from the set.
%*n...	Ignore n characters of the field, where n is an integer less than or equal to the number of characters in the field (e.g., %*4s).

Specifying Field Length

To read a certain number of characters or digits from a field, specify that number directly following the percent sign. For example, if the file you are reading contains the string

```
'Blackbird singing in the dead of night'
```

then the following command returns only five characters of the first field:

```
C = textscan(fid, '%5s', 1);
C{:}
ans =
   'Black'
```

If you continue reading from the file, `textscan` resumes the operation at the point in the string where you left off. It applies the next format specifier to that portion of the field. For example, execute this command on the same file:

```
C = textscan(fid, '%s %s', 1);
```

Note Spaces between the conversion specifiers are shown only to make the example easier to read. They are not required.

`textscan` reads starting from where it left off and continues to the next whitespace, returning `'bird'`. The second `%s` reads the word `'singing'`.

The results are

```
C{:}
ans =
    'bird'
ans =
    'singing'
```

Skipping Fields

To skip any field, put an asterisk directly after the percent sign. MATLAB does not create an output cell for any fields that are skipped.

Refer to the example from the last section, where the file you are reading contains the string

```
'Blackbird singing in the dead of night'
```

Seek to the beginning of the file and reread the line, this time skipping the second, fifth, and sixth fields:

```
fseek(fid, 0, -1);
C = textscan(fid, '%s %*s %s %s %*s %*s %s', 1);
```

C is a cell array of cell arrays, each containing a string. Piece together the string and display it:

```
str = '';
for k = 1:length(C)
   str = [str char(C{k}) ' '];
   if k == 4,  disp(str),  end
end

Blackbird in the night
```

Skipping Literal Strings

In addition to skipping entire fields, you can have `textscan` skip leading literal characters in a string. Reading a file containing the following data,

```
Sally    Level1  12.34
Joe      Level2  23.54
Bill     Level3  34.90
```

this command removes the substring `'Level'` from the output and converts the level number to a `uint8`:

```
C = textscan(fid, '%s Level%u8 %f');
```

This returns a cell array `C` with the second cell containing only the unsigned integers:

```
C{1} = {'Sally'; 'Joe'; 'Bill'}       class cell
C{2} = [1; 2; 3]                      class uint8
C{3} = [12.34; 23.54; 34.90]          class double
```

Specifying Numeric Field Length and Decimal Digits

With numeric fields, you can specify the number of digits to read in the same manner described for strings in the section "Specifying Field Length" on page 2-3602. The next example uses a file containing the line

```
'405.36801 551.94387 298.00752 141.90663'
```

This command returns the starting 7 digits of each number in the line. Note that the decimal point counts as a digit.

```
C = textscan(fid, '%7f32 %*n');
C{:} =
   [405.368; 551.943; 298.007; 141.906]
```

You can also control the number of digits that are read to the right of the decimal point for any numeric field of type `%f`, `%f32`, or `%f64`. The format specifier in this command uses a `%9.1` prefix to cause `textscan` to read the first 9 digits of each number, but only include 1 digit of the decimal value in the number it returns:

```
C = textscan(fid, '%9.1f32 %*n');
C{:} =
   [405.3; 551.9; 298.0; 141.9]
```

Conversion of Numeric Fields

This table shows how `textscan` interprets the numeric field specifiers.

Format Specifier	Action Taken
`%n`, `%d`, `%u`, `%f`, and variants thereof	Read to the first delimiter. Example: `%n` reads `'473.238 '` as `473.238`.

Format Specifier	Action Taken
%Nn, %Nd, %Nu, %Nf, and variants thereof	Read N digits (counting a decimal point as a digit), or up to the first delimiter, whichever comes first. Example: %5f32 reads '473.238 ' as 473.2.
Specifiers that start with %N.Df	Read N digits (counting a decimal point as a digit), or up to the first delimiter, whichever comes first. Return D decimal digits in the output. Example: %7.2f reads '473.238 ' as 473.23.

Conversion specifiers %n, %d, %u, %f, or any variant thereof (e.g., %d16) return a K-by-1 MATLAB numeric vector of the type indicated by the conversion specifier, where K is the number of times that specifier was found in the file. textscan converts the numeric fields from the field content to the output type according to the conversion specifier and MATLAB rules regarding overflow and truncation. NaN, Inf, and -Inf are converted according to applicable MATLAB rules.

textscan imports any complex number as a whole into a complex numeric field, converting the real and imaginary parts to the specified numeric type. Valid forms for a complex number are

<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.

Conversion of Strings

This table shows how textscan interprets the string field specifiers.

Format Specifier	Action Taken
`%s` or `%q`	Read to the first delimiter. Example: %s reads 'summer ' as 'summer'.
`%Ns` or `%Nq`	Read N characters, or to the first delimiter, whichever comes first. Example: %3s reads 'summer ' as 'sum'.
`%[abc]`	Read those characters that match any character specified within the brackets, stopping just before the first character that does not match. Example: `%[mus]` reads `'summer '` as `'summ'`.
`%N[abc]`	Read as many as `N` characters that match any character specified within the brackets, stopping just before the first character that does not match. Example: `%2[mus]` reads `'summer'` as `'su'`.
`%[^abc]`	Read those characters that do not match any character specified within the brackets, stopping just before the first character that does match. Example: `%[^xrg]` reads `'summer '` as `'summe'`.
`%N[^abc]`	Read as many as `N` characters that do not match any character specified within the brackets, stopping just before the first character that does match. Example: `%2[^xrg]` reads `'summer '` as `'su'`.

Conversion specifiers `%s`, `%q`, `%[...]`, and `%[^...]` return a `K`-by-1 MATLAB cell vector of strings, where `K` is the number of times that specifier was found in the file. If you set the `delimiter` parameter to a non-white-space character, or set the `whitespace` parameter to `''`, `textscan` returns all characters in the string field, including white-space. Otherwise each string terminates at the beginning of white-space.

Conversion of Characters

This table shows how `textscan` interprets the character field specifiers.

Format Specifier	Action Taken
`%c`	Read one character. Example: `%c` reads `'Let's go!'` as `'L'`.
`%Nc`	Read `N` characters, including delimiter characters. Example: `%9c` reads `'Let's go!'` as `'Let's go!'`.

Conversion specifier `%Nc` returns a `K`-by-`N` MATLAB character array, where `K` is the number of times that specifier was found in the file. `textscan` returns all characters, including white-space, but excluding the delimiter.

Conversion of Empty Fields

An empty field in the text file is defined by two adjacent delimiters indicating an empty set of characters, or, in all cases except `%c`, white-space. The empty field is returned as `NaN` by default, but is user definable. In addition, you may specify custom strings to be used as empty values, in *numeric fields only*. `textscan` does not examine nonnumeric fields for custom empty values. See "User Configurable Options" on page 2-3608.

Note MATLAB represents integer `NaN` as zero. If `textscan` reads an empty field that is assigned an integer format specifier (one that starts with `%d` or `%u`), it returns the empty value as zero rather than as `NaN`. (See the value returned in C{5} in Example 6 — Using a Nondefault Empty Value.

User Configurable Options

This table shows the valid `param-value` options and their default values. Parameter names are not case-sensitive.

Parameter	Value	Default
BufSize	Maximum string length in bytes	4095
CollectOutput	If true, MATLAB concatenates consecutive cells of the output that have the same data type into a single array.	0 (false)
CommentStyle	Symbol(s) designating text to be ignored (see "Values for commentStyle" on page 2-3610, below)	None
Delimiter	Delimiter characters	Whitespace
EmptyValue	Empty cell value in delimited files	NaN
endOfLine	End-of-line character	Determined from the file
expChars	Exponent characters	'eEdD'
HeaderLines	Number of lines to skip. (This includes the remainder of the current line, unless you are positioned at the beginning of the file.)	0
MultipleDelimsAsOne	If set to 1, textscan treats consecutive delimiters as a single delimiter. If set to 0, textscan treats them as separate delimiters. Only valid if the delimiter option is specified.	0

Parameter	Value	Default
ReturnOnError	Behavior on failing to read or convert (1=true, or 0)	1
TreatAsEmpty	String(s) to be treated as an empty value. A single string or cell array of strings can be used.	None
Whitespace	White-space characters	' \b\t'

White-Space Characters

Leading white-space characters are not included in the processing of any of the data fields. When processing numeric data, trailing whitespace is also assumed to have no significance.

Values for commentStyle

Possible values for the commentStyle parameter are

Value	Description	Example
Single string, S	Ignore any characters that follow string S and are on the same line.	'%', '//'
Cell array of two strings, C	Ignore any characters that lie between the opening and closing strings in C.	{'/*', '*/'}, {'/%', '%/'}

Resuming a Text Scan

If textscan fails to convert a data field, it stops reading and returns all fields read before the failure. When reading from a file, you can resume reading from the same file by calling textscan again using the same file identifier, fid. When reading from a string, the two-output argument syntax enables you to resume reading from the string at the point where the last read terminated. The following command is an example of how you can do this:

```
textscan(str(position+1:end), ...)
```

Remarks

For information on how to use `textscan` to import large data sets, see "Reading Files with Large Data Sets" in the MATLAB Programming Fundamentals documentation.

Examples

Example 1 — Reading Different Types of Data

Text file `scan1.dat` contains data in the following form:

```
Sally  Level1 12.34 45 1.23e10 inf NaN Yes
Joe    Level2 23.54 60 9e19 -inf 0.001 No
Bill   Level3 34.90 12 2e5 10 100 No
```

Read each column into a variable:

```
fid = fopen('scan1.dat');
C = textscan(fid, '%s %s %f32 %d8 %u %f %f %s');
fclose(fid);
```

Note Spaces between the conversion specifiers are shown only to make the example easier to read. They are not required.

`textscan` returns a 1-by-8 cell array `C` with the following cells:

```
C{1} = {'Sally'; 'Joe'; 'Bill'}          class cell
C{2} = {'Level1'; 'Level2'; 'Level3'}    class cell
C{3} = [12.34; 23.54; 34.9]              class single
C{4} = [45; 60; 12]                      class int8
C{5} = [4294967295; 4294967295; 200000]  class uint32
C{6} = [Inf; -Inf; 10]                   class double
C{7} = [NaN; 0.001; 100]                 class double
C{8} = {'Yes'; 'No'; 'No'}               class cell
```

The first two elements of C{5} are the maximum values for a 32-bit unsigned integer, or intmax('uint32').

Example 2 — Reading All But One Field

Read the file as a fixed-format file, skipping the third field:

```
fid = fopen('scan1.dat');
C = textscan(fid, '%7c %6s %*f %d8 %u %f %f %s');
fclose(fid);
```

textscan returns a 1-by-8 cell array C with the following cells:

```
C{1} = ['Sally  '; 'Joe    '; 'Bill   ']   class char
C{2} = {'Level1'; 'Level2'; 'Level3'}      class cell
C{3} = [45; 60; 12]                        class int8
C{4} = [4294967295; 4294967295; 200000]    class uint32
C{5} = [Inf; -Inf; 10]                     class double
C{6} = [NaN; 0.001; 100]                   class double
C{7} = {'Yes'; 'No'; 'No'}                 class cell
```

Example 3 — Reading Only the First Field

Read the first column into a cell array, skipping the rest of the line:

```
fid = fopen('scan1.dat');
names = textscan(fid, '%s%*[^\n]');
fclose(fid);
```

textscan returns a 1-by-1 cell array names:

```
size(names)
ans =
     1     1
```

The one cell contains

```
names{1} = {'Sally'; 'Joe'; 'Bill'}       class cell
```

Example 4 — Removing a Literal String in the Output

The second `format` specifier in this example, `%sLevel`, tells `textscan` to read the second field from a line in the file, but to ignore the initial string `'Level'` within that field. All that is left of the field is a numeric digit. `textscan` assigns the next specifier, `%f`, to that digit, converting it to a `double`.

See `C{2}` in the results:

```
fid = fopen('scan1.dat');
C = textscan(fid, '%s Level%u8 %f32 %d8 %u %f %f %s');
fclose(fid);
```

`textscan` returns a 1-by-8 cell array, `C`, with cells

```
C{1} = {'Sally'; 'Joe'; 'Bill'}          class cell
C{2} = [1; 2; 3]                         class uint8
C{3} = [12.34; 23.54; 34.90]             class single
C{4} = [45; 60; 12]                      class int8
C{5} = [4294967295; 4294967295; 200000]  class uint32
C{6} = [Inf; -Inf; 10]                   class double
C{7} = [NaN; 0.001; 100]                 class double
C{8} = {'Yes'; 'No'; 'No'}               class cell
```

Example 5 — Using a Nondefault Delimiter and White-Space

Read the M-file into a cell array of strings:

```
fid = fopen('fft.m');
file = textscan(fid, '%s', 'delimiter', '\n', ...
                'whitespace', '');
fclose(fid);
```

`textscan` returns a 1-by-1 cell array, `file`, that contains a 37-by-1 cell array:

```
file =
    {37x1 cell}
```

Show some of the text from the first three lines of the file:

```
lines = file{1};
lines{1:3, :}
ans =
%FFT Discrete Fourier transform.
ans =
%   FFT(X) is the discrete Fourier transform (DFT) of vector X.  For
ans =
%   matrices, the FFT operation is applied to each column. For N-D
```

Example 6 — Using a Nondefault Empty Value

Read files with empty cells, setting the `emptyvalue` parameter. The file `data.csv` contains

```
1,  2,  3,  4,   ,  6
7,  8,  9,   , 11, 12
```

Read the file as shown here, using `-Inf` in empty cells:

```
fid = fopen('data.csv');
C = textscan(fid, '%f%f%f%f%u32%f', 'delimiter', ',', ...
             'emptyValue', -Inf);
fclose(fid);
```

`textscan` returns a 1-by-6 cell array `C` with the following cells:

```
C{1} = [1; 7]           class double
C{2} = [2; 8]           class double
C{3} = [3; 9]           class double
C{4} = [4; NaN]         class double
C{5} = [-Inf; 11]       class uint32 (-Inf converted to 0)
C{6} = [6; 12]          class double
```

Example 7 — Using Custom Empty Values and Comments

You have a file `data.csv` that contains the lines

```
abc, 2, NA, 3, 4
// Comment Here
def, na, 5, 6, 7
```

Designate what should be treated as empty values and as comments. Read in all other values from the file:

```
fid = fopen('data.csv');
C = textscan(fid, '%s%n%n%n%n', 'delimiter', ',', ...
             'treatAsEmpty', {'NA', 'na'}, ...
             'commentStyle', '//');
fclose(fid);
```

This returns the following data in cell array `C`:

```
C{:}
ans =
    'abc'
    'def'
ans =
     2
   NaN
ans =
   NaN
     5
ans =
     3
     6
ans =
     4
     7
```

Example 8 — Reading From a String

Read in a string (quoted from Albert Einstein) using `textscan`:

```
str = ...
  ['Do not worry about your difficulties in Mathematics.' ...
   'I can assure you mine are still greater.'];
```

```
s = textscan(str, '%s', 'delimiter', '.');

s{:}
ans =
    'Do not worry about your difficulties in Mathematics'
    'I can assure you mine are still greater'
```

Example 9 — Handling Multiple Delimiters

This example takes a comma-separated list of names, the test pilots known as the Mercury Seven, and uses `textscan` to return a list of their names in a cell array. When some names are removed from the input list, leaving multiple sequential delimiters, `textscan`, by default, accounts for this. If you override that default by calling `textscan` with the `multipleDelimsAsOne` option, `textscan` ignores the missing names.

Here is the full list of the astronauts:

```
Mercury7 = ...
  'Shepard,Grissom,Glenn,Carpenter,Schirra,Cooper,Slayton';
```

Remove the names Grissom and Cooper from the input string, and `textscan`, by default, does not treat the multiple delimiters as one, and returns an empty string for each missing name:

```
Mercury7 = 'Shepard,,Glenn,Carpenter,Schirra,,Slayton';
names = textscan(Mercury7, '%s', 'delimiter', ',');
names{:}'
ans =
  'Shepard' '' 'Glenn' 'Carpenter' 'Schirra' '' 'Slayton'
```

Using the same input string, but this time setting the `multipleDelimsAsOne` switch, `textscan` ignores the multiple delimiters:

```
names = textscan(Mercury7, '%s', 'delimiter', ',', ...
                 'multipledelimsasone', 1);
names{:}'
```

```
ans =
  'Shepard'  'Glenn'  'Carpenter'  'Schirra'  'Slayton'
```

Example 10 — Using the CollectOutput Switch

Shown below are the contents of a file `wire_gage.txt`. The first line contains four column headers in text. The lines that follow that are numeric data:

```
 AWG |  Area    | Resistance |   Diameter
0000   211600      0.049         0.46
000    167810      0.0618        0.40965
00     133080      0.078         0.3648
0      105530      0.0983        0.32485
1       83694      0.124         0.2893
2       66373      0.1563        0.25763
3       52634      0.197         0.22942
4       41742      0.2485        0.20431
5       33102      0.3133        0.18194
6       26250      0.3951        0.16202
7       20816      0.4982        0.14428
8       16509      0.6282        0.12849
9       13094      0.7921        0.11443
10      10381      0.9989        0.10189
```

When you read the file with `textscan` and with the `CollectOutput` switch set to 0, MATLAB returns each column of the numeric data in a separate `int32` or `double` array. These arrays are packaged inside the `C_data0` cell array:

```
format long g
fid = fopen('wire_gage.txt', 'r');

C_text = textscan(fid, '%s', 4, 'delimiter', '|');

C_data0 = textscan(fid, '%d %f %f %f', 'CollectOutput', 0)
C_data0 =
  [44x1 int32]  [44x1 double]  [44x1 double]  [44x1 double]
```

Reading the file with CollectOutput set to 1 collects each column of data that is of the same class (e.g., double) into a single array. Note that, in this case, the output cell array contains only one array of class double, and this array holds all three columns of the double data read from the file:

```
frewind(fid)

C_text = textscan(fid, '%s', 4, 'delimiter', '|');

C_data1 = textscan(fid, '%d %f %f %f', 'CollectOutput', 1)
C_data1 =
    [44x1 int32]    [44x3 double]
```

See Also

dlmread, dlmwrite, xlswrite, fopen, fseek, importdata

Purpose

Wrapped string matrix for given uicontrol

Syntax

```
outstring = textwrap(h,instring)
[outstring,position]=textwrap(h,instring)
```

Description

`outstring = textwrap(h,instring)` returns a wrapped string cell array, `outstring`, that fits inside the uicontrol with handle `h`. `instring` is a cell array, with each cell containing a single line of text. `outstring` is the wrapped string matrix in cell array format. Each cell of the input string is considered a paragraph.

`[outstring,position]=textwrap(h,instring)` returns the recommended position of the uicontrol in the units of the uicontrol. `position` considers the extent of the multiline text in the *x* and *y* directions.

Remarks

When programming a GUI, do not call `copyobj` or `textwrap` (which calls `copyobj`) inside a `CreateFcn`. The act of copying the uicontrol object fires the `CreateFcn` repeatedly, which raises a series of error messages after exceeding the root object's `RecursionLimit` property.

Example

Place a text-wrapped string in a uicontrol:

```
pos = [10 10 100 10];
h = uicontrol('Style','Text','Position',pos);
string = {'This is a string for the uicontrol.',
          'It should be correctly wrapped inside.'};
[outstring,newpos] = textwrap(h,string);
pos(4) = newpos(4);
set(h,'String',outstring,'Position',[pos(1),pos(2),pos(3)+10,po
s(4)])
```

See Also

`uicontrol`

throw (MException)

Purpose Terminate function and issue exception

Syntax

```
throw(ME)
```

Description

`throw(ME)` terminates the currently running function, issues an exception based on `MException` object `ME`, and returns control to the keyboard or to any enclosing `catch` block. A thrown `MException` displays a message in the Command Window unless it is caught by `try-catch`. `throw` also sets the `MException` stack field to the location from which the `throw` method was called.

Examples

Example 1

This example tests the output of M-file `evaluate_plots` and throws an exception if it is not acceptable:

```
[minval, maxval] = evaluate_plots(p24, p28, p41);
if minval < lower_bound || maxval > upper_bound
    ME = MException('VerifyOutput:OutOfBounds', ...
       'Results are outside the allowable limits');
    throw(ME);
end
```

Example 2

This example attempts to open a file in a directory that is not on the MATLAB path. It uses a nested `try-catch` block to give the user the opportunity to extend the path. If the file still cannot be found, the program issues an exception with the first error appended to the second:

```
function data = read_it(filename);
try
   fid = fopen(filename, 'r');
   data = fread(fid);
catch eObj1
   if strcmp(eObj1.identifier, 'MATLAB:FileIO:InvalidFid')
      msg = sprintf('\n%s%s%s', 'Cannot open file ', ...
         filename, '. Try another location?  ');
```

```
        reply = input(msg, 's')
        if reply(1) == 'y'
            newdir = input('Enter directory name:  ', 's');
        else
            throw(eObj1);
        end
        addpath(newdir);
        try
           fid = fopen(filename, 'r');
           data = fread(fid);
        catch eObj2
           eObj3 = addCause(eObj2, eObj1)
           throw(eObj3);
        end
        rmpath(newdir);
     end
  end
  fclose(fid);
```

If you run this function in a `try-catch` block at the command line, you can look at the `MException` object by assigning it to a variable (`e`) with the `catch` command.

```
try
   d = read_it('anytextfile.txt');
catch e
end

e
e =
 MException object with properties:

    identifier: 'MATLAB:FileIO:InvalidFid'
       message: 'Invalid file identifier.  Use fopen to
generate a valid file identifier.'
         stack: [1x1 struct]
         cause: {[1x1 MException]}
```

```
  Cannot open file anytextfile.txt. Try another location?y
Enter directory name:  xxxxxxx
Warning: Name is nonexistent or not a directory: xxxxxxx.
> In path at 110
  In addpath at 89
```

See Also

error, try, catch, assert, MException, rethrow(MException), throwAsCaller(MException), addCause(MException), getReport(MException), disp(MException), isequal(MException), eq(MException), ne(MException), last(MException),

Purpose

Throw exception, as if from calling function

Syntax

`throwAsCaller(ME)`

Description

`throwAsCaller(ME)` throws an exception from the currently running M-file based on `MException` object `ME`. The MATLAB software exits the currently running function and returns control to either the keyboard or an enclosing `catch` block in a calling function. Unlike the `throw` function, MATLAB omits the current stack frame from the `stack` field of the `MException`, thus making the exception look as if it is being thrown by the caller of the function.

In some cases, it is not relevant to show the person running your program the true location that generated an exception, but is better to point to the calling function where the problem really lies. You might also find `throwAsCaller` useful when you want to simplify the error display, or when you have code that you do not want made public.

Examples

The function `klein_bottle`, in this example, generates a Klein Bottle figure by revolving the figure-eight curve defined by XYKLEIN. It defines a few variables and calls the function `draw_klein`, which executes three functions in a `try-catch` block. If there is an error, the `catch` block issues an exception using either `throw` or `throwAsCaller`:

```
function klein_bottle(ab, pq)
rtr = [2 0.5 1];
box = [-3 3 -3 3 -2 2];
vue = [55 60];
draw_klein(ab, rtr, pq, box, vue)


function draw_klein(ab, rtr, pq, box, vue)
clf
try
   tube('xyklein',ab, rtr, pq, box, vue);
   shading interp
   colormap(pink);
```

```
catch ME
   throw(ME)
%   throwAsCaller(ME)
end
```

Call the `klein_bottle` function, passing an incorrect value for the second argument. (The correct value would be a vector, such as `[40 40]`.) Because the `catch` block issues the exception using `throw`, MATLAB displays error messages for line 15 of function `draw_klein`, and for line 5 of function `klein_bottle`:

```
klein_bottle(ab, pi)
??? Attempted to access pq(2); index out of bounds because
   numel(pq)=1.

Error in ==> klein_bottle>draw_klein at 15
   throw(ME);

Error in ==> klein_bottle at 5
draw_figure(ab, rtr, pq, box, vue)
```

Run the function again, this time changing the `klein_bottle.m` file so that the `catch` block uses `throwAsCaller` instead of `throw`. This time, MATLAB only displays the error at line 5 of the main program:

```
klein_bottle(ab, pi)
??? Attempted to access pq(2); index out of bounds because
   numel(pq)=1.

Error in ==> klein_bottle at 5
draw_figure(ab, rtr, pq, box, vue)
```

See Also

`error`, `try`, `catch`, `assert`, `MException`, `throw(MException)`, `rethrow(MException)`, `addCause(MException)`, `getReport(MException)`, `disp(MException)`, `isequal(MException)`, `eq(MException)`, `ne(MException)`, `last(MException)`

Purpose

Measure performance using stopwatch timer

Syntax

```
tic; any_statements; toc;
tic; any_statements; tElapsed = toc;
tStart = tic; any_statements; toc(tStart);
```

Description

`tic; any_statements; toc;` measures the time it takes MATLAB to execute the one or more lines of MATLAB code shown here as `any_statements`. The `tic` command starts a stopwatch timer, MATLAB executes the block of statements, and `toc` stops the timer, displaying the time elapsed in seconds.

`tic; any_statements; tElapsed = toc;` makes the same time measurement, but assigns the elapsed time output to a variable, `tElapsed`. MATLAB does not display the elapsed time unless you omit the terminating semicolon. The value returned by `toc` is a scalar double that represents the elapsed time in seconds.

`tStart = tic; any_statements; toc(tStart);` makes the same time measurement, but allows you the option of running more than one stopwatch timer concurrently. You assign the output of

assigns the starting time for the stopwatch to a unique output variable such as `tStart`, giving you the option of running more than one concurrent stopwatch timer. The `tic` command starts one of possibly several concurrent stopwatch timers, recording a separate starting time for each in a unique output variable such as `tStart`. MATLAB executes one or more statements, and `toc` stops the timer and displays the elapsed time. MATLAB records the time that `tic` executes in variable `tStart`, and then uses the value of that variable upon execution of any `toc` that follows it to measure the time elapsed between the two:

This syntax enables you to time multiple concurrent operations, including the timing of nested operations.

Remarks

Using the second syntax shown above, you can nest `tic`-`toc` pairs.

When using the simpler `tic` and `toc` syntax, avoid using consecutive `tic`s as they merely overwrite the internally-recorded starting time.

Consecutive tocs however, may be useful as each toc returns the increasing time that has elapsed since the most recent tic. Using this mechanism, you can take multiple measurements from a single point in time.

When using the tStart=tic and toc(tStart) syntax, it is advisable to select a unique variable for tStart. If you accidentally overwrite this variable prior to the toc for which it is needed, you will get inaccurate results for the time measurement.

tStart is an 64-bit unsigned integer, scalar value. This value is only useful as an input argument for a subsequent call to toc.

The clear function does not reset the starting time recorded by a tic command.

Examples

Measure how the time required to solve a linear system varies with the order of a matrix:

```
for n = 1:100
    A = rand(n,n);
    b = rand(n,1);
    tic
    x = A\b;
    t(n) = toc;
end
plot(t)
```

Measure the minimum and average time to compute a sum of Bessel functions:

```
REPS = 1000;   minTime = Inf;   nsum = 10;
tic;

for i=1:REPS
   tStart = tic;   sum = 0;
   for j=1:nsum,
      sum = sum + besselj(j,REPS);
   end
```

```
   tElapsed = toc(tStart);
   minTime = min(tElapsed, minTime);
end
averageTime = toc/REPS;
```

See Also

clock, cputime, etime, profile

Purpose

Construct timer object

Syntax

```
T = timer
T = timer('PropertyName1', PropertyValue1, 'PropertyName2',
   PropertyValue2,...)
```

Description

`T = timer` constructs a timer object with default attributes.

`T = timer('PropertyName1', PropertyValue1, 'PropertyName2', PropertyValue2,...)` constructs a timer object in which the given property name/value pairs are set on the object. See "Timer Object Properties" on page 2-3628 for a list of all the properties supported by the timer object.

Note that the property name/property value pairs can be in any format supported by the `set` function, i.e., property/value string pairs, structures, and property/value cell array pairs.

Examples

This example constructs a timer object with a timer callback function handle, `mycallback`, and a 10 second interval.

```
t = timer('TimerFcn',@mycallback, 'Period', 10.0);
```

See Also

`delete(timer)`, `disp(timer)`, `get(timer)`, `isvalid(timer)`, `set(timer)`, `start`, `startat`, `stop`, `timerfind`, `timerfindall`, `wait`

Timer Object Properties

The timer object supports the following properties that control its attributes. The table includes information about the data type of each property and its default value.

To view the value of the properties of a particular timer object, use the `get(timer)` function. To set the value of the properties of a timer object, use the `set(timer)` function.

Property Name	Property Description	Data Types, Values, Defaults, Access	
AveragePeriod	Average time between TimerFcn executions since the timer started. Note: Value is NaN until timer executes two timer callbacks.	Data type	double
		Default	NaN
		Read only	Always
BusyMode	Action taken when a timer has to execute TimerFcn before the completion of previous execution of TimerFcn. 'drop' — Do not execute the function. 'error' — Generate an error. Requires ErrorFcn to be set. 'queue' — Execute function at next opportunity.	Data type	Enumerated string
		Values	'drop' 'error' 'queue'
		Default	'drop'
		Read only	While Running = 'on'
ErrorFcn	Function that the timer executes when an error occurs. This function executes before the StopFcn. See "Creating Callback Functions" for more information.	Data type	Text string, function handle, or cell array
		Default	None
		Read only	Never

<table>
<tr><th>Property Name</th><th>Property Description</th><th colspan="2">Data Types, Values, Defaults, Access</th></tr>
<tr><td rowspan="4"><code>ExecutionMode</code></td><td rowspan="4">Determines how the timer object schedules timer events. See “Timer Object Execution Modes” for more information.</td><td>Data type</td><td>Enumerated string</td></tr>
<tr><td>Values</td><td><code>'singleShot'</code>
<code>'fixedDelay'</code>
<code>'fixedRate'</code>
<code>'fixedSpacing'</code></td></tr>
<tr><td>Default</td><td><code>'singleShot'</code></td></tr>
<tr><td>Read only</td><td>While <code>Running = 'on'</code></td></tr>
<tr><td rowspan="3"><code>InstantPeriod</code></td><td rowspan="3">The time between the last two executions of <code>TimerFcn</code>.</td><td>Data type</td><td><code>double</code></td></tr>
<tr><td>Default</td><td><code>NaN</code></td></tr>
<tr><td>Read only</td><td>Always</td></tr>
<tr><td rowspan="3"><code>Name</code></td><td rowspan="3">User-supplied name.</td><td>Data type</td><td>Text string</td></tr>
<tr><td>Default</td><td><code>'timer-i'</code>, where i is a number indicating the ith timer object created this session. To reset i to 1, execute the <code>clear classes</code> command.</td></tr>
<tr><td>Read only</td><td>Never</td></tr>
</table>

Property Name	Property Description	Data Types, Values, Defaults, Access	
ObjectVisibility	Provides a way for application developers to prevent end-user access to the timer objects created by their application. The timerfind function does not return an object whose ObjectVisibility property is set to 'off'. Objects that are not visible are still valid. If you have access to the object (for example, from within the M-file that created it), you can set its properties.	Data type	Enumerated string
		Values	'off' 'on'
		Default	'on'
		Read only	Never
Period	Specifies the delay, in seconds, between executions of TimerFcn.	Data type	double
		Value	Any number >= 0.001
		Default	1.0
		Read only	While Running = 'on'
Running	Indicates whether the timer is currently executing.	Data type	Enumerated string
		Values	'off' 'on'
		Default	'off'
		Read only	Always

Property Name	Property Description	Data Types, Values, Defaults, Access	
StartDelay	Specifies the delay, in seconds, between the start of the timer and the first execution of the function specified in TimerFcn.	Data type	double
		Values	Any number >= 0
		Default	0
		Read only	While Running ='on'
StartFcn	Function the timer calls when it starts. See "Creating Callback Functions" for more information.	Data type	Text string, function handle, or cell array
		Default	None
		Read only	Never

Property Name	Property Description	Data Types, Values, Defaults, Access	
StopFcn	Function the timer calls when it stops. The timer stops when • You call the timer stop function • The timer finishes executing TimerFcn, i.e., the value of TasksExecuted reaches the limit set by TasksToExecute. • An error occurs (The ErrorFcn is called first, followed by the StopFcn.) See "Creating Callback Functions" for more information.	Date type	Text string, function handle, or cell array
		Default	None
		Read only	Never
Tag	User supplied label.	Data type	Text string
		Default	Empty string ('')
		Read only	Never

Property Name	Property Description	Data Types, Values, Defaults, Access	
`TasksToExecute`	Specifies the number of times the timer should execute the function specified in the `TimerFcn` property.	Data type	`double`
		Values	Any number > 0
		Default	1
		Read only	Never
`TasksExecuted`	The number of times the timer has called `TimerFcn` since the timer was started.	Data type	`double`
		Values	Any number >= 0
		Default	0
		Read only	Always
`TimerFcn`	Timer callback function. See "Creating Callback Functions" for more information.	Data type	Text string, function handle, or cell array
		Default	None
		Read only	Never
`Type`	Identifies the object type.	Data type	Text string
		Values	`'timer'`
		Read only	Always
`UserData`	User-supplied data.	Data type	User-defined
		Default	`[]`
		Read only	Never

Purpose

Find timer objects

Syntax

```
out = timerfind
out = timerfind('P1', V1, 'P2', V2,...)
out = timerfind(S)
out = timerfind(obj, 'P1', V1, 'P2', V2,...)
```

Description

`out = timerfind` returns an array, `out`, of all the timer objects that exist in memory.

`out = timerfind('P1', V1, 'P2', V2,...)` returns an array, `out`, of timer objects whose property values match those passed as parameter/value pairs, `P1`, `V1`, `P2`, `V2`. Parameter/value pairs may be specified as a cell array.

`out = timerfind(S)` returns an array, `out`, of timer objects whose property values match those defined in the structure, `S`. The field names of `S` are timer object property names and the field values are the corresponding property values.

`out = timerfind(obj, 'P1', V1, 'P2', V2,...)` restricts the search for matching parameter/value pairs to the timer objects listed in `obj`. `obj` can be an array of timer objects.

Note When specifying parameter/value pairs, you can use any mixture of strings, structures, and cell arrays in the same call to `timerfind`.

Note that, for most properties, `timerfind` performs case-sensitive searches of property values. For example, if the value of an object's `Name` property is `'MyObject'`, `timerfind` will not find a match if you specify `'myobject'`. Use the `get` function to determine the exact format of a property value. However, properties that have an enumerated list of possible values are not case sensitive. For example, `timerfind` will find an object with an `ExecutionMode` property value of `'singleShot'` or `'singleshot'`.

Examples

These examples use `timerfind` to find timer objects with the specified property values.

```
t1 = timer('Tag', 'broadcastProgress', 'Period', 5);
t2 = timer('Tag', 'displayProgress');
out1 = timerfind('Tag', 'displayProgress')
out2 = timerfind({'Period', 'Tag'}, {5, 'broadcastProgress'})
```

See Also

`get(timer)`, `timer`, `timerfindall`

Purpose

Find timer objects, including invisible objects

Syntax

```
out = timerfindall
out = timerfindall('P1', V1, 'P2', V2,...)
out = timerfindall(S)
out = timerfindall(obj, 'P1', V1, 'P2', V2,...)
```

Description

`out = timerfindall` returns an array, `out`, containing all the timer objects that exist in memory, regardless of the value of the object's `ObjectVisibility` property.

`out = timerfindall('P1', V1, 'P2', V2,...)` returns an array, `out`, of timer objects whose property values match those passed as parameter/value pairs, `P1`, `V1`, `P2`, `V2`. Parameter/value pairs may be specified as a cell array.

`out = timerfindall(S)` returns an array, `out`, of timer objects whose property values match those defined in the structure, `S`. The field names of `S` are timer object property names and the field values are the corresponding property values.

`out = timerfindall(obj, 'P1', V1, 'P2', V2,...)` restricts the search for matching parameter/value pairs to the timer objects listed in `obj`. `obj` can be an array of timer objects.

Note When specifying parameter/value pairs, you can use any mixture of strings, structures, and cell arrays in the same call to `timerfindall`.

Note that, for most properties, `timerfindall` performs case-sensitive searches of property values. For example, if the value of an object's `Name` property is `'MyObject'`, `timerfindall` will not find a match if you specify `'myobject'`. Use the `get` function to determine the exact format of a property value. However, properties that have an enumerated list of possible values are not case sensitive. For example, `timerfindall` will find an object with an `ExecutionMode` property value of `'singleShot'` or `'singleshot'`.

Examples

Create several timer objects.

```
t1 = timer;
t2 = timer;
t3 = timer;
```

Set the `ObjectVisibility` property of one of the objects to `'off'`.

```
t2.ObjectVisibility = 'off';
```

Use `timerfind` to get a listing of all the timer objects in memory. Note that the listing does not include the timer object (`timer-2`) whose `ObjectVisibility` property is set to `'off'`.

```
timerfind

Timer Object Array

   Index:  ExecutionMode:  Period:  TimerFcn:   Name:
   1       singleShot      1        ''          timer-1
   2       singleShot      1        ''          timer-3
```

Use `timerfindall` to get a listing of all the timer objects in memory. This listing includes the timer object whose `ObjectVisibility` property is set to `'off'`.

```
timerfindall

Timer Object Array

   Index:  ExecutionMode:  Period:  TimerFcn:   Name:
   1       singleShot      1        ''          timer-1
   2       singleShot      1        ''          timer-2
   3       singleShot      1        ''          timer-3
```

See Also

`get(timer)`, `timer`, `timerfind`

Purpose

Create `timeseries` object

Syntax

```
ts = timeseries
ts = timeseries(Data)
ts = timeseries(Name)
ts = timeseries(Data,Time)
ts = timeseries(Data,Time,Quality)
ts = timeseries(Data,...,'Parameter',Value,...)
```

Description

`ts = timeseries` creates an empty time-series object.

`ts = timeseries(Data)` creates a time series with the specified `Data`. `ts` has a default time vector that ranges from `0` to `N-1` with a 1-second interval, where `N` is the number of samples. The default name of the `timeseries` object is `'unnamed'`.

`ts = timeseries(Name)` creates an empty time series with the name specified by a string `Name`. This name can differ from the time-series variable name.

`ts = timeseries(Data,Time)` creates a time series with the specified `Data` array and `Time`. When time values are date strings, you must specify `Time` as a cell array of date strings.

`ts = timeseries(Data,Time,Quality)` creates a `timeseries` object. The `Quality` attribute is an integer vector with values`-128` to `127` that specifies the quality in terms of codes defined by `QualityInfo.Code`.

`ts = timeseries(Data,...,'Parameter',Value,...)` creates a `timeseries` object with optional parameter-value pairs after the `Data`, `Time`, and `Quality` arguments. You can specify the following parameters:

- `Name` — Time-series name entered as a string
- `IsTimeFirst` — Logical value (`true` or `false`) specifying whether the first or last dimension of the data array is aligned with the time vector. You can set this property when the data array is square and, therefore, the dimension that is aligned with time is ambiguous.

Remarks

Definition: timeseries

The time-series object, called `timeseries`, is a MATLAB variable that contains time-indexed data and properties in a single, coherent structure. For example, in addition to data and time values, you can also use the time-series object to store events, descriptive information about data and time, data quality, and the interpolation method.

Definition: Data Sample

A time-series *data sample* consists of one or more values recorded at a specific time. The number of data samples in a time series is the same as the length of the time vector.

For example, suppose that `ts.data` has the size 5-by-4-by-3 and the time vector has the length 5. Then, the number of samples is `5` and the total number of data values is `5 x 4 x 3 = 60`.

Notes About Quality

When `Quality` is a vector, it must have the same length as the time vector. In this case, each `Quality` value applies to the corresponding data sample. When `Quality` is an array, it must have the same size as the data array. In this case, each `Quality` value applies to the corresponding data value of the `ts.data` array.

Examples

Example 1 — Using Default Time Vector

Create a `timeseries` object called `'LaunchData'` that contains four data sets, each stored as a column of length `5` and using the default time vector:

```
b = timeseries(rand(5, 4),'Name','LaunchData')
```

Example 2 — Using Uniform Time Vector

Create a `timeseries` object containing a single data set of length `5` and a time vector starting at `1` and ending at `5`:

```
b = timeseries(rand(5,1),[1 2 3 4 5])
```

Example 3

Create a `timeseries` object called `'FinancialData'` containing five data points at a single time point:

```
b = timeseries(rand(1,5),1,'Name','FinancialData')
```

See Also

`addsample`, `tscollection`, `tsdata.event`, `tsprops`

Purpose

Add title to current axes

GUI Alternative

To create or modify a plot's title from a GUI, use **Insert Title** from the figure menu. Use the Property Editor, one of the plotting tools , to modify the position, font, and other properties of a legend. For details, see The Property Editor in the MATLAB Graphics documentation.

Syntax

```
title('string')
title(fname)
title(...,'PropertyName',PropertyValue,...)
title(axes_handle,...)
h = title(...)
```

Description

Each `axes` graphics object can have one title. The title is located at the top and in the center of the axes.

`title('string')` outputs the string at the top and in the center of the current axes.

`title(fname)` evaluates the function that returns a string and displays the string at the top and in the center of the current axes.

`title(...,'`*`PropertyName`*`',PropertyValue,...)` specifies property name and property value pairs for the `text` graphics object that `title` creates. Do not use the `'String'` text property to set the title string; the content of the title should be given by the first argument.

`title(axes_handle,...)` adds the title to the specified axes.

`h = title(...)` returns the handle to the text object used as the title.

Examples

Display today's date in the current axes:

```
title(date)
```

Include a variable's value in a title:

```
f = 70;
c = (f-32)/1.8;
```

```
title(['Temperature is ',num2str(c),'C'])
```

Include a variable's value in a title and set the color of the title to yellow:

```
n = 3;
title(['Case number #',int2str(n)],'Color','y')
```

Include Greek symbols in a title:

```
title('\ite^{\omega\tau} = cos(\omega\tau) + isin(\omega\tau)')
```

Include a superscript character in a title:

```
title('\alpha^2')
```

Include a subscript character in a title:

```
title('X_1')
```

The text object `String` property lists the available symbols.

Create a multiline title using a multiline cell array.

```
title({'First line';'Second line'})
```

Remarks

`title` sets the `Title` property of the current axes graphics object to a new text graphics object. See the text `String` property for more information.

See Also

`gtext`, `int2str`, `num2str`, `text`, `xlabel`, `ylabel`, `zlabel`

"Annotating Plots" on page 1-91 for related functions

Text Properties for information on setting parameter/value pairs in titles

Adding Titles to Graphs for more information on ways to add titles

todatenum

Purpose

Convert CDF epoch object to MATLAB datenum

Syntax

```
n = todatenum(obj)
```

Description

`n = todatenum(obj)` converts the CDF epoch object `ep_obj` into a MATLAB serial date number. Note that a CDF epoch is the number of milliseconds since `01-Jan-0000` whereas a MATLAB datenum is the number of days since 00`-Jan-0000`.

Examples

Construct a CDF epoch object from a date string, and then convert the object back into a MATLAB date string:

```
dstr = datestr(today)
dstr =
   08-Oct-2003

obj = cdfepoch(dstr)
obj =
     cdfepoch object:
     08-Oct-2003 00:00:00

dstr2 = datestr(todatenum(obj))
dstr2 =
   08-Oct-2003
```

See Also

`cdfepoch`, `cdfinfo`, `cdfread`, `cdfwrite`, `datenum`

Purpose

Toeplitz matrix

Syntax

```
T = toeplitz(c,r)
T = toeplitz(r)
```

Description

A *Toeplitz* matrix is defined by one row and one column. A *symmetric Toeplitz* matrix is defined by just one row. `toeplitz` generates Toeplitz matrices given just the row or row and column description.

`T = toeplitz(c,r)` returns a nonsymmetric Toeplitz matrix `T` having `c` as its first column and `r` as its first row. If the first elements of `c` and `r` are different, a message is printed and the column element is used.

For a real vector `r`, `T = toeplitz(r)` returns the symmetric Toeplitz matrix formed from vector `r`, where `r` defines the first row of the matrix. For a complex vector `r` with a real first element, `T = toeplitz(r)` returns the Hermitian Toeplitz matrix formed from `r`, where `r` defines the first row of the matrix and `r'` defines the first column. When the first element of `r` is not real, the resulting matrix is Hermitian off the main diagonal, i.e., $T_{ij} = \mathrm{conj}(T_{ji})$ for $i \neq j$.

Examples

A Toeplitz matrix with diagonal disagreement is

```
c = [1  2  3  4  5];
r = [1.5  2.5  3.5  4.5  5.5];
toeplitz(c,r)
Column wins diagonal conflict:
ans =
    1.000    2.500    3.500    4.500    5.500
    2.000    1.000    2.500    3.500    4.500
    3.000    2.000    1.000    2.500    3.500
    4.000    3.000    2.000    1.000    2.500
    5.000    4.000    3.000    2.000    1.000
```

See Also

`hankel`, `kron`

toolboxdir

Purpose

Root directory for specified toolbox

Syntax

```
toolboxdir('tbxdirname')
s = toolboxdir('tbxdirname')
s = toolboxdir tbxdirname
```

Description

`toolboxdir('tbxdirname')` returns a string that is the absolute path to the specified toolbox, `tbxdirname`, where `tbxdirname` is the directory name for the toolbox.

`s = toolboxdir('tbxdirname')` returns the absolute path to the specified toolbox to the output argument, `s`.

`s = toolboxdir tbxdirname` is the command form of the syntax.

Remarks

`toolboxdir` is particularly useful for MATLAB Compiler software. The base directory of all toolboxes installed with MATLAB software is:

```
matlabroot/toolbox/tbxdirname
```

However, in deployed mode, the base directories of the toolboxes are different. `toolboxdir` returns the correct root directory, whether running from MATLAB or from an application deployed with the MATLAB Compiler software.

Example

To obtain the path for the Control System Toolbox software, run

```
s = toolboxdir('control')
```

MATLAB returns

```
s = \\myhome\r2008b\matlab\toolbox\control
```

See Also

`ctfroot` (in the MATLAB Compiler product), `fullfile`, `matlabroot`, `partialpath`, `path`,

"Managing Files and Working with the Current Directory"

Purpose Sum of diagonal elements

Syntax `b = trace(A)`

Description `b = trace(A)` is the sum of the diagonal elements of the matrix `A`.

Algorithm `trace` is a single-statement M-file.

```
t = sum(diag(A));
```

See Also `det`, `eig`

transpose (timeseries)

Purpose

Transpose `timeseries` object

Syntax

```
ts1 = transpose(ts)
```

Description

`ts1 = transpose(ts)` returns a new `timeseries` object `ts1` with `IsTimeFirst` value set to the opposite of what it is for `ts`. For example, if `ts` has the first data dimension aligned with the time vector, `ts1` has the last data dimension aligned with the time vector.

Remarks

The `transpose` function that is overloaded for the `timeseries` objects does not transpose the data. Instead, this function changes whether the first or the last dimension of the data is aligned with the time vector.

Note To transpose the data, you must transpose the `Data` property of the time series. For example, you can use the syntax `transpose(ts.Data)` or `(ts.Data).'`. `Data` must be a 2-D array.

Consider a time series with 10 samples with the property `IsTimeFirst = True`. When you transpose this time series, the data size is changed from 10-by-1 to 1-by-1-by-10. Note that the first dimension of the `Data` property is shown explicitly.

The following table summarizes how the size for time-series data (up to three dimensions) display before and after transposing.

Data Size Before and After Transposing

Size of Original Data	Size of Transposed Data
N-by-1	1-by-1-by-N
N-by-M	M-by-1-by-N
N-by-M-by-L	M-by-L-by-N

Examples

Suppose that a `timeseries` object `ts` has `ts.Data` size 10-by-3-by-2 and its time vector has a length of 10. The `IsTimeFirst` property of `ts` is set to `true`, which means that the first dimension of the data is aligned with the time vector. `transpose(ts)` modifies the `timeseries` object such that the last dimension of the data is now aligned with the time vector. This permutes the data such that the size of `ts.Data` becomes 3-by-2-by-10.

See Also

`ctranspose (timeseries)`, `tsprops`

Purpose Trapezoidal numerical integration

Syntax

```
Z = trapz(Y)
Z = trapz(X,Y)
Z = trapz(...,dim)
```

Description

`Z = trapz(Y)` computes an approximation of the integral of `Y` via the trapezoidal method (with unit spacing). To compute the integral for spacing other than one, multiply `Z` by the spacing increment. Input `Y` can be complex.

If `Y` is a vector, `trapz(Y)` is the integral of `Y`.

If `Y` is a matrix,`trapz(Y)` is a row vector with the integral over each column.

If `Y` is a multidimensional array, `trapz(Y)` works across the first nonsingleton dimension.

`Z = trapz(X,Y)` computes the integral of `Y` with respect to `X` using trapezoidal integration. Inputs `X` and `Y` can be complex.

If `X` is a column vector and `Y` an array whose first nonsingleton dimension is `length(X)`, `trapz(X,Y)` operates across this dimension.

`Z = trapz(...,dim)` integrates across the dimension of `Y` specified by scalar `dim`. The length of `X`, if given, must be the same as `size(Y,dim)`.

Examples

Example 1

The exact value of $\int_0^{\pi} \sin(x)dx$ is 2.

To approximate this numerically on a uniformly spaced grid, use

```
X = 0:pi/100:pi;
Y = sin(X);
```

Then both

```
Z = trapz(X,Y)
```

and

```
Z = pi/100*trapz(Y)
```

produce

```
Z =
    1.9998
```

Example 2

A nonuniformly spaced example is generated by

```
X = sort(rand(1,101)*pi);
Y = sin(X);
Z = trapz(X,Y);
```

The result is not as accurate as the uniformly spaced grid. One random sample produced

```
Z =
    1.9984
```

Example 3

This example uses two complex inputs:

```
z = exp(1i*pi*(0:100)/100);

trapz(z, 1./z)
ans =
   0.0000 + 3.1411i
```

See Also

`cumsum`, `cumtrapz`

treelayout

Purpose

Lay out tree or forest

Syntax

```
[x,y] = treelayout(parent,post)
[x,y,h,s] = treelayout(parent,post)
```

Description

`[x,y] = treelayout(parent,post)` lays out a tree or a forest. `parent` is the vector of parent pointers, with `0` for a root. `post` is an optional postorder permutation on the tree nodes. If you omit `post`, `treelayout` computes it. `x` and `y` are vectors of coordinates in the unit square at which to lay out the nodes of the tree to make a nice picture.

`[x,y,h,s] = treelayout(parent,post)` also returns the height of the tree `h` and the number of vertices `s` in the top-level separator.

See Also

`etree`, `treeplot`, `etreeplot`, `symbfact`

Purpose

Plot picture of tree

Syntax

```
treeplot(p)
treeplot(p,nodeSpec,edgeSpec)
```

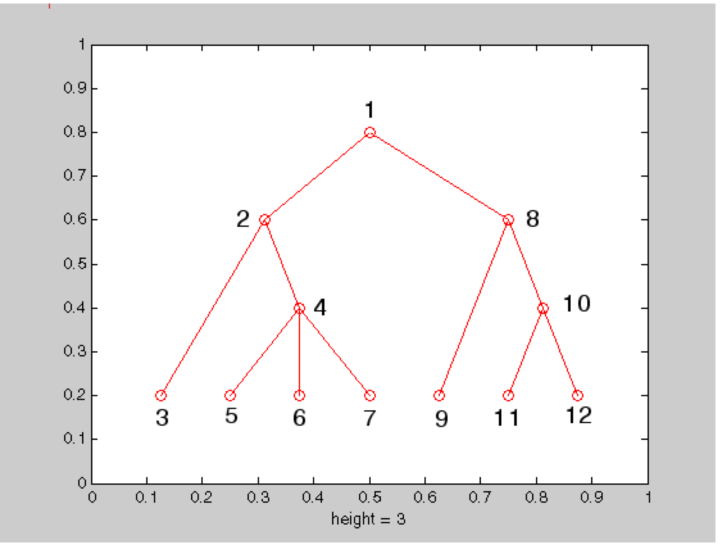
Description

`treeplot(p)` plots a picture of a tree given a vector of parent pointers, with `p(i)` = 0 for a root.

`treeplot(p,nodeSpec,edgeSpec)` allows optional parameters `nodeSpec` and `edgeSpec` to set the node or edge color, marker, and linestyle. Use `''` to omit one or both.

Examples

To plot a tree with 12 nodes, call `treeplot` with a 12-element input vector. The index of each element in the vector is shown adjacent to each node in the figure below. (These indices are shown only for the point of illustrating the example; they are not part of the `treeplot` output.)



To generate this plot, set the value of each element in the `nodes` vector to the index of its parent, (setting the parent of the root node to zero).

The node marked 1 in the figure is represented by `nodes(1)` in the input vector, and because this is the root node which has a parent of zero, you set its value to zero:

```
nodes(1) = 0;     % Root node
```

`nodes(2)` and `nodes(8)` are children of `nodes(1)`, so set these elements of the input vector to 1:

```
nodes(2) = 1;     nodes(8) = 1;
```

`nodes(5:7)` are children of `nodes(4)`, so set these elements to 4:

```
nodes(5) = 4;     nodes(6) = 4;     nodes(7) = 4;
```

Continue in this manner until each element of the vector identifies its parent. For the plot shown above, the `nodes` vector now looks like this:

```
nodes = [0 1 2 2 4 4 4 1 8 8 10 10];
```

Now call `treeplot` to generate the plot:

```
treeplot(nodes)
```

See Also

`etree`, `etreeplot`, `treelayout`

Purpose

Lower triangular part of matrix

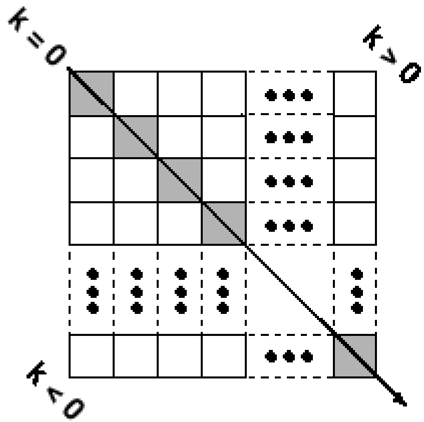
Syntax

```
L = tril(X)
L = tril(X,k)
```

Description

`L = tril(X)` returns the lower triangular part of `X`.

`L = tril(X,k)` returns the elements on and below the kth diagonal of `X`. `k = 0` is the main diagonal, `k > 0` is above the main diagonal, and `k < 0` is below the main diagonal.



Examples

```
tril(ones(4,4),-1)

ans =

     0     0     0     0
     1     0     0     0
     1     1     0     0
     1     1     1     0
```

See Also

`diag`, `triu`

trimesh

Purpose

Triangular mesh plot

Syntax

```
trimesh(Tri,X,Y,Z)
trimesh(Tri,X,Y,Z,C)
trimesh(...'PropertyName',PropertyValue...)
h = trimesh(...)
```

Description

`trimesh(Tri,X,Y,Z)` displays triangles defined in the *m*-by-3 face matrix `Tri` as a mesh. Each row of `Tri` defines a single triangular face by indexing into the vectors or matrices that contain the `X`, `Y`, and `Z` vertices.

`trimesh(Tri,X,Y,Z,C)` specifies color defined by `C` in the same manner as the `surf` function. The MATLAB software performs a linear transformation on this data to obtain colors from the current colormap.

`trimesh(...'PropertyName',PropertyValue...)` specifies additional patch property names and values for the patch graphics object created by the function.

`h = trimesh(...)` returns a handle to a patch graphics object.

Example

Create vertex vectors and a face matrix, then create a triangular mesh plot.

```
x = rand(1,50);
y = rand(1,50);
z = peaks(6*x-3,6*x-3);
tri = delaunay(x,y);
trimesh(tri,x,y,z)
```

See Also

`patch`, `tetramesh`, `triplot`, `trisurf`, `delaunay`

"Surface and Mesh Creation" on page 1-101 for related functions

Purpose

Numerically evaluate triple integral

Syntax

```
triplequad(fun,xmin,xmax,ymin,ymax,zmin,zmax)
triplequad(fun,xmin,xmax,ymin,ymax,zmin,zmax,tol)
triplequad(fun,xmin,xmax,ymin,ymax,zmin,zmax,tol,method)
```

Description

`triplequad(fun,xmin,xmax,ymin,ymax,zmin,zmax)` evaluates the triple integral `fun(x,y,z)` over the three dimensional rectangular region `xmin <= x <= xmax`, `ymin <= y <= ymax`, `zmin <= z <= zmax`. `fun` is a function handle. See "Function Handles" in the MATLAB Programming documentation for more information.`fun(x,y,z)` must accept a vector `x` and scalars `y` and `z`, and return a vector of values of the integrand.

"Parametrizing Functions", in the MATLAB Mathematics documentation, explains how to provide additional parameters to the function `fun`, if necessary.

`triplequad(fun,xmin,xmax,ymin,ymax,zmin,zmax,tol)` uses a tolerance `tol` instead of the default, which is `1.0e-6`.

`triplequad(fun,xmin,xmax,ymin,ymax,zmin,zmax,tol,method)` uses the quadrature function specified as `method`, instead of the default `quad`. Valid values for `method` are `@quadl` or the function handle of a user-defined quadrature method that has the same calling sequence as `quad` and `quadl`.

Examples

Pass M-file function handle `@integrnd` to `triplequad`:P

```
Q = triplequad(@integrnd,0,pi,0,1,-1,1);
```

where the M-file `integrnd.m` is

```
function f = integrnd(x,y,z)
f = y*sin(x)+z*cos(x);
```

Pass anonymous function handle `F` to `triplequad`:

```
F = @(x,y,z)y*sin(x)+z*cos(x);
```

```
Q = triplequad(F,0,pi,0,1,-1,1);
```

This example integrates `y*sin(x)+z*cos(x)` over the region `0 <= x <= pi`, `0 <= y <= 1`, `-1 <= z <= 1`. Note that the integrand can be evaluated with a vector `x` and scalars `y` and `z`.

See Also

`dblquad`, `quad`, `quadgk`, `quadl`, `function handle` (`@`), “Anonymous Functions”

Purpose

2-D triangular plot

Syntax

```
triplot(TRI,x,y)
triplot(TRI,x,y,color)
h = triplot(...)
triplot(...,'param','value','param','value'...)
```

Description

`triplot(TRI,x,y)` displays the triangles defined in the `m`-by-3 matrix `TRI`. A row of `TRI` contains indices into the vectors `x` and `y` that define a single triangle. The default line color is blue.

`triplot(TRI,x,y,color)` uses the string `color` as the line color. `color` can also be a line specification. See `ColorSpec` for a list of valid color strings. See `LineSpec` for information about line specifications.

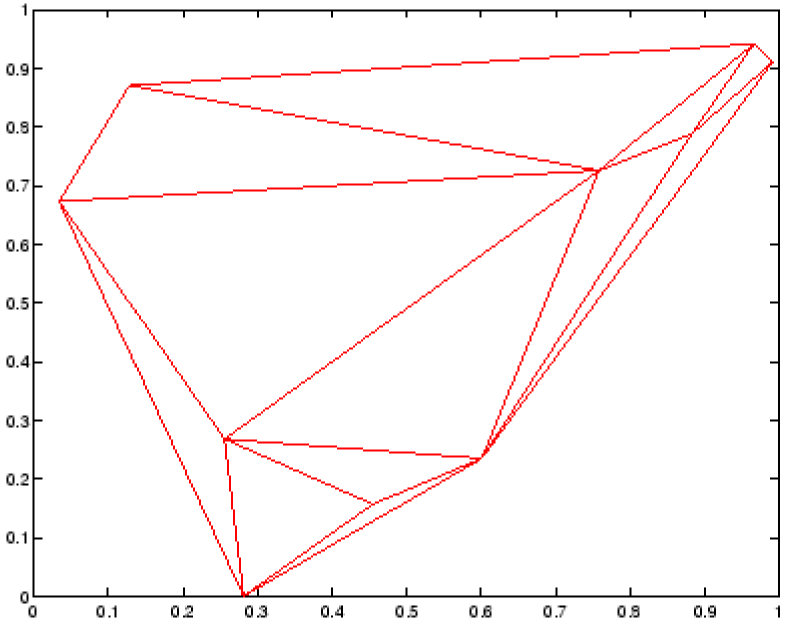
`h = triplot(...)` returns a vector of handles to the displayed triangles.

`triplot(...,'param','value','param','value'...)` allows additional line property name/property value pairs to be used when creating the plot. See `Line Properties` for information about the available properties.

Examples

This code plots the Delaunay triangulation for 10 randomly generated points.

```
rand('state',7);
x = rand(1,10);
y = rand(1,10);
TRI = delaunay(x,y);
triplot(TRI,x,y,'red')
```



See Also

`ColorSpec`, `delaunay`, `line`, `Line Properties`, `LineSpec`, `plot`, `trimesh`, `trisurf`

Purpose

Triangular surface plot

Syntax

```
trisurf(Tri,X,Y,Z)
trisurf(Tri,X,Y,Z,C)
trisurf(...'PropertyName',PropertyValue...)
h = trisurf(...)
```

Description

`trisurf(Tri,X,Y,Z)` displays triangles defined in the *m*-by-3 face matrix `Tri` as a surface. Each row of `Tri` defines a single triangular face by indexing into the vectors or matrices that contain the `X`, `Y`, and `Z` vertices.

`trisurf(Tri,X,Y,Z,C)` specifies color defined by `C` in the same manner as the `surf` function. The MATLAB software performs a linear transformation on this data to obtain colors from the current colormap.

`trisurf(...'`*`PropertyName`*`',PropertyValue...)` specifies additional patch property names and values for the patch graphics object created by the function.

`h = trisurf(...)` returns a patch handle.

Example

Create vertex vectors and a face matrix, then create a triangular surface plot.

```
x = rand(1,50);
y = rand(1,50);
z = peaks(6*x-3,6*x-3);
tri = delaunay(x,y);
trisurf(tri,x,y,z)
```

See Also

`patch`, `surf`, `tetramesh`, `trimesh`, `triplot`, `delaunay`

“Surface and Mesh Creation” on page 1-101 for related functions

triu

Purpose

Upper triangular part of matrix

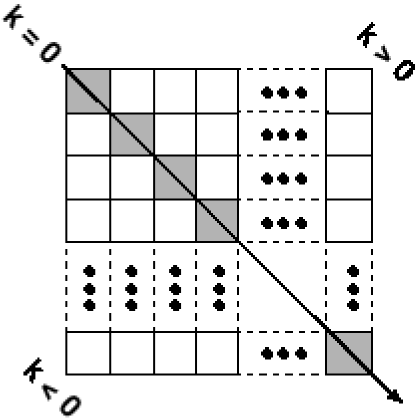
Syntax

```
U = triu(X)
U = triu(X,k)
```

Description

`U = triu(X)` returns the upper triangular part of `X`.

`U = triu(X,k)` returns the element on and above the kth diagonal of `X`. `k = 0` is the main diagonal, `k > 0` is above the main diagonal, and `k < 0` is below the main diagonal.



Examples

```
triu(ones(4,4),-1)

ans =

     1     1     1     1
     1     1     1     1
     0     1     1     1
     0     0     1     1
```

See Also

`diag`, `tril`

Purpose

Logical 1 (true)

Syntax

```
true
true(n)
true(m, n)
true(m, n, p, ...)
true(size(A))
```

Description

`true` is shorthand for `logical 1`.

`true(n)` is an `n`-by-`n` matrix of logical ones.

`true(m, n)` or `true([m, n])` is an `m`-by-`n` matrix of logical ones.

`true(m, n, p, ...)` or `true([m n p ...])` is an `m`-by-`n`-by-`p`-by-`...` array of logical ones.

Note The size inputs `m`, `n`, `p`, `...` should be nonnegative integers. Negative integers are treated as 0.

`true(size(A))` is an array of logical ones that is the same size as array `A`.

Remarks

`true(n)` is much faster and more memory efficient than `logical(ones(n))`.

See Also

`false`, `logical`

Purpose Attempt to execute block of code, and catch errors

Syntax `try`

Description `try` marks the start of a *try block* in a `try-catch` statement. If the MATLAB software detects an error while executing code in the `try` block, it immediately jumps to the start of the respective *catch block* and executes the error handling code in that block.

A `try-catch` statement is a programming device that enables you to define how certain errors are to be handled in your program. This bypasses the default MATLAB error-handling mechanism when these errors are detected. The `try-catch` statement consists of two blocks of MATLAB code, a *try block* and a *catch block*, delimited by the keywords `try`, `catch`, and `end`:

```
try
   MATLAB commands     % Try block
catch ME
   MATLAB commands     % Catch block
end
```

Each of these blocks consists of one or more MATLAB commands. The `try` block is just another piece of your program code; the commands in this block execute just like any other part of your program. Any errors MATLAB encounters in the `try` block are dealt with by the respective `catch` block. This is where you write your error-handling code. If the `try` block executes without error, MATLAB skips the `catch` block entirely. If an error occurs while executing the `catch` block, the program terminates unless this error is caught by another `try-catch` block.

Specifying the `try`, `catch`, and `end` commands, as well as the commands that make up the `try` and `catch` blocks, on separate lines is recommended. If you combine any of these components on the same line, separate them with commas:

```
try, surf, catch ME, ME.stack, end
ans =
```

```
file: 'matlabroot\toolbox\matlab\graph3d\surf.m'
name: 'surf'
line: 54
```

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

catch, rethrow, end, lasterror, eval, evalin

Purpose

Create `tscollection` object

Syntax

```
tsc = tscollection(TimeSeries)
tsc = tscollection(Time)
tsc = tscollection(Time,TimeSeries,'Parameter',Value,...)
```

Description

`tsc = tscollection(TimeSeries)` creates a `tscollection` object `tsc` with one or more `timeseries` objects already in the MATLAB workspace. The argument `TimeSeries` can be a

- Single `timeseries` object
- Cell array of `timeseries` objects

`tsc = tscollection(Time)` creates an empty `tscollection` object with the time vector `Time`. When time values are date strings, you must specify `Time` as a cell array of date strings.

`tsc = tscollection(Time,TimeSeries,'Parameter',Value,...)` creates a `tscollection` object with optional parameter-value pairs you enter after the `Time` and `TimeSeries` arguments. You can specify the following parameter:

- `Name` — String that specifies the name of this `tscollection` object

Remarks

Definition: Time Series Collection

A time series collection object is a MATLAB variable that groups several time series with a common time vector. The time series that you include in the collection are called members of this collection.

Properties of Time Series Collection Objects

This table lists the properties of the `tscollection` object. You can specify the `Time`, `TimeSeries`, and `Name` properties as input arguments in the constructor.

Property	Description
Name	`tscollection` name as a string. This can differ from the `tscollection` name in the MATLAB workspace.
Time	When `TimeInfo.StartDate` is empty, values are measured relative to `0` . When `TimeInfo.StartDate` is defined, values represent date strings measured relative to the `StartDate`. The length of `Time` must be the same as the first or the last dimension of `Data` for each collection .
TimeInfo	Contains fields for contextual information about `Time`: • `Units` — Time units with any of the following values: `'weeks'`, `'days'`, `'hours'`, `'minutes'`, `'seconds'`, `'milliseconds'`, `'microseconds'`, `'nanoseconds'` • `Start` — Start time • `End` — End time (read only) • `Increment` — Interval between subsequent time values. `NaN` when times are not uniformly sampled. • `Length` — Length of the time vector (read only) • `Format` — String defining the date string display format. See `datestr`. • `StartDate` — Date string defining the reference date. See `setabstime (tscollection)`. • `UserData` — Any additional user-defined information

Examples

The following example shows how to create a `tscollection` object.

1 Import the sample data.

```
load count.dat
```

2. Create three `timeseries` objects to store each set of data:

```
count1 = timeseries(count(:,1),1:24,'name', 'ts1');
count2 = timeseries(count(:,2),1:24,'name', 'ts2');
```

3. Create a `tscollection` object named `tsc` and add to it two out of three time series already in the MATLAB workspace, by using the following syntax:

```
tsc = tscollection({count1 count2},'name','tsc')
```

See Also

`addts`, `datestr`, `setabstime (tscollection)`, `timeseries`, `tsprops`

Purpose

Construct event object for `timeseries` object

Syntax

```
e = tsdata.event(Name,Time)
e = tsdata.event(Name,Time,'Datenum')
```

Description

`e = tsdata.event(Name,Time)` creates an event object with the specified Name that occurs at the time Time. Time can either be a real value or a date string.

`e = tsdata.event(Name,Time,'Datenum')` uses `'Datenum'` to indicate that the `Time` value is a serial date number generated by the `datenum` function. The `Time` value is converted to a date string after the event is created.

Remarks

You add events by using the `addevent` method.

Fields of the `tsdata.event` object include the following:

- `EventData` — MATLAB array that stores any user-defined information about the event
- `Name` — String that specifies the name of the event
- `Time` — Time value when this event occurs, specified as a real number
- `Units` — Time units
- `StartDate` — A reference date, specified in MATLAB `datestr` format. `StartDate` is empty when you have a numerical (non-date-string) time vector.

Purpose Search for enclosing Delaunay triangle

Syntax

```
T = tsearch(x,y,TRI,xi,yi)
```

Description `T = tsearch(x,y,TRI,xi,yi)` returns an index into the rows of `TRI` for each point in `xi`, `yi`. The `tsearch` command returns `NaN` for all points outside the convex hull. Requires a triangulation `TRI` of the points `x,y` obtained from `delaunay`.

See Also `delaunay`, `delaunayn`, `dsearch`, `tsearchn`

Purpose N-D closest simplex search

Syntax

```
t = tsearchn(X,TES,XI)
[t,P] = tsearchn(X,TES,XI)
```

Description `t = tsearchn(X,TES,XI)` returns the indices `t` of the enclosing simplex of the Delaunay tessellation `TES` 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. `tsearchn` returns `NaN` for all points outside the convex hull of `X`. `tsearchn` requires a tessellation `TES` of the points `X` obtained from `delaunayn`.

`[t,P] = tsearchn(X,TES,XI)` also returns the barycentric coordinate `P` of `XI` in the simplex `TES`. `P` is a `p`-by-`n+1` matrix. Each row of `P` is the Barycentric coordinate of the corresponding point in `XI`. It is useful for interpolation.

Algorithm `tsearchn` 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 `delaunayn`, `griddatan`, `tsearch`

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 Help on `timeseries` object properties

Syntax `help timeseries/tsprops`

Description `help timeseries/tsprops` lists the properties of the `timeseries` object and briefly describes each property.

Time Series Object Properties

Property	Description
`Data`	Time-series data, where each data sample corresponds to a specific time. The data can be a scalar, a vector, or a multidimensional array. Either the first or last dimension of the data must be aligned with `Time`. By default, `NaN`s are used to represent missing or unspecified data. Set the `TreatNaNasMissing` property to determine how missing data is treated in calculations.
`DataInfo`	Contains fields for storing contextual information about `Data`: • `Unit` — String that specifies data units • `Interpolation` — A `tsdata.interpolation` object that specifies the interpolation method for this time series. Fields of the `tsdata.interpolation` object include: - `Fhandle` — Function handle to a user-defined interpolation function - `Name` — String that specifies the name of the interpolation method. Predefined methods include `'linear'` and `'zoh'` (zero-order hold). `'linear'` is the default. • `UserData` — Any user-defined information entered as a string

Time Series Object Properties (Continued)

Property	Description
`Events`	An array of `tsdata.event` objects that stores event information for this time series. You add events by using the `addevent` method. Fields of the `tsdata.event` object include the following: • `EventData` — Any user-defined information about the event • `Name` — String that specifies the name of the event • `Time` — Time value when this event occurs, specified as a real number or a date string • `Units` — Time units • `StartDate` — A reference date specified in MATLAB date-string format. `StartDate` is empty when you have a numerical (non-date-string) time vector.

Time Series Object Properties (Continued)

Property	Description
`IsTimeFirst`	Logical value (`true` or `false`) specifies whether the first or last dimension of the `Data` array is aligned with the time vector. You can set this property when the `Data` array is square and it is ambiguous which dimension is aligned with time. By default, the first `Data` dimension that matches the length of the time vector is aligned with the time vector. When you set this property to: • `true` — The first dimension of the data array is aligned with the time vector. For example: `ts=timeseries(rand(3,3),1:3, 'IsTimeFirst',true);` • `false` — The last dimension of the data array is aligned with the time vector. For example: `ts=timeseries(rand(3,3),1:3, 'IsTimeFirst',false);` After a time series is created, this property is read only.
`Name`	Time-series name entered as a string. This name can differ from the name of the time-series variable in the MATLAB workspace.
`Quality`	An integer vector or array containing values `-128` to `127` that specifies the quality in terms of codes defined by `QualityInfo.Code`. When `Quality` is a vector, it must have the same length as the time vector. In this case, each `Quality` value applies to a corresponding data sample. When `Quality` is an array, it must have the same size as the data array. In this case, each `Quality` value applies to the corresponding value of the data array.

Time Series Object Properties (Continued)

Property	Description
QualityInfo	Provides a lookup table that converts numerical Quality codes to readable descriptions. QualityInfo fields include the following: • Code — Integer vector containing values -128 to 127 that define the "dictionary" of quality codes, which you can assign to each Data value by using the Quality property • Description — Cell vector of strings, where each element provides a readable description of the associated quality Code • UserData — Stores any additional user-defined information Lengths of Code and Description must match.
Time	Array of time values. When TimeInfo.StartDate is empty, the numerical Time values are measured relative to 0 in specified units. When TimeInfo.StartDate is defined, the time values are date strings measured relative to the StartDate in specified units. The length of Time must be the same as either the first or the last dimension of Data.

Time Series Object Properties (Continued)

Property	Description
TimeInfo	Uses the following fields for storing contextual information about Time: • Units — Time units can have any of following values: 'weeks', 'days', 'hours', 'minutes', 'seconds', 'milliseconds', 'microseconds', or 'nanoseconds' • Start — Start time • End — End time (read only) • Increment — Interval between two subsequent time values • Length — Length of the time vector (read only) • Format — String defining the date string display format. See the MATLAB datestr function reference page for more information. • StartDate — Date string defining the reference date. See the MATLAB setabstime (timeseries) function reference page for more information. • UserData — Stores any additional user-defined information
TreatNaNasMissing	Logical value that specifies how to treat NaN values in Data: • true — (Default) Treat all NaN values as missing data except during statistical calculations. • false — Include NaN values in statistical calculations, in which case NaN values are propagated to the result.

See Also `datestr`, `get (timeseries)`, `set (timeseries)`, `setabstime (timeseries)`

Purpose

Open Time Series Tools GUI

Syntax

```
tstool
tstool(ts)
tstool(tsc)
tstool(sldata)
tstool(ModelDataLogs,'replace')
```

Description

`tstool` starts the Time Series Tools GUI without loading any data.

`tstool(ts)` starts the Time Series Tools GUI and loads the time-series object `ts` from the MATLAB workspace.

`tstool(tsc)` starts the Time Series Tools GUI and loads the time-series collection object `tsc` from the MATLAB workspace.

`tstool(sldata)` starts the Time Series Tools GUI and loads the logged-signal data `sldata` from a Simulink model. If a Simulink logged signal `Name` property contains a `/`, the entire logged signal, including all levels of the signal hierarchy, is not imported into Time Series Tools.

`tstool(ModelDataLogs,'replace')` replaces the logged-signal data object `ModelDataLogs` in the Time Series Tools GUI with an updated logged signal after you rerun the Simulink model. Use this command to update the `ModelDataLogs` object in the Time Series Tools GUI if you change the model or the logged-signal data settings.

See Also

`timeseries`, `tscollection`

type

Purpose

Display contents of file

Syntax

```
type('filename')
type filename
```

Description

`type('filename')` displays the contents of the specified file in the MATLAB Command Window. Use the full path for `filename`, or use a MATLAB relative `partialpath`.

If you do not specify a file extension and there is no `filename` file without an extension, the `type` function adds the `.m` extension by default. The `type` function checks the directories specified in the MATLAB search path, which makes it convenient for listing the contents of M-files on the screen. Use `type` with `more on` to see the listing one screen at a time.

`type filename` is the command form of the syntax.

Examples

`type('foo.bar')` lists the contents of the file `foo.bar`.

`type foo` lists the contents of the file `foo.` If `foo` does not exist, `type foo` lists the contents of the file `foo.m`.

See Also

`cd`, `dbtype`, `delete`, `dir`, `more`, `partialpath`, `path`, `what`, `who`

Purpose

Convert data types without changing underlying data

Syntax

```
Y = typecast(X, type)
```

Description

`Y = typecast(X, type)` converts a numeric value in `X` to the data type specified by `type`. Input `X` must be a full, noncomplex, numeric scalar or vector. The `type` input is a string set to one of the following: `'uint8'`, `'int8'`, `'uint16'`, `'int16'`, `'uint32'`, `'int32'`, `'uint64'`, `'int64'`, `'single'`, or `'double'`.

`typecast` is different from the MATLAB `cast` function in that it does not alter the input data. `typecast` always returns the same number of bytes in the output `Y` as were in the input `X`. For example, casting the 16-bit integer 1000 to `uint8` with `typecast` returns the full 16 bits in two 8-bit segments (3 and 232) thus keeping its original value (3*256 + 232 = 1000). The `cast` function, on the other hand, truncates the input value to 255.

The output of `typecast` can be formatted differently depending on what system you use it on. Some computer systems store data starting with its most significant byte (an ordering called *big-endian*), while others start with the least significant byte (called *little-endian*).

Note MATLAB issues an error if `X` contains fewer values than are needed to make an output value.

Examples

Example 1

This example converts between data types of the same size:

```
typecast(uint8(255), 'int8')
ans =
   -1

typecast(int16(-1), 'uint16')
ans =
```

```
65535
```

Example 2

Set X to a 1-by-3 vector of 32-bit integers, then cast it to an 8-bit integer type:

```
X = uint32([1 255 256])
X =
           1         255         256
```

Running this on a little-endian system produces the following results. Each 32-bit value is divided up into four 8-bit segments:

```
Y = typecast(X, 'uint8')
Y =
   1   0   0   0  255   0   0   0   0   1   0   0
```

The third element of `X`, 256, exceeds the 8 bits that it is being converted to in `Y`(9) and thus overflows to `Y`(10):

```
Y(9:12)
ans =
    0    1    0    0
```

Note that `length(Y)` is equal to `4.*length(X)`. Also note the difference between the output of `typecast` versus that of `cast`:

```
Z = cast(X, 'uint8')
Z =
    1  255  255
```

Example 3

This example casts a smaller data type (`uint8`) into a larger one (`uint16`). Displaying the numbers in hexadecimal format makes it easier to see just how the data is being rearranged:

```
format hex
X = uint8([44 55 66 77])
X =
```

```
    2c   37   42   4d
```

The first `typecast` is done on a big-endian system. The four 8-bit segments of the input data are combined to produce two 16-bit segments:

```
Y = typecast(X, 'uint16')
Y =
    2c37   424d
```

The second is done on a little-endian system. Note the difference in byte ordering:

```
Y = typecast(X, 'uint16')
Y =
    372c   4d42
```

You can format the little-endian output into big-endian (and vice versa) using the `swapbytes` function:

```
Y = swapbytes(typecast(X, 'uint16'))
Y =
    2c37   424d
```

Example 4

This example attempts to make a 32-bit value from a vector of three 8-bit values. MATLAB issues an error because there are an insufficient number of bytes in the input:

```
format hex

typecast(uint8([120 86 52]), 'uint32')
??? Too few input values to make output type.

Error in ==> typecast at 29
out = typecastc(in, datatype);
```

Repeat the example, but with a vector of four 8-bit values, and it returns the expected answer:

```
typecast(uint8([120 86 52 18]), 'uint32')
ans =
   12345678
```

See Also

`cast`, `class`, `swapbytes`

Purpose

Create container object to exclusively manage radio buttons and toggle buttons

Syntax

```
uibuttongroup('PropertyName1',Value1,'PropertyName2',Value2,
   ...)
handle = uibuttongroup(...)
```

Description

A uibuttongroup groups components and manages exclusive selection behavior for radio buttons and toggle buttons that it contains. It can also contain other user interface controls, axes, uipanels, and uibuttongroups. It cannot contain ActiveX controls.

`uibuttongroup('`*`PropertyName1`*`',Value1,'`*`PropertyName2`*`',Value2,...)` creates a visible container component in the current figure window. This component manages exclusive selection behavior for uicontrols of style `radiobutton` and `togglebutton`.

`handle = uibuttongroup(...)` creates a uibuttongroup object and returns a handle to it in `handle`.

A `uibuttongroup` object can have `axes`, `uicontrol`, `uipanel`, and `uibuttongroup` objects as children. However, only uicontrols of style `radiobutton` and `togglebutton` are managed by the component.

When programming a button group, you do not code callbacks for the individual buttons; instead, use its `SelectionChangeFcn` callback to manage responses to selections. The following example illustrates how you use `uibuttongroup` event data to do this.

For the children of a `uibuttongroup` object, the `Position` property is interpreted relative to the button group. If you move the button group, the children automatically move with it and maintain their positions in the button group.

If you have a button group that contains a set of radio buttons and toggle buttons and you want:

- An immediate action to occur when a radio button or toggle button is selected, you must include the code to control the radio and toggle buttons in the button group's `SelectionChangeFcn` callback function, not in the individual toggle button `Callback` functions. See the `SelectionChangeFcn` property and the example on this reference page for more information.

- Another component such as a push button to base its action on the selection, then that component's `Callback` callback can get the handle of the selected radio button or toggle button from the button group's `SelectedObject` property.

Use the `Parent` property to specify the parent as a figure, uipanel, or uibuttongroup. If you do not specify a parent, `uibuttongroup` adds the button group to the current figure. If no figure exists, one is created.

See the Uibuttongroup Properties reference page for more information.

After creating a uibuttongroup, you can set and query its property values using `set` and `get`. Run `get(handle)` to see a list of properties and their current values. Run `set(handle)` to see a list of object properties you can set and their legal values.

Examples

This example creates a uibuttongroup with three radiobuttons. It manages the radiobuttons with the `SelectionChangeFcn` callback, `selcbk`.

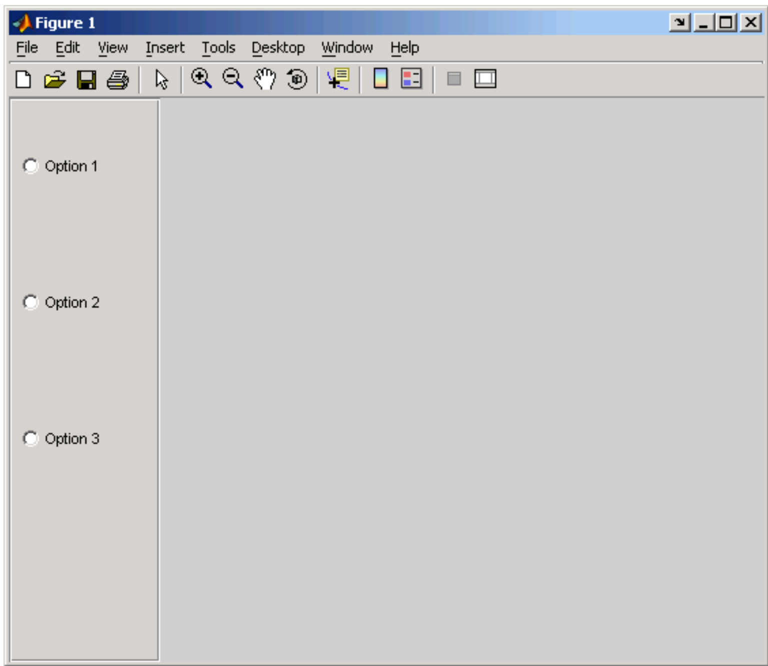
When you select a new radio button, `selcbk` displays the uibuttongroup handle on one line, the `EventName`, `OldValue`, and `NewValue` fields of the event data structure on a second line, and the value of the `SelectedObject` property on a third line.

```
% Create the button group.
h = uibuttongroup('visible','off','Position',[0 0 .2 1]);
% Create three radio buttons in the button group.
u0 = uicontrol('Style','Radio','String','Option 1',...
    'pos',[10 350 100 30],'parent',h,'HandleVisibility','off');
u1 = uicontrol('Style','Radio','String','Option 2',...
    'pos',[10 250 100 30],'parent',h,'HandleVisibility','off');
u2 = uicontrol('Style','Radio','String','Option 3',...
    'pos',[10 150 100 30],'parent',h,'HandleVisibility','off');
% Initialize some button group properties.
```

```
set(h,'SelectionChangeFcn',@selcbk);
set(h,'SelectedObject',[]);  % No selection
set(h,'Visible','on');
```

For the `SelectionChangeFcn` callback, `selcbk`, the source and event data structure arguments are available only if `selcbk` is called using a function handle. See `SelectionChangeFcn` for more information.

```
function selcbk(source,eventdata)
disp(source);
disp([eventdata.EventName,'  ',...
     get(eventdata.OldValue,'String'),'  ', ...
     get(eventdata.NewValue,'String')]);
disp(get(get(source,'SelectedObject'),'String'));
```



If you click `Option 2` with no option selected, the `SelectionChangeFcn` callback, `selcbk`, displays:

```
    3.0011

SelectionChanged    Option 2
Option 2
```

If you then click `Option 1`, the `SelectionChangeFcn` callback, `selcbk`, displays:

```
    3.0011

SelectionChanged  Option 2  Option 1
Option 1
```

See Also

`uicontrol`, `uipanel`

Purpose

Describe button group properties

Modifying Properties

You can set and query graphics object properties in two ways:

- The Property Inspector is an interactive tool that enables you to see and change object property values. The Property inspector is available from GUIDE, or use the `inspect` function at the command line.
- The `set` and `get` functions enable you to set and query the values of properties.

Uibuttongroup takes its default property values from uipanel. To set a uibuttongroup default property value, set the default for the corresponding `uipanel` property. Note that you can set no default values for the uibuttongroup `SelectedObject` and `SelectionChangeFcn` properties.

For more information about changing the default value of a property see “Setting Default Property Values”. For an example, see the `CreateFcn` property.

Uibuttongroup Properties

This section describes all properties useful to `uibuttongroup` objects and lists valid values. Curly braces { } enclose default values.

Property Name	Description
`BackgroundColor`	Color of the button group background
`BorderType`	Type of border around the button group
`BorderWidth`	Width of the button group border in pixels
`BusyAction`	Interruption of other callback routines
`ButtonDownFcn`	Button-press callback routine
`Children`	All children of the button group

Property Name	Description
Clipping	Clipping of child axes, panels, and button groups to the button group. Does not affect child user interface controls (uicontrol)
CreateFcn	Callback routine executed during object creation
DeleteFcn	Callback routine executed during object deletion
FontAngle	Title font angle
FontName	Title font name
FontSize	Title font size
FontUnits	Title font units
FontWeight	Title font weight
ForegroundColor	Title font color and color of 2-D border line
HandleVisibility	Handle accessibility from command line and GUIs
HighlightColor	3-D frame highlight color
Interruptible	Callback routine interruption mode
Parent	uibuttongroup object's parent
Position	Button group position relative to parent figure, panel, or button group
ResizeFcn	User-specified resize routine
Selected	Whether object is selected
SelectedObject	Currently selected uicontrol of style radiobutton or togglebutton
SelectionChangeFcn	Callback routine executed when the selected radio button or toggle button changes
SelectionHighlight	Object highlighted when selected

Property Name	Description
`ShadowColor`	3-D frame shadow color
`Tag`	User-specified object identifier
`Title`	Title string
`TitlePosition`	Location of title string in relation to the button group
`Type`	Object class
`UIContextMenu`	Associate context menu with the button group
`Units`	Units used to interpret the position vector
`UserData`	User-specified data
`Visible`	Button group visibility **Note** Controls the `Visible` property of child axes, panels, and button groups. Does not affect child user interface controls (`uicontrol`).

`BackgroundColor`
`ColorSpec`

Color of the uibuttongroup background. A three-element RGB vector or one of the MATLAB predefined names, specifying the background color. See the `ColorSpec` reference page for more information on specifying color.

`BorderType`
`none | {etchedin} | etchedout |`
`beveledin | beveledout | line`

Border of the uibuttongroup area. Used to define the button group area graphically. Etched and beveled borders provide a 3-D look. Use the `HighlightColor` and `ShadowColor` properties to specify the border color of etched and beveled borders. A line border is 2-D. Use the `ForegroundColor` property to specify its color.

`BorderWidth`
integer

Width of the button group border. The width of the button group borders in pixels. The default border width is 1 pixel. 3-D borders wider than 3 may not appear correctly at the corners.

`BusyAction`
`cancel | {queue}`

Callback routine interruption. If a callback is executing and the user triggers an event (such as a mouse click) on an object for which a callback is defined, the callback associated with the new event uses the value of `BusyAction` to decide whether or not to attempt to interrupt the executing callback.

- If the value is `cancel`, the event is discarded and the second callback does not execute.
- If the value is `queue`, and the `Interruptible` property of the first callback is `on`, the second callback is added to the event queue and executes in its turn after the first callback finishes execution.

Note If the interrupting callback is a `DeleteFcn` or `CreateFcn` callback or a figure's `CloseRequest` or `ResizeFcn` callback, it interrupts an executing callback regardless of the value of that object's `Interruptible` property. See the `Interruptible` property for information about controlling a callback's interruptibility.

`ButtonDownFcn`
string or function handle

Button-press callback routine. A callback routine that executes when you press a mouse button while the pointer is in a 5-pixel wide border around the uibuttongroup. This is useful for implementing actions to interactively modify object properties, such as size and position, when they are clicked on (using the `selectmoveresize` function, for example).

If you define this routine as a string, the string can be a valid MATLAB expression or the name of an M-file. The expression executes in the MATLAB workspace.

`Children`
vector of handles

Children of the uibuttongroup. A vector containing the handles of all children of the uibuttongroup. Although a uibuttongroup manages only uicontrols of style `radiobutton` and `togglebutton`, its children can be axes, uipanels, uibuttongroups, and other uicontrols. You can use this property to reorder the children.

`Clipping`
`{on} | off`

Clipping mode. By default, MATLAB clips a uibuttongroup's child axes, uipanels, and uibuttongroups to the uibuttongroup rectangle. If you set `Clipping` to `off`, the axis, uipanel, or uibuttongroup is displayed outside the button group rectangle. This property does not affect child uicontrols which, by default, can display outside the button group rectangle.

`CreateFcn`
string or function handle

Callback routine executed during object creation. The specified function executes when MATLAB creates a `uibuttongroup` object. MATLAB sets all property values for the uibuttongroup before executing the `CreateFcn` callback so these values are available to the callback. Within the function, use `gcbo` to get the handle of the uibuttongroup being created.

Setting this property on an existing uibuttongroup object has no effect.

To define a default `CreateFcn` callback for all new uibuttongroups you must define the same default for all uipanels. This default applies unless you override it by specifying a different `CreateFcn` callback when you call `uibuttongroup`. For example, the code

```
set(0,'DefaultUipanelCreateFcn','set(gcbo,...
    ''FontName'',''arial'',''FontSize'',12)')
```

creates a default `CreateFcn` callback that runs whenever you create a new panel or button group. It sets the default font name and font size of the uipanel or uibuttongroup title.

To override this default and create a button group whose `FontName` and `FontSize` properties are set to different values, call `uibuttongroup` with code similar to

```
hpt = uibuttongroup(...,'CreateFcn','set(gcbo,...
''FontName'',''times'',''FontSize'',14)')
```

Note To override a default `CreateFcn` callback you must provide a new callback and not just provide different values for the specified properties. This is because the `CreateFcn` callback runs after the property values are set, and can override property values you have set explicitly in the `uibuttongroup` call. In the example above, if instead of redefining the `CreateFcn` property for this uibuttongroup, you had explicitly set `FontSize` to `14`, the default `CreateFcn` callback would have set `FontSize` back to the system dependent default.

Do not call `copyobj` or `textwrap` (which calls `copyobj`) inside a `CreateFcn`. The act of copying the uicontrol object fires the `CreateFcn` repeatedly, which raises a series of error messages after exceeding the root object's `RecursionLimit` property.

See "Function Handle Callbacks" for information on how to use function handles to define a callback function.

`DeleteFcn`
string or function handle

Callback routine executed during object deletion. A callback routine that executes when you delete the `uibuttongroup` object (e.g., when you issue a delete command or clear the figure containing the uibuttongroup). MATLAB executes the routine before destroying the object's properties so these values are available to the callback routine. The handle of the object whose `DeleteFcn` is being executed is accessible only through the root `CallbackObject` property, which you can query using `gcbo`.

`FontAngle`
`{normal} | italic | oblique`

Character slant used in the Title. MATLAB uses this property to select a font from those available on your particular system. Setting this property to `italic` or `oblique` selects a slanted version of the font, when it is available on your system.

`FontName`
string

Font family used in the Title. The name of the font in which to display the `Title`. To display and print properly, this must be a font that your system supports. The default font is system dependent. To eliminate the need to hard code the name of a fixed-width font, which may not display text properly on systems that do not use ASCII character encoding (such as in Japan), set

FontName to the string FixedWidth. This string value is case insensitive.

```
set(uicontrol_handle,'FontName','FixedWidth')
```

This then uses the value of the root FixedWidthFontName property, which can be set to the appropriate value for a locale from startup.m in the end user's environment. Setting the root FixedWidthFontName property causes an immediate update of the display to use the new font.

FontSize
integer

Title font size. A number specifying the size of the font in which to display the Title, in units determined by the FontUnits property. The default size is system dependent.

FontUnits
inches | centimeters | normalized | {points} |pixels

Title font size units. Normalized units interpret FontSize as a fraction of the height of the uibuttongroup. When you resize the uibuttongroup, MATLAB modifies the screen FontSize accordingly. pixels, inches, centimeters, and points are absolute units (1 point = 1/72 inch).

FontWeight
light | {normal} | demi | bold

Weight of characters in the title. MATLAB uses this property to select a font from those available on your particular system. Setting this property to bold causes MATLAB to use a bold version of the font, when it is available on your system.

ForegroundColor
ColorSpec

Color used for title font and 2-D border line. A three-element RGB vector or one of the MATLAB predefined names, specifying the font or line color. See the `ColorSpec` reference page for more information on specifying color.

`HandleVisibility`
`{on} | callback | off`

Control access to object's handle. This property determines when an object's handle is visible in its parent's list of children. When a handle is not visible in its parent's list of children, it is not returned by functions that obtain handles by searching the object hierarchy or querying handle properties. This includes `get`, `findobj`, `gca`, `gcf`, `gco`, `newplot`, `cla`, `clf`, and `close`. Neither is the handle visible in the parent figure's `CurrentObject` property. Handles that are hidden are still valid. If you know an object's handle, you can `set` and `get` its properties, and pass it to any function that operates on handles.

- Handles are always visible when `HandleVisibility` is `on`.
- Setting `HandleVisibility` to `callback` causes handles to be visible from within callback routines or functions invoked by callback routines, but not from within functions invoked from the command line. This provides a means to protect GUIs from command-line users, while allowing callback routines to have complete access to object handles.
- Setting `HandleVisibility` to `off` makes handles invisible at all times. This may be necessary when a callback routine invokes a function that might potentially damage the GUI (such as evaluating a user-typed string), and so temporarily hides its own handles during the execution of that function.

Note Uicontrols of style `radiobutton` and `togglebutton` that are managed by a uibuttongroup should not be accessed outside the button group. Set the `HandleVisibility` of such radio buttons and toggle buttons to `off` or `callback` to prevent inadvertent access.

You can set the root `ShowHiddenHandles` property to `on` to make all handles visible, regardless of their `HandleVisibility` settings. This does not affect the values of the `HandleVisibility` properties.

`HighlightColor`
`ColorSpec`

3-D frame highlight color. A three-element RGB vector or one of the MATLAB predefined names, specifying the highlight color. See the `ColorSpec` reference page for more information on specifying color.

`Interruptible`
`{on} | off`

Callback routine interruption mode. If a callback is executing and the user triggers an event (such as a mouse click) on an object for which a callback is defined, that callback attempts to interrupt the first callback. MATLAB processes the callbacks according to these factors:

- The `Interruptible` property of the object whose callback is executing
- Whether the executing callback contains `drawnow`, `figure`, `getframe`, `pause`, or `waitfor` statements
- The `BusyAction` property of the object whose callback is waiting to execute

If the `Interruptible` property of the object whose callback is executing is `on` (the default), the callback can be interrupted. Whenever the callback calls one of the `drawnow`, `figure`, `getframe`, `pause`, or `waitfor` functions, the function processes any events in the event queue, including the waiting callback, before performing its defined task.

If the `Interruptible` property of the object whose callback is executing is `off`, the callback cannot be interrupted (except by certain callbacks; see the note below). The `BusyAction` property of the object whose callback is waiting to execute determines what happens to the waiting callback.

Note If the interrupting callback is a `DeleteFcn` or `CreateFcn` callback or a figure's `CloseRequest` or `ResizeFcn` callback, it interrupts an executing callback regardless of the value of that object's `Interruptible` property. The interrupting callback starts execution at the next `drawnow`, `figure`, `getframe`, `pause`, or `waitfor` statement. A figure's `WindowButtonDownFcn` callback routine, or an object's `ButtonDownFcn` or `Callback` routine is processed according to the rules described above.

`Parent`

handle

Uibuttongroup parent. The handle of the uibuttongroup's parent figure, uipanel, or uibuttongroup. You can move a uibuttongroup object to another figure, uipanel, or uibuttongroup by setting this property to the handle of the new parent.

`Position`

position rectangle

Size and location of uibuttongroup relative to parent. The rectangle defined by this property specifies the size and location of the button group within the parent figure window, uipanel, or uibuttongroup. Specify `Position` as

```
[left bottom width height]
```

`left` and `bottom` are the distance from the lower-left corner of the parent object to the lower-left corner of the `uibuttongroup` object. `width` and `height` are the dimensions of the uibuttongroup rectangle, including the title. All measurements are in units specified by the `Units` property.

`ResizeFcn`

string or function handle

Resize callback routine. MATLAB executes this callback routine whenever a user resizes the uibuttongroup and the figure `Resize` property is set to `on`, or in GUIDE, the **Resize behavior** option is set to `Other`. You can query the uibuttongroup `Position` property to determine its new size and position. During execution of the callback routine, the handle to the figure being resized is accessible only through the root `CallbackObject` property, which you can query using `gcbo`.

You can use `ResizeFcn` to maintain a GUI layout that is not directly supported by the MATLAB `Position`/`Units` paradigm.

For example, consider a GUI layout that maintains an object at a constant height in pixels and attached to the top of the figure, but always matches the width of the figure. The following `ResizeFcn` accomplishes this; it keeps the uicontrol whose `Tag` is `'StatusBar'` 20 pixels high, as wide as the figure, and attached to the top of the figure. Note the use of the `Tag` property to retrieve the uicontrol handle, and the `gcbo` function to retrieve the figure handle. Also note the defensive programming regarding figure `Units`, which the callback requires to be in pixels in order to work correctly, but which the callback also restores to their previous value afterwards.

```
u = findobj('Tag','StatusBar');
fig = gcbo;
old_units = get(fig,'Units');
set(fig,'Units','pixels');
figpos = get(fig,'Position');
upos = [0, figpos(4) - 20, figpos(3), 20];
set(u,'Position',upos);
set(fig,'Units',old_units);
```

You can change the figure `Position` from within the `ResizeFcn` callback; however, the `ResizeFcn` is not called again as a result.

Note that the `print` command can cause the `ResizeFcn` to be called if the `PaperPositionMode` property is set to `manual` and you have defined a resize function. If you do not want your resize function called by `print`, set the `PaperPositionMode` to `auto`.

See "Function Handle Callbacks" for information on how to use function handles to define the callback function.

`Selected`
: `on | off` (read only)

Is object selected? This property indicates whether the button group is selected. When this property is `on`, MATLAB displays selection handles if the `SelectionHighlight` property is also `on`. You can, for example, define the `ButtonDownFcn` function to set this property, allowing users to select the object with the mouse.

`SelectedObject`
: scalar handle

Currently selected radio button or toggle button uicontrol in the managed group of components. Use this property to determine the currently selected component or to initialize selection of one of the radio buttons or toggle buttons. By default, `SelectedObject` is set to the first uicontrol radio button or toggle button that is added. Set it to `[]` if you want no selection. Note that

`SelectionChangeFcn` does not execute when this property is set by the user.

`SelectionChangeFcn`

string or function handle

Callback routine executed when the selected radio button or toggle button changes. If this routine is called as a function handle, `uibuttongroup` passes it two arguments. The first argument, `source`, is the handle of the uibuttongroup. The second argument, `eventdata`, is an event data structure that contains the fields shown in the following table.

Event Data Structure Field	Description
`EventName`	`'SelectionChanged'`
`OldValue`	Handle of the object selected before this event. `[]` if none was selected.
`NewValue`	Handle of the currently selected object.

If you have a button group that contains a set of radio buttons and/or toggle buttons and you want an immediate action to occur when a radio button or toggle button is selected, you must include the code to control the radio and toggle buttons in the button group's `SelectionChangeFcn` callback function, not in the individual toggle button `Callback` functions.

If you want another component such as a push button to base its action on the selection, then that component's `Callback` callback can get the handle of the selected radio button or toggle button from the button group's `SelectedObject` property.

Note For GUIDE GUIs, `hObject` contains the handle of the selected radio button or toggle button. See "Examples: Programming GUIDE GUI Components" for more information.

`SelectionHighlight`
`{on} | off`

Object highlighted when selected. When the `Selected` property is `on`, MATLAB indicates the selected state by drawing four edge handles and four corner handles. When `SelectionHighlight` is `off`, MATLAB does not draw the handles.

`ShadowColor`
`ColorSpec`

3-D frame shadow color. `ShadowColor` is a three-element RGB vector or one of the MATLAB predefined names, specifying the shadow color. See the `ColorSpec` reference page for more information on specifying color.

`Tag`
string

User-specified object identifier. The `Tag` property provides a means to identify graphics objects with a user-specified label. You can define `Tag` as any string.

With the `findobj` function, you can locate an object with a given `Tag` property value. This saves you from defining object handles as global variables. For example, this function call returns the handles of all children (of the specified figures) that have the `Tag` value `'FormatTb'`.

```
h = findobj(figurehandles,'Tag','FormatTb')
```

`Title`

string

Title string. The text displayed in the button group title. You can position the title using the `TitlePosition` property.

If the string value is specified as a cell array of strings or padded string matrix, only the first string in the cell array or padded string matrix is displayed; the rest are ignored. Vertical slash ('`|`') characters are not interpreted as line breaks and instead show up in the text displayed in the uibuttongroup title.

Setting a property value to `default`, `remove`, or `factory` produces the effect described in "Defining Default Values". To set `Title` to one of these words, you must precede the word with the backslash character. For example,

```
hp = uibuttongroup(...,'Title','\Default');
```

`TitlePosition`

`{lefttop} | centertop | righttop |`
`leftbottom | centerbottom | rightbottom`

Location ofthe title. This property determines the location of the title string, in relation to the uibuttongroup.

`Type`

`string` (read-only)

Object class. This property identifies the kind of graphics object. For uibuttongroup objects, `Type` is always the string `'uibuttongroup'`.

`UIContextMenu`

handle

Associate a context menu with a uibuttongroup. Assign this property the handle of a `Uicontextmenu` object. MATLAB displays the context menu whenever you right-click the `uibuttongroup`. Use the `uicontextmenu` function to create the context menu.

`Units`

`inches | centimeters | {normalized} |`
`points | pixels | characters`

Units of measurement. MATLAB uses these units to interpret the `Position` property. For the button group itself, units are measured from the lower-left corner of its parent figure window, panel, or button group. For children of the button group, they are measured from the lower-left corner of the button group.

- `Normalized` units map the lower-left corner of the button group or figure window to (0,0) and the upper-right corner to (1.0,1.0).
- `pixels`, `inches`, `centimeters`, and `points` are absolute units (1 point = 1/72 inch).
- `Character` units are characters using the default system font; the width of one character is the width of the letter x, the height of one character is the distance between the baselines of two lines of text.

If you change the value of `Units`, it is good practice to return it to its default value after completing your computation so as not to affect other functions that assume `Units` is set to the default value.

`UserData`

matrix

User-specified data. Any data you want to associate with the `uibuttongroup` object. MATLAB does not use this data, but you can access it using `set` and `get`.

`Visible`

`{on} | off`

Uibuttongroup visibility. By default, a `uibuttongroup` object is visible. When set to `off`, the uibuttongroup is not visible, but still exists and you can query and set its properties.

Note The value of a uibuttongroup's `Visible` property also controls the `Visible` property of child axes, uipanels, and uibuttongroups. This property does not affect the `Visible` property of child uicontrols.

Purpose

Create context menu

Syntax

`handle = uicontextmenu('`*`PropertyName`*`',PropertyValue,...)`

Description

`handle = uicontextmenu('`*`PropertyName`*`',PropertyValue,...)` creates a context menu, which is a menu that appears when the user right-clicks on a graphics object. See the Uicontextmenu Properties reference page for more information.

You create context menu items using the `uimenu` function. Menu items appear in the order the `uimenu` statements appear. You associate a context menu with an object using the `UIContextMenu` property for the object and specifying the context menu's handle as the property value.

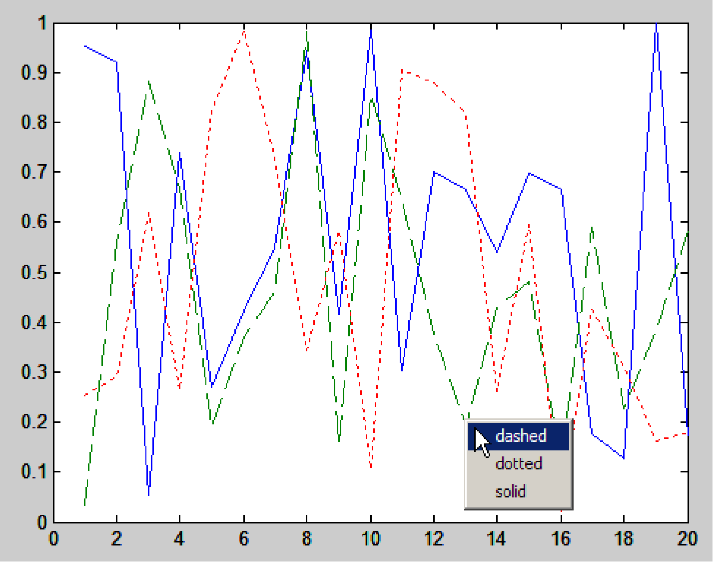
Example

These statements define a context menu associated with a line. When the user right clicks or presses **Alt+click** anywhere on the line, the menu appears. Menu items enable the user to change the line style.

```
% Create axes and save handle
hax = axes;
% Plot three lines
plot(rand(20,3));
% Define a context menu; it is not attached to anything
hcmenu = uicontextmenu;
% Define callbacks for context menu items that change linestyle
hcb1 = ['set(gco, ''LineStyle'', ''--'')'];
hcb2 = ['set(gco, ''LineStyle'', '':'')'];
hcb3 = ['set(gco, ''LineStyle'', ''-'')'];
% Define the context menu items and install their callbacks
item1 = uimenu(hcmenu, 'Label', 'dashed', 'Callback', hcb1);
item2 = uimenu(hcmenu, 'Label', 'dotted', 'Callback', hcb2);
item3 = uimenu(hcmenu, 'Label', 'solid',  'Callback', hcb3);
% Locate line objects
hlines = findall(hax,'Type','line');
% Attach the context menu to each line
for line = 1:length(hlines)
    set(hlines(line),'uicontextmenu',hcmenu)
```

```
end
```

When the user right clicks or presses **Alt+click** on the line, the context menu appears, as shown in this figure:



Generally, you need to attach context menus to lines at the time they are plotted in order to be sure that the menus are available to users at once. Therefore, code such as the above could be placed in or called from the callbacks that perform plotting for the GUI.

You should only define callbacks as strings if they need to perform simple actions. For example, if you wanted to add check marks to menu items (using the `Checked` uimenu property) to indicate the current style for a each line, you should define the menu item callbacks as function handles and place the code for them in the GUI's M-file rather than placing callback strings in the figure.

See Also

"Context Menus" in the MATLAB Creating Graphical User Interfaces documentation `uibuttongroup`, `uicontrol`, `uimenu`, `uipanel`

Uicontextmenu Properties

Purpose

Describe context menu properties

Modifying Properties

You can set and query graphics object properties in two ways:

- The Property Inspector is an interactive tool that enables you to see and change object property values. The Property inspector is available from GUIDE, or use the `inspect` function at the command line.
- The `set` and `get` functions enable you to set and query the values of properties.

For more information about changing the default value of a property see "Setting Default Property Values". For an example, see the `CreateFcn` property.

Uicontextmenu Properties

This section lists all properties useful to `uicontextmenu` objects along with valid values and descriptions of their use. Curly braces {} enclose default values.

Property	Purpose
`BusyAction`	Callback routine interruption
`Callback`	Control action
`Children`	The uimenus defined for the uicontextmenu
`CreateFcn`	Callback routine executed during object creation
`DeleteFcn`	Callback routine executed during object deletion
`HandleVisibility`	Whether handle is accessible from command line and GUIs
`Interruptible`	Callback routine interruption mode
`Parent`	Uicontextmenu object's parent

Property	Purpose
Position	Location of uicontextmenu when Visible is set to on
Tag	User-specified object identifier
Type	Class of graphics object
UserData	User-specified data
Visible	Uicontextmenu visibility

BusyAction

cancel | {queue}

Callback routine interruption. If a callback is executing and the user triggers an event (such as a mouse click) on an object for which a callback is defined, the callback associated with the new event uses the value of BusyAction to decide whether or not to attempt to interrupt the executing callback.

- If the value is cancel, the event is discarded and the second callback does not execute.
- If the value is queue, and the Interruptible property of the first callback is on, the second callback is added to the event queue and executes in its turn after the first callback finishes execution.

Note If the interrupting callback is a DeleteFcn or CreateFcn callback or a figure's CloseRequest or ResizeFcn callback, it interrupts an executing callback regardless of the value of that object's Interruptible property. See the Interruptible property for information about controlling a callback's interruptibility.

`Callback`
string

Control action. A routine that executes whenever you right-click an object for which a context menu is defined. The routine executes immediately before the context menu is posted. Define this routine as a string that is a valid MATLAB expression or the name of an M-file. The expression executes in the MATLAB workspace.

`Children`
matrix

The uimenu items defined for the uicontextmenu.

`CreateFcn`
string or function handle

Callback routine executed during object creation. The specified function executes when MATLAB creates a `uicontextmenu` object. MATLAB sets all property values for the uicontextmenu before executing the `CreateFcn` callback so these values are available to the callback. Within the function, use `gcbo` to get the handle of the uicontextmenu being created.

Setting this property on an existing uicontextmenu object has no effect.

You can define a default `CreateFcn` callback for all new uicontextmenus. This default applies unless you override it by specifying a different `CreateFcn` callback when you call `uicontextmenu`. For example, the code

```
set(0,'DefaultUicontextmenuCreateFcn','set(gcbo,...
    ''Visible'',''on'')')
```

creates a default `CreateFcn` callback that runs whenever you create a new context menu. It sets the default `Visible` property of a context menu.

To override this default and create a context menu whose `Visible` property is set to a different value, call `uicontextmenu` with code similar to

```
hpt = uicontextmenu(...,'CreateFcn','set(gcbo,...
''Visible'',''off'')')
```

Note To override a default `CreateFcn` callback you must provide a new callback and not just provide different values for the specified properties. This is because the `CreateFcn` callback runs after the property values are set, and can override property values you have set explicitly in the `uicontextmenu` call. In the example above, if instead of redefining the `CreateFcn` property for this uicontextmenu, you had explicitly set `Visible` to `off`, the default `CreateFcn` callback would have set `Visible` back to the default, i.e., `on`.

Do not call `copyobj` or `textwrap` (which calls `copyobj`) inside a `CreateFcn`. The act of copying the uicontrol object fires the `CreateFcn` repeatedly, which raises a series of error messages after exceeding the root object's `RecursionLimit` property.

See "Function Handle Callbacks" for information on how to use function handles to define a callback function.

`DeleteFcn`

string or function handle

Delete uicontextmenu callback routine. A callback routine that executes when you delete the uicontextmenu object (e.g., when you issue a `delete` command or clear the figure containing the uicontextmenu). MATLAB executes the routine before destroying the object's properties so these values are available to the callback routine.

The handle of the object whose DeleteFcn is being executed is accessible only through the root `CallbackObject` property, which you can query using `gcbo`.

See "Function Handle Callbacks" for information on how to use function handles to define a callback function.

`HandleVisibility`
`{on} | callback | off`

Control access to object's handle. This property determines when an object's handle is visible in its parent's list of children. When a handle is not visible in its parent's list of children, it is not returned by functions that obtain handles by searching the object hierarchy or querying handle properties. This includes `get`, `findobj`, `gca`, `gcf`, `gco`, `newplot`, `cla`, `clf`, and `close`. Neither is the handle visible in the parent figure's `CurrentObject` property. Handles that are hidden are still valid. If you know an object's handle, you can `set` and `get` its properties, and pass it to any function that operates on handles.

- Handles are always visible when `HandleVisibility` is `on`.
- Setting `HandleVisibility` to `callback` causes handles to be visible from within callback routines or functions invoked by callback routines, but not from within functions invoked from the command line. This provides a means to protect GUIs from command-line users, while allowing callback routines to have complete access to object handles.
- Setting `HandleVisibility` to `off` makes handles invisible at all times. This may be necessary when a callback routine invokes a function that might potentially damage the GUI (such as evaluating a user-typed string), and so temporarily hides its own handles during the execution of that function.

You can set the root ShowHiddenHandles property to on to make all handles visible, regardless of their HandleVisibility settings. This does not affect the values of the HandleVisibility properties.

Interruptible

{on} | off

Callback routine interruption mode. If a callback is executing and the user triggers an event (such as a mouse click) on an object for which a callback is defined, that callback attempts to interrupt the first callback. MATLAB processes the callbacks according to these factors:

- The Interruptible property of the object whose callback is executing
- Whether the executing callback contains drawnow, figure, getframe, pause, or waitfor statements
- The BusyAction property of the object whose callback is waiting to execute

If the Interruptible property of the object whose callback is executing is on (the default), the callback can be interrupted. Whenever the callback calls one of the drawnow, figure, getframe, pause, or waitfor functions, the function processes any events in the event queue, including the waiting callback, before performing its defined task.

If the Interruptible property of the object whose callback is executing is off, the callback cannot be interrupted (except by certain callbacks; see the note below). The BusyAction property of the object whose callback is waiting to execute determines what happens to the callback.

Note If the interrupting callback is a DeleteFcn or CreateFcn callback or a figure's CloseRequest or ResizeFcn callback, it interrupts an executing callback regardless of the value of that object's Interruptible property. The interrupting callback starts execution at the next drawnow, figure, getframe, pause, or waitfor statement. A figure's WindowButtonDownFcn callback routine, or an object's ButtonDownFcn or Callback routine are processed according to the rules described above.

Parent
handle

Uicontextmenu's parent. The handle of the uicontextmenu's parent object, which must be a figure.

Position
vector

Uicontextmenu's position. A two-element vector that defines the location of a context menu posted by setting the Visible property value to on. Specify Position as

```
[x y]
```

where vector elements represent the horizontal and vertical distances in pixels from the bottom left corner of the figure window, panel, or button group to the top left corner of the context menu.

Tag
string

User-specified object label. The Tag property provides a means to identify graphics objects with a user-specified label. This is particularly useful when constructing interactive graphics programs that would otherwise need to define object handles as global variables or pass them as arguments between callback routines. You can define `Tag` as any string.

`Type`
string

Class of graphics object. For uicontextmenu objects, `Type` is always the string `'uicontextmenu'`.

`UserData`
matrix

User-specified data. Any data you want to associate with the uicontextmenu object. MATLAB does not use this data, but you can access it using `set` and `get`.

`Visible`
`on | {off}`

Uicontextmenu visibility. The `Visible` property can be used in two ways:

- Its value indicates whether the context menu is currently posted. While the context menu is posted, the property value is `on`; when the context menu is not posted, its value is `off`.
- Its value can be set to `on` to force the posting of the context menu. Similarly, setting the value to `off` forces the context menu to be removed. When used in this way, the `Position` property determines the location of the posted context menu.

Purpose

Create user interface control object

Syntax

```
handle = uicontrol('PropertyName',PropertyValue,...)
handle = uicontrol(parent,'PropertyName',PropertyValue,...)
handle = uicontrol
uicontrol(uich)
```

Description

`uicontrol` creates a uicontrol graphics objects (user interface controls), which you use to implement graphical user interfaces.

`handle = uicontrol('`*`PropertyName`*`',PropertyValue,...)` creates a uicontrol and assigns the specified properties and values to it. It assigns the default values to any properties you do not specify. The default uicontrol style is a pushbutton. The default parent is the current figure. See the Uicontrol Properties reference page for more information.

`handle = uicontrol(parent,'`*`PropertyName`*`',PropertyValue,...)` creates a uicontrol in the object specified by the handle, `parent`. If you also specify a different value for the `Parent` property, the value of the `Parent` property takes precedence. `parent` can be the handle of a figure, uipanel, or uibuttongroup.

`handle = uicontrol` creates a pushbutton in the current figure. The `uicontrol` function assigns all properties their default values.

`uicontrol(uich)` gives focus to the uicontrol specified by the handle, `uich`.

When selected, most uicontrol objects perform a predefined action. MATLAB software supports numerous styles of uicontrols, each suited for a different purpose:

- Check boxes
- Editable text fields
- Frames
- List boxes

- Pop-up menus
- Push buttons
- Radio buttons
- Sliders
- Static text labels
- Toggle buttons

For information on using these uicontrols within GUIDE, the MATLAB GUI development environment, see Examples: Programming GUI Components in the MATLAB Creating GUIs documentation

Specifying the Uicontrol Style

To create a specific type of uicontrol, set the `Style` property as one of the following strings:

- `'checkbox'` – Check boxes generate an action when selected. These devices are useful when providing the user with a number of independent choices. To activate a check box, click the mouse button on the object. The state of the device is indicated on the display.
- `'edit'` – Editable text fields enable users to enter or modify text values. Use editable text when you want text as input. If `Max-Min>1`, then multiple lines are allowed. For multi-line edit boxes, a vertical scrollbar enables scrolling, as do the arrow keys.
- `'frame'` – Frames are rectangles that provide a visual enclosure for regions of a figure window. Frames can make a user interface easier to understand by grouping related controls. Frames have no callback routines associated with them. Only other uicontrols can appear within frames.

  Frames are opaque, not transparent, so the order in which you define uicontrols is important in determining whether uicontrols within a frame are covered by the frame or are visible. *Stacking order* determines the order objects are drawn: objects defined first are drawn first; objects defined later are drawn over existing objects. If you use a frame to enclose objects, you must define the frame before you define the objects.

Note Most frames in existing GUIs can now be replaced with panels (`uipanel`) or button groups (`uibuttongroup`). GUIDE continues to support frames in those GUIs that contain them, but the frame component does not appear in the GUIDE Layout Editor component palette.

- `'listbox'` – List boxes display a list of items and enable users to select one or more items. The `Min` and `Max` properties control the selection mode:

  If `Max-Min>1`, then multiple selection is allowed.

  If `Max-Min<=1`, then only single selection is allowed.

  The `Value` property indicates selected entries and contains the indices into the list of strings; a vector value indicates multiple selections. MATLAB evaluates the list box's callback routine after any mouse button up event that changes the `Value` property. Therefore, you may need to add a "Done" button to delay action caused by multiple clicks on list items.

  List boxes whose `Enable` property is `on` differentiate between single and double left clicks and set the figure `SelectionType` property to `normal` or `open` accordingly before evaluating the list box's `Callback` property. For such list boxes, **Ctrl**-left click and **Shift**-left click also set the figure `SelectionType` property to `normal` or `open` to indicate a single or double click.

- `'popupmenu'` – Pop-up menus (also known as drop-down menus or combo boxes) open to display a list of choices when pressed. When not open, a pop-up menu indicates the current choice. Pop-up menus are useful when you want to provide users with a number of mutually exclusive choices, but do not want to take up the amount of space that a series of radio buttons requires.

- `'pushbutton'` – Push buttons generate an action when pressed. To activate a push button, click the mouse button on the push button.
- `'radiobutton'` – Radio buttons are similar to check boxes, but are intended to be mutually exclusive within a group of related radio buttons (i.e., only one is in a pressed state at any given time). To activate a radio button, click the mouse button on the object. The state of the device is indicated on the display. Note that your code can implement mutually exclusive behavior for radio buttons.
- `'slider'` – Sliders accept numeric input within a specific range by enabling the user to move a sliding bar. Users move the bar by pressing the mouse button and dragging the pointer over the bar, or by clicking in the trough or on an arrow. The location of the bar indicates a numeric value, which is selected by releasing the mouse button. You can set the minimum, maximum, and current values of the slider.
- `'text'` – Static text boxes display lines of text. Static text is typically used to label other controls, provide directions to the user, or indicate values associated with a slider. Users cannot change static text interactively and there is no way to invoke the callback routine associated with it.
- `'togglebutton'` – Toggle buttons are controls that execute callbacks when clicked on and indicate their state, either on or off. Toggle buttons are useful for building toolbars.

Remarks

- Adding a uicontrol to a figure removes the figure toolbar when the figure's `Toolbar` property is set to `'auto'` (which is the default). To prevent this from happening, set the `Toolbar` property to `'figure'`. The user can restore the toolbar by selecting **Figure Toolbar** from the **View** menu regardless of this property setting.
- The `uicontrol` function accepts property name/property value pairs, structures, and cell arrays as input arguments and optionally returns the handle of the created object. You can also set and query property values after creating the object using the `set` and `get` functions.

- A `uicontrol` object is a child of a figure, uipanel, or uibuttongroup and therefore does not require an axes to exist when placed in a figure window, uipanel, or uibuttongroup.
- When MATLAB is paused and a uicontrol has focus, pressing a keyboard key does not cause MATLAB to resume. Click anywhere outside a uicontrol and then press any key. See the `pause` function for more information.

Examples

Example 1

The following statement creates a push button that clears the current axes when pressed.

```
h = uicontrol('Style', 'pushbutton', 'String', 'Clear',...
    'Position', [20 150 100 70], 'Callback', 'cla');
```

This statement gives focus to the pushbutton.

```
uicontrol(h)
```

Example 2

You can create a uicontrol object that changes figure colormaps by specifying a pop-up menu and supplying an M-file name as the object's `Callback`:

```
hpop = uicontrol('Style', 'popup',...
       'String', 'hsv|hot|cool|gray',...
       'Position', [20 320 100 50],...
       'Callback', 'setmap');
```

The above call to `uicontrol` defines four individual choices in the menu: `hsv`, `hot`, `cool`, and `gray`. You specify these choices with the `String` property, separating the choices with the "`|`" character.

The `Callback`, in this case `setmap`, is the name of an M-file that defines a more complicated set of instructions than a single MATLAB command. `setmap` contains these statements:

```
val = get(hpop,'Value');
```

```
if val == 1
    colormap(hsv)
elseif val == 2
    colormap(hot)
elseif val == 3
    colormap(cool)
elseif val == 4
    colormap(gray)
end
```

The `Value` property contains a number that indicates the selected choice. The choices are numbered sequentially from one to four. The `setmap` M-file can get and then test the contents of the `Value` property to determine what action to take.

See Also

`textwrap`, `uibuttongroup`, `uimenu`, `uipanel`

Uicontrol Properties

Purpose

Describe user interface control (`uicontrol`) properties

Modifying Properties

You can set and query graphics object properties in two ways:

- The Property Inspector is an interactive tool that enables you to see and change object property values. The Property inspector is available from GUIDE, or use the `inspect` function at the command line.
- The `set` and `get` commands enable you to set and query the values of properties

To change the default value of properties see "Setting Default Property Values". You can also set default uicontrol properties on the root and figure levels:

```
set(0,'DefaultUicontrolProperty',PropertyValue...)
set(gcf,'DefaultUicontrolProperty',PropertyValue...)
```

where *`Property`* is the name of the uicontrol property whose default value you want to set and `PropertyValue` is the value you are specifying as the default. Use `set` and `get` to access uicontrol properties.

For information on using these uicontrols within GUIDE, the MATLAB GUI development environment, see Programming GUI Components in the MATLAB Creating GUIs documentation.

Uicontrol Properties

This section lists all properties useful to `uicontrol` objects along with valid values and descriptions of their use. Curly braces `{}` enclose default values.

Property	Purpose
`BackgroundColor`	Object background color
`BusyAction`	Callback routine interruption
`ButtonDownFcn`	Button-press callback routine
`Callback`	Control action

Property	Purpose
CData	Truecolor image displayed on the control
Children	Uicontrol objects have no children
CreateFcn	Callback routine executed during object creation
DeleteFcn	Callback routine executed during object deletion
Enable	Enable or disable the uicontrol
Extent	position rectangle (read only)
FontAngle	Character slant
FontName	Font family
FontSize	Font size
FontUnits	Font size units
FontWeight	Weight of text characters
ForegroundColor	Color of text
HandleVisibility	Whether handle is accessible from command line and GUIs
HitTest	Whether selectable by mouse click
HorizontalAlignment	Alignment of label string
Interruptible	Callback routine interruption mode
KeyPressFcn	Key press callback routine
ListboxTop	Index of top-most string displayed in list box
Max	Maximum value (depends on uicontrol object)
Min	Minimum value (depends on uicontrol object)
Parent	Uicontrol object's parent

Property	Purpose
Position	Size and location of uicontrol object
Selected	Whether object is selected
SelectionHighlight	Object highlighted when selected
SliderStep	Slider step size
String	Uicontrol object label, also list box and pop-up menu items
Style	Type of uicontrol object
Tag	User-specified object identifier
TooltipString	Content of object's tooltip
Type	Class of graphics object
UIContextMenu	Uicontextmenu object associated with the uicontrol
Units	Units to interpret `position` vector
UserData	User-specified data
Value	Current value of uicontrol object
Visible	Uicontrol visibility

`BackgroundColor`
`ColorSpec`

Object background color. The color used to fill the uicontrol rectangle. Specify a color using a three-element RGB vector or one of the MATLAB predefined names. The default color is determined by system settings. See `ColorSpec` for more information on specifying color.

Note On Solaris 2 systems, setting the background color of a slider has no effect.

`BusyAction`
`cancel | {queue}`

Callback routine interruption. If a callback is executing and the user triggers an event (such as a mouse click) on an object for which a callback is defined, the callback associated with the new event uses the value of `BusyAction` to decide whether or not to attempt to interrupt the executing callback.

- If the value is `cancel`, the event is discarded and the second callback does not execute.
- If the value is `queue`, and the `Interruptible` property of the first callback is `on`, the second callback is added to the event queue and executes in its turn after the first callback finishes execution.

Note If the interrupting callback is a `DeleteFcn` or `CreateFcn` callback or a figure's `CloseRequest` or `ResizeFcn` callback, it interrupts an executing callback regardless of the value of that object's `Interruptible` property. See the `Interruptible` property for information about controlling a callback's interruptibility.

`ButtonDownFcn`
string or function handle (GUIDE sets this property)

Button-press callback routine. A callback routine that can execute when you press a mouse button while the pointer is on or near a uicontrol. Specifically:

- If the uicontrol's `Enable` property is set to `on`, the `ButtonDownFcn` callback executes when you click the right or left mouse button in a 5-pixel border around the uicontrol or when you click the right mouse button on the control itself.
- If the uicontrol's `Enable` property is set to `inactive` or `off`, the `ButtonDownFcn` executes when you click the right or left mouse button in the 5-pixel border or on the control itself.

This is useful for implementing actions to interactively modify control object properties, such as size and position, when they are clicked on (using selectmoveresize, for example).

Define this routine as a string that is a valid MATLAB expression or the name of an M-file. The expression executes in the MATLAB workspace.

To add a `ButtonDownFcn` callback in GUIDE, select **View Callbacks** from the Layout Editor **View** menu, then select `ButtonDownFcn`. GUIDE sets this property to the appropriate string and adds the callback to the M-file the next time you save the GUI. Alternatively, you can set this property to the string `%automatic`. The next time you save the GUI, GUIDE sets this property to the appropriate string and adds the callback to the M-file.

Use the `Callback` property to specify the callback routine that executes when you activate the enabled uicontrol (e.g., click a push button).

`Callback`

string or function handle (GUIDE sets this property)

Control action. A routine that executes whenever you activate the uicontrol object (e.g., when you click on a push button or move a slider). Define this routine as a string that is a valid MATLAB expression or the name of an M-file. The expression executes in the MATLAB workspace.

For examples of `Callback` callbacks for each style of component:

- For GUIDE GUIs, see "Examples: Programming GUIDE GUI Components".
- For programmatically created GUIs, see "Examples: Programming GUI Components".

Callback routines defined for static text do not execute because no action is associated with these objects.

To execute the callback routine for an edit text control, type in the desired text and then do one of the following:

- Click another component, the menu bar, or the background of the GUI.
- For a single line editable text box, press **Enter**.
- For a multiline editable text box, press **Ctl+Enter**.

`CData`

matrix

Truecolor image displayed on control. A three-dimensional matrix of RGB values that defines a truecolor image displayed on a control, which must be a **push button** or **toggle button**. Each value must be between `0.0` and `1.0`. Setting `CData` on a **radio button** or **checkbox** will replace the default `CData` on these controls. The control will continue to work as expected, but its state is not reflected by its appearance when clicked.

For **push buttons** and **toggle buttons**, `CData` overlaps the `String`. In the case of **radio buttons** and **checkboxes**, `CData` takes precedence over `String` and, depending on its size, it can displace the text.

Setting `CData` to `[]` restores the default `CData` for **radio buttons** and **checkboxes**.

`Children`
matrix

The empty matrix; `uicontrol` objects have no children.

`Clipping`
`{on} | off`

This property has no effect on `uicontrol` objects.

`CreateFcn`
string or function handle

Callback routine executed during object creation. The specified function executes when MATLAB creates a `uicontrol` object. MATLAB sets all property values for the uicontrol before executing the `CreateFcn` callback so these values are available to the callback. Within the function, use `gcbo` to get the handle of the uicontrol being created.

Setting this property on an existing uicontrol object has no effect.

You can define a default `CreateFcn` callback for all new uicontrols. This default applies unless you override it by specifying a different `CreateFcn` callback when you call `uicontrol`. For example, the code

```
set(0,'DefaultUicontrolCreateFcn','set(gcbo,...
    ''BackgroundColor'',''white'')')
```

creates a default `CreateFcn` callback that runs whenever you create a new uicontrol. It sets the default background color of all new uicontrols.

To override this default and create a uicontrol whose `BackgroundColor` is set to a different value, call `uicontrol` with code similar to

```
hpt = uicontrol(...,'CreateFcn','set(gcbo,...
```

```
''BackgroundColor'',''blue'')')
```

Note To override a default `CreateFcn` callback you must provide a new callback and not just provide different values for the specified properties. This is because the `CreateFcn` callback runs after the property values are set, and can override property values you have set explicitly in the `uicontrol` call. In the example above, if instead of redefining the `CreateFcn` property for this uicontrol, you had explicitly set `BackgroundColor` to `blue`, the default `CreateFcn` callback would have set `BackgroundColor` back to the default, i.e., `white`.

Do not call `copyobj` or `textwrap` (which calls `copyobj`) inside a `CreateFcn`. The act of copying the uicontrol object fires the `CreateFcn` repeatedly, which raises a series of error messages after exceeding the root object's `RecursionLimit` property.

See "Function Handle Callbacks" for information on how to use function handles to define a callback function.

`DeleteFcn`

string or function handle

Delete uicontrol callback routine. A callback routine that executes when you delete the uicontrol object (e.g., when you issue a `delete` command or clear the figure containing the uicontrol). MATLAB executes the routine before destroying the object's properties so these values are available to the callback routine.

The handle of the object whose `DeleteFcn` is being executed is accessible only through the root CallbackObject property, which you can query using `gcbo`.

See "Function Handle Callbacks" for information on how to use function handles to define a callback function.

`Enable`

`{on} | inactive | off`

Enable or disable the uicontrol. This property controls how uicontrols respond to mouse button clicks, including which callback routines execute.

- `on` – The uicontrol is operational (the default).
- `inactive` – The uicontrol is not operational, but looks the same as when `Enable` is `on`.
- `off` – The uicontrol is not operational and its image (set by the `Cdata` property) is grayed out.

When you left-click on a uicontrol whose `Enable` property is `on`, MATLAB performs these actions in this order:

1. Sets the figure's `SelectionType` property.
2. Executes the uicontrol's `ClickedCallback` routine.
3. Does not set the figure's `CurrentPoint` property and does not execute either the control's `ButtonDownFcn` or the figure's `WindowButtonDownFcn` callback.

When you left-click on a uicontrol whose `Enable` property is `off`, or when you right-click a uicontrol whose `Enable` property has any value, MATLAB performs these actions in this order:

1. Sets the figure's `SelectionType` property.
2. Sets the figure's `CurrentPoint` property.
3. Executes the figure's `WindowButtonDownFcn` callback.

`Extent`

position rectangle (read only)

Size of uicontrol character string. A four-element vector that defines the size and position of the character string used to label the uicontrol. It has the form:

```
[0,0,width,height]
```

The first two elements are always zero. `width` and `height` are the dimensions of the rectangle. All measurements are in units specified by the `Units` property.

Since the `Extent` property is defined in the same units as the uicontrol itself, you can use this property to determine proper sizing for the uicontrol with regard to its label. Do this by

- Defining the `String` property and selecting the font using the relevant properties.
- Getting the value of the `Extent` property.
- Defining the `width` and `height` of the `Position` property to be somewhat larger than the `width` and `height` of the `Extent`.

For multiline strings, the `Extent` rectangle encompasses all the lines of text. For single line strings, the `height` element of the `Extent` property returned always indicates the height of a single line, and its `width` element always indicates the width of the longest line, even if the string wraps when displayed on the control. Edit boxes are considered multiline if `Max` - `Min` > 1.

`FontAngle`

`{normal} | italic | oblique`

Character slant. MATLAB uses this property to select a font from those available on your particular system. Setting this property to `italic` or `oblique` selects a slanted version of the font, when it is available on your system.

`FontName`

string

Font family. The name of the font in which to display the String. To display and print properly, this must be a font that your system supports. The default font is system dependent.

Note MATLAB GUIs do not support the `Marlett` and `Symbol` font families.

To use a fixed-width font that looks good in any locale (and displays properly in Japan, where multibyte character sets are used), set `FontName` to the string `FixedWidth` (this string value is case sensitive):

```
set(uicontrol_handle, 'FontName', 'FixedWidth')
```

This parameter value eliminates the need to hard code the name of a fixed-width font, which may not display text properly on systems that do not use ASCII character encoding (such as in Japan). A properly written MATLAB application that needs to use a fixed-width font should set `FontName` to `FixedWidth` and rely on the root `FixedWidthFontName` property to be set correctly in the end user's environment.

End users can adapt a MATLAB application to different locales or personal environments by setting the root `FixedWidthFontName` property to the appropriate value for that locale from `startup.m`. Setting the root `FixedWidthFontName` property causes an immediate update of the display to use the new font.

Tip To determine what fonts exist on your system (which can differ from the GUI user's system), use the `uisetfont` GUI to select a font and return its name and other characteristics in a MATLAB structure.

`FontSize`

size in `FontUnits`

Font size. A number specifying the size of the font in which to display the String, in units determined by the `FontUnits` property. The default point size is system dependent.

`FontUnits`
`{points} | normalized | inches |`
`centimeters | pixels`

Font size units. This property determines the units used by the `FontSize` property. `Normalized` units interpret `FontSize` as a fraction of the height of the uicontrol. When you resize the uicontrol, MATLAB modifies the screen `FontSize` accordingly. `pixels`, `inches`, `centimeters`, and `points` are absolute units (1 point = $^{1}/_{72}$ inch).

`FontWeight`
`light | {normal} | demi | bold`

Weight of text characters. MATLAB uses this property to select a font from those available on your particular system. Setting this property to `bold` causes MATLAB to use a bold version of the font, when it is available on your system.

`ForegroundColor`
`ColorSpec`

Color of text. This property determines the color of the text defined for the `String` property (the uicontrol label). Specify a color using a three-element RGB vector or one of the MATLAB predefined names. The default text color is black. See `ColorSpec` for more information on specifying color.

`HandleVisibility`
`{on} | callback | off`

Control access to object's handle. This property determines when an object's handle is visible in its parent's list of children. When a handle is not visible in its parent's list of children, it is not returned by functions that obtain handles by searching the object hierarchy or querying handle properties. This includes `get`, `findobj`, `gca`, `gcf`, `gco`, `newplot`, `cla`, `clf`, and `close`. Neither is the handle visible in the parent figure's `CurrentObject` property. Handles that are hidden are still valid. If you know an object's handle, you can `set` and `get` its properties, and pass it to any function that operates on handles.

- Handles are always visible when `HandleVisibility` is `on`.
- Setting `HandleVisibility` to `callback` causes handles to be visible from within callback routines or functions invoked by callback routines, but not from within functions invoked from the command line. This provides a means to protect GUIs from command-line users, while allowing callback routines to have complete access to object handles.
- Setting `HandleVisibility` to `off` makes handles invisible at all times. This may be necessary when a callback routine invokes a function that might potentially damage the GUI (such as evaluating a user-typed string), and so temporarily hides its own handles during the execution of that function.

You can set the root `ShowHiddenHandles` property to on to make all handles visible, regardless of their `HandleVisibility` settings. This does not affect the values of the `HandleVisibility` properties.

Note Radio buttons and toggle buttons that are managed by a uibuttongroup should not be accessed outside the button group. Set the `HandleVisibility` of such radio buttons and toggle buttons to `off` to prevent inadvertent access.

`HitTest`
`{on} | off`

Selectable by mouse click. This property has no effect on uicontrol objects.

`HorizontalAlignment`

`left | {center} | right`

Horizontal alignment of label string. This property determines the justification of the text defined for the `String` property (the uicontrol label):

- `left` — Text is left justified with respect to the uicontrol.
- `center` — Text is centered with respect to the uicontrol.
- `right` — Text is right justified with respect to the uicontrol.

On Microsoft Windows systems, this property affects only `edit` and `text` uicontrols.

`Interruptible`

`{on} | off`

Callback routine interruption mode. If a callback is executing and the user triggers an event (such as a mouse click) on an object for which a callback is defined, that callback attempts to interrupt the first callback. MATLAB processes the callbacks according to these factors:

- The `Interruptible` property of the object whose callback is executing
- Whether the executing callback contains `drawnow`, `figure`, `getframe`, `pause`, or `waitfor` statements
- The `BusyAction` property of the object whose callback is waiting to execute

If the `Interruptible` property of the object whose callback is executing is `on` (the default), the callback can be interrupted. Whenever the callback calls one of the `drawnow`, `figure`, `getframe`, `pause`, or `waitfor` functions, the function processes any events in the event queue, including the waiting callback, before performing its defined task.

If the Interruptible property of the object whose callback is executing is off, the callback cannot be interrupted (except by certain callbacks; see the note below). The BusyAction property of the object whose callback is waiting to execute determines what happens to the callback.

Note If the interrupting callback is a DeleteFcn or CreateFcn callback or a figure's CloseRequest or ResizeFcn callback, it interrupts an executing callback regardless of the value of that object's Interruptible property. The interrupting callback starts execution at the next drawnow, figure, getframe, pause, or waitfor statement. A figure's WindowButtonDownFcn callback routine, or an object's ButtonDownFcn or Callback routine are processed according to the rules described above.

KeyPressFcn
string or function handle

Key press callback function. A callback routine invoked by a key press when the callback's uicontrol object has focus. Focus is denoted by a border or a dotted border, respectively, in UNIX and Microsoft Windows. If no uicontrol has focus, the figure's key press callback function, if any, is invoked. KeyPressFcn can be a function handle, the name of an M-file, or any legal MATLAB expression.

If the specified value is the name of an M-file, the callback routine can query the figure's CurrentCharacter property to determine what particular key was pressed and thereby limit the callback execution to specific keys.

If the specified value is a function handle, the callback routine can retrieve information about the key that was pressed from its event data structure argument.

Event Data Structure Field	Description	Examples:			
		a	=	Shift	Shift/a
Character	Character interpretation of the key that was pressed.	'a'	'='	''	'A'
Modifier	Current modifier, such as 'control', or an empty cell array if there is no modifier	{1x0 cell}	{1x0 cell}	{'shift'}	{'shift'}
Key	Name of the key that was pressed.	'a'	'equal'	'shift'	'a'

See "Function Handle Callbacks" for information on how to use function handles to define the callback function.

`ListboxTop`
scalar

Index of top-most string displayed in list box. This property applies only to the `listbox` style of uicontrol. It specifies which string appears in the top-most position in a list box that is not large enough to display all list entries. `ListboxTop` is an index into the array of strings defined by the `String` property and must have a value between 1 and the number of strings. Noninteger values are fixed to the next lowest integer.

`Max`
scalar

Maximum value. This property specifies the largest value allowed for the `Value` property. Different styles of uicontrols interpret `Max` differently:

- Check boxes – `Max` is the setting of the `Value` property while the check box is selected.
- Editable text – The `Value` property does not apply. If `Max - Min` > 1, then editable text boxes accept multiline input. If `Max - Min` <= 1, then editable text boxes accept only single line input. The absolute values of `Max` and `Min` have no effect on the number of lines an edit box can contain; a multiline edit box can contain any number of lines.
- List boxes – If `Max - Min` > 1, then list boxes allow multiple item selection. If `Max - Min` <= 1, then list boxes do not allow multiple item selection. When they do, `Value` can be a vector of indices.
- Radio buttons – `Max` is the setting of the `Value` property when the radio button is selected.
- Sliders – `Max` is the maximum slider value and must be greater than the `Min` property. The default is 1.
- Toggle buttons – `Max` is the value of the `Value` property when the toggle button is selected. The default is 1.
- Pop-up menus, push buttons, and static text do not use the `Max` property.

`Min`

scalar

Minimum value. This property specifies the smallest value allowed for the `Value` property. Different styles of uicontrols interpret `Min` differently:

- Check boxes – `Min` is the setting of the `Value` property while the check box is not selected.
- Editable text – The `Value` property does not apply. If `Max - Min` > 1, then editable text boxes accept multiline input. If `Max - Min` <= 1, then editable text boxes accept only single line input. The absolute values of `Max` and `Min` have no effect on the number of

lines an edit box can contain; a multiline edit box can contain any number of lines.

- List boxes – If `Max - Min` > 1, then list boxes allow multiple item selection. If `Max - Min` <= 1, then list boxes allow only single item selection. When they do, `Value` can be a vector of indices.
- Radio buttons – `Min` is the setting of the `Value` property when the radio button is not selected.
- Sliders – `Min` is the minimum slider value and must be less than `Max`. The default is 0.
- Toggle buttons – `Min` is the value of the `Value` property when the toggle button is not selected. The default is 0.
- Pop-up menus, push buttons, and static text do not use the `Min` property.

`Parent`

handle

Uicontrol parent. The handle of the uicontrol's parent object. You can move a uicontrol object to another figure, uipanel, or uibuttongroup by setting this property to the handle of the new parent.

`Position`

position rectangle

Size and location of uicontrol. The rectangle defined by this property specifies the size and location of the control within the parent figure window, uipanel, or uibuttongroup. Specify `Position` as

```
[left bottom width height]
```

`left` and `bottom` are the distance from the lower-left corner of the parent object to the lower-left corner of the uicontrol object. `width` and `height` are the dimensions of the uicontrol rectangle. All measurements are in units specified by the `Units` property.

On Microsoft Windows systems, the height of pop-up menus is automatically determined by the size of the font. The value you specify for the `height` of the `Position` property has no effect.

The `width` and `height` values determine the orientation of sliders. If `width` is greater than `height`, then the slider is oriented horizontally, If `height` is greater than `width`, then the slider is oriented vertically.

Note The height of a pop-up menu is determined by the font size. The height you set in the position vector is ignored. The height element of the position vector is not changed.

On Mac platforms, the height of a horizontal slider is constrained. If the height you set in the position vector exceeds this constraint, the displayed height of the slider is the maximum allowed. The height element of the position vector is not changed.

`Selected`

`on | {off}` (read only)

Is object selected. When this property is `on`, MATLAB displays selection handles if the `SelectionHighlight` property is also `on`. You can, for example, define the `ButtonDownFcn` to set this property, allowing users to select the object with the mouse.

`SelectionHighlight`

`{on} | off`

Object highlight when selected. When the `Selected` property is on, MATLAB indicates the selected state by drawing four edge handles and four corner handles. When `SelectionHighlight` is `off`, MATLAB does not draw the handles.

`SliderStep`

`[min_step max_step]`

Slider step size. This property controls the amount the slider Value changes when you click the mouse on the arrow button (min_step) or on the slider trough (max_step). Specify SliderStep as a two-element vector; each value must be in the range [0,1], and min_step should be less than max_step. Numbers outside [0 1] can cause the slider not to render or produce unexpected results. The actual step size is a function of the specified SliderStep and the total slider range (Max - Min). The default, [0.01 0.10], provides a 1 percent change for clicks on the arrow button and a 10 percent change for clicks in the trough. and both should be positive numbers less then 1.

For example, if you create the following slider,

```
uicontrol('Style','slider','Min',1,'Max',7,...
          'Value',2,'SliderStep',[0.1 0.6])
```

clicking on the arrow button moves the indicator by,

```
0.1*(7-1)
ans =
     0.6000
```

and clicking in the trough moves the indicator by,

```
0.6*(7-1)
ans =
     3.6000
```

Note that if the specified step size moves the slider to a value outside the range, the indicator moves only to the Max or Min value.

See also the Max, Min, and Value properties.

String
string

Uicontrol label, *list box items*, *pop-up menu choices.*

For check boxes, editable text, push buttons, radio buttons, static text, and toggle buttons, the text displayed on the object. For list boxes and pop-up menus, the set of entries or items displayed in the object.

Note If you specify a numerical value for `String`, MATLAB converts it to `char` but the result may not be what you expect. If you have numerical data, you should first convert it to a string, e.g., using `num2str`, before assigning it to the `String` property.

For uicontrol objects that display only one line of text (check box, push button, radio button, toggle button), if the string value is specified as a cell array of strings or padded string matrix, only the first string of a cell array or of a padded string matrix is displayed; the rest are ignored. Vertical slash ('`|`') characters are not interpreted as line breaks and instead show up in the text displayed in the uicontrol.

For multiple line editable text or static text controls, line breaks occur between each row of the string matrix, and each cell of a cell array of strings. Vertical slash ('`|`') characters and `\n` characters are not interpreted as line breaks, and instead show up in the text displayed in the uicontrol.

For multiple items on a list box or pop-up menu, you can specify the items in any of the formats shown in the following table.

String Property Format	Example
Cell array of strings	`{'one' 'two' 'three'}`

String Property Format	Example
Padded string matrix	`['one ';'two ';'three']`
String vector separated by vertical slash (|) characters	`['one|two|three']`

If you specify a component width that is too small to accommodate one or more of the specified strings, MATLAB truncates those strings with an ellipsis. Use the `Value` property to set the index of the initial item selected.

For **check boxes**, **push buttons**, **radio buttons**, **toggle buttons**, and the selected item in **popup menus**, when the specified text is clipped because it is too long for the uicontrol, an ellipsis (...) is appended to the text in the active GUI to indicate that it has been clipped.

For **push buttons** and **toggle buttons**, `CData` overlaps the `String`. In the case of **radio buttons** and **checkboxes**, `CData` takes precedence over `String` and, depending on its size, can displace the text.

For **editable text**, the `String` property value is set to the string entered by the user.

Reserved Words There are three reserved words: `default`, `remove`, `factory` (case sensitive). If you want to use one of these reserved words in the `String` property, you must precede it with a backslash ('\') character. For example,

```
h = uicontrol('Style','edit','String','\default');
```

`Style`
`{pushbutton} | togglebutton | radiobutton | checkbox | edit | text | slider | frame | listbox | popupmenu`

Style of uicontrol object to create. The `Style` property specifies the kind of uicontrol to create. See the `uicontrol` Description section for information on each type.

`Tag`
string (GUIDE sets this property)

User-specified object label. The `Tag` property provides a means to identify graphics objects with a user-specified label. This is particularly useful when constructing interactive graphics programs that would otherwise need to define object handles as global variables or pass them as arguments between callback routines. You can define `Tag` as any string.

`TooltipString`
string

Content of tooltip for object. The `TooltipString` property specifies the text of the tooltip associated with the uicontrol. When the user moves the mouse pointer over the control and leaves it there, the tooltip is displayed.

`Type`
string (read only)

Class of graphics object. For uicontrol objects, `Type` is always the string `'uicontrol'`.

`UIContextMenu`
handle

Associate a context menu with uicontrol. Assign this property the handle of a `uicontextmenu` object. MATLAB displays the context menu whenever you right-click over the uicontrol. Use the `uicontextmenu` function to create the context menu.

`Units`
`{pixels} | normalized | inches | centimeters | points | characters` (GUIDE default: `normalized`)

Units of measurement. MATLAB uses these units to interpret the `Extent` and `Position` properties. All units are measured from the lower-left corner of the parent object.

- `Normalized` units map the lower-left corner of the parent object to (0,0) and the upper-right corner to (1.0,1.0).
- `pixels`, `inches`, `centimeters`, and `points` are absolute units (1 point = 1/72 inch).
- `Character` units are characters using the default system font; the width of one character is the width of the letter x, the height of one character is the distance between the baselines of two lines of text.

If you change the value of `Units`, it is good practice to return it to its default value after completing your computation so as not to affect other functions that assume `Units` is set to the default value.

`UserData`
matrix

User-specified data. Any data you want to associate with the uicontrol object. MATLAB does not use this data, but you can access it using `set` and `get`.

`Value`
scalar or vector

Current value of uicontrol. The uicontrol style determines the possible values this property can have:

- Check boxes set `Value` to `Max` when they are on (when selected) and `Min` when off (not selected).
- List boxes set `Value` to a vector of indices corresponding to the selected list entries, where 1 corresponds to the first item in the list.
- Pop-up menus set `Value` to the index of the item selected, where 1 corresponds to the first item in the menu. The Examples section shows how to use the `Value` property to determine which item has been selected.
- Radio buttons set `Value` to `Max` when they are on (when selected) and `Min` when off (not selected).
- Sliders set `Value` to the number indicated by the slider bar.
- Toggle buttons set `Value` to `Max` when they are down (selected) and `Min` when up (not selected).
- Editable text, push buttons, and static text do not set this property.

Set the `Value` property either interactively with the mouse or through a call to the `set` function. The display reflects changes made to `Value`.

`Visible`
`{on} | off`

Uicontrol visibility. By default, all uicontrols are visible. When set to `off`, the uicontrol is not visible, but still exists and you can query and set its properties.

Note Setting `Visible` to `off` for uicontrols that are not displayed initially in the GUI, can result in faster startup time for the GUI.

---

uigetdir

Purpose

Open standard dialog box for selecting a directory

Syntax

```
uigetdir
directory_name = uigetdir
directory_name = uigetdir(start_path)
directory_name = uigetdir(start_path,dialog_title)
```

Description

`uigetdir` displays a modal dialog box enabling the user to browse through the directory structure and select a directory or type the name of a directory. If the directory exists, `uigetdir` returns the selected path when the user clicks **OK**. For Microsoft Windows platforms, `uigetdir` opens a dialog box in the base directory (the Windows desktop) with the current directory selected. See "Remarks" on page 2-3751 for information about UNIX and Mac platforms.

Note A modal dialog box prevents the user from interacting with other windows before responding. To block MATLAB program execution as well, use the `uiwait` function. For more information about modal dialog boxes, see `WindowStyle` in the MATLAB Figure Properties.

`directory_name = uigetdir` returns the path to the selected directory when the user clicks **OK**. If the user clicks **Cancel** or closes the dialog window, `directory_name` is set to`0`.

`directory_name = uigetdir(start_path)` opens a dialog box with the directory specified by `start_path` selected. If `start_path` is a valid directory path, the dialog box opens in the specified directory.

If `start_path` is an empty string (`''`), the dialog box opens in the current directory. If `start_path` is not a valid directory path, the dialog box opens in the base directory. For Windows, this is the Windows desktop. See "Remarks" on page 2-3751 for information about UNIX and Mac platforms.

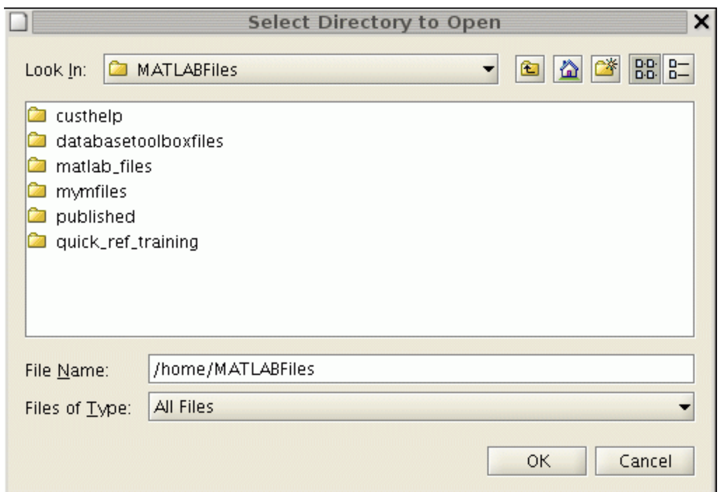
`directory_name = uigetdir(start_path,dialog_title)` opens a dialog box with the specified title. On Windows platforms, the string replaces the default caption inside the dialog box for specifying instructions to the user. The default `dialog_title` is `Select Directory to Open`. See "Remarks" on page 2-3751 for information about UNIX and Mac platforms.

Note On Windows platforms, users can click the **New Folder** button to add a new directory to the directory structure displayed. Users can also drag and drop existing directories.

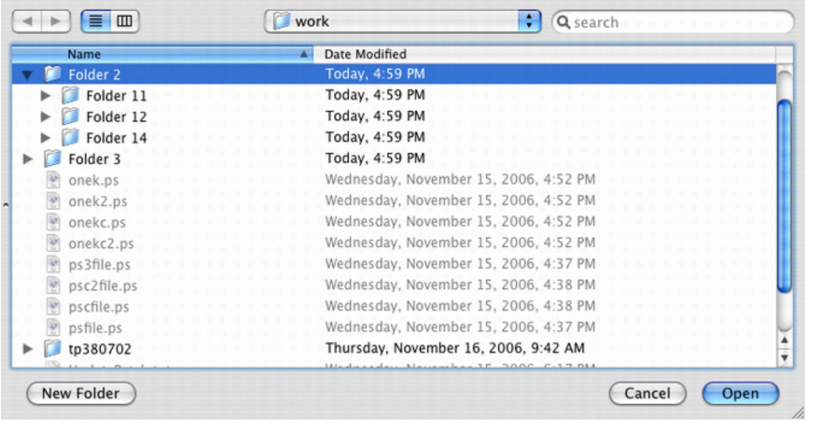
Remarks

For Windows platforms, the dialog box is similar to those shown in the "Examples" on page 2-3752 below.

For UNIX platforms, `uigetdir` opens a dialog box in the base directory (the directory from which MATLAB is started) with the current directory selected. The `dialog_title` string replaces the default title of the dialog box. The dialog box is similar to the one shown in the following figure.



For Mac platforms,`uigetdir` opens a dialog box in the base directory (the current directory) with the current directory open. The `dialog_title` string, if any, is ignored. The dialog box is similar to the one shown in the following figure.



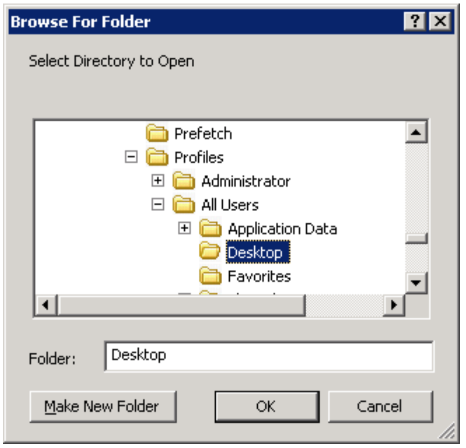
Examples

Example 1

The following statement displays directories on the `C:` drive.

```
dname = uigetdir('C:\');
```

The dialog box is shown in the following figure.



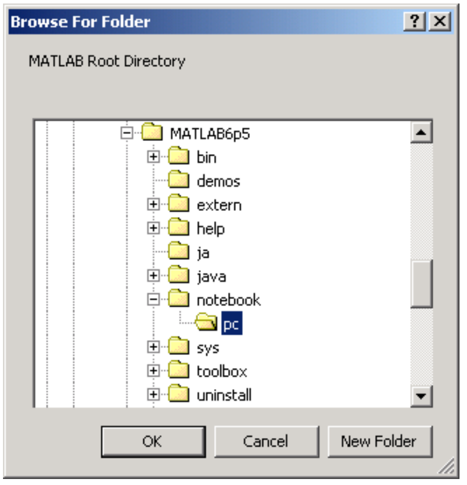
If the user selects the directory `Desktop`, as shown in the figure, and clicks **OK**, `uigetdir` returns

```
dname =
C:\WINNT\Profiles\All Users\Desktop
```

Example 2

The following statement uses the `matlabroot` command to display the MATLAB root directory in the dialog box:

```
uigetdir(matlabroot,'MATLAB Root Directory')
```



If the user selects the directory `MATLAB6.5/notebook/pc`, as shown in the figure, `uigetdir` returns a string like

```
C:\MATLAB6.5\notebook\pc
```

assuming that MATLAB is installed on drive `C:\`.

See Also

`uigetfile`, `uiputfile`

Purpose

Open standard dialog box for retrieving files

Syntax

```
uigetfile
[FileName,PathName,FilterIndex] = uigetfile(FilterSpec)
[FileName,PathName,FilterIndex] = uigetfile(FilterSpec,
   DialogTitle)
[FileName,PathName,FilterIndex] = uigetfile(FilterSpec,
   DialogTitle,DefaultName)
[FileName,PathName,FilterIndex] = uigetfile(...,'MultiSelect',
   selectmode)
```

Description

`uigetfile` displays a modal dialog box that lists files in the current directory and enables the user to select or type the name of a file to be opened. If the filename is valid and if the file exists, `uigetfile` returns the filename when the user clicks **Open**. Otherwise `uigetfile` displays an appropriate error message from which control returns to the dialog box. The user can then enter another filename or click **Cancel**. If the user clicks **Cancel** or closes the dialog window, `uigetfile` returns `0`.

Note A modal dialog box prevents the user from interacting with other windows before responding. To block MATLAB program execution, use the `uiwait` function. For more information about modal dialog boxes, see `WindowStyle` in the MATLAB Figure Properties.

`[FileName,PathName,FilterIndex] = uigetfile(FilterSpec)` displays only those files with extensions that match `FilterSpec`. The `uigetfile` function appends `'All Files'` to the list of file types.`FilterSpec` can be a string or a cell array of strings, and can include the `*` wildcard.

- If `FilterSpec` is a string that contains a filename, the filename is displayed and selected in the **File name** field and the file's extension is used as the default filter.

- If `FilterSpec` is a string, it can include a path. That path can contain `'.'`,`'..'`, or `'/'`. For example, `'../*.m'` lists all M-files in the directory above the current directory.
- If `FilterSpec` is a cell array of strings, the first column contains a list of file extensions. The optional second column contains a corresponding list of descriptions. These descriptions replace standard descriptions in the **Files of type** field. A description cannot be an empty string. "Example 2" on page 2-3759 and "Example 3" on page 2-3760 illustrate use of a cell array as `FilterSpec`.

If `FilterSpec` is not specified, `uigetfile` uses the default list of file types (i.e., all MATLAB files).

After the user clicks **Open** and if the filename exists,`uigetfile` returns the name of the file in `FileName` and its path in `PathName`. If the user clicks **Cancel** or closes the dialog window, `FileName` and `PathName` are set to `0`.

`FilterIndex` is the index of the filter selected in the dialog box. Indexing starts at 1. If the user clicks **Cancel** or closes the dialog window, `FilterIndex` is set to `0`.

`[FileName,PathName,FilterIndex] = uigetfile(FilterSpec,DialogTitle)` displays a dialog box that has the title `DialogTitle`. To use the default file types and specify a dialog title, enter

```
uigetfile('',DialogTitle)
```

`[FileName,PathName,FilterIndex] = uigetfile(FilterSpec,DialogTitle,DefaultName)` displays a dialog box in which the filename specified by `DefaultName` appears in the **File name** field. `DefaultName` can also be a path or a path/filename. In this case, `uigetfile` opens the dialog box in the directory specified by the path. See "Example 6" on page 2-3763 . Note that you can use `'.'`,`'..'`, or `'/'` in the `DefaultName` argument.

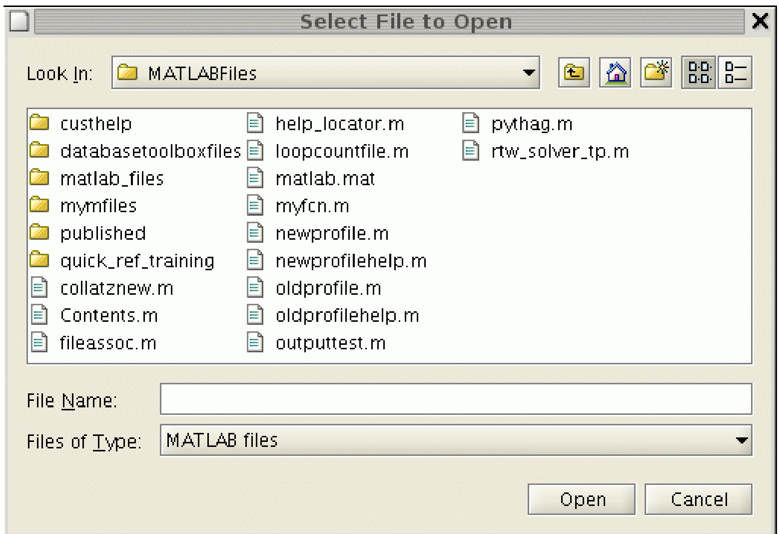
If the specified path does not exist, `uigetfile` opens the dialog box in the current directory.

`[FileName,PathName,FilterIndex] = uigetfile(...,'MultiSelect',`*`selectmode`*`)` sets the multiselect mode to specify if multiple file selection is enabled for the `uigetfile` dialog. Valid values for *`selectmode`* are `'on'` and `'off'` (default). If `'MultiSelect'` is `'on'` and the user selects more than one file in the dialog box, then `FileName` is a cell array of strings, each of which represents the name of a selected file. Filenames in the cell array are in the sort order native to your platform. Because multiple selections are always in the same directory, `PathName` is always a string that represents a single directory.

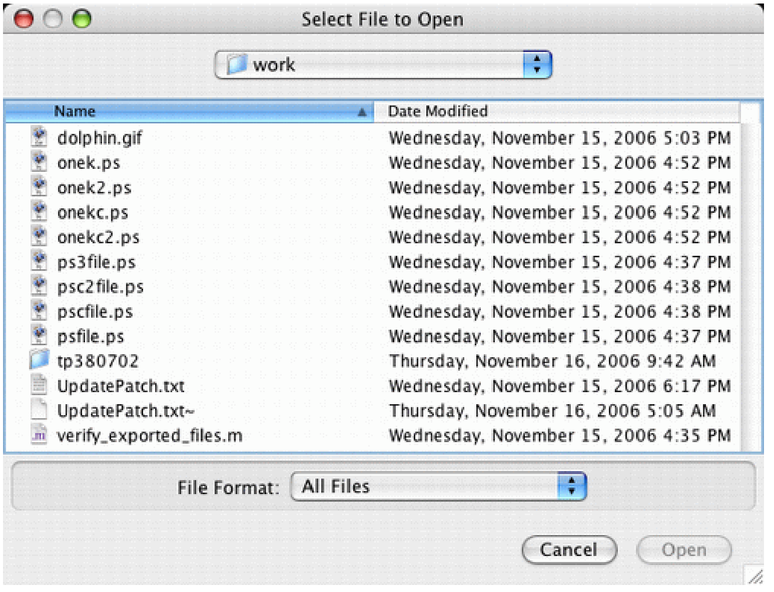
Remarks

For Microsoft Windows platforms, the dialog box is the Windows dialog box native to your platform. Because of this, it may differ from those shown in “Examples” on page 2-3758 below.

For UNIX platforms, the dialog box is similar to the one shown in the following figure.



For Mac platforms, the dialog box is similar to the one shown in the following figure.



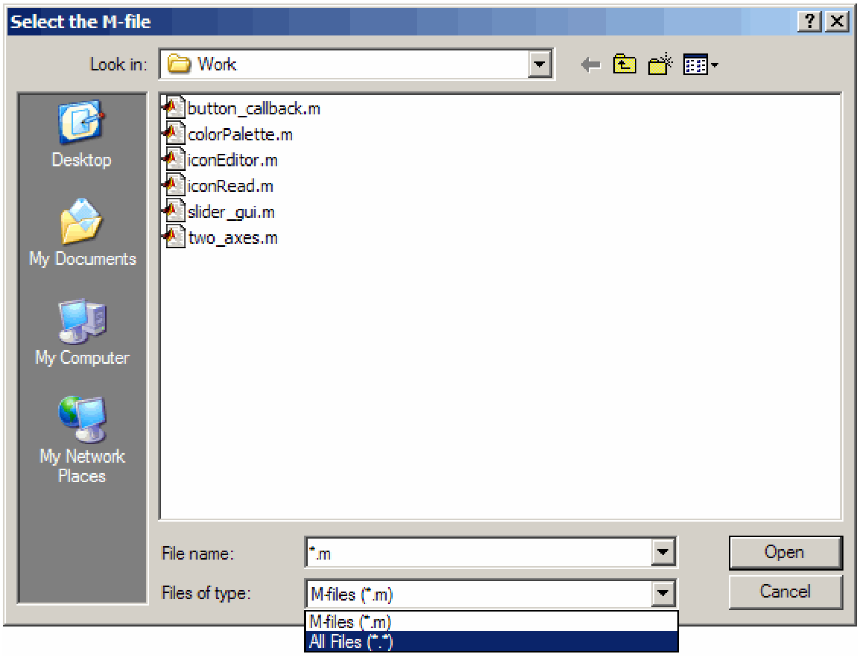
Examples

Example 1

The following statement displays a dialog box that enables the user to retrieve a file. The statement lists all MATLAB M-files within a selected directory. The name and path of the selected file are returned in `FileName` and `PathName`. Note that `uigetfile` appends `All Files(*.*)` to the file types when `FilterSpec` is a string.

```
[FileName,PathName] = uigetfile('*.m','Select the M-file');
```

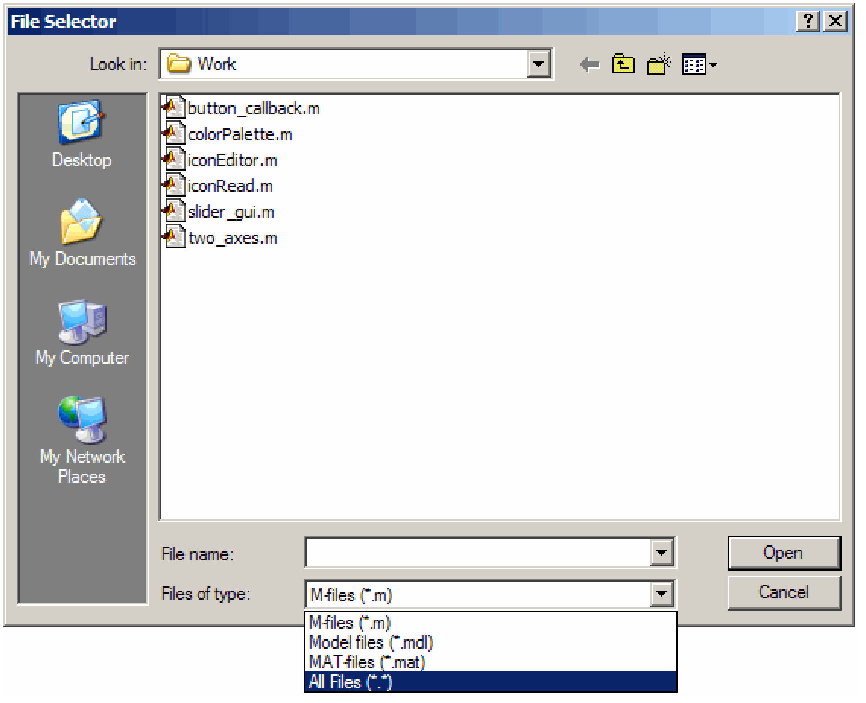
The dialog box is shown in the following figure.



Example 2

To create a list of file types that appears in the **Files of type** list box, separate the file extensions with semicolons, as in the following code. Note that `uigetfile` displays a default description for each known file type, such as "Simulink Models" for `.mdl` files.

```
[filename, pathname] = ...
     uigetfile({'*.m';'*.mdl';'*.mat';'*.*'},'File Selector');
```

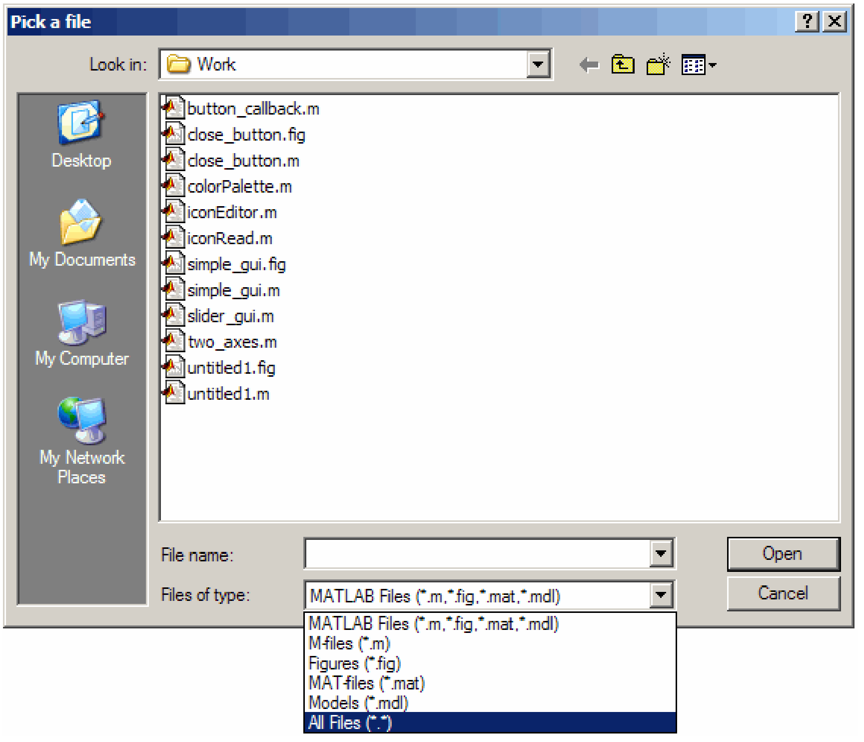


Example 3

If you want to create a list of file types and give them descriptions that are different from the defaults, use a cell array, as in the following code. This example also associates multiple file types with the `'MATLAB Files'` description.

```
[filename, pathname] = uigetfile( ...
{'*.m;*.fig;*.mat;*.mdl','MATLAB Files (*.m,*.fig,*.mat,*.mdl)';
   '*.m',  'M-files (*.m)'; ...
   '*.fig','Figures (*.fig)'; ...
   '*.mat','MAT-files (*.mat)'; ...
   '*.mdl','Models (*.mdl)'; ...
   '*.*',  'All Files (*.*)'}, ...
   'Pick a file');
```

The first column of the cell array contains the file extensions, while the second contains the descriptions you want to provide for the file types. Note that the first entry of column one contains several extensions, separated by semicolons, all of which are associated with the description `'MATLAB Files (*.m,*.fig,*.mat,*.mdl)'`. The code produces the dialog box shown in the following figure.

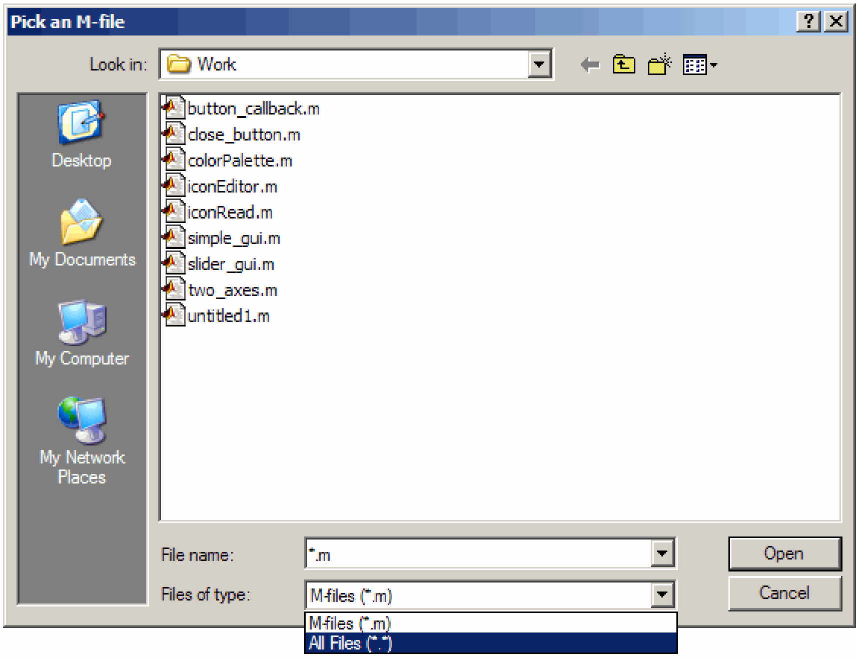


Example 4

The following code checks for the existence of the file and displays a message about the result of the open operation.

```
[filename, pathname] = uigetfile('*.m', 'Pick an M-file');
```

```
if isequal(filename,0)
   disp('User selected Cancel')
else
   disp(['User selected', fullfile(pathname, filename)])
end
```

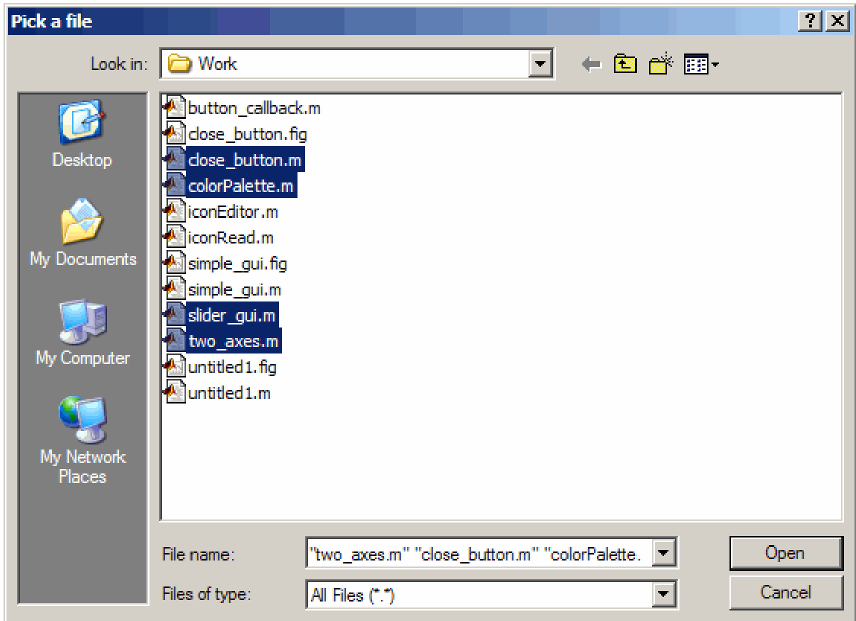


Example 5

This example creates a list of file types and gives them descriptions that are different from the defaults, then enables multiple file selection. The user can select multiple files by holding down the **Shift** or **Ctrl** key and clicking on a file.

```
[filename, pathname, filterindex] = uigetfile( ...
{  '*.mat','MAT-files (*.mat)'; ...
   '*.mdl','Models (*.mdl)'; ...
   '*.*',  'All Files (*.*)'}, ...
```

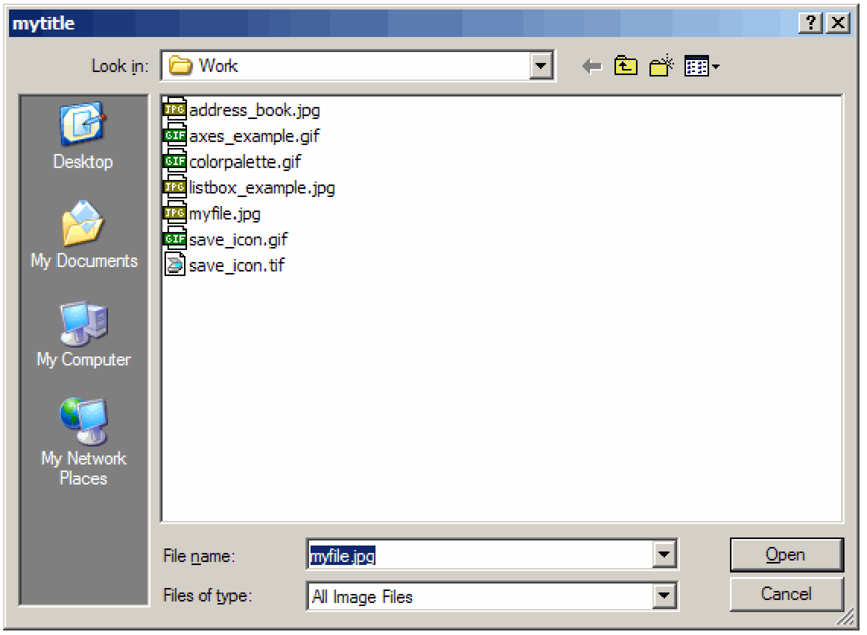
```
'Pick a file', ...
'MultiSelect', 'on');
```



Example 6

This example uses the `DefaultName` argument to specify a start path and a default filename for the dialog box.

```
uigetfile({'*.jpg;*.tif;*.png;*.gif','All Image Files';...
          '*.*','All Files' },'mytitle',...
          'C:\Work\myfile.jpg')
```



See Also

`uigetdir`, `uiputfile`

Purpose

Open dialog box for retrieving preferences

Syntax

```
value = uigetpref(group,pref,title,question,pref_choices)
[val,dlgshown] = uigetpref(...)
```

Description

`value = uigetpref(group,pref,title,question,pref_choices)` returns one of the strings in `pref_choices`, by doing one of the following:

- Prompting the user with a multiple-choice question dialog box
- Returning a previous answer stored in the preferences database

By default, the dialog box is shown, with each choice on a different pushbutton, and with a checkbox controlling whether the returned value should be stored in preferences and automatically reused in subsequent invocations.

If the user checks the checkbox before choosing one of the push buttons, the push button choice is stored in preferences and returned in `value`. Subsequent calls to `uigetpref` detect that the last choice was stored in preferences, and return that choice immediately without displaying the dialog.

If the user does not check the checkbox before choosing a pushbutton, the selected preference is not stored in preferences. Rather, a special value, `'ask'`, is stored, indicating that subsequent calls to `uigetpref` should display the dialog box.

Note `uigetpref` uses the same preference database as `addpref`, `getpref`, `ispref`, `rmpref`, and `setpref`. However, it registers the preferences it sets in a separate list so that it, and `uisetpref`, can distinguish those preferences that are being managed with `uigetpref`.

For preferences registered with `uigetpref`, you can use `setpref` and `uisetpref` to explicitly change preference values to `'ask'`.

---

group and pref define the preference. If the preference does not already exist, uigetpref creates it.

title defines the string displayed in the dialog box titlebar.

question is a descriptive paragraph displayed in the dialog, specified as a string array or cell array of strings. This should contain the question the user is being asked, and should be detailed enough to give the user a clear understanding of their choice and its impact. uigetpref inserts line breaks between rows of the string array, between elements of the cell array of strings, or between '|' or newline characters in the string vector.

pref_choices is either a string, cell array of strings, or '|'-separated strings specifying the strings to be displayed on the push buttons. Each string element is displayed in a separate push button. The string on the selected pushbutton is returned.

Make pref_choices a 2-by-n cell array of strings if the internal preference values are different from the strings displayed on the pushbuttons. The first row contains the preference strings, and the second row contains the related pushbutton strings. Note that the preference values are returned in value, not the button labels.

[val,dlgshown] = uigetpref(...) returns whether or not the dialog was shown.

Additional arguments can be passed in as parameter-value pairs:

(...'CheckboxState',state) sets the initial state of the checkbox, either checked or unchecked. state can be either 0 (unchecked) or 1 (checked). By default it is 0.

(...'CheckboxString',cbstr) sets the string cbstr on the checkbox. By default it is 'Never show this dialog again'.

(...'HelpString',hstr) sets the string hstr on the help button. By default the string is empty and there is no help button.

(...'HelpFcn',hfcn) sets the callback that is executed when the help button is pressed. By default it is doc('uigetpref'). Note that if there is no 'HelpString' option, a button is not created.

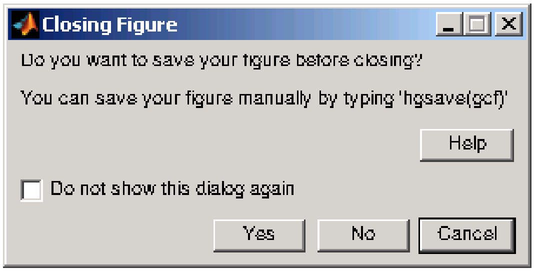
(...'ExtraOptions',eo)creates extra buttons which are not mapped to any preference settings. eo can be a string or a cell array of strings. By default it is {} and no extra buttons are created. If the user chooses one of these buttons, the dialog is closed and the string is returned in value.

(...'DefaultButton',dbstr) sets the string value dbstr that is returned if the dialog is closed. By default, it is the first button. Note that dbstr does not have to correspond to a preference or ExtraOption.

Note If the preference does not already exist in the preference database, uigetpref creates it. Preference values are persistent and maintain their values between MATLAB sessions. Where they are stored is system dependent.

Examples

This example creates the following preference dialog for the 'savefigurebeforeclosing' preference in the 'mygraphics' group.



It uses the cell array {'always','never';'Yes','No'} to define the preference values as 'always' and 'never', and their corresponding button labels as 'Yes' and 'No'.

```
[selectedButton,dlgShown]=uigetpref('mygraphics',... % Group
       'savefigurebeforeclosing',...           % Preference
       'Closing Figure',...                    % Window title
       {'Do you want to save your figure before closing?'
```

```
 ''
 'You can save your figure manually by typing ''hgsave(gcf)'''},...
{'always','never';'Yes','No'},...       % Values and button strings
'ExtraOptions','Cancel',...             % Additional button
'DefaultButton','Cancel',...            % Default choice
'HelpString','Help',...                 % String for Help button
'HelpFcn','doc(''closereq'');')         % Callback for Help button
```

See Also

addpref, getpref, ispref, rmpref, setpref, uisetpref

Purpose

Open Import Wizard to import data

Syntax

```
uiimport
uiimport(filename)
uiimport('-file')
uiimport('-pastespecial')
S = uiimport(...)
```

Description

`uiimport` starts the Import Wizard in the current directory, presenting options to load data from a file or the clipboard.

`uiimport(filename)` starts the Import Wizard, opening the file specified in `filename`. The Import Wizard displays a preview of the data in the file.

`uiimport('-file')` works as above but presents the file selection dialog first.

`uiimport('-pastespecial')` works as above but presents the clipboard contents first.

`S = uiimport(...)` works as above with resulting variables stored as fields in the struct `S`.

Note For ASCII data, you must verify that the Import Wizard correctly identified the column delimiter.

See Also

`load`, `clipboard`

uimenu

Purpose

Create menus on figure windows

Syntax

```
handle = uimenu('PropertyName',PropertyValue,...)
handle = uimenu(parent,'PropertyName',PropertyValue,...)
```

Description

`uimenu` creates a hierarchy of menus and submenus that are displayed in the figure window's menu bar. You also use `uimenu` to create menu items for context menus.

`handle = uimenu('PropertyName',PropertyValue,...)` creates a menu in the current figure's menu bar using the values of the specified properties and assigns the menu handle to `handle`.

See the Uimenu Properties reference page for more information.

`handle = uimenu(parent,'PropertyName',PropertyValue,...)` creates a submenu of a parent menu or a menu item on a context menu specified by `parent` and assigns the menu handle to `handle`. If `parent` refers to a figure instead of another uimenu object or a uicontextmenu, MATLAB software creates a new menu on the referenced figure's menu bar.

Remarks

MATLAB adds the new menu to the existing menu bar. If the figure does not have a menu bar, MATLAB creates one. Each menu choice can itself be a menu that displays its submenu when selected. `uimenu` accepts property name/property value pairs, as well as structures and cell arrays of properties as input arguments.

The uimenu `Callback` property defines the action taken when you activate the created menu item.

Uimenus only appear in figures whose `Window Style` is `normal`. If a figure containing uimenu children is changed to `modal`, the uimenu children still exist and are contained in the `Children` list of the figure, but are not displayed until the `WindowStyle` is changed to `normal`.

The value of the figure `MenuBar` property affects the content of the figure menu bar. When `MenuBar` is `figure`, a set of built-in menus precedes any user-created uimenus on the menu bar (MATLAB controls the built-in menus and their handles are not available to the user). When `MenuBar` is `none`, uimenus are the only items on the menu bar (that is, the built-in menus do not appear).

You can set and query property values after creating the menu using `set` and `get`.

Examples

This example creates a menu labeled **Workspace** whose choices allow users to create a new figure window, save workspace variables, and exit out of MATLAB. In addition, it defines an accelerator key for the Quit option.

```
f = uimenu('Label','Workspace');
    uimenu(f,'Label','New Figure','Callback','figure');
    uimenu(f,'Label','Save','Callback','save');
    uimenu(f,'Label','Quit','Callback','exit',...
           'Separator','on','Accelerator','Q');
```

See Also

`uicontrol`, `uicontextmenu`, `gcbo`, `set`, `get`, `figure`

Uimenu Properties

Purpose

Describe menu properties

Modifying Properties

You can set and query graphics object properties in two ways:

- The Property Inspector is an interactive tool that enables you to see and change object property values. The Property inspector is available from GUIDE, or use the `inspect` function at the command line.
- The `set` and `get` commands enable you to set and query the values of properties

You can set default Uimenu properties on the root, figure and menu levels:

```
set(0,'DefaultUimenuPropertyName',PropertyValue...)
set(gcf,'DefaultUimenuPropertyName',PropertyValue...)
set(menu_handle,'DefaultUimenuPropertyName',PropertyValue...)
```

Where *`PropertyName`* is the name of the Uimenu property and `PropertyValue` is the value you specify as the default for that property.

For more information about changing the default value of property see "Setting Default Property Values"

Uimenu Properties

This section lists all properties useful to `uimenu` objects along with valid values and instructions for their use. Curly braces { } enclose default values.

Property Name	Property Description
`Accelerator`	Keyboard equivalent
`BusyAction`	Callback routine interruption
`Callback`	Control action
`Checked`	Menu check indicator
`Children`	Handles of submenus

Property Name	Property Description
`CreateFcn`	Callback routine executed during object creation
`DeleteFcn`	Callback routine executed during object deletion
`Enable`	Enable or disable the uimenu
`ForegroundColor`	Color of text
`HandleVisibility`	Whether handle is accessible from command line and GUIs
`Interruptible`	Callback routine interruption mode
`Label`	Menu label
`Parent`	Uimenu object's parent
`Position`	Relative uimenu position
`Separator`	Separator line mode
`Tag`	User-specified object identifier
`Type`	Class of graphics object
`UserData`	User-specified data
`Visible`	Uimenu visibility

`Accelerator`

character

Keyboard equivalent. An alphabetic character specifying the keyboard equivalent for the menu item. This allows users to select a particular menu choice by pressing the specified character in conjunction with another key, instead of selecting the menu item with the mouse. The key sequence is platform specific:

- For Microsoft Windows systems, the sequence is **Ctrl**+`Accelerator`. These keys are reserved for default menu items: c, v, and x.
- For UNIX systems, the sequence is **Ctrl**+`Accelerator`. These keys are reserved for default menu items: o, p, s, and w.

You can define an accelerator only for menu items that do not have children menus. Accelerators work only for menu items that directly execute a callback routine, not items that bring up other menus.

Note that the menu item does not have to be displayed (e.g., a submenu) for the accelerator key to work. However, the window focus must be in the figure when the key sequence is entered.

To remove an accelerator, set `Accelerator` to an empty string, `''`.

`BusyAction`
`cancel | {queue}`

Callback routine interruption. If a callback is executing and the user triggers an event (such as a mouse click) on an object for which a callback is defined, the callback associated with the new event uses the value of `BusyAction` to decide whether or not to attempt to interrupt the executing callback.

- If the value is `cancel`, the event is discarded and the second callback does not execute.
- If the value is `queue`, and the `Interruptible` property of the first callback is `on`, the second callback is added to the event queue and executes in its turn after the first callback finishes execution.

Note If the interrupting callback is a `DeleteFcn` or `CreateFcn` callback or a figure's `CloseRequest` or `ResizeFcn` callback, it interrupts an executing callback regardless of the value of that object's `Interruptible` property. See the`Interruptible` property for information about controlling a callback's interruptibility.

`Callback`
string or function handle

Menu action. A callback routine that executes whenever you select the menu. Define this routine as a string that is a valid MATLAB expression or the name of an M-file. The expression executes in the MATLAB workspace.

A menu with children (submenus) executes its callback routine before displaying the submenus. A menu without children executes its callback routine when you *release* the mouse button (i.e., on the button up event).

`Checked`
`on | {off}`

Menu check indicator. Setting this property to `on` places a check mark next to the corresponding menu item. Setting it to `off` removes the check mark. You can use this feature to create menus that indicate the state of a particular option. For example, suppose you have a menu item called **Show axes** that toggles the visibility of an axes between visible and invisible each time the user selects the menu item. If you want a check to appear next to the menu item when the axes are visible, add the following code to the callback for the **Show axes** menu item:

```
if strcmp(get(gcbo, 'Checked'),'on')
    set(gcbo, 'Checked', 'off');
else
```

```
    set(gcbo, 'Checked', 'on');
end
```

This changes the value of the `Checked` property of the menu item from `on` to `off` or vice versa each time a user selects the menu item.

Note that there is no formal mechanism for indicating that an unchecked menu item will become checked when selected.

Note This property is ignored for top level and parent menus.

`Children`
vector of handles

Handles of submenus. A vector containing the handles of all children of the uimenu object. The children objects of uimenus are other uimenus, which function as submenus. You can use this property to reorder the menus.

`CreateFcn`
string or function handle

Callback routine executed during object creation. The specified function executes when MATLAB creates a `uimenu` object. MATLAB sets all property values for the uimenu before executing the `CreateFcn` callback so these values are available to the callback. Within the function, use `gcbo` to get the handle of the uimenu being created.

Setting this property on an existing uimenu object has no effect.

You can define a default `CreateFcn` callback for all new uimenus. This default applies unless you override it by specifying a different `CreateFcn` callback when you call `uimenu`. For example, the code

```
set(0,'DefaultUimenuCreateFcn','set(gcbo,...
    ''Visible'',''on'')')
```

creates a default `CreateFcn` callback that runs whenever you create a new menu. It sets the default `Visible` property of a `uimenu` object.

To override this default and create a menu whose `Visible` property is set to a different value, call `uimenu` with code similar to

```
hpt = uimenu(...,'CreateFcn','set(gcbo,...
''Visible'',''off'')')
```

Note To override a default `CreateFcn` callback you must provide a new callback and not just provide different values for the specified properties. This is because the `CreateFcn` callback runs after the property values are set, and can override property values you have set explicitly in the `uimenu` call. In the example above, if instead of redefining the `CreateFcn` property for this uimenu, you had explicitly set `Visible` to `off`, the default `CreateFcn` callback would have set `Visible` back to the default, i.e., `on`.

Do not call `copyobj` or `textwrap` (which calls `copyobj`) inside a `CreateFcn`. The act of copying the uicontrol object fires the `CreateFcn` repeatedly, which raises a series of error messages after exceeding the root object's `RecursionLimit` property.

See "Function Handle Callbacks" for information on how to use function handles to define a callback function.

`DeleteFcn`

string or function handle

Delete uimenu callback routine. A callback routine that executes when you delete the uimenu object (e.g., when you issue a `delete` command or cause the figure containing the uimenu to reset).

MATLAB executes the routine before destroying the object's properties so these values are available to the callback routine.

The handle of the object whose DeleteFcn is being executed is accessible only through the root `CallbackObject` property, which is more simply queried using gcbo.

See "Function Handle Callbacks" for information on how to use function handles to define a callback function.

`Enable`
`{on} | off`

Enable or disable the uimenu. This property controls whether a menu item can be selected. When not enabled (set to `off`), the menu `Label` appears dimmed, indicating the user cannot select it.

`ForegroundColor`
`ColorSpec` X-Windows only

Color of menu label string. This property determines color of the text defined for the `Label` property. Specify a color using a three-element RGB vector or one of the MATLAB predefined names. The default text color is black. See `ColorSpec` for more information on specifying color.

`HandleVisibility`
`{on} | callback | off`

Control access to object's handle. This property determines when an object's handle is visible in its parent's list of children. When a handle is not visible in its parent's list of children, it is not returned by functions that obtain handles by searching the object hierarchy or querying handle properties. This includes `get`, `findobj`, `gca`, `gcf`, `gco`, `newplot`, `cla`, `clf`, and `close`. Neither is the handle visible in the parent figure's `CurrentObject` property. Handles that are hidden are still valid. If you know an object's handle, you can `set` and `get` its properties, and pass it to any function that operates on handles.

- Handles are always visible when `HandleVisibility` is `on`.
- Setting `HandleVisibility` to `callback` causes handles to be visible from within callback routines or functions invoked by callback routines, but not from within functions invoked from the command line. This provides a means to protect GUIs from command-line users, while allowing callback routines to have complete access to object handles.
- Setting `HandleVisibility` to `off` makes handles invisible at all times. This may be necessary when a callback routine invokes a function that might potentially damage the GUI (such as evaluating a user-typed string), and so temporarily hides its own handles during the execution of that function.

You can set the root `ShowHiddenHandles` property to on to make all handles visible, regardless of their `HandleVisibility` settings. This does not affect the values of the `HandleVisibility` properties.

`Interruptible`
`{on} | off`

Callback routine interruption mode. If a callback is executing and the user triggers an event (such as a mouse click) on an object for which a callback is defined, that callback attempts to interrupt the first callback. MATLAB processes the callbacks according to these factors:

- The `Interruptible` property of the object whose callback is executing
- Whether the executing callback contains `drawnow`, `figure`, `getframe`, `pause`, or `waitfor` statements
- The `BusyAction` property of the object whose callback is waiting to execute

If the `Interruptible` property of the object whose callback is executing is `on` (the default), the callback can be interrupted. Whenever the callback calls one of the `drawnow`, `figure`, `getframe`, `pause`, or `waitfor` functions, the function processes any events in the event queue, including the waiting callback, before performing its defined task.

If the `Interruptible` property of the object whose callback is executing is `off`, the callback cannot be interrupted (except by certain callbacks; see the note below). The `BusyAction` property of the object whose callback is waiting to execute determines what happens to the callback.

Note If the interrupting callback is a `DeleteFcn` or `CreateFcn` callback or a figure's `CloseRequest` or `ResizeFcn` callback, it interrupts an executing callback regardless of the value of that object's `Interruptible` property. The interrupting callback starts execution at the next `drawnow`, `figure`, `getframe`, `pause`, or `waitfor` statement. A figure's `WindowButtonDownFcn` callback routine, or an object's `ButtonDownFcn` or `Callback` routine are processed according to the rules described above.

`Label`

string

Menu label. A string specifying the text label on the menu item. You can specify a mnemonic for the label using the `'&'` character. Except as noted below, the character that follows the `'&'` in the string appears underlined and selects the menu item when you type **Alt+** followed by that character while the menu is visible. The `'&'` character is not displayed. To display the `'&'` character in a label, use two `'&'` characters in the string:

'O&pen selection' yields **Open selection**

’Save && Go’ yields **Save & Go**

`'Save&&Go'` yields **Save & Go**

`'Save& Go'` yields **Save& Go** (the space is not a mnemonic)

There are three reserved words: `default`, `remove`, `factory` (case sensitive). If you want to use one of these reserved words in the `Label` property, you must precede it with a backslash (`'\'`) character. For example:

`'\remove'` yields **remove**

`'\default'` yields **default**

`'\factory'` yields **factory**

`Parent`
handle

Uimenu’s parent. The handle of the uimenu’s parent object. The parent of a uimenu object is the figure on whose menu bar it displays, or the uimenu of which it is a submenu. You can move a uimenu object to another figure by setting this property to the handle of the new parent.

`Position`
scalar

Relative menu position. The value of `Position` indicates placement on the menu bar or within a menu. Top-level menus are placed from left to right on the menu bar according to the value of their `Position` property, with 1 representing the left-most position. The individual items within a given menu are placed from top to bottom according to the value of their `Position` property, with 1 representing the top-most position.

`Separator`

`on | {off}`

Separator line mode. Setting this property to `on` draws a dividing line above the menu item.

`Tag`

string

User-specified object label. The `Tag` property provides a means to identify graphics objects with a user-specified label. This is particularly useful when constructing interactive graphics programs that would otherwise need to define object handles as global variables or pass them as arguments between callback routines. You can define `Tag` as any string.

`Type`

string (read only)

Class of graphics object. For uimenu objects, `Type` is always the string `'uimenu'`.

`UserData`

matrix

User-specified data. Any matrix you want to associate with the uimenu object. MATLAB does not use this data, but you can access it using the `set` and `get` commands.

`Visible`

`{on} | off`

Uimenu visibility. By default, all uimenus are visible. When set to `off`, the uimenu is not visible, but still exists and you can query and set its properties.

Purpose

Convert to unsigned integer

Syntax

```
I = uint8(X)
I = uint16(X)
I = uint32(X)
I = uint64(X)
```

Description

`I = uint*(X)` converts the elements of array `X` into unsigned integers. `X` can be any numeric object (such as a `double`). The results of a `uint*` operation are shown in the next table.

Operation	Output Range	Output Type	Bytes per Element	Output Class
`uint8`	0 to 255	Unsigned 8-bit integer	1	`uint8`
`uint16`	0 to 65,535	Unsigned 16-bit integer	2	`uint16`
`uint32`	0 to 4,294,967,295	Unsigned 32-bit integer	4	`uint32`
`uint64`	0 to 18,446,744,073,709,551,615	Unsigned 64-bit integer	8	`uint64`

`double` and `single` values are rounded to the nearest `uint*` value on conversion. A value of `X` that is above or below the range for an integer class is mapped to one of the endpoints of the range. For example,

```
uint16(70000)
ans =
   65535
```

If `X` is already an unsigned integer of the same class, then `uint*` has no effect.

You can define or overload your own methods for `uint*` (as you can for any object) by placing the appropriately named method in an `@uint*` directory within a directory on your path. Type `help datatypes` for the names of the methods you can overload.

Remarks

Most operations that manipulate arrays without changing their elements are defined for integer values. Examples are `reshape`, `size`, the logical and relational operators, subscripted assignment, and subscripted reference.

Some arithmetic operations are defined for integer arrays on interaction with other integer arrays of the same class (e.g., where both operands are `uint16`). Examples of these operations are `+`, `-`, `.*`, `./`, `.\` and `.^`. If at least one operand is scalar, then `*`, `/`, `\`, and `^` are also defined. Integer arrays may also interact with scalar `double` variables, including constants, and the result of the operation is an integer array of the same class. Integer arrays saturate on overflow in arithmetic.

Note Only the lower order integer data types support math operations. Math operations are not supported for `int64` and `uint64`.

A particularly efficient way to initialize a large array is by specifying the data type (i.e., class name) for the array in the `zeros`, `ones`, or `eye` function. For example, to create a 100-by-100 `uint64` array initialized to zero, type

```
I = zeros(100, 100, 'uint64');
```

An easy way to find the range for any MATLAB integer type is to use the `intmin` and `intmax` functions as shown here for `uint32`:

```
intmin('uint32')                intmax('uint32')
ans =                           ans =
   0                               4294967295
```

See Also

`double`, `single`, `int8`, `int16`, `int32`, `int64`, `intmax`, `intmin`

Purpose

Open file selection dialog box with appropriate file filters

Syntax

```
uiopen
uiopen('MATLAB')
uiopen('LOAD')
uiopen('FIGURE')
uiopen('SIMULINK')
uiopen('EDITOR')
```

Description

`uiopen` displays a modal file selection dialog from which a user can select a file to open. The dialog is the same as the one displayed when you select **Open** from the **File** menu in the MATLAB desktop.

Selecting a file in the dialog and clicking **Open** does the following:

- Gets the file using `uigetfile`
- Opens the file in the base workspace using the `open` command

Note A modal dialog box prevents the user from interacting with other windows before responding. For more information, see `WindowStyle` in the MATLAB Figure Properties.

Note `uiopen` cannot be compiled. If you want to create a file selection dialog that can be compiled, use `uigetfile`.

`uiopen` or `uiopen('MATLAB')` displays the dialog with the file filter set to all MATLAB files.

`uiopen('LOAD')` displays the dialog with the file filter set to MAT-files (*.mat).

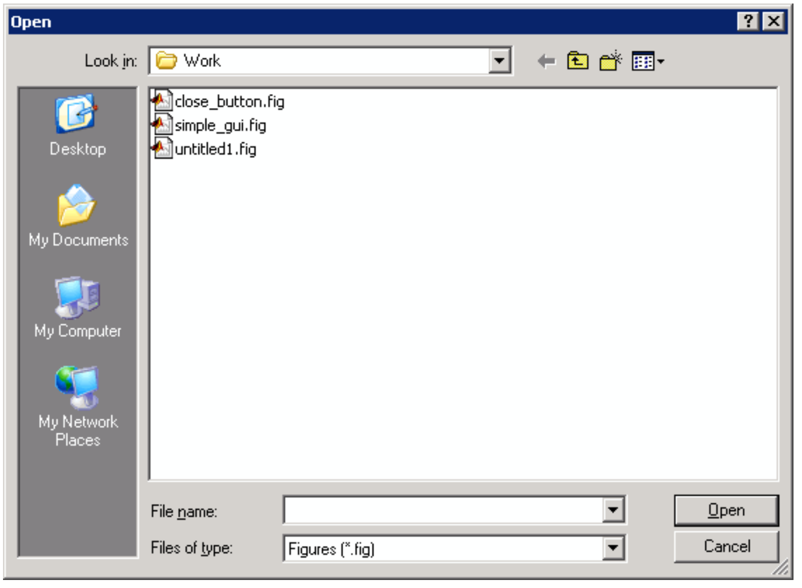
`uiopen('FIGURE')` displays the dialog with the file filter set to figure files (*.fig).

uiopen('SIMULINK') displays the dialog with the file filter set to model files (*.mdl).

uiopen('EDITOR') displays the dialog with the file filter set to all MATLAB files except for MAT-files and FIG-files. All files are opened in the MATLAB Editor.

Examples

Typing uiopen('figure') sets the **Files of type** field to Figures (*.fig):



See Also

uigetfile, uiputfile, uisave

Purpose

Create panel container object

Syntax

```
h = uipanel('PropertyName1',value1,'PropertyName2',value2,
    ...)
h = uipanel(parent,'PropertyName1',value1,'PropertyName2',
    value2,...)
```

Description

A uipanel groups components. It can contain user interface controls with which the user interacts directly. It can also contain axes, other uipanels, and uibuttongroups. It cannot contain ActiveX controls.

`h = uipanel('PropertyName1',value1,'PropertyName2',value2,...)` creates a `uipanel` container object in a figure, uipanel, or uibuttongroup. Use the `Parent` property to specify the parent figure, uipanel, or uibuttongroup. If you do not specify a parent, `uipanel` adds the panel to the current figure. If no figure exists, one is created. See the Uipanel Properties reference page for more information.

`h = uipanel(parent,'PropertyName1',value1,'PropertyName2',value2,...)` creates a uipanel in the object specified by the handle, `parent`. If you also specify a different value for the `Parent` property, the value of the `Parent` property takes precedence. `parent` must be a figure, uipanel, or uibuttongroup.

A `uipanel` object can have `axes`, `uicontrol`, `uipanel`, and `uibuttongroup` objects as children. For the children of a uipanel, the `Position` property is interpreted relative to the uipanel. If you move the panel, the children automatically move with it and maintain their positions relative to the panel.

After creating a `uipanel` object, you can set and query its property values using `set` and `get`.

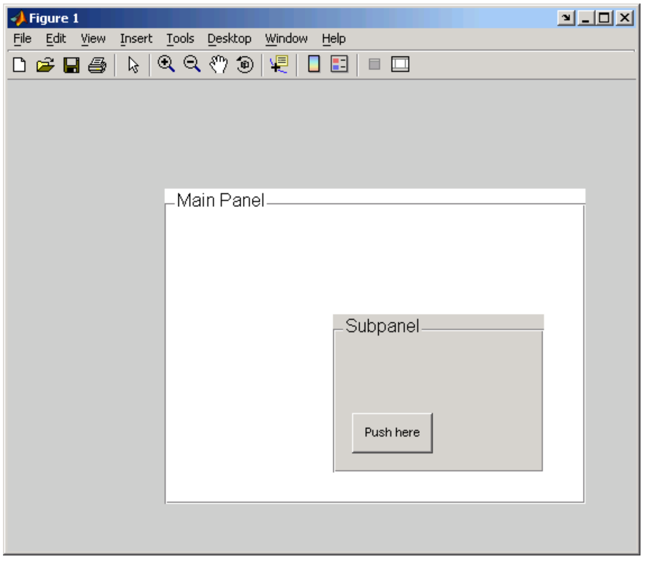
Remarks

If you set the `Visible` property of a uipanel object to `'off'`, any child objects it has (buttons, button groups, axes, etc.) will become invisible as well as the panel itself. Changing the panel's visibility does not affect the settings of the Visible property for any of its child objects, but all of them remain invisible until the uipanel's visibility is set to 'on'.

Examples

This example creates a uipanel in a figure, then creates a subpanel in the first panel. Finally, it adds a pushbutton to the subpanel. Both panels use the default Units property value, normalized. Note that default Units for the uicontrol pushbutton is pixels.

```
h = figure;
hp = uipanel('Title','Main Panel','FontSize',12,...
             'BackgroundColor','white',...
             'Position',[.25 .1 .67 .67]);
hsp = uipanel('Parent',hp,'Title','Subpanel','FontSize',12,...
              'Position',[.4 .1 .5 .5]);
hbsp = uicontrol('Parent',hsp,'String','Push here',...
              'Position',[18 18 72 36]);
```



See Also

hgtransform, uibuttongroup, uicontrol

Purpose

Describe panel properties

Modifying Properties

You can set and query graphics object properties in two ways:

- The Property Inspector is an interactive tool that enables you to see and change object property values. The Property inspector is available from GUIDE, or use the `inspect` function at the command line.
- The `set` and `get` functions enable you to set and query the values of properties.

You can set default uipanel properties by typing:

```
set(h,'DefaultUipanelPropertyName',PropertyValue...)
```

Where h can be the root handle (0), a figure handle, or a uipanel handle. *`PropertyName`* is the name of the uipanel property and `PropertyValue` is the value you specify as the default for that property.

Note Default properties you set for uipanels also apply to uibuttongroups.

For more information about changing the default value of a property see “Setting Default Property Values”. For an example, see the `CreateFcn` property.

Uipanel Properties

This section lists all properties useful to `uipanel` objects along with valid values and a descriptions of their use. Curly braces { } enclose default values.

Property Name	Description
`BackgroundColor`	Color of the uipanel background
`BorderType`	Type of border around the uipanel area.

Property Name	Description
BorderWidth	Width of the panel border.
BusyAction	Interruption of other callback routines
ButtonDownFcn	Button-press callback routine
Children	All children of the uipanel
Clipping	Clipping of child axes, uipanels, and uibuttongroups to the uipanel. Does not affect child uicontrols.
CreateFcn	Callback routine executed during object creation
DeleteFcn	Callback routine executed during object deletion
FontAngle	Title font angle
FontName	Title font name
FontSize	Title font size
FontUnits	Title font units
FontWeight	Title font weight
ForegroundColor	Title font color and/or color of 2-D border line
HandleVisibility	Handle accessibility from commandline and GUIs
HighlightColor	3-D frame highlight color
Interruptible	Callback routine interruption mode
Parent	Uipanel object's parent
Position	Panel position relative to parent figure or uipanel
ResizeFcn	User-specified resize routine
Selected	Whether object is selected

Property Name	Description
SelectionHighlight	Object highlighted when selected
ShadowColor	3-D frame shadow color
Tag	User-specified object identifier
Title	Title string
TitlePosition	Location of title string in relation to the panel
Type	Object class
UIContextMenu	Associates uicontextmenu with the uipanel
Units	Units used to interpret the position vector
UserData	User-specified data
Visible	Uipanel visibility. **Note** Controls the `Visible` property of child axes, uibuttongroups. and uipanels. Does not affect child uicontrols.

`BackgroundColor`

`ColorSpec`

Color of the uipanel background. A three-element RGB vector or one of the MATLAB predefined names, specifying the background color. See the `ColorSpec` reference page for more information on specifying color.

`BorderType`

`none | {etchedin} | etchedout | beveledin | beveledout | line`

Border of the uipanel area. Used to define the panel area graphically. Etched and beveled borders provide a 3-D look. Use the `HighlightColor` and `ShadowColor` properties to specify the border color of etched and beveled borders. A line border is 2-D. Use the `ForegroundColor` property to specify its color.

`BorderWidth`
`integer`

Width of the panel border. The width of the panel borders in pixels. The default border width is 1 pixel. 3-D borders wider than 3 may not appear correctly at the corners.

`BusyAction`
`cancel | {queue}`

Callback routine interruption. If a callback is executing and the user triggers an event (such as a mouse click) on an object for which a callback is defined, the callback associated with the new event uses the value of `BusyAction` to decide whether or not to attempt to interrupt the executing callback.

- If the value is `cancel`, the event is discarded and the second callback does not execute.
- If the value is `queue`, and the `Interruptible` property of the first callback is `on`, the second callback is added to the event queue and executes in its turn after the first callback finishes execution.

Note If the interrupting callback is a `DeleteFcn` or `CreateFcn` callback or a figure's `CloseRequest` or `ResizeFcn` callback, it interrupts an executing callback regardless of the value of that object's `Interruptible` property. See the `Interruptible` property for information about controlling a callback's interruptibility.

`ButtonDownFcn`
string or function handle

Button-press callback routine. A callback routine that executes when you press a mouse button while the pointer is in a 5-pixel wide border around the uipanel. This is useful for implementing actions to interactively modify control object properties, such as size and position, when they are clicked on (using the selectmoveresize function, for example).

If you define this routine as a string, the string can be a valid MATLAB expression or the name of an M-file. The expression executes in the MATLAB workspace.

`Children`

vector of handles

Children of the uipanel. A vector containing the handles of all children of the uipanel. A `uipanel` object's children are axes, uipanels, uibuttongroups, and uicontrols. You can use this property to reorder the children.

`Clipping`

`{on} | off`

Clipping mode. By default, MATLAB clips a uipanel's child axes, uipanels, and uibuttongroups to the uipanel rectangle. If you set `Clipping` to `off`, the axis, uipanel, or uibuttongroup is displayed outside the panel rectangle. This property does not affect child uicontrols which, by default, can display outside the panel rectangle.

`CreateFcn`

string or function handle

Callback routine executed during object creation. The specified function executes when MATLAB creates a `uipanel` object. MATLAB sets all property values for the uipanel before executing the `CreateFcn` callback so these values are available to the callback. Within the function, use `gcbo` to get the handle of the uipanel being created.

Setting this property on an existing uipanel object has no effect.

You can define a default `CreateFcn` callback for all new uipanels. This default applies unless you override it by specifying a different `CreateFcn` callback when you call `uipanel`. For example, the code

```
set(0,'DefaultUipanelCreateFcn','set(gcbo,...
    ''FontName'',''arial'',''FontSize'',12)')
```

creates a default `CreateFcn` callback that runs whenever you create a new panel. It sets the default font name and font size of the uipanel title.

Note Uibuttongroup takes its default property values from uipanel. Defining a default property for all uipanels defines the same default property for all uibuttongroups.

To override this default and create a panel whose `FontName and` `FontSize` properties are set to different values, call `uipanel` with code similar to

```
hpt = uipanel(...,'CreateFcn','set(gcbo,...
''FontName'',''times'',''FontSize'',14)')
```

Note To override a default `CreateFcn` callback you must provide a new callback and not just provide different values for the specified properties. This is because the `CreateFcn` callback runs after the property values are set, and can override property values you have set explicitly in the `uipushtool` call. In the example above, if instead of redefining the `CreateFcn` property for this uipanel, you had explicitly set `Fontsize` to `14`, the default `CreateFcn` callback would have set `FontSize` back to the system dependent default.

Do not call `copyobj` or `textwrap` (which calls `copyobj`) inside a `CreateFcn`. The act of copying the uicontrol object fires the `CreateFcn` repeatedly, which raises a series of error messages after exceeding the root object's `RecursionLimit` property.

See "Function Handle Callbacks" for information on how to use function handles to define a callback function.

`DeleteFcn`
string or function handle

Callback routine executed during object deletion. A callback routine that executes when you delete the uipanel object (e.g., when you issue a delete command or clear the figure containing the uipanel). MATLAB executes the routine before destroying the object's properties so these values are available to the callback routine. The handle of the object whose `DeleteFcn` is being executed is accessible only through the root `CallbackObject` property, which you can query using `gcbo`.

`FontAngle`
`{normal} | italic | oblique`

Character slant used in the Title. MATLAB uses this property to select a font from those available on your particular system. Setting this property to `italic` or `oblique` selects a slanted version of the font, when it is available on your system.

`FontName`
string

Font family used in the Title. The name of the font in which to display the `Title`. To display and print properly, this must be a font that your system supports. The default font is system dependent. To eliminate the need to hard code the name of a fixed-width font, which may not display text properly on systems that do not use ASCII character encoding (such as in Japan), set `FontName` to the string `FixedWidth` (this string value is case insensitive).

```
set(uicontrol_handle,'FontName','FixedWidth')
```

This then uses the value of the root `FixedWidthFontName` property which can be set to the appropriate value for a locale from `startup.m` in the end user's environment. Setting the root `FixedWidthFontName` property causes an immediate update of the display to use the new font

`FontSize`
`integer`

Title font size. A number specifying the size of the font in which to display the Title, in units determined by the `FontUnits` property. The default size is system dependent.

`FontUnits`
`inches | centimeters | normalized | {points} |pixels`

Title font size units. `Normalized` units interpret `FontSize` as a fraction of the height of the uipanel. When you resize the uipanel, MATLAB modifies the screen `FontSize` accordingly. `pixels`, `inches`, `centimeters`, and `points` are absolute units (1 point = 1/72 inch).

`FontWeight`
`light | {normal} | demi | bold`

Weight of characters in the title. MATLAB uses this property to select a font from those available on your particular system. Setting this property to bold causes MATLAB to use a bold version of the font, when it is available on your system.

`ForegroundColor`
`ColorSpec`

Color used for title font and 2-D border line. A three-element RGB vector or one of the MATLAB predefined names, specifying the font or line color. See the `ColorSpec` reference page for more information on specifying color.

`HandleVisibility`

`{on} | callback | off`

Control access to object's handle. This property determines when an object's handle is visible in its parent's list of children. When a handle is not visible in its parent's list of children, it is not returned by functions that obtain handles by searching the object hierarchy or querying handle properties. This includes `get`, `findobj`, `gca`, `gcf`, `gco`, `newplot`, `cla`, `clf`, and `close`. Neither is the handle visible in the parent figure's `CurrentObject` property. Handles that are hidden are still valid. If you know an object's handle, you can `set` and `get` its properties, and pass it to any function that operates on handles.

- Handles are always visible when `HandleVisibility` is `on`.
- Setting `HandleVisibility` to `callback` causes handles to be visible from within callback routines or functions invoked by callback routines, but not from within functions invoked from the command line. This provides a means to protect GUIs from command-line users, while allowing callback routines to have complete access to object handles.
- Setting `HandleVisibility` to `off` makes handles invisible at all times. This may be necessary when a callback routine invokes a function that might potentially damage the GUI (such as evaluating a user-typed string), and so temporarily hides its own handles during the execution of that function.

You can set the root `ShowHiddenHandles` property to on to make all handles visible, regardless of their `HandleVisibility` settings. This does not affect the values of the `HandleVisibility` properties.

`HighlightColor`
`ColorSpec`

3-D frame highlight color. A three-element RGB vector or one of the MATLAB predefined names, specifying the highlight color. See the `ColorSpec` reference page for more information on specifying color.

`Interruptible`
`{on} | off`

Callback routine interruption mode. If a callback is executing and the user triggers an event (such as a mouse click) on an object for which a callback is defined, that callback attempts to interrupt the first callback. MATLAB processes the callbacks according to these factors:

- The `Interruptible` property of the object whose callback is executing
- Whether the executing callback contains `drawnow`, `figure`, `getframe`, `pause`, or `waitfor` statements
- The `BusyAction` property of the object whose callback is waiting to execute

If the `Interruptible` property of the object whose callback is executing is `on` (the default), the callback can be interrupted. Whenever the callback calls one of the `drawnow`, `figure`, `getframe`, `pause`, or `waitfor` functions, the function processes any events in the event queue, including the waiting callback, before performing its defined task.

If the `Interruptible` property of the object whose callback is executing is `off`, the callback cannot be interrupted (except by certain callbacks; see the note below). The `BusyAction` property of the object whose callback is waiting to execute determines what happens to the callback.

Note If the interrupting callback is a `DeleteFcn` or `CreateFcn` callback or a figure's `CloseRequest` or `ResizeFcn` callback, it interrupts an executing callback regardless of the value of that object's `Interruptible` property. The interrupting callback starts execution at the next `drawnow`, `figure`, `getframe`, `pause`, or `waitfor` statement. A figure's `WindowButtonDownFcn` callback routine, or an object's `ButtonDownFcn` or `Callback` routine are processed according to the rules described above.

`Parent`
handle

Uipanel parent. The handle of the uipanel's parent figure, uipanel, or uibuttongroup. You can move a uipanel object to another figure, uipanel, or uibuttongroup by setting this property to the handle of the new parent.

`Position`
position rectangle

Size and location of uipanel relative to parent. The rectangle defined by this property specifies the size and location of the panel within the parent figure window, uipanel, or uibuttongroup. Specify `Position` as

```
[left bottom width height]
```

`left` and `bottom` are the distance from the lower-left corner of the parent object to the lower-left corner of the `uipanel` object. `width` and `height` are the dimensions of the uipanel rectangle, including the title. All measurements are in units specified by the `Units` property.

`ResizeFcn`
string or function handle

Resize callback routine. MATLAB executes this callback routine whenever a user resizes the uipanel and the figure Resize property is set to on, or in GUIDE, the Resize behavior option is set to Other. You can query the uipanel Position property to determine its new size and position. During execution of the callback routine, the handle to the figure being resized is accessible only through the root CallbackObject property, which you can query using gcbo.

You can use ResizeFcn to maintain a GUI layout that is not directly supported by the MATLAB Position/Units paradigm.

For example, consider a GUI layout that maintains an object at a constant height in pixels and attached to the top of the figure, but always matches the width of the figure. The following ResizeFcn accomplishes this; it keeps the uicontrol whose Tag is 'StatusBar' 20 pixels high, as wide as the figure, and attached to the top of the figure. Note the use of the Tag property to retrieve the uicontrol handle, and the gcbo function to retrieve the figure handle. Also note the defensive programming regarding figure Units, which the callback requires to be in pixels in order to work correctly, but which the callback also restores to their previous value afterwards.

```
u = findobj('Tag','StatusBar');
fig = gcbo;
old_units = get(fig,'Units');
set(fig,'Units','pixels');
figpos = get(fig,'Position');
upos = [0, figpos(4) - 20, figpos(3), 20];
set(u,'Position',upos);
set(fig,'Units',old_units);
```

You can change the figure Position from within the ResizeFcn callback; however, the ResizeFcn is not called again as a result.

Note that the `print` command can cause the `ResizeFcn` to be called if the `PaperPositionMode` property is set to `manual` and you have defined a resize function. If you do not want your resize function called by `print`, set the `PaperPositionMode` to `auto`.

See "Function Handle Callbacks" for information on how to use function handles to define the callback function.

See Resize Behavior for information on creating resize functions using GUIDE.

`Selected`
`on | off` (read only)

Is object selected? This property indicates whether the panel is selected. When this property is `on`, MATLAB displays selection handles if the `SelectionHighlight` property is also `on`. You can, for example, define the `ButtonDownFcn` to set this property, allowing users to select the object with the mouse.

`SelectionHighlight`
`{on} | off`

Object highlighted when selected. When the `Selected` property is `on`, MATLAB indicates the selected state by drawing four edge handles and four corner handles. When `SelectionHighlight` is `off`, MATLAB does not draw the handles.

`ShadowColor`
`ColorSpec`

3-D frame shadow color. A three-element RGB vector or one of the MATLAB predefined names, specifying the shadow color. See the `ColorSpec` reference page for more information on specifying color.

`Tag`
string

User-specified object identifier. The `Tag` property provides a means to identify graphics objects with a user-specified label. You can define `Tag` as any string.

With the `findobj` function, you can locate an object with a given `Tag` property value. This saves you from defining object handles as global variables. For example, this function call returns the handles of all children (of the specified figures) that have the `Tag` value `'FormatTb'`.

```
h = findobj(figurehandles,'Tag','FormatTb')
```

`Title`
string

Title string. The text displayed in the panel title. You can position the title using the `TitlePosition` property.

If the string value is specified as a cell array of strings or padded string matrix, only the first string of a cell array or of a padded string matrix is displayed; the rest are ignored. Vertical slash ('`|`') characters are not interpreted as line breaks and instead show up in the text displayed in the uipanel title.

Setting a property value to `default`, `remove`, or `factory` produces the effect described in "Defining Default Values". To set `Title` to one of these words, you must precede the word with the backslash character. For example,

```
hp = uipanel(...,'Title','\Default');
```

`TitlePosition`
`{lefttop} | centertop | righttop | leftbottom | centerbottom | rightbottom`

Location of the title. This property determines the location of the title string, in relation to the uipanel.

`Type`

`string` (read-only)

Object class. This property identifies the kind of graphics object. For uipanel objects, `Type` is always the string `'uipanel'`.

`UIContextMenu`

handle

Associate a context menu with a uipanel. Assign this property the handle of a `Uicontextmenu` object. MATLAB displays the context menu whenever you right-click the `uipanel`. Use the `uicontextmenu` function to create the context menu.

`Units`

`inches | centimeters | {normalized} | points | pixels | characters`

Units of measurement. MATLAB uses these units to interpret the `Position` property. For the panel itself, units are measured from the lower-left corner of the figure window. For children of the panel, they are measured from the lower-left corner of the panel.

- `Normalized` units map the lower-left corner of the panel or figure window to (0,0) and the upper-right corner to (1.0,1.0).
- `pixels`, `inches`, `centimeters`, and `points` are absolute units (1 point = 1/72 inch).
- `Character` units are characters using the default system font; the width of one character is the width of the letter x, the height of one character is the distance between the baselines of two lines of text.

If you change the value of `Units`, it is good practice to return it to its default value after completing your computation so as not to affect other functions that assume `Units` is set to the default value.

`UserData`

matrix

User-specified data. Any data you want to associate with the `uipanel` object. MATLAB does not use this data, but you can access it using `set` and `get`.

`Visible`

`{on} | off`

Uipanel visibility. By default, a `uipanel` object is visible. When set to `off`, the uipanel is not visible, but still exists and you can query and set its properties.

Note The value of a uipanel's `Visible` property also controls the `Visible` property of child axes, uipanels, and uibuttongroups. This property does not affect the `Visible` property of child uicontrols.

Purpose

Create push button on toolbar

Syntax

```
hpt = uipushtool('PropertyName1',value1,'PropertyName2',
   value2,...)
hpt = uipushtool(ht,...)
```

Description

`hpt = uipushtool('PropertyName1',value1,'PropertyName2',value2,...)` creates a push button on the uitoolbar at the top of the current figure window, and returns a handle to it. `uipushtool` assigns the specified property values, and assigns default values to the remaining properties. You can change the property values at a later time using the `set` function.

Type `get(hpt)` to see a list of uipushtool object properties and their current values. Type `set(hpt)` to see a list of uipushtool object properties that you can set and their legal property values. See the Uipushtool Properties reference page for more information.

`hpt = uipushtool(ht,...)` creates a button with `ht` as a parent. `ht` must be a uitoolbar handle.

Remarks

`uipushtool` accepts property name/property value pairs, as well as structures and cell arrays of properties as input arguments.

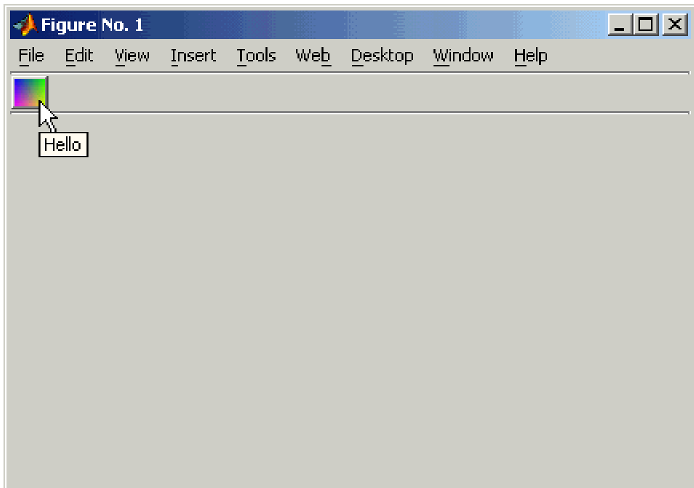
Uipushtools appear in figures whose `Window Style` is `normal` or `docked`. They do not appear in figures whose `WindowStyle` is `modal`. If the `WindowStyle`of a figure containing a uitoolbar and its uipushtool children is changed to `modal`, the uipushtools still exist and are contained in the `Children` list of the uitoolbar, but are not displayed until the figure `WindowStyle` is changed to `normal` or `docked`.

Examples

This example creates a uitoolbar object and places a uipushtool object on it.

```
h = figure('ToolBar','none')
ht = uitoolbar(h)
a = [.20:.05:0.95];
```

```
b(:,:,1) = repmat(a,16,1)';
b(:,:,2) = repmat(a,16,1);
b(:,:,3) = repmat(flipdim(a,2),16,1);
hpt = uipushtool(ht,'CData',b,'TooltipString','Hello')
```



See Also

`get`, `set`, `uicontrol`, `uitoggletool`, `uitoolbar`

Purpose

Describe push tool properties

Modifying Properties

You can set and query graphics object properties in two ways:

- The Property Inspector is an interactive tool that enables you to see and change object property values. The Property inspector is available from GUIDE, or use the `inspect` function at the command line.
- The `set` and `get` functions enable you to set and query the values of properties.

You can set default Uipushtool properties by typing:

```
set(h,'DefaultUipushtoolPropertyName',PropertyValue...)
```

Where h can be the root handle (0), a figure handle, a uitoolbar handle, or a uipushtool handle. *`PropertyName`* is the name of the `Uipushtool` property and `PropertyValue` is the value you specify as the default for that property.

For more information about changing the default value of a property see Setting Default Property Values.

Uipushtool Properties

This section lists all properties useful to `uipushtool` objects along with valid values and a descriptions of their use. Curly braces { } enclose default values.

Property	Purpose
`BeingDeleted`	This object is being deleted.
`BusyAction`	Callback routine interruption.
`CData`	Truecolor image displayed on the control.
`ClickedCallback`	Control action.
`CreateFcn`	Callback routine executed during object creation.
`DeleteFcn`	Delete uipushtool callback routine.

Property	Purpose
Enable	Enable or disable the uipushtool.
HandleVisibility	Control access to object's handle.
HitTest	Whether selectable by mouse click
Interruptible	Callback routine interruption mode.
Parent	Handle of uipushtool's parent.
Separator	Separator line mode
Tag	User-specified object label.
TooltipString	Content of object's tooltip.
Type	Object class.
UIContextMenu	Uicontextmenu object associated with the uipushtool
UserData	User specified data.
Visible	Uipushtool visibility.

BeingDeleted
on | {off} (read only)

This object is being deleted. The BeingDeleted property provides a mechanism that you can use to determine if objects are in the process of being deleted. MATLAB software sets the BeingDeleted property to on when the object's delete function callback is called (see the DeleteFcn property). It remains set to on while the delete function executes, after which the object no longer exists.

For example, some functions may not need to perform actions on objects that are being deleted, and therefore, can check the object's BeingDeleted property before acting.

`BusyAction`

`cancel | {queue}`

Callback routine interruption. If a callback is executing and the user triggers an event (such as a mouse click) on an object for which a callback is defined, the callback associated with the new event uses the value of `BusyAction` to decide whether or not to attempt to interrupt the executing callback.

- If the value is `cancel`, the event is discarded and the second callback does not execute.
- If the value is `queue`, and the `Interruptible` property of the first callback is `on`, the second callback is added to the event queue and executes in its turn after the first callback finishes execution.

Note If the interrupting callback is a `DeleteFcn` or `CreateFcn` callback or a figure's `CloseRequest` or `ResizeFcn` callback, it interrupts an executing callback regardless of the value of that object's `Interruptible` property. See the `Interruptible` property for information about controlling a callback's interruptibility.

`CData`

3-dimensional array

Truecolor image displayed on control. An *n*-by-*m*-by-3 array of RGB values that defines a truecolor image displayed on either a push button or toggle button. Each value must be between 0.0 and 1.0. If your `CData` array is larger than 16 in the first or second dimension, it may be clipped or cause other undesirable effects. If the array is clipped, only the center 16-by-16 part of the array is used.

`ClickedCallback`

string or function handle

Control action. A routine that executes when the uipushtool's `Enable` property is set to `on`, and you press a mouse button while the pointer is on the push tool itself or in a 5-pixel wide border around it.

`CreateFcn`

string or function handle

Callback routine executed during object creation. The specified function executes when MATLAB creates a uipushtool object. MATLAB sets all property values for the uipushtool before executing the `CreateFcn` callback so these values are available to the callback. Within the function, use `gcbo` to get the handle of the push tool being created.

Setting this property on an existing uipushtool object has no effect.

You can define a default `CreateFcn` callback for all new uipushtools. This default applies unless you override it by specifying a different `CreateFcn` callback when you call `uipushtool`. For example, the code

```
imga(:,:,1) = rand(20);
imga(:,:,2) = rand(20);
imga(:,:,3) = rand(20);
set(0,'DefaultUipushtoolCreateFcn','set(gcbo,''Cdata'',imga)')
```

creates a default `CreateFcn` callback that runs whenever you create a new push tool. It sets the default image `imga` on the push tool.

To override this default and create a push tool whose `Cdata` property is set to a different image, call `uipushtool` with code similar to

```
a = [.05:.05:0.95];
imgb(:,:,1) = repmat(a,19,1)';
imgb(:,:,2) = repmat(a,19,1);
imgb(:,:,3) = repmat(flipdim(a,2),19,1);
hpt = uipushtool(...,'CreateFcn','set(gcbo,''CData'',imgb)',...
```

Note To override a default `CreateFcn` callback you must provide a new callback and not just provide different values for the specified properties. This is because the `CreateFcn` callback runs after the property values are set, and can override property values you have set explicitly in the `uipushtool` call. In the example above, if instead of redefining the `CreateFcn` property for this push tool, you had explicitly set `CData` to `imgb`, the default `CreateFcn` callback would have set `CData` back to `imga`.

Do not call `copyobj` or `textwrap` (which calls `copyobj`) inside a `CreateFcn`. The act of copying the uicontrol object fires the `CreateFcn` repeatedly, which raises a series of error messages after exceeding the root object's `RecursionLimit` property.

See "Function Handle Callbacks" for information on how to use function handles to define a callback function.

`DeleteFcn`

string or function handle

Callback routine executed during object deletion. A callback routine that executes when you delete the uipushtool object (e.g., when you call the `delete` function or cause the figure containing the uipushtool to reset). MATLAB executes the routine before destroying the object's properties so these values are available to the callback routine.

The handle of the object whose DeleteFcn is being executed is accessible only through the root `CallbackObject` property, which you can query using `gcbo`.

See "Function Handle Callbacks" for information on how to use function handles to define a callback function.

`Enable`
`{on} | off`

Enable or disable the uipushtool. This property controls how uipushtools respond to mouse button clicks, including which callback routines execute.

- `on` – The uipushtool is operational (the default).
- `off` – The uipushtool is not operational and its image (set by the `Cdata` property) is grayed out.

When you left-click on a uipushtool whose `Enable` property is `on`, MATLAB performs these actions in this order:

1. Sets the figure's `SelectionType` property.
2. Executes the push tool's `ClickedCallback` routine.
3. Does not set the figure's `CurrentPoint` property and does not execute the figure's `WindowButtonDownFcn` callback.

When you left-click on a uipushtool whose `Enable` property is `off`, or when you right-click a uipushtool whose `Enable` property has any value, MATLAB performs these actions in this order:

1. Sets the figure's `SelectionType` property.
2. Sets the figure's `CurrentPoint` property.
3. Executes the figure's `WindowButtonDownFcn` callback.
4. Does not execute the push tool's `ClickedCallback` routine.

`HandleVisibility`
`{on} | callback | off`

Control access to object's handle. This property determines when an object's handle is visible in its parent's list of children. When a handle is not visible in its parent's list of children, it is not returned by functions that obtain handles by searching the object hierarchy or querying handle properties. This includes `get`, `findobj`, `gca`, `gcf`, `gco`, `newplot`, `cla`, `clf`, and `close`. Neither is the handle visible in the parent figure's `CurrentObject` property. Handles that are hidden are still valid. If you know an object's handle, you can `set` and `get` its properties, and pass it to any function that operates on handles.

- Handles are always visible when `HandleVisibility` is `on`.
- Setting `HandleVisibility` to `callback` causes handles to be visible from within callback routines or functions invoked by callback routines, but not from within functions invoked from the command line. This provides a means to protect GUIs from command-line users, while allowing callback routines to have complete access to object handles.
- Setting `HandleVisibility` to `off` makes handles invisible at all times. This may be necessary when a callback routine invokes a function that might potentially damage the GUI (such as evaluating a user-typed string), and so temporarily hides its own handles during the execution of that function.

You can set the root `ShowHiddenHandles` property to on to make all handles visible, regardless of their `HandleVisibility` settings. This does not affect the values of the `HandleVisibility` properties.

`HitTest`

`{on} | off`

Selectable by mouse click. This property has no effect on uipushtool objects.

`Interruptible`

`{on} | off`

Callback routine interruption mode. If a callback is executing and the user triggers an event (such as a mouse click) on an object for which a callback is defined, that callback attempts to interrupt the first callback. MATLAB processes the callbacks according to these factors:

- The `Interruptible` property of the object whose callback is executing
- Whether the executing callback contains `drawnow`, `figure`, `getframe`, `pause`, or `waitfor` statements
- The `BusyAction` property of the object whose callback is waiting to execute

If the `Interruptible` property of the object whose callback is executing is `on` (the default), the callback can be interrupted. Whenever the callback calls one of the `drawnow`, `figure`, `getframe`, `pause`, or `waitfor` functions, the function processes any events in the event queue, including the waiting callback, before performing its defined task.

If the `Interruptible` property of the object whose callback is executing is `off`, the callback cannot be interrupted (except by certain callbacks; see the note below). The `BusyAction` property of the object whose callback is waiting to execute determines what happens to the callback.

Note If the interrupting callback is a `DeleteFcn` or `CreateFcn` callback or a figure's `CloseRequest` or `ResizeFcn` callback, it interrupts an executing callback regardless of the value of that object's `Interruptible` property. The interrupting callback starts execution at the next `drawnow`, `figure`, `getframe`, `pause`, or `waitfor` statement. A figure's `WindowButtonDownFcn` callback routine, or an object's `ButtonDownFcn` or `Callback` routine are processed according to the rules described above.

`Parent`
handle

Uipushtool parent. The handle of the uipushtool's parent toolbar. You can move a uipushtool object to another toolbar by setting this property to the handle of the new parent.

`Separator`
`on | {off}`

Separator line mode. Setting this property to `on` draws a dividing line to the left of the uipushtool.

`Tag`
string

User-specified object identifier. The `Tag` property provides a means to identify graphics objects with a user-specified label. You can define `Tag` as any string.

With the `findobj` function, you can locate an object with a given `Tag` property value. This saves you from defining object handles as global variables. For example, this function call returns the handles of all children (of the specified toolbars) that have the `Tag` value `'Copy'`.

```
h = findobj(uitoolbarhandles,'Tag','Copy')
```

`TooltipString`
string

Content of tooltip for object. The `TooltipString` property specifies the text of the tooltip associated with the uipushtool. When the user moves the mouse pointer over the control and leaves it there, the tooltip is displayed.

`Type`
string (read-only)

Object class. This property identifies the kind of graphics object. For uipushtool objects, `Type` is always the string `'uipushtool'`.

`UIContextMenu`
handle

Associate a context menu with uicontrol. This property has no effect on uipushtool objects.

`UserData`
array

User specified data. You can specify `UserData` as any array you want to associate with the uipushtool object. The object does not use this data, but you can access it using the `set` and `get` functions.

`Visible`
`{on} | off`

Uipushtool visibility. By default, all uipushtools are visible. When set to `off`, the uipushtool is not visible, but still exists and you can query and set its properties.

Purpose

Open standard dialog box for saving files

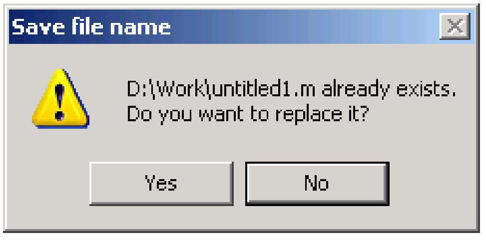
Syntax

```
uiputfile
[FileName,PathName,FilterIndex] = uiputfile(FilterSpec)
[FileName,PathName,FilterIndex] = uiputfile(FilterSpec,
   DialogTitle)
[FileName,PathName,FilterIndex] = uiputfile(FilterSpec,
   DialogTitle,DefaultName)
```

Description

`uiputfile` displays a modal dialog box used to select or specify a file for saving. The dialog box lists the files and directories in the current directory. If the selected or specified filename is valid, it is returned in `ans`.

If an existing filename is selected or specified, the following warning dialog box is displayed.



The user can select **Yes** to replace the existing file or **No** to return to the dialog to select another filename. If the user selects **Yes**, `uiputfile` returns the name of the file. If the user selects **No**, `uiputfile` returns `0`.

Note A modal dialog box prevents the user from interacting with other windows before responding. To block MATLAB program execution as well, use the `uiwait` function. For more information about modal dialog boxes, see `WindowStyle` in the MATLAB Figure Properties.

[FileName,PathName,FilterIndex] = uiputfile(FilterSpec) displays only those files with extensions that match FilterSpec. The uiputfile function appends 'All Files' to the list of file types.FilterSpec can be a string or a cell array of strings, and can include the * wildcard. For example, '*.m' lists all the MATLAB M-files.

- If FilterSpec is a string that contains a filename, the filename is displayed and selected in the **File name** field and the file's extension is used as the default filter.
- If FilterSpec is a string, it can include a path. That path can contain '.','..', or '/'. For example, '../*.m' lists all M-files in the directory above the current directory.
- If FilterSpec is a cell array of strings, the first column contains a list of file extensions. The optional second column contains a corresponding list of descriptions. These descriptions replace standard descriptions in the **Save as type** field. A description cannot be an empty string. "Example 3" on page 2-3822 and "Example 4" on page 2-3823 illustrate use of a cell array as FilterSpec.

If FilterSpec is not specified, uiputfile uses the default list of file types (i.e., all MATLAB files).

After the user clicks **Save** and if the filename is valid,uiputfile returns the name of the selected file in FileName and its path in PathName. If the user clicks the **Cancel** button, closes the dialog window, or if the filename is not valid, FileName and PathName are set to 0.

FilterIndex is the index of the filter selected in the dialog box. Indexing starts at 1. If the user clicks the **Cancel** button, closes the dialog window, or if the file does not exist, FilterIndex is set to 0.

If no output arguments are specified, the filename is returned in ans.

[FileName,PathName,FilterIndex] = uiputfile(FilterSpec,DialogTitle) displays a dialog box that has the title DialogTitle. To use the default file types and specify a dialog title, enter

```
uiputfile('',DialogTitle)
```

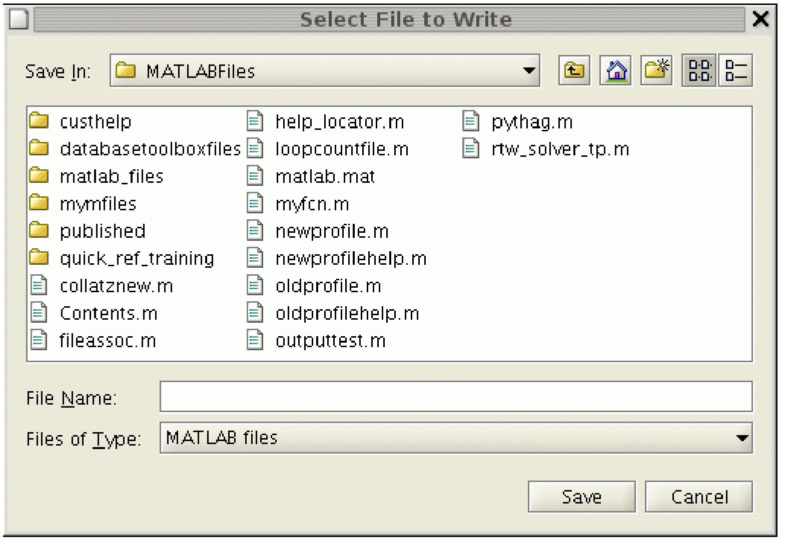
`[FileName,PathName,FilterIndex] = uiputfile(FilterSpec,DialogTitle,DefaultName)` displays a dialog box in which the filename specified by `DefaultName` appears in the **File name** field. `DefaultName` can also be a path or a path/filename. In this case, `uiputfile` opens the dialog box in the directory specified by the path. See "Example 6" on page 2-3825. Note that you can use `'.'`,`'..'`, or `'/'` in the `DefaultName` argument.

If the specified path does not exist, `uiputfile` opens the dialog box in the current directory.

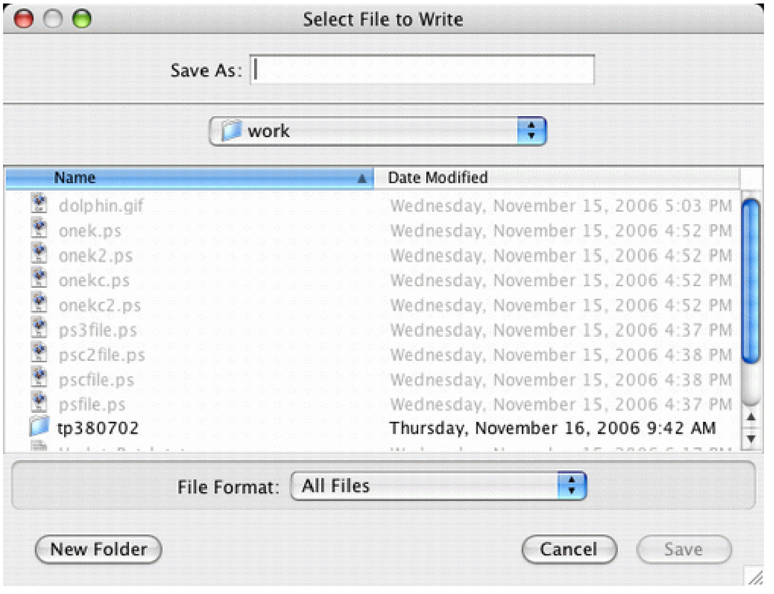
Remarks

For Microsoft Windows platforms, the dialog box is the Windows dialog box native to your platform. Because of this, it may differ from those shown in the examples below.

For UNIX platforms, the dialog box is similar to the one shown in the following figure.



For Mac platforms, the dialog box is similar to the one shown in the following figure.

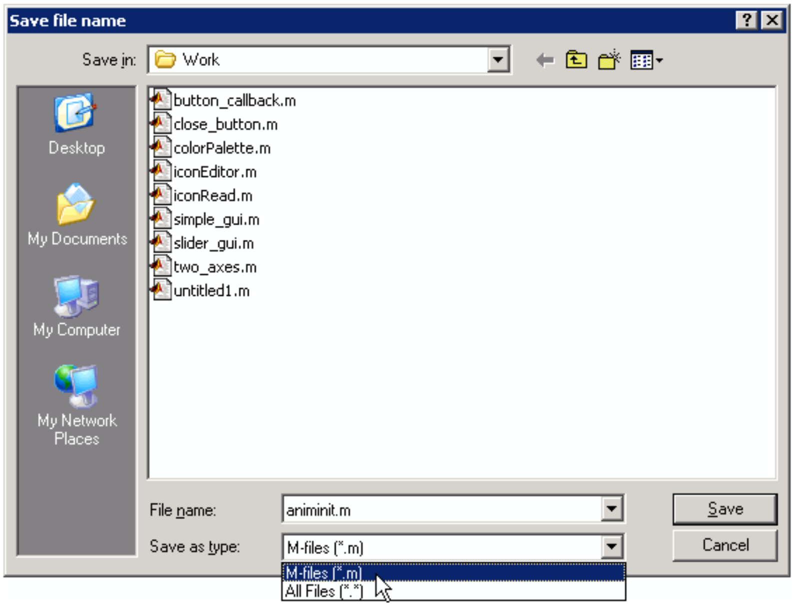


Examples

Example 1

The following statement displays a dialog box titled `'Save file name'` with the **Filename** field set to `animinit.m` and the filter set to `M-files (*.m)`. Because `FilterSpec` is a string, the filter also includes `All Files (*.*)`

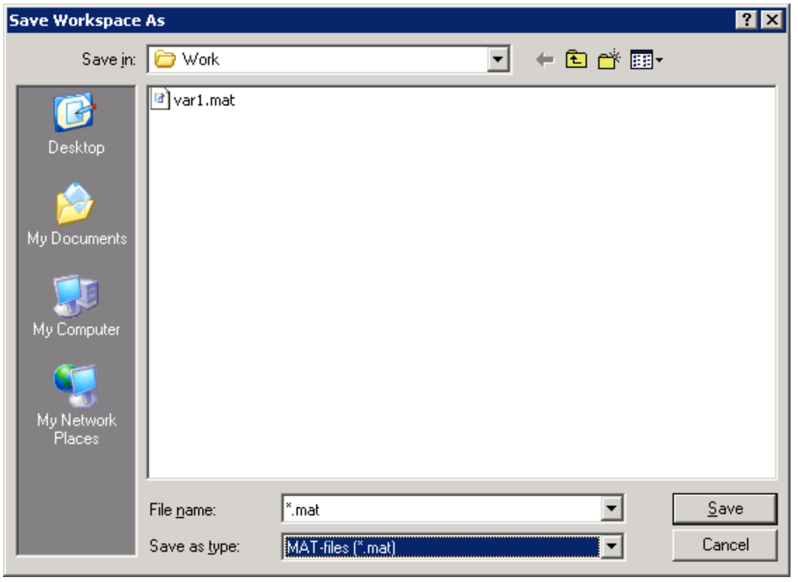
```
[file,path] = uiputfile('animinit.m','Save file name');
```



Example 2

The following statement displays a dialog box titled `'Save Workspace As'` with the filter specifier set to MAT-files.

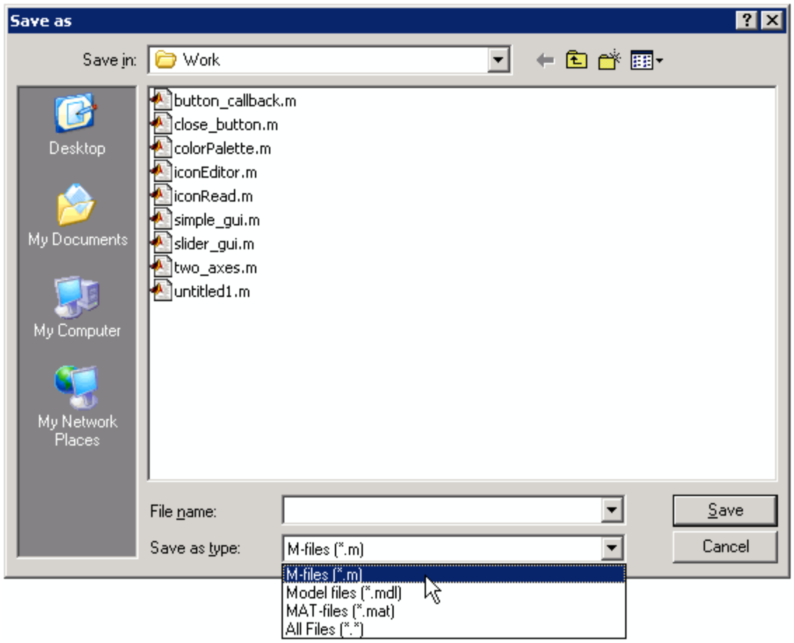
```
[file,path] = uiputfile('*.mat','Save Workspace As');
```



Example 3

To display several file types in the **Save as type** list box, separate each file extension with a semicolon, as in the following code. Note that `uiputfile` displays a default description for each known file type, such as "Simulink Models" for `.mdl` files.

```
[filename, pathname] = uiputfile(...
 {'*.m';'*.mdl';'*.mat';'*.*'},...
 'Save as');
```

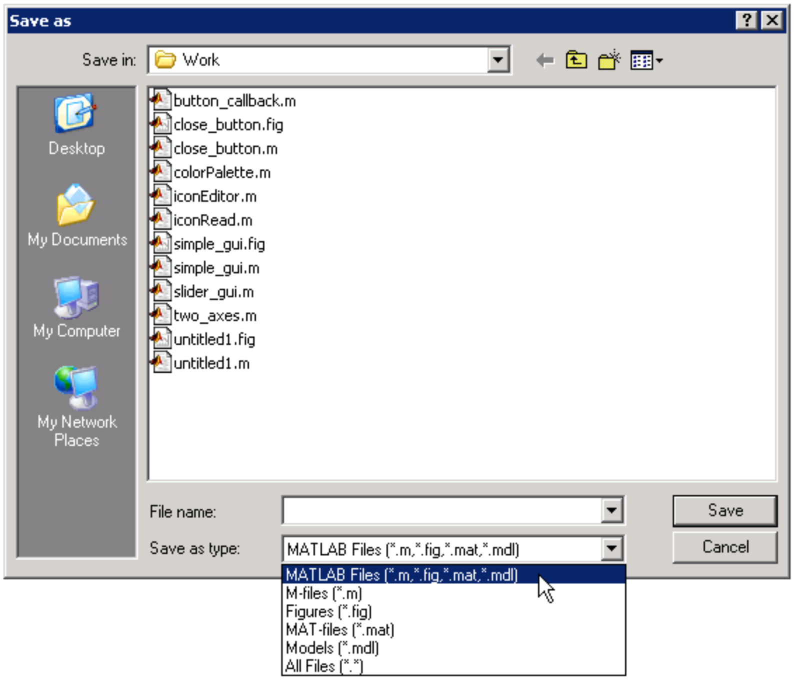


Example 4

If you want to create a list of file types and give them descriptions that are different from the defaults, use a cell array, as in the following code. This example also associates multiple file types with the `'MATLAB Files'` description.

```
[filename, pathname, filterindex] = uiputfile( ...
{'*.m;*.fig;*.mat;*.mdl','MATLAB Files (*.m,*.fig,*.mat,*.mdl)';
 '*.m', 'M-files (*.m)';...
 '*.fig','Figures (*.fig)';...
 '*.mat','MAT-files (*.mat)';...
 '*.mdl','Models (*.mdl)';...
 '*.*',  'All Files (*.*)'},...
 'Save as');
```

The first column of the cell array contains the file extensions, while the second contains the descriptions you want to provide for the file types. Note that the first entry of column one contains several extensions, separated by semicolons, all of which are associated with the description `'MATLAB Files (*.m,*.fig,*.mat,*.mdl)'`. The code produces the dialog box shown in the following figure.



Example 5

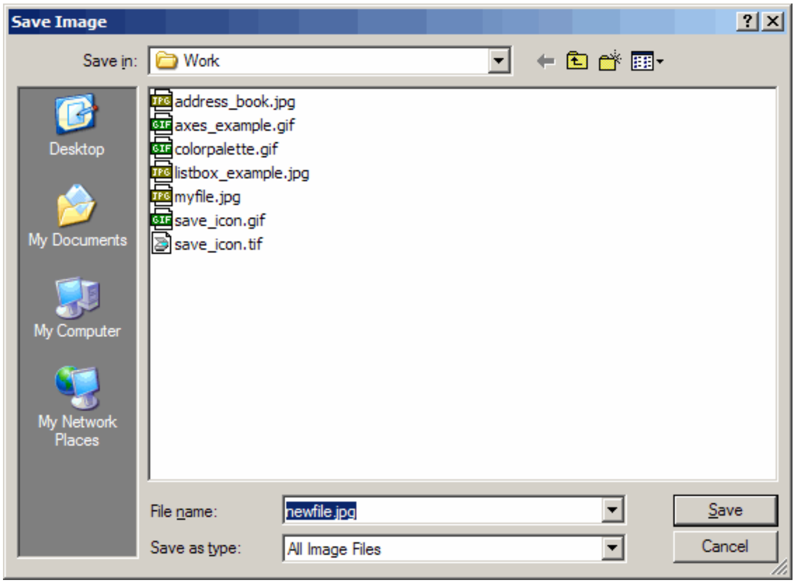
The following code checks for the existence of the file and displays a message about the result of the open operation.

```
[filename, pathname] = uiputfile('*.m','Pick an M-file');
if isequal(filename,0) || isequal(pathname,0)
   disp('User selected Cancel')
else
```

```
    disp(['User selected',fullfile(pathname,filename)])
end
```

Example 6

```
uiputfile({'*.jpg;*.tif;*.png;*.gif','All Image Files';...
          '*.*','All Files' },'Save Image',...
          'C:\Work\newfile.jpg')
```



See Also

`uigetdir`, `uigetfile`

Purpose

Resume execution of blocked M-file

Syntax

```
uiresume(h)
```

Description

`uiresume(h)` resumes the M-file execution that `uiwait` suspended.

Remarks

The `uiwait` and `uiresume` functions block and resume MATLAB program execution. When creating a dialog, you should have a uicontrol component with a callback that calls `uiresume` or a callback that destroys the dialog box. These are the only methods that resume program execution after the `uiwait` function blocks execution.

When used in conjunction with a modal dialog, `uiresume` can resume the execution of the M-file that `uiwait` suspended while presenting a dialog box.

Example

This example creates a GUI with a **Continue** push button. The example calls `uiwait` to block MATLAB execution until `uiresume` is called. This happens when the user clicks the **Continue** push button because the push button's `Callback` callback, which responds to the click, calls `uiresume`.

```
f = figure;
h = uicontrol('Position',[20 20 200 40],'String','Continue',...
              'Callback','uiresume(gcbf)');
disp('This will print immediately');
uiwait(gcf);
disp('This will print after you click Continue');
close(f);
```

`gcbf` is the handle of the figure that contains the object whose callback is executing.

"Using a Modal Dialog to Confirm an Operation" is a more complex example for a GUIDE GUI. See "Icon Editor" for an example for a programmatically created GUI.

See Also

`dialog`, `figure`, `uicontrol`, `uimenu`, `uiwait`, `waitfor`

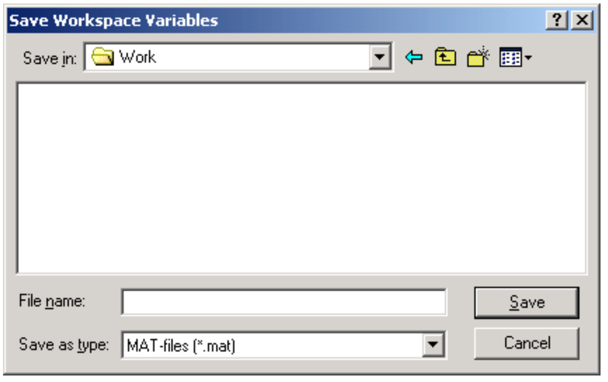
uisave

Purpose Open standard dialog box for saving workspace variables

Syntax

```
uisave
uisave(variables)
uisave(variables,filename)
```

Description `uisave` displays the Save Workspace Variables dialog box for saving workspace variables to a MAT-file, as shown in the figure below. By default, the dialog box opens in your current directory.



Note The `uisave` dialog box is modal. A modal dialog box prevents the user from interacting with other windows before responding. For more information, see `WindowStyle` in the MATLAB Figure Properties.

If you type a name in the **File name** field, such as `my_vars`, and click **Save**, the dialog saves all workspace variables in the file `my_vars.mat`. The default filename is `matlab.mat`.

`uisave(variables)` saves only the variables listed in `variables`. For a single variable, `variables` can be a string. For more than one variable, `variables` must be a cell array of strings.

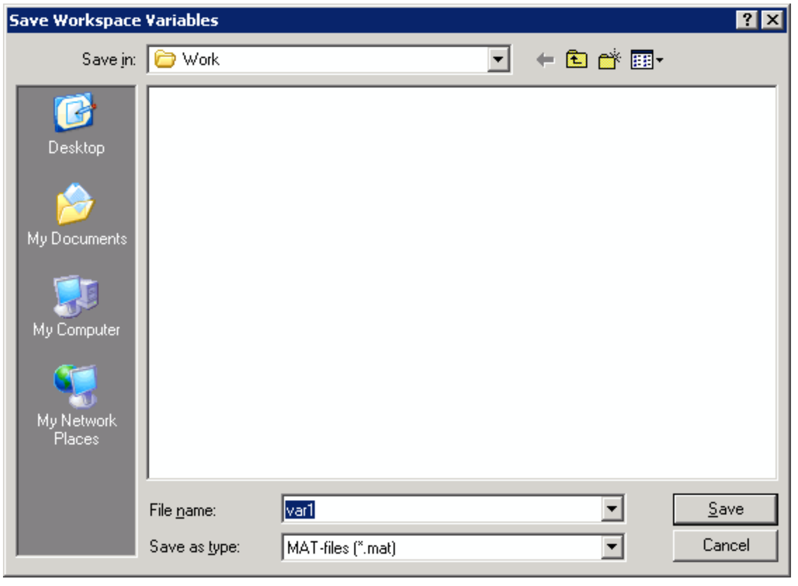
`uisave(variables,filename)` uses the specified `filename` as the default **File name** in the Save Workspace Variables dialog box.

Note `uisave` cannot be compiled. If you want to create a dialog that can be compiled, use `uiputfile`.

Example

This example creates workspace variables `h` and `g`, and then displays the Save Workspace Variables dialog box in the current directory with the default **File name** set to `var1`.

```
h = 365;
g = 52;
uisave({'h','g'},'var1');
```



Clicking **Save** stores the workspace variables `h` and `g` in the file `var1.mat` in the displayed directory.

See Also

`uigetfile`, `uiputfile`, `uiopen`

Purpose

Open standard dialog box for setting object's `ColorSpec`

Syntax

```
c = uisetcolor
c = uisetcolor([r g b])
c = uisetcolor(h)
c = uisetcolor(...,'dialogTitle')
```

Description

`c = uisetcolor` displays a modal color selection dialog appropriate to the platform, and returns the color selected by the user. The dialog box is initialized to `white`.

`c = uisetcolor([r g b])` displays a dialog box initialized to the specified color, and returns the color selected by the user. `r`, `g`, and `b` must be values between 0 and 1.

`c = uisetcolor(h)` displays a dialog box initialized to the color of the object specified by handle `h`, returns the color selected by the user, and applies it to the object. `h` must be the handle to an object containing a color property.

`c = uisetcolor(...,'dialogTitle')` displays a dialog box with the specified title.

If the user presses **Cancel** from the dialog box, or if any error occurs, the output value is set to the input RGB triple, if provided; otherwise, it is set to 0.

Note A modal dialog box prevents the user from interacting with other windows before responding. For more information, see `WindowStyle` in the MATLAB Figure Properties.

See Also

`ColorSpec`

uisetfont

Purpose

Open standard dialog box for setting object's font characteristics

Syntax

```
uisetfont
uisetfont(h)
uisetfont(S)
uisetfont(...,'DialogTitle')
S = uisetfont(...)
```

Description

`uisetfont` enables you to change font properties (`FontName`, `FontUnits`, `FontSize`, `FontWeight`, and `FontAngle`) for a `text`, `axes`, or `uicontrol` object. The function returns a structure consisting of font properties and values. You can specify an alternate title for the dialog box.

`uisetfont` displays a modal dialog box and returns the selected font properties.

Note A modal dialog box prevents the user from interacting with other windows before responding. For more information, see `WindowStyle` in the MATLAB Figure Properties.

`uisetfont(h)` displays a modal dialog box, initializing the font property values with the values of those properties for the object whose handle is `h`. Selected font property values are applied to the current object. If a second argument is supplied, it specifies a name for the dialog box.

`uisetfont(S)` displays a modal dialog box, initializing the font property values with the values defined for the specified structure (`S`). `S` must define legal values for one or more of these properties: `FontName`, `FontUnits`, `FontSize`, `FontWeight`, and `FontAngle` and the field names must match the property names exactly. If other properties are defined, they are ignored. If a second argument is supplied, it specifies a name for the dialog box.

`uisetfont(...,'DialogTitle')` displays a modal dialog box with the title `DialogTitle` and returns the values of the font properties selected in the dialog box.

`S = uisetfont(...)` returns the properties `FontName`, `FontUnits`, `FontSize`, `FontWeight`, and `FontAngle` as fields in a structure. If the user presses **Cancel** from the dialog box or if an error occurs, the output value is set to 0.

Example

These statements create a text object, then display a dialog box (labeled Update Font) that enables you to change the font characteristics:

```
h = text(.5,.5,'Figure Annotation');
uisetfont(h,'Update Font')
```

These statements create two push buttons, then set the font properties of one based on the values set for the other:

```
% Create push button with string ABC
c1 = uicontrol('Style', 'pushbutton', ...
     'Position', [10 10 100 20], 'String', 'ABC');
% Create push button with string XYZ
c2 = uicontrol('Style', 'pushbutton', ...
     'Position', [10 50 100 20], 'String', 'XYZ');
% Display set font dialog box for c1, make selections,
& and save to d
d = uisetfont(c1);
% Apply those settings to c2
set(c2, d)
```

See Also

`axes`, `text`, `uicontrol`

uisetpref

Purpose Manage preferences used in `uigetpref`

Syntax

```
uisetpref('clearall')
```

Description `uisetpref('clearall')` resets the value of all preferences registered through `uigetpref` to `'ask'`. This causes the dialog box to display when you call `uigetpref`.

Note Use `setpref` to set the value of a particular preference to `'ask'`.

See Also `setpref`, `uigetpref`

Purpose

Reorder visual stacking order of objects

Syntax

```
uistack(h)
uistack(h,stackopt)
uistack(h,stackopt,step)
```

Description

`uistack(h)` raises the visual stacking order of the objects specified by the handles in `h` by one level (`step` of 1). All handles in `h` must have the same parent.

`uistack(h,stackopt)` moves the objects specified by `h` in the stacking order, where *`stackopt`* is one of the following:

- `'up'` – moves `h` up one position in the stacking order
- `'down'` – moves `h` down one position in the stacking order
- `'top'` – moves `h` to the top of the current stack
- `'bottom'` – moves `h` to the bottom of the current stack

`uistack(h,stackopt,step)` moves the objects specified by `h` up or down the number of levels specified by `step`.

Note In a GUI, `axes` objects are always at a lower level than `uicontrol` objects. You cannot stack an `axes` object on top of a `uicontrol` object.

See "Setting Tab Order" in the MATLAB documentation for information about changing the tab order.

Example

The following code moves the child that is third in the stacking order of the figure handle `hObject` down two positions.

```
v = allchild(hObject)
uistack(v(3),'down',2)
```

uitable

Purpose

Create 2-D graphic table GUI component

Syntax

```
uitable
uitable('PropertyName1', value1,'PropertyName2',value2,...)
uitable(parent,...)
handle = uitable(...)
```

Description

`uitable` creates a 1-by-1 `uitable` object in the current figure window, using default property values. If no figure exists, a new figure window opens.

`uitable('PropertyName1', value1,'PropertyName2',value2,...)` creates a `uitable` object with specified property values. Properties that you do not specify assume the default property values. See the Uitable Properties reference page for information about the available properties.

`uitable(parent,...)` creates a `uitable` object as a child of the specified parent handle `parent`. The parent can be a figure or `uipanel` handle. If you also specify a different value for the `Parent` property, the value of the `Parent` property takes precedence.

`handle = uitable(...)` creates a `uitable` object and returns its handle.

After creating a `uitable` object, you can set and query its property values using the `set` and `get` functions.

Remarks

Users can change values in a table if the `ColumnEditable` property is true for the column they attempt to edit. By default, this property is false for all columns. If the column contains pop-up choices, only the current choice is visible (and not the pop-up menu control) when its column cannot be edited.

After editing a value, the edited value is displayed and the `CellEditCallback` fires when the user does any of the following:

- Types **Enter**
- Clicks another table cell

- Clicks anywhere else within the table
- Clicks another control or area within the same figure window

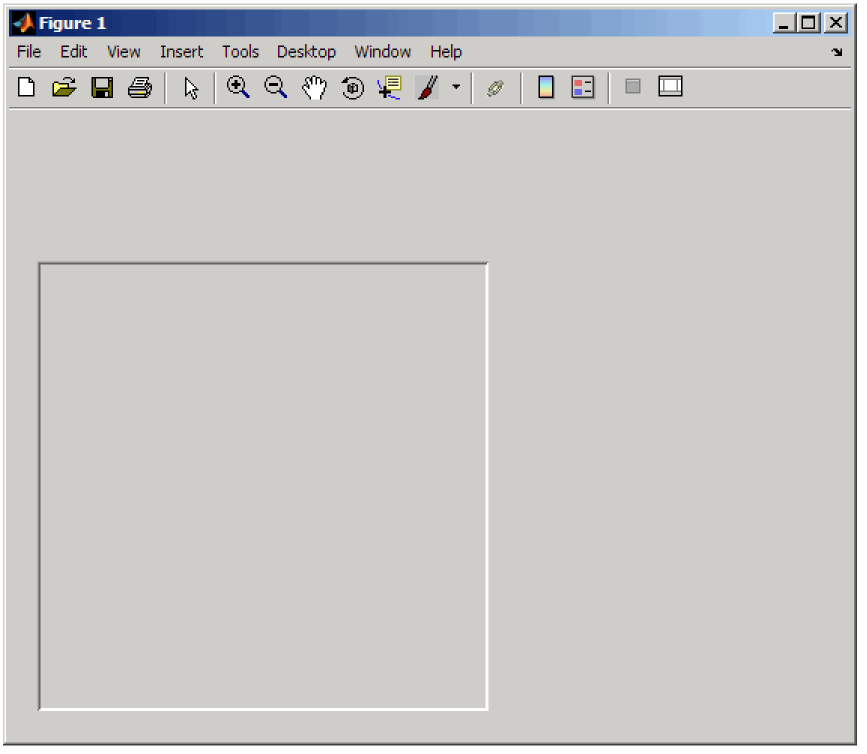
However, the `CellEditCallback` does not fire if the user edits a cell and clicks in another figure window or desktop tool. If the user then returns to the table to edit a different cell, the previous `CellEditCallback` still does not fire. Even though the table displays the results of the previous edit, the underlying data matrix (the table's `Data` property) is not updated to contain the value that appears in the cell.

Examples

Example 1

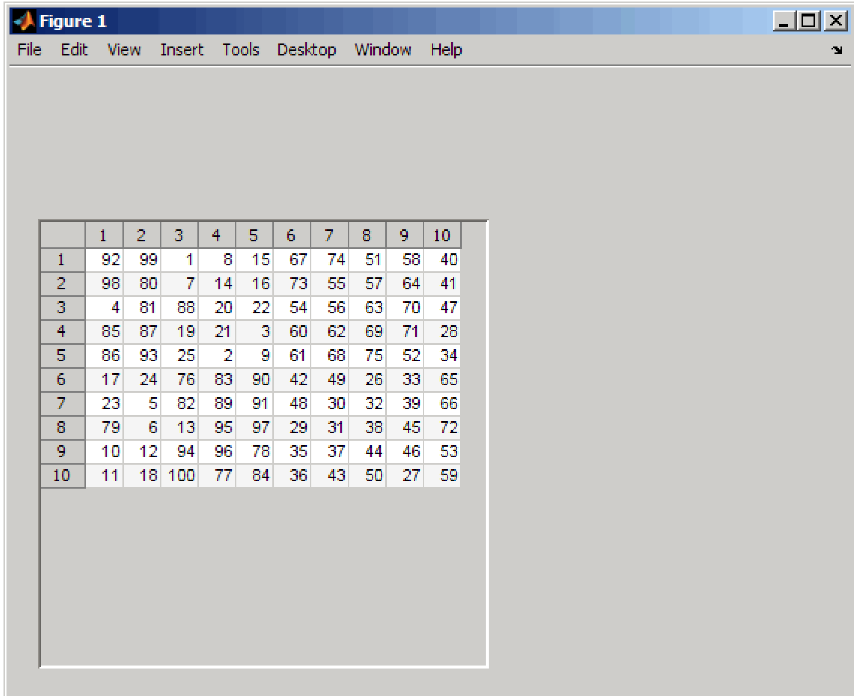
This example creates atable in the current figure. If no figure exists, one is created.

```
t = uitable;
```



As the table has no content (its `Data` property is empty), it initially displays no rows or columns. Provide data (a magic square), and set column widths to 25 pixels uniformly to make the entire table visible.

```
set(t,'Data',magic(10))
set(t,'ColumnWidth',{25})
```



The uitable `ColumnWidth` property is specified as a cell array. It can contain:

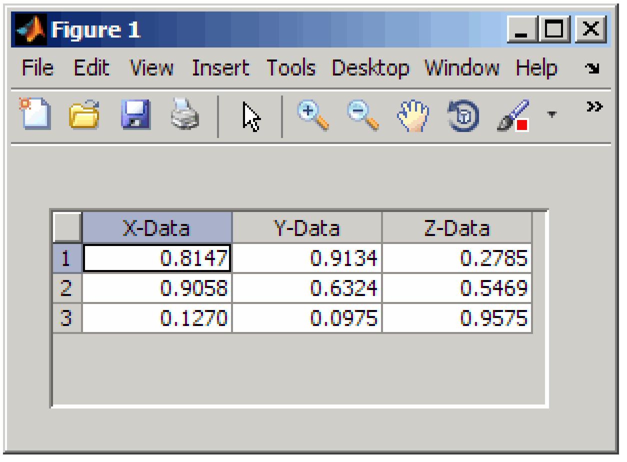
- One number (a width measured in pixels) or the string `'auto'`
- A cell array containing a list of pixel sizes having up to as many entries as the table has columns

If a list has `n` entries, where `n` is smaller than the number of columns, it sets the first `n` column widths only. You can substitute `'auto'` for any value in the cell array to have the width of that column calculated automatically.

Example 2

This example creates a table with a 3-by-3 data matrix. This example specifies the column names, parent, and position of the table:

```
f = figure('Position',[100 100 300 150]);
dat = rand(3);
cnames = {'X-Data','Y-Data','Z-Data'};
t = uitable('Data',dat,'ColumnName',cnames,...
            'Parent',f,'Position',[20 20 250 100]);
```

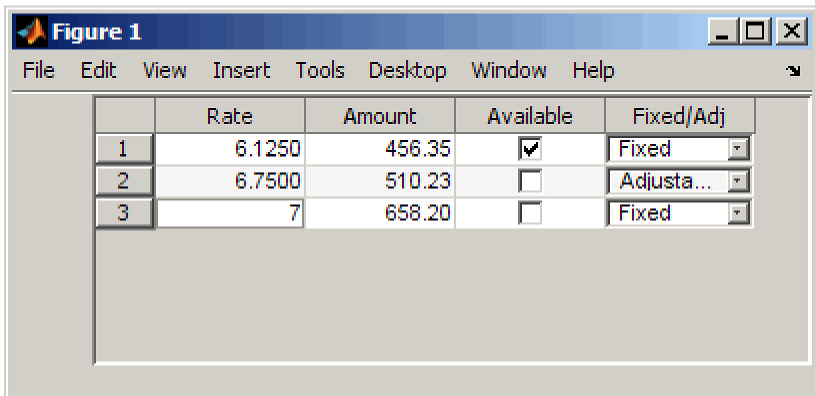


Example 3

This example creates a table with a 3-by-4 array that contains numeric, logical, and string data in the following columns:

- First column (**Rate**): Numeric, with three decimals (not editable)
- Second column (**Amount**): Currency (not editable)
- Third column (**Available**): Check box (editable)
- Fourth column (**Fixed/Adj**): Pop-up menu with two choices: `Fixed` and `Adjustable` (editable)

```
f = figure('Position',[100 100 400 150]);
dat =  {6.125, 456.3457, true,  'Fixed';...
        6.75,  510.2342, false, 'Adjustable';...
        7,     658.2,    false, 'Fixed';};
columnname =   {'Rate', 'Amount', 'Available', 'Fixed/Adj'};
columnformat = {'numeric', 'bank', [], {'Fixed' 'Adjustable'}};
columneditable =  [false false true true];
t = uitable('Units','normalized','Position',...
            [0.1 0.1 0.9 0.9], 'Data', dat,...
            'ColumnName', columnname,...
            'ColumnFormat', columnformat,...
            'ColumnEditable', columneditable);
```



For more information about working with uitables, see the following examples in the MATLAB Creating Graphical User Interfaces documentation:

- "GUI to Interactively Explore Data in a Table" (GUIDE example)
- "GUI that Displays and Graphs Tabular Data" (programmatic example)

See Also

`figure`, `format`, `inspect`, `uicontrol`, `uimenu`, `uipanel`

Uitable Properties

Purpose

Describe table properties

Modifying Properties

You can set and query graphics object properties in two ways:

- The Property Inspector is an interactive tool that enables you to see and change object property values. The Property inspector is available from GUIDE, or use the `inspect` function at the command line.
- The `set` and `get` functions enable you to set and query the values of properties.

You can set default uitable properties by typing:

```
set(h,'DefaultUitablePropertyName',PropertyValue...)
```

Where `h` can be the root handle (`0`), a figure handle, or a uitable handle. *`PropertyName`* is the name of the uitable property and `PropertyValue` is the value you specify as the default for that property.

For more information about changing the default value of a property see "Setting Default Property Values". For an example, see the `CreateFcn` property.

Uitable Properties

This section lists all properties useful to `uitable` objects along with valid values and descriptions of their use. In the property descriptions, curly braces { } enclose default values.

Property Name	Description
`BackgroundColor`	Background color of cells.
`BeingDeleted`	This object is being deleted.
`BusyAction`	Callback routine interruption
`ButtonDownFcn`	Button-press callback routine

Property Name	Description
CellEditCallback	Callback when data in a cell is changed.
CellSelectionCallback	Callback when cell is selected
Children	uitable objects have no children
Clipping	Does not apply to uitable objects
ColumnEditable	Determines data in a column as editable
ColumnFormat	Determines display and editablility of columns
ColumnName	Column header label
ColumnWidth	Width of each column in pixels
CreateFcn	Callback routine during object creation
Data	Table data
DeleteFcn	Callback routine during object deletion
Enable	Enable or disable the uitable
Extent	Size of uitable rectangle
FontAngle	Character slant of cell content
FontName	Font family for cell content
FontSize	Font size of cell content
FontUnits	Font size units for cell content
FontWeight	Weight of cell text characters
ForegroundColor	Color of text in cells
HandleVisibility	Control access to object's handle
HitTest	Selectable by mouse click
Interruptible	Callback routine interruption mode
KeyPressFcn	Key press callback function

Property Name	Description
Parent	uitable parent
Position	Size and location of uitable
RearrangeableColumn	Location of the column
RowName	Row header label names
RowStriping	Color striping of label rows
Selected	Is object selected?
SelectionHighlight	Object highlight when selected
Tag	Use-specified object label
TooltipString	Content of tooltip for object
Type	Class of graphics object
UIContextMenu	Associate context menu with uitable
Units	Units of measurement
UserData	User-specified data
Visible	uitable visibility

BackgroundColor
2-by-3 matrix of RGB triples

Cell background color. Color used to fill the uitable cells. Specify as an 2-by-3 matrix of RGB triples, such as [1 1.9; .9 1 1]. Each row is an RGB triplet of real numbers between 0.0 and 1.0 that defines one color. The default is a 1–by-3 matrix of platform-dependent colors. See ColorSpec for information about RGB colors.

Row 2 and subsequent rows of the matrix are used only if the `RowStriping` property is `on`.

`BeingDeleted`

`on | {off}` (read-only)

This object is being deleted. The `BeingDeleted` property provides a mechanism that you can use to determine if objects are in the process of being deleted. MATLAB software sets the `BeingDeleted` property to `on` when the object's delete function callback is called (see the `DeleteFcn` property) It remains set to `on` while the delete function executes, after which the object no longer exists.

For example, some functions may not need to perform actions on objects that are being deleted, and therefore, can check the object's `BeingDeleted` property before acting.

`BusyAction`

`cancel | {queue}`

Callback routine interruption. If a callback is executing and the user triggers an event (such as a mouse click) on an object for which a callback is defined, the callback associated with the new event uses the value of `BusyAction` to decide whether or not to attempt to interrupt the executing callback.

- If the value is `cancel`, the new event is discarded and the second callback does not execute.
- If the value is `queue`, and the `Interruptible` property of the first callback is `on`, the second callback is added to the event queue and executes in its turn after the first callback finishes execution.

Note If the interrupting callback is `DeleteFcn` or `CreateFcn` or a figure's `CloseRequest` or `ResizeFcn` callback, it interrupts an executing callback regardless of the value of that object's `Interruptible` property. See the `Interruptible` property for information about controlling a callback's interruptibility.

`ButtonDownFcn`
string or function handle (GUIDE sets this property)

Button-press callback routine. A callback routine that can execute when you press a mouse button while the pointer is on or near a `uitable`. Specifically:

- If the `uitable` `Enable` property is set to `on`, the `ButtonDownFcn` callback executes when you click the right or left mouse button in a 5-pixel border around the `uitable` or when you click the right mouse button on the control itself.
- If the `uitable` `Enable` property is set to `inactive` or `off`, the `ButtonDownFcn` executes when you click the right or left mouse button in the 5-pixel border or on the control itself.

This is useful for implementing actions to interactively modify control object properties, such as size and position, when they are clicked on (using the `selectmoveresize` function, for example).

Define this routine as a string that is a valid MATLAB expression or the name of an M-file. The expression executes in the MATLAB workspace.

To add a `ButtonDownFcn` callback in GUIDE, select **View Callbacks** from the Layout Editor **View** menu, then select `ButtonDownFcn`. GUIDE sets this property to the appropriate string and adds the callback to the M-file the next time you save the GUI. Alternatively, you can set this property to the string `%automatic`. The next time you save the GUI, GUIDE sets this property to the appropriate string and adds the callback to the M-file.

`CellEditCallback`

function handle, cell array containing function handle and additional arguments, or string (not recommended)

Callback to edit user-entered data

Callback function executed when the user modifies a table cell. It can perform evaluations, validations, or other customizations. If this function is called as a function handle, `uitable` passes it two arguments. The first argument, `source`, is the handle of the `uitable`. The second argument, `eventdata`, is an event data structure that contains the fields shown in the following table. All fields in the event data structure are read only.

Event Data Structure Field	Type	Description
`Indices`	1-by-2 matrix	Row index and column index of the cell the user edited.
`PreviousData`	1-by-1 matrix or cell array	Previous data for the changed cell. The default is an empty matrix, `[]`.
`EditData`	String	User-entered string.

Event Data Structure Field	Type	Description
NewData	1-by-1 matrix or cell array	Value that uitable wrote to Data. It is either the same as EditData or a converted value, for example, 2 where EditData is '2' and the cell is numeric. Empty if uitable detected an error in the user-entered data and did not write it to Data.
Error	String	Error that occurred when uitable tried to convert the EditData string into a value appropriate for Data. For example, uitable could not convert the EditData string consistent with the Column Format property, if any, or the data type for the changed cell. Empty if uitable wrote the value to Data. If Error is not empty, the CellEditCallback can pass the error string to the user or can attempt to manipulate the data. For example, the string 'pi' would raise an error in a numeric cell but the CellEditCallback could convert it to its numerical equivalent and store it in Data without passing the error to the user.

When a user edits a cell, uitable first attempts to store the user-entered value in Data, converting the value if necessary. It then calls the CellEditCallback and passes it the event data structure. If there is no CellEditCallback and the user-entered data results it an error, the contents of the cell reverts to its previous value and no error is displayed.

Note In order for the `CellEditCallback` to be issued, after modifying a table cell the user must hit **Enter** or click somewhere else within the figure containing the table. Editing a cell's value and then clicking another figure or other window does not save the new value to the data table, and does not fire the `CellEditCallback`.

`CellSelectionCallback`

function handle, cell array containing function handle and additional arguments, or string (not recommended)

Callback that executes when cell is selected. Callback function that executes when the user highlights a cell by navigating to it or clicking it. For multiple selection, this callback executes when new cells are added to the selection.

`Children`

matrix

The empty matrix; `uitable` objects have no children.

`Clipping`

`{on} | off`

This property has no effect on `uitable` objects.

`ColumnEditable`

logical 1–by-n matrix | scalar logical value |{ empty matrix (`[]`)}

Determines if column is user-editable.

Determines if the data can be edited by the end user. Each value in the cell array corresponds to a column. False is default because the developer needs to have control over changes users potentially might make to data.

Specify elements of a logical matrix as true if the data in a column is editable by the user or false if it is not. An empty matrix indicates that no columns are editable.

Columns that contain check boxes or pop-up menus must be editable for the user to manipulate these controls. If a column that contains pop-up menus is not editable, the currently selected choice appears without displaying the pop-up control. The Elements of the ColumnEditable matrix must be in the same order as columns in the Data property. If you do not specify ColumnEditable, the default is an empty matrix ([]).

ColumnFormat
cell array of strings

Cell display formatting. Determines how the data in each column displays and is edited. Elements of the cell array must be in the same order as table columns in the Data property. If you do not want to specify a display format for a particular column, enter [] as a placeholder. If no format is specified for a column, the default display is determined by the data type of the data in the cell. Default ColumnFormat is an empty cell array ({}). In most cases, the default is similar to the command window.

Elements of the cell array must be one of the strings described in the following table.

Cell Format	Description
'char'	Displays a left-aligned string. To edit, the user types a string that replaces the existing string.

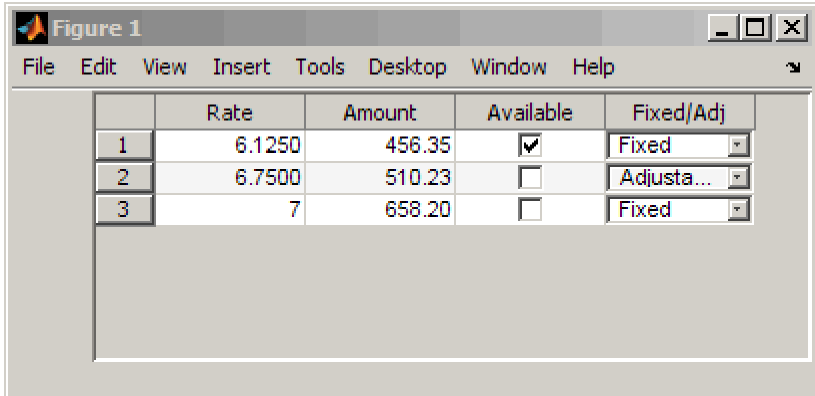
Cell Format	Description
`'logical'`	Displays a check box. To edit, the user checks or unchecks the check box. `uitable` sets the corresponding `Data` value to `true` or `false` accordingly. Initially, the check box is checked if the corresponding `Data` value would produce
`'numeric'`	Displays a right-aligned string equivalent to the command window, for numeric data. If the cell `Data` value is boolean, then 1 or 0 is displayed. If the cell `Data` value is not numeric and not boolean, then `NaN` is displayed. To edit, the user can enter any string. This enables a user to enter a value such as `'pi'` that can be converted to its numeric equivalent by a `CellEditCallback`. The `uitable` function first attempts to convert the user-entered string to a numeric value and store it in `Data`. It then calls the `CellEditCallback`. See `CellEditCallback` for more information.

Cell Format	Description
1–by-n cell array of strings that define a pop-up menu, e.g., {'one' 'two' 'three'}	Displays a pop-up menu. To edit, the user makes a selection from the pop-up menu. uitable sets the corresponding Data value to the selected menu item. The initial values for the pop-up menus in the column are the corresponding strings in Data. These initial values do not have to be items in the pop-up menu. See Example 3 on the uitable reference page.
Valid string accepted by the format function, e.g.,'format short', '$ FORMAT BANK USD'	Displays the Data value using the specified format.

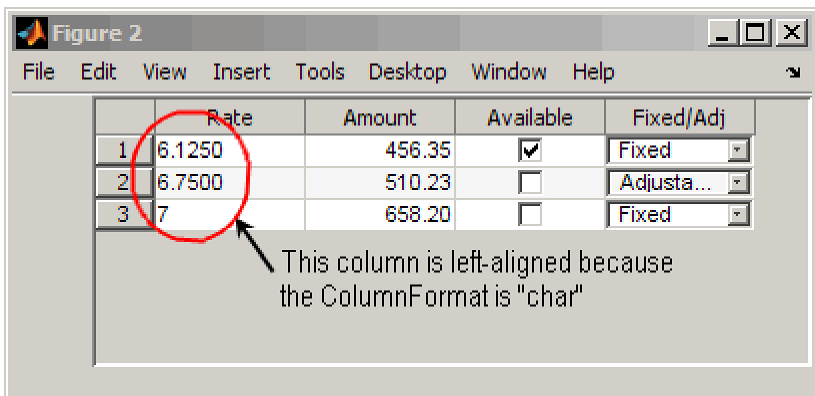
In some cases, you may need to insert an appropriate column in Data. If Data is a numerical or logical matrix, you must first convert it to a cell array using the mat2cell function.

Data and ColumnFormat

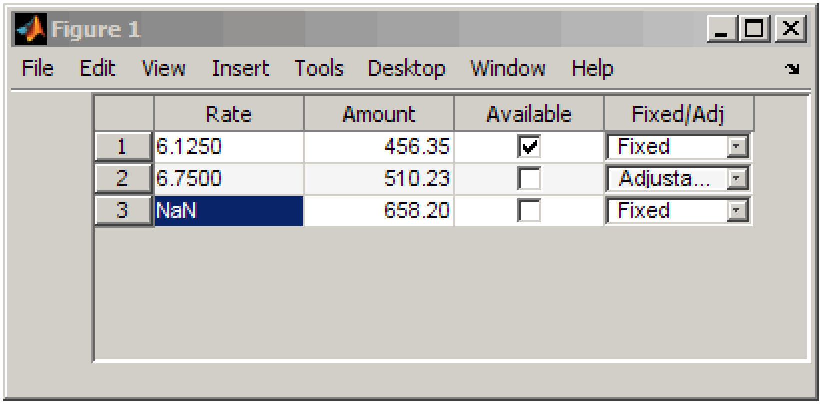
When you create a table, you must specify value of Data. The Data property dictates what type of data can exist in any given cell. By default, the value of the Data also dictates the display of the cell to the end user, unless you specify a different format using the ColumnFormat property.



`ColumnFormat` controls the presentation of the `Data` to the end user. Therefore, if you specify a `ColumnFormat` of `char` (or pick **Text** from the Table Property Editor), you are asking the table to display the `Data` associated with that column as a string. For example, if the `Data` for a particular column is `numeric`, and you specify the `ColumnFormat` as `char`, then the display of the numeric data will be left-aligned



If your column is editable and the user enters a number, the number will be left-aligned. However, if the user enters a text string, the table displays a **NaN**.



Another possible scenario is that the value `Data` is `char` and you set the `ColumnFormat` to be a pop-up menu. Here, if the value of the `Data` in the cell matches one of the pop-up menu choices you define in `ColumnFormat`, then the `Data` is shown in the cell. If it does not match, then the cell defaults to display the first option from the choices you specify in `ColumnFormat`. Similarly, if `Data` is numeric or logical with the `ColumnFormat` as pop-up menu, if the `Data` value in the cell does not match any of the choices you specify in `ColumnFormat`, the cell defaults to display the first option in the pop-menu choice.

This table describes how `Data` values correspond with your `ColumnFormat` when the columns are editable.

	`ColumnFormat` Selections		
	`numeric`	`char`	`logical`

Data Type	`numeric`	Values match. MATLAB displays numbers as is.	MATLAB converts the text string entered to a double. See `str2double` for more information. If string cannot be converted, **NaN** is displayed.	Does not work: warning is thrown. **Note** If you have defined `CellEditCallback`, this warning will not be thrown
	`char`	MATLAB converts the entered number to a text string.	Values match. MATLAB displays the string as is.	Does not work: warning is thrown. **Note** If you have defined `CellEditCallback`, this warning will not be thrown
	`logical`	Does not work: warning is thrown. **Note** If you have defined `CellEditCallback`, this warning will not be thrown	If text string entered is `true` or `false`, MATLAB converts string to the corresponding logical value and displays it. For all others, it Does not work: warning is thrown. **Note** If you have defined `CellEditCallback`, this warning will not be thrown	Values match. MATLAB displays logical value as a check box as is.

If you get a mismatch error, you have the following options:

- Change the `ColumnFormat` or value of `Data` to match.
- Implement the `CellEditCallback` to handle custom data conversion.

`ColumnName`

1–by-*n* cell array of strings | {`'numbered'`} | empty matrix (`[]`)

Column heading names. Each element of the cell array is the name of a column. Multiline column names can be expressed as a string vector separated by vertical slash (`|`) characters, e.g.,`'Standard|Deviation'`

For sequentially numbered column headings starting with `1`, specify `ColumnName` as `'numbered'`. This is the default.

To remove the column headings, specify `ColumnName` as the empty matrix (`[]`).

The number of columns in the table is the larger of `ColumnName` and the number of columns in the `Data` property matrix or cell array.

`ColumnWidth`

1–by-*n* cell array or `'auto'`

Column widths. The width of each column in units of pixels. Column widths are always specified in pixels; they do not obey the `Units` property. Each column in the cell array corresponds to a column in the uitable. By default, the width of the column name, as specified in `ColumnName`, along with some other factors, is used to determine the width of a column. If `ColumnWidth` is a cell array and the width of a column is set to `'auto'`or if **auto** is selected for that column in the Property Inspector GUI for columns, the column width defaults to a size determined by the table. The table decides the default size using a number of factors, including the `ColumnName` and the minimum column size.

To default all column widths in an existing table, use

```
set(uitable_handle,'ColumnWidth','auto')
```

To default some column widths but not others, use a cell array containing a mixture of pixel values and `'auto'`. For example,

```
set(uitable_handle,'ColumnWidth',{64 'auto' 40 40 'auto' 72})
```

`CreateFcn`
string or function handle

Callback routine executed during object creation. The specified function executes when MATLAB creates a `uitable` object. MATLAB sets all property values for the uitable before executing the `CreateFcn` callback so these values are available to the callback. Within the function, use `gcbo` to get the handle of the uitable being created.

Setting this property on an existing uitable object has no effect.

You can define a default `CreateFcn` callback for all new uitables. This default applies unless you override it by specifying a different `CreateFcn` callback when you call `uitable`. For example, the code

```
set(0,'DefaultUitableCreateFcn','set(gcbo,...
    ''BackGroundColor'',''blue'')')
```

creates a default `CreateFcn` callback that runs whenever you create a new uitable. It sets the default background color of all new uitables.

To override this default and create a uitable whose `BackgroundColor` is set to a different value, call `uitable` with code similar to

```
hpt = uitable(...,'CreateFcn','set(gcbo,...
''BackgroundColor'',''white'')')
```

Note To override a default CreateFcn callback you must provide a new callback and not just provide different values for the specified properties. This is because the CreateFcn callback runs after the property values are set, and can override property values you have set explicitly in the uitable call. In the example above, if instead of redefining the CreateFcn property for this uitable, you had explicitly set BackgroundColor to white, the default CreateFcn callback would have set BackgroundColor back to the default, i.e., blue.

Do not call copyobj or textwrap (which calls copyobj) inside a CreateFcn. The act of copying the uicontrol object fires the CreateFcn repeatedly, which raises a series of error messages after exceeding the root object's RecursionLimit property.

See "Function Handle Callbacks" for information on how to use function handles to define a callback function.

Data

matrix or cell array of numeric, logical, or character data

Data content of uitable. The matrix or cell array must be 2–dimensional. A cell array can mix data types.

Use get and set to modify Data. For example,

```
data = get(tablehandle,'Data')
data(event.indices(1),event.indices(2)) = pi();
set(tablehandle,'Data',data);
```

See CellEditCallback for information about the event data structure. See ColumnFormat for information about specifying the data display format.

The number of rows in the table is the larger of `RowName` and the number of rows in `Data`. The number of columns in the table is the larger of `ColumnName` and the number of columns in `Data`.

`DeleteFcn`

string or function handle

Delete uitable callback routine. A callback routine that executes when you delete the `uitable` object (e.g., when you issue a `delete` command or clear the figure containing the `uitable`). MATLAB executes the routine before destroying the object's properties so these values are available to the callback routine.

The handle of the object whose `DeleteFcn` is being executed is accessible only through the root CallbackObject property, which you can query using `gcbo`.

See "Function Handle Callbacks" for information on how to use function handles to define a callback function.

`Enable`

`{on} | inactive | off`

Enable or disable the uitable. This property determines how uitables respond to mouse button clicks, including which callback routines execute.

- `on` – The uitable is operational (the default).
- `inactive` – The uitable is not operational, but looks the same as when `Enable` is `on`.
- `off` – The uitable is not operational and its image is grayed out.

When you left-click on a uitable whose `Enable` property is `on`, MATLAB performs these actions in this order:

1 Sets the figure's `SelectionType` property.

2 Executes the uitable's `CellSelectionCallback` routine (but only for table cells, not header cells). Row and column indices of the cells the user selects continuously update the `Indices` field in the `eventdata` passed to the callback.

3 Does not set the figure's `CurrentPoint` property and does not execute either the table's `ButtonDownFcn` or the figure's `WindowButtonDownFcn` callback.

When you left-click on a uitable whose `Enable` property is `off`, or when you right-click a uitable whose `Enable` property has any value, MATLAB performs these actions in this order:

1 Sets the figure's `SelectionType` property.

2 Sets the figure's `CurrentPoint` property.

3 Executes the figure's `WindowButtonDownFcn` callback.

`Extent`

position rectangle (read only)

Size of uitable rectangle. A four-element vector of the form `[0,0,width,height]` that contains the calculated values of the largest extent of the table based on the current `Data`, `RowNames` and `ColumnNames` property values. Calculation depends on column and row widths, when they are available. The calculated extent can be larger than the figure.

The first two elements are always zero. `width` and `height` are the dimensions of the rectangle. All measurements are in units specified by the `Units` property.

When the uitable's `Units` property is set to `'Normalized'`, its `Extent` is measured relative to the figure, regardless of whether the table is contained in (parented to) a uipanel or not.

You can use this property to determine proper sizing for the uitable with respect to its content. Do this by setting the `width` and `height` of the uitable `Position` property to the width and height of the `Extent` property. However, doing this can cause the table to extend beyond the right or top edge of the figure and/or its uipanel parent, if any, for tables with large extents.

`FontAngle`

`{normal} | italic | oblique`

Character slant of cell content. MATLAB uses this property to select a font from those available on your particular system. Setting this property to `italic` or `oblique` selects a slanted version of the font, when it is available on your system.

`FontName`

string

Font family for cell content. The name of the font in which to display cell content. To display and print properly, this must be a font that your system supports. The default font is system dependent.

To use a fixed-width font that looks good in any locale (and displays properly in Japan, where multibyte character sets are used), set `FontName` to the string `FixedWidth` (this string value is case sensitive):

```
set(uitable_handle,'FontName','FixedWidth')
```

This parameter value eliminates the need to hard code the name of a fixed-width font, which may not display text properly on systems that do not use ASCII character encoding (such as in Japan). A properly written MATLAB application that needs to use a fixed-width font should set `FontName` to `FixedWidth` and rely on the root `FixedWidthFontName` property to be set correctly in the end user's environment.

End users can adapt a MATLAB application to different locales or personal environments by setting the root `FixedWidthFontName` property to the appropriate value for that locale from `startup.m`. Setting the root `FixedWidthFontName` property causes an immediate update of the display to use the new font.

`FontSize`
size in `FontUnits`

Font size for cell contents. A number specifying the size of the font in which to display cell contents, in units determined by the `FontUnits` property. The default point size is system dependent. If `FontUnits` is set to `normalized`, `FontSize` is a number between 0 and 1.

`FontUnits`
`{points} | normalized | inches |`
`centimeters | pixels`

Font size units for cell contents. This property determines the units used by the `FontSize` property. `Normalized` units interpret `FontSize` as a fraction of the height of the uitable. When you resize the uitable, MATLAB modifies the screen `FontSize` accordingly. `pixels`, `inches`, `centimeters`, and `points` are absolute units (1 point = $^1/_{72}$ inch).

`FontWeight`
`light | {normal} | demi | bold`

Weight of cell text characters. MATLAB uses this property to select a font from those available on your particular system. Setting this property to `bold` causes MATLAB to use a bold version of the font, when it is available on your system.

`ForegroundColor`
`1-by-3 matrix of RGB triples`

Color of text in cells. Determines the color of the text defined for cell contents. Specify as an n-by-3 matrix of RGB triples, such as `[0 0 .8; .8 0 0]`. Each row is an RGB triplet of real numbers between 0.0 and 1.0 that defines one color. The default is a 1–by-3 matrix of platform-dependent colors. See `ColorSpec` for information about RGB colors.

Row 2 and subsequent rows of the matrix are used only if the `RowStriping` property is `on`.

`HandleVisibility`

`{on} | callback | off`

Control access to object's handle. This property determines when an object's handle is visible in its parent's list of children. When a handle is not visible in its parent's list of children, it is not returned by functions that obtain handles by searching the object hierarchy or querying handle properties. This includes `get`, `findobj`, `gca`, `gcf`, `gco`, `newplot`, `cla`, `clf`, and `close`. Neither is the handle visible in the parent figure's `CurrentObject` property. Handles that are hidden are still valid. If you know an object's handle, you can `set` and `get` its properties, and pass it to any function that operates on handles.

- Handles are always visible when `HandleVisibility` is `on`.
- Setting `HandleVisibility` to `callback` causes handles to be visible from within callback routines or functions invoked by callback routines, but not from within functions invoked from the command line. This provides a means to protect GUIs from command-line users, while allowing callback routines to have complete access to object handles.
- Setting `HandleVisibility` to `off` makes handles invisible at all times. This may be necessary when a callback routine invokes a function that might potentially damage the GUI (such as evaluating a user-typed string), and so temporarily hides its own handles during the execution of that function.

You can set the root `ShowHiddenHandles` property to `on` to make all handles visible, regardless of their `HandleVisibility` settings. This does not affect the values of the `HandleVisibility` properties.

`HitTest`
`{on} | off`

Selectable by mouse click. When `HitTest` is `off`, the `ButtonDownFcn` callback does not execute.

`Interruptible`
`{on} | off`

Callback routine interruption mode. If a callback is executing and the user triggers an event (such as a mouse click) on an object for which a callback is defined, that callback attempts to interrupt the first callback. The MATLAB processes the callbacks according to these factors:

- The `Interruptible` property of the object whose callback is executing
- Whether the executing callback contains `drawnow`, `figure`, `getframe`, `pause`, or `waitfor` statements
- The `BusyAction` property of the object whose callback is waiting to execute

If the `Interruptible` property of the object whose callback is executing is `on` (the default), the callback can be interrupted. Whenever the callback calls one of the `drawnow`, `figure`, `getframe`, `pause`, or `waitfor` functions, the function processes any events in the event queue, including the waiting callback, before performing its defined task.

If the `Interruptible` property of the object whose callback is executing is `off`, the callback cannot be interrupted (except by certain callbacks; see the note below). The `BusyAction` property of the object whose callback is waiting to execute determines what happens to the callback.

Note If the interrupting callback is a `DeleteFcn` or `CreateFcn` callback or a figure's `CloseRequest` or `ResizeFcn` callback, it interrupts an executing callback regardless of the value of that object's `Interruptible` property. The interrupting callback starts execution at the next `drawnow`, `figure`, `getframe`, `pause`, or `waitfor` statement. A figure's `WindowButtonDownFcn` callback routine, or an object's `ButtonDownFcn` or `Callback` routine are processed according to the rules described above.

`KeyPressFcn`

string or function handle

Key press callback function. A callback routine invoked by a key press when the callback's uitable object has focus. Focus is denoted by a border or a dotted border, respectively, in UNIX and Microsoft Windows. If no uitable has focus, the figure's key press callback function, if any, is invoked. `KeyPressFcn` can be a function handle, the name of an M-file, or any legal MATLAB expression.

If the specified value is the name of an M-file, the callback routine can query the figure's `CurrentCharacter` property to determine what particular key was pressed and thereby limit the callback execution to specific keys.

If the specified value is a function handle, the callback routine can retrieve information about the key that was pressed from its event data structure argument.

Event Data Structure Field	Description	Examples:			
		a	=	Shift	Shift/a
`Character`	Character interpretation of the key that was pressed.	`'a'`	`'='`	`''`	`'A'`

Event Data Structure Field	Description	Examples:			
		a	=	Shift	Shift/a
Modifier	Current modifier, such as 'control', or an empty cell array if there is no modifier	{1x0 cell}	{1x0 cell}	{'shift'}	{'shift'}
Key	Name of the key that was pressed.	'a'	'equal'	'shift'	'a'

The uitable `KeyPressFcn` callback executes for all keystrokes, including arrow keys or when a user edits cell content.

See "Function Handle Callbacks" for information on how to use function handles to define the callback function.

`Parent`
handle

Uitable parent. The handle of the uitable's parent object. You can move a uitable object to another figure, uipanel, or uibuttongroup by setting this property to the handle of the new parent.

`Position`
position rectangle

Size and location of uitable. The rectangle defined by this property specifies the size and location of the table within the parent figure window, ui, or uibuttongroup. Specify `Position` as a 4–element vector:

```
[left bottom width height]
```

`left` and `bottom` are the distance from the lower-left corner of the parent object to the lower-left corner of the uitable object. `width` and `height` are the dimensions of the uitable rectangle. All measurements are in units specified by the `Units` property.

Note If you are specifying both `Units` and `Position` in the same call to `uitable`, specify `Units` first if you want `Position` to be interpreted using those units.

`RearrangeableColumn`

`on | {off}`

This object can be rearranged. The `RearrangeableColumn` property provides a mechanism that you can use to reorder the columns in the table. All columns are rearrangable when this property is turned on. MATLAB software sets the `RearrangeableColumn` property to `off` by default.

When this property is on, the user of a table can move any column of data (but not the row labels) at a time left or right to reorder it by clicking and dragging its header. Rearranging columns does not affect the ordering of columns in the table's `Data`, only the user's view of it.

`RowName`

1–by-n cell array of strings`|` {`'numbered'`} `|` empty matrix (`[]`)

Row heading names. Each element of the cell array is the name of a row. Multiline row names can be expressed as a string vector separated by vertical slash (`|`) characters, e.g.,`'Standard|Deviation'`

For sequentially numbered row headings starting with `1`, specify `RowName` as `'numbered'`. This is the default.

To remove the row headings, specify `RowName` as the empty matrix (`[]`).

The number of rows in the table is the larger of `RowName` and the number of rows in the `Data` property matrix or cell array.

`RowStriping`
`{on} | off`

Color striping of table rows. When `RowStriping` is `on`, consecutive rows of the table display in the colors you specify for the `BackgroundColor` and `ForegroundColor` properties. For both `BackgroundColor` and `ForegroundColor`, the first color applies to the first row, the second color to the second row, etc.

When `RowStriping` is `off`, the first color specified for both `BackgroundColor` and `ForegroundColor` is used for all rows.

`Selected`
`on | {off}`

Is object selected. When this property is `on`, MATLAB displays selection handles if the `SelectionHighlight` property is also `on`. You can, for example, define the `ButtonDownFcn` to set this property, allowing users to select the object with the mouse.

`SelectionHighlight`
`{on} | off`

Object highlight when selected. When the `Selected` property is `on`, MATLAB indicates the selected state by drawing four edge handles and four corner handles. When `SelectionHighlight` is `off`, MATLAB does not draw the handles.

`Tag`
string (GUIDE sets this property)

User-specified object label. The `Tag` property provides a means to identify graphics objects with a user-specified label. This is particularly useful when constructing interactive graphics programs that would otherwise need to define object handles as global variables or pass them as arguments between callback routines. You can define `Tag` as any string.

`TooltipString`
string

Content of tooltip for object. The `TooltipString` property specifies the text of the tooltip associated with the uitable. When the user moves the mouse pointer over the table and leaves it there, the tooltip is displayed.

`Type`
string (read only)

Class of graphics object. For uitable objects, `Type` is always the string `'uitable'`.

`UIContextMenu`
handle

Associate a context menu with uitable. Assign this property the handle of a `uicontextmenu` object. MATLAB displays the context menu whenever you right-click over the uitable. Use the `uicontextmenu` function to create the context menu.

`Units`
`{pixels} | normalized | inches | centimeters | points | characters` (GUIDE default: `normalized`)

Units of measurement. MATLAB uses these units to interpret the `Extent` and `Position` properties. All units are measured from the lower-left corner of the parent object.

- `Normalized` units map the lower-left corner of the parent object to (0,0) and the upper-right corner to (1.0,1.0).
- `pixels`, `inches`, `centimeters`, and `points` are absolute units (1 point = 1/72 inch).
- `Character` units are characters using the default system font; the width of one character is the width of the letter x, the height of one character is the distance between the baselines of two lines of text.

If you change the value of `Units`, it is good practice to return it to its default value after completing your computation so as not to affect other functions that assume `Units` is set to the default value.

`UserData`

matrix

User-specified data. Any data you want to associate with the uitable object. MATLAB does not use this data, but you can access it using `set` and `get`.

`Visible`

`{on} | off`

Uitable visibility. By default, all uitables are visible. When set to `off`, the uitable is not visible, but still exists and you can query and set its properties.

Note Setting `Visible` to `off` for uitables that are not displayed initially in the GUI, can result in faster startup time for the GUI.

Purpose Create toggle button on toolbar

Syntax

```
htt = uitoggletool('PropertyName1',value1,'PropertyName2',
   value2,...)
htt = uitoggletool(ht,...)
```

Description

`htt = uitoggletool('PropertyName1',value1,'PropertyName2',value2,...)` creates a toggle button on the uitoolbar at the top of the current figure window, and returns a handle to it. `uitoggletool` assigns the specified property values, and assigns default values to the remaining properties. You can change the property values at a later time using the `set` function.

Type `get(htt)` to see a list of uitoggletool object properties and their current values. Type `set(htt)` to see a list of uitoggletool object properties you can set and legal property values. See the Uitoggletool Properties reference page for more information.

`htt = uitoggletool(ht,...)` creates a button with `ht` as a parent. `ht` must be a uitoolbar handle.

Remarks

`uitoggletool` accepts property name/property value pairs, as well as structures and cell arrays of properties as input arguments.

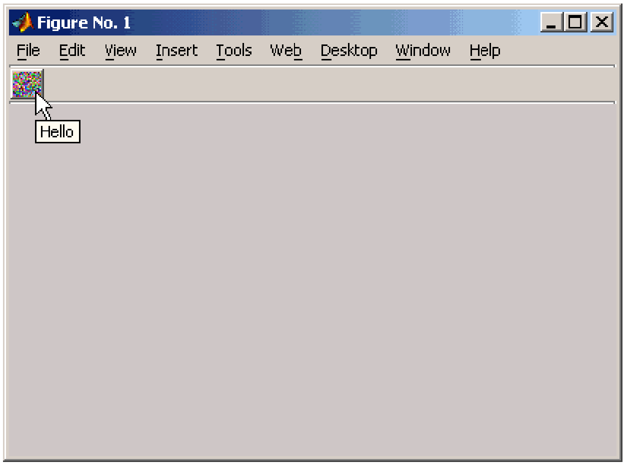
Toggle tools appear in figures whose `Window Style` is `normal` or `docked`. They do not appear in figures whose `WindowStyle` is `modal`. If the `WindowStyle` property of a figure containing a tool bar and its toggle tool children is changed to `modal`, the toggle tools still exist and are contained in the `Children` list of the tool bar, but are not displayed until the `WindowStyle` is changed to `normal` or `docked`.

Examples

This example creates a `uitoolbar` object and places a `uitoggletool` object on it.

```
h = figure('ToolBar','none');
ht = uitoolbar(h);
a = rand(16,16,3);
```

```
htt = uitoggletool(ht,'CData',a,'TooltipString','Hello');
```



See Also

get, set, uicontrol, uipushtool, uitoolbar

Purpose

Describe toggle tool properties

Modifying Properties

You can set and query graphics object properties in two ways:

- The Property Inspector is an interactive tool that enables you to see and change object property values. The Property inspector is available from GUIDE, or use the `inspect` function at the command line.
- The `set` and `get` functions enable you to set and query the values of properties.

You can set default Uitoggletool properties by typing:

```
set(h,'DefaultUitoggletoolPropertyName',PropertyValue...)
```

Where h can be the root handle (0), a figure handle, a uitoolbar handle, or a uitoggletool handle. *PropertyName* is the name of the Uitoggletool property and `PropertyValue` is the value you specify as the default for that property.

For more information about changing the default value of a property see "Setting Default Property Values".

Properties

This section lists all properties useful to `uitoggletool` objects along with valid values and a descriptions of their use. Curly braces { } enclose default values.

Property	Purpose
`BeingDeleted`	This object is being deleted.
`BusyAction`	Callback routine interruption.
`CData`	Truecolor image displayed on the toggle tool.
`ClickedCallback`	Control action independent of the toggle tool position.

Property	Purpose
`CreateFcn`	Callback routine executed during object creation.
`DeleteFcn`	Callback routine executed during object deletion.
`Enable`	Enable or disable the uitoggletool.
`HandleVisibility`	Control access to object's handle.
`HitTest`	Whether selectable by mouse click
`Interruptible`	Callback routine interruption mode.
`OffCallback`	Control action when toggle tool is set to the off position.
`OnCallback`	Control action when toggle tool is set to the on position.
`Parent`	Handle of uitoggletool's parent toolbar.
`Separator`	Separator line mode.
`State`	Uitoggletool state.
`Tag`	User-specified object label.
`TooltipString`	Content of object's tooltip.
`Type`	Object class.
`UIContextMenu`	Uicontextmenu object associated with the uitoggletool
`UserData`	User specified data.
`Visible`	Uitoggletool visibility.

`BeingDeleted`

`on | {off}` (read only)

This object is being deleted. The `BeingDeleted` property provides a mechanism that you can use to determine if objects are in the process of being deleted. MATLAB software sets the `BeingDeleted` property to `on` when the object's delete function callback is called (see the `DeleteFcn` property) It remains set to `on` while the delete function executes, after which the object no longer exists.

For example, some functions may not need to perform actions on objects that are being deleted, and therefore, can check the object's `BeingDeleted` property before acting.

`BusyAction`
`cancel | {queue}`

Callback routine interruption. If a callback is executing and the user triggers an event (such as a mouse click) on an object for which a callback is defined, the callback associated with the new event uses the value of `BusyAction` to decide whether or not to attempt to interrupt the executing callback.

- If the value is `cancel`, the event is discarded and the second callback does not execute.
- If the value is `queue`, and the `Interruptible` property of the first callback is `on`, the second callback is added to the event queue and executes in its turn after the first callback finishes execution.

Note If the interrupting callback is a `DeleteFcn` or `CreateFcn` callback or a figure's `CloseRequest` or `ResizeFcn` callback, it interrupts an executing callback regardless of the value of that object's `Interruptible` property. See the`Interruptible` property for information about controlling a callback's interruptibility.

`CData`
3-dimensional array

Truecolor image displayed on control. An *n*-by-*m*-by-3 array of RGB values that defines a truecolor image displayed on either a push button or toggle button. Each value must be between 0.0 and 1.0. If your `CData` array is larger than 16 in the first or second dimension, it may be clipped or cause other undesirable effects. If the array is clipped, only the center 16-by-16 part of the array is used.

`ClickedCallback`

string or function handle

Control action independent of the toggle tool position. A routine that executes after either the `OnCallback` routine or `OffCallback` routine runs to completion. The uitoggletool's `Enable` property must be set to `on`.

`CreateFcn`

string or function handle

Callback routine executed during object creation. The specified function executes when MATLAB creates a uitoggletool object. MATLAB sets all property values for the uitoggletool before executing the `CreateFcn` callback so these values are available to the callback. Within the function, use `gcbo` to get the handle of the toggle tool being created.

Setting this property on an existing uitoggletool object has no effect.

You can define a default `CreateFcn` callback for all new uitoggletools. This default applies unless you override it by specifying a different `CreateFcn` callback when you call `uitoggletool`. For example, the statement,

```
set(0,'DefaultUitoggletoolCreateFcn',...
    'set(gcbo,''Enable'',''off'')'
```

creates a default `CreateFcn` callback that runs whenever you create a new toggle tool. It sets the toggle tool `Enable` property to `off`.

To override this default and create a toggle tool whose `Enable` property is set to `on`, you could call `uitoggletool` with code similar to

```
htt = uitoggletool(...,'CreateFcn',...
                 'set(gcbo,''Enable'',''on'')',...)
```

Note To override a default `CreateFcn` callback you must provide a new callback and not just provide different values for the specified properties. This is because the `CreateFcn` callback runs after the property values are set, and can override property values you have set explicitly in the `uitoggletool` call. In the example above, if instead of redefining the `CreateFcn` property for this toggle tool, you had explicitly set `Enable` to `on`, the default `CreateFcn` callback would have set `CData` back to `off`.

Do not call `copyobj` or `textwrap` (which calls `copyobj`) inside a `CreateFcn`. The act of copying the uicontrol object fires the `CreateFcn` repeatedly, which raises a series of error messages after exceeding the root object's `RecursionLimit` property.

See Function Handle Callbacks for information on how to use function handles to define a callback function.

`DeleteFcn`

string or function handle

Callback routine executed during object deletion. A callback routine that executes when you delete the uitoggletool object (e.g., when you call the `delete` function or cause the figure containing the uitoggletool to reset). MATLAB executes the routine before destroying the object's properties so these values are available to the callback routine.

The handle of the object whose `DeleteFcn` is being executed is accessible only through the root `CallbackObject` property, which you can query using `gcbo`.

See Function Handle Callbacks for information on how to use function handles to define a callback function.

`Enable`

{on} | off

Enable or disable the uitoggletool. This property controls how uitoggletools respond to mouse button clicks, including which callback routines execute.

- `on` – The uitoggletool is operational (the default).
- `off` – The uitoggletool is not operational and its image (set by the `Cdata` property) is grayed out.

When you left-click on a uitoggletool whose `Enable` property is `on`, MATLAB performs these actions in this order:

1. Sets the figure's `SelectionType` property.
2. Executes the toggle tool's `ClickedCallback` routine.
3. Does not set the figure's `CurrentPoint` property and does not execute the figure's `WindowButtonDownFcn` callback.

When you left-click on a uitoggletool whose `Enable` property is `off`, or when you right-click a uitoggletool whose `Enable` property has any value, MATLAB performs these actions in this order:

4. Sets the figure's `SelectionType` property.
5. Sets the figure's `CurrentPoint` property.
6. Executes the figure's `WindowButtonDownFcn` callback.

7 Does not execute the toggle tool's `OnCallback`, `OffCallback`, or `ClickedCallback` routines.

`HandleVisibility`

`{on} | callback | off`

Control access to object's handle. This property determines when an object's handle is visible in its parent's list of children. When a handle is not visible in its parent's list of children, it is not returned by functions that obtain handles by searching the object hierarchy or querying handle properties. This includes `get`, `findobj`, `gca`, `gcf`, `gco`, `newplot`, `cla`, `clf`, and `close`. Neither is the handle visible in the parent figure's `CurrentObject` property. Handles that are hidden are still valid. If you know an object's handle, you can `set` and `get` its properties, and pass it to any function that operates on handles.

- Handles are always visible when `HandleVisibility` is `on`.
- Setting `HandleVisibility` to `callback` causes handles to be visible from within callback routines or functions invoked by callback routines, but not from within functions invoked from the command line. This provides a means to protect GUIs from command-line users, while allowing callback routines to have complete access to object handles.
- Setting `HandleVisibility` to `off` makes handles invisible at all times. This may be necessary when a callback routine invokes a function that might potentially damage the GUI (such as evaluating a user-typed string), and so temporarily hides its own handles during the execution of that function.

You can set the root `ShowHiddenHandles` property to on to make all handles visible, regardless of their `HandleVisibility` settings. This does not affect the values of the `HandleVisibility` properties.

`HitTest`

`{on} | off`

Selectable by mouse click. This property has no effect on uitoggletool objects.

`Interruptible`
`{on} | off`

Callback routine interruption mode. If a callback is executing and the user triggers an event (such as a mouse click) on an object for which a callback is defined, that callback attempts to interrupt the first callback. MATLAB processes the callbacks according to these factors:

- The `Interruptible` property of the object whose callback is executing
- Whether the executing callback contains `drawnow`, `figure`, `getframe`, `pause`, or `waitfor` statements
- The `BusyAction` property of the object whose callback is waiting to execute

If the `Interruptible` property of the object whose callback is executing is `on` (the default), the callback can be interrupted. Whenever the callback calls one of the `drawnow`, `figure`, `getframe`, `pause`, or `waitfor` functions, the function processes any events in the event queue, including the waiting callback, before performing its defined task.

If the `Interruptible` property of the object whose callback is executing is `off`, the callback cannot be interrupted (except by certain callbacks; see the note below).

Note If the interrupting callback is a `DeleteFcn` or `CreateFcn` callback or a figure's `CloseRequest` or `ResizeFcn` callback, it interrupts an executing callback regardless of the value of that object's `Interruptible` property. The interrupting callback starts execution at the next `drawnow`, `figure`, `getframe`, `pause`, or `waitfor` statement.

`OffCallback`
string or function handle

Control action. A routine that executes if the uitoggletool's `Enable` property is set to `on`, and either

- The toggle tool `State` is set to `off`.
- The toggle tool is set to the `off` position by pressing a mouse button while the pointer is on the toggle tool itself or in a 5-pixel wide border around it.

The `ClickedCallback` routine, if there is one, runs after the `OffCallback` routine runs to completion.

`OnCallback`
string or function handle

Control action. A routine that executes if the uitoggletool's `Enable` property is set to `on`, and either

- The toggle tool `State` is set to `on`.
- The toggle tool is set to the `on` position by pressing a mouse button while the pointer is on the toggle tool itself or in a 5-pixel wide border around it.

The `ClickedCallback` routine, if there is one, runs after the `OffCallback` routine runs to completion.

`Parent`
handle

Uitoggletool parent. The handle of the uitoggletool's parent toolbar. You can move a uitoggletool object to another toolbar by setting this property to the handle of the new parent.

`Separator`
`on | {off}`

Separator line mode. Setting this property to `on` draws a dividing line to left of the uitoggletool.

`State`
`on | {off}`

Uitoggletool state. When the state is `on`, the toggle tool appears in the down, or pressed, position. When the state is `off`, it appears in the up position. Changing the state causes the appropriate `OnCallback` or `OffCallback` routine to run.

`Tag`
string

User-specified object identifier. The `Tag` property provides a means to identify graphics objects with a user-specified label. You can define `Tag` as any string.

With the `findobj` function, you can locate an object with a given `Tag` property value. This saves you from defining object handles as global variables. For example, this function call returns the handles of all children (of the specified toolbars) that have the `Tag` value `'Bold'`.

```
h = findobj(uitoolbarhandles, 'Tag', 'Bold')
```

`TooltipString`
string

Content of tooltip for object. The `TooltipString` property specifies the text of the tooltip associated with the uitoggletool. When the user moves the mouse pointer over the control and leaves it there, the tooltip is displayed.

`Type`

`string` (read-only)

Object class. This property identifies the kind of graphics object. For uitoggletool objects, `Type` is always the string `'uitoggletool'`.

`UIContextMenu`

handle

Associate a context menu with uicontrol. This property has no effect on uitoggletool objects.

`UserData`

array

User specified data. You can specify `UserData` as any array you want to associate with the uitoggletool object. The object does not use this data, but you can access it using the `set` and `get` functions.

`Visible`

`{on} | off`

Uitoggletool visibility. By default, all uitoggletools are visible. When set to `off`, the uitoggletool is not visible, but still exists and you can query and set its properties.

Purpose

Create toolbar on figure

Syntax

```
ht =
uitoolbar('PropertyName1',value1,'PropertyName2',value2,
   ...)
ht = uitoolbar(h,...)
```

Description

`ht =`
`uitoolbar('PropertyName1',value1,'PropertyName2',value2,...)` creates an empty toolbar at the top of the current figure window, and returns a handle to it. `uitoolbar` assigns the specified property values, and assigns default values to the remaining properties. You can change the property values at a later time using the `set` function.

Type `get(ht)` to see a list of `uitoolbar` object properties and their current values. Type `set(ht)` to see a list of `uitoolbar` object properties that you can set and legal property values. See the Uitoolbar Properties reference page for more information.

`ht = uitoolbar(h,...)` creates a toolbar with `h` as a parent. `h` must be a figure handle.

Remarks

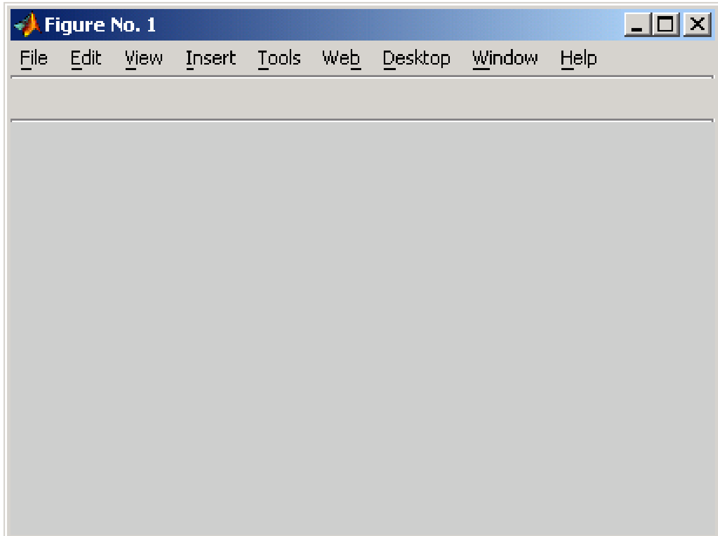
`uitoolbar` accepts property name/property value pairs, as well as structures and cell arrays of properties as input arguments.

Uitoolbars appear in figures whose `Window Style` is `normal` or `docked`. They do not appear in figures whose `WindowStyle` is `modal`. If the `WindowStyle` property of a figure containing a uitoolbar is changed to `modal`, the uitoolbar still exists and is contained in the `Children` list of the figure, but is not displayed until the `WindowStyle` is changed to `normal` or `docked`.

Example

This example creates a figure with no toolbar, then adds a toolbar to it.

```
h = figure('ToolBar','none')
ht = uitoolbar(h)
```



For more information on using the menus and toolbar in a MATLAB figure window, see the online MATLAB Graphics documentation.

See Also

`set`, `get`, `uicontrol`, `uipushtool`, `uitoggletool`

Uitoolbar Properties

Purpose

Describe toolbar properties

Modifying Properties

You can set and query graphics object properties in two ways:

- The Property Inspector is an interactive tool that enables you to see and change object property values. The Property inspector is available from GUIDE, or use the `inspect` function at the command line.
- The `set` and `get` functions enable you to set and query the values of properties.

You can set default Uitoolbar properties by typing:

```
set(h,'DefaultUitoolbarPropertyName',PropertyValue...)
```

Where h can be the root handle (0), a figure handle, or a uitoolbar handle. *`PropertyName`* is the name of the Uitoolbar property and `PropertyValue` is the value you specify as the default for that property.

For more information about changing the default value of a property see Setting Default Property Values.

Uitoolbar Properties

This section lists all properties useful to `uitoolbar` objects along with valid values and a descriptions of their use. Curly braces { } enclose default values.

Property	Purpose
`BeingDeleted`	This object is being deleted.
`BusyAction`	Callback routine interruption.
`Children`	Handles of uitoolbar's children.
`CreateFcn`	Callback routine executed during object creation.
`DeleteFcn`	Callback routine executed during object deletion.

Property	Purpose
`HandleVisibility`	Control access to object's handle.
`HitTest`	Whether selectable by mouse click
`Interruptible`	Callback routine interruption mode.
`Parent`	Handle of uitoolbar's parent.
`Tag`	User-specified object identifier.
`Type`	Object class.
`UIContextMenu`	Uicontextmenu object associated with the uitoolbar
`UserData`	User specified data.
`Visible`	Uitoolbar visibility.

`BeingDeleted`

`on | {off}` (read-only)

This object is being deleted. The `BeingDeleted` property provides a mechanism that you can use to determine if objects are in the process of being deleted. MATLAB software sets the `BeingDeleted` property to `on` when the object's delete function callback is called (see the `DeleteFcn` property) It remains set to `on` while the delete function executes, after which the object no longer exists.

For example, some functions may not need to perform actions on objects that are being deleted, and therefore, can check the object's `BeingDeleted` property before acting.

`BusyAction`

`cancel | {queue}`

Callback routine interruption. If a callback is executing and the user triggers an event (such as a mouse click) on an object for which a callback is defined, the callback associated with the new event uses the value of BusyAction to decide whether or not to attempt to interrupt the executing callback.

- If the value is cancel, the event is discarded and the second callback does not execute.
- If the value is queue, and the Interruptible property of the first callback is on, the second callback is added to the event queue and executes in its turn after the first callback finishes execution.

Note If the interrupting callback is a DeleteFcn or CreateFcn callback or a figure's CloseRequest or ResizeFcn callback, it interrupts an executing callback regardless of the value of that object's Interruptible property. See the Interruptible property for information about controlling a callback's interruptibility.

Children
vector of handles

Handles of tools on the toolbar. A vector containing the handles of all children of the uitoolbar object, in the order in which they appear on the toolbar. The children objects of uitoolbars are uipushtools and uitoggletools. You can use this property to reorder the children.

CreateFcn
string or function handle

Callback routine executed during object creation. The specified function executes when MATLAB creates a uitoolbar object. MATLAB sets all property values for the uitoolbar before executing the CreateFcn callback so these values are available to the callback. Within the function, use gcbo to get the handle of the toolbar being created.

Setting this property on an existing uitoolbar object has no effect.

You can define a default `CreateFcn` callback for all new uitoolbars. This default applies unless you override it by specifying a different `CreateFcn` callback when you call `uitoolbar`. For example, the statement,

```
set(0,'DefaultUitoolbarCreateFcn',...
    'set(gcbo,''Visibility'',''off'')')
```

creates a default `CreateFcn` callback that runs whenever you create a new toolbar. It sets the toolbar visibility to `off`.

To override this default and create a toolbar whose `Visibility` property is set to `on`, you could call `uitoolbar` with a call similar to

```
ht = uitoolbar(...,'CreateFcn',...
               'set(gcbo,''Visibility'',''on'')',...)
```

Note To override a default `CreateFcn` callback you must provide a new callback and not just provide different values for the specified properties. This is because the `CreateFcn` callback runs after the property values are set, and can override property values you have set explicitly in the `uitoolbar` call. In the example above, if instead of redefining the `CreateFcn` property for this toolbar, you had explicitly set `Visibility` to `on`, the default `CreateFcn` callback would have set `Visibility` back to `off`.

Do not call `copyobj` or `textwrap` (which calls `copyobj`) inside a `CreateFcn`. The act of copying the uicontrol object fires the `CreateFcn` repeatedly, which raises a series of error messages after exceeding the root object's `RecursionLimit` property.

See Function Handle Callbacks for information on how to use function handles to define a callback function.

`DeleteFcn`
string or function handle

Callback routine executed during object deletion. A callback function that executes when the uitoolbar object is deleted (e.g., when you call the `delete` function or cause the figure containing the uitoolbar to reset). MATLAB executes the routine before destroying the object's properties so these values are available to the callback routine.

Within the function, use `gcbo` to get the handle of the toolbar being deleted.

`HandleVisibility`
`{on} | callback | off`

Control access to object's handle. This property determines when an object's handle is visible in its parent's list of children. When a handle is not visible in its parent's list of children, it is not returned by functions that obtain handles by searching the object hierarchy or querying handle properties. This includes `get`, `findobj`, `gca`, `gcf`, `gco`, `newplot`, `cla`, `clf`, and `close`. Neither is the handle visible in the parent figure's `CurrentObject` property. Handles that are hidden are still valid. If you know an object's handle, you can `set` and `get` its properties, and pass it to any function that operates on handles.

- Handles are always visible when `HandleVisibility` is `on`.
- Setting `HandleVisibility` to `callback` causes handles to be visible from within callback routines or functions invoked by callback routines, but not from within functions invoked from the command line. This provides a means to protect GUIs from command-line users, while allowing callback routines to have complete access to object handles.

- Setting `HandleVisibility` to `off` makes handles invisible at all times. This may be necessary when a callback routine invokes a function that might potentially damage the GUI (such as evaluating a user-typed string), and so temporarily hides its own handles during the execution of that function.

You can set the root `ShowHiddenHandles` property to on to make all handles visible, regardless of their `HandleVisibility` settings. This does not affect the values of the `HandleVisibility` properties.

`HitTest`
`{on} | off`

Selectable by mouse click. This property has no effect on uitoolbar objects.

`Interruptible`
`{on} | off`

Callback routine interruption mode. If a callback is executing and the user triggers an event (such as a mouse click) on an object for which a callback is defined, that callback attempts to interrupt the first callback. MATLAB processes the callbacks according to these factors:

- The `Interruptible` property of the object whose callback is executing
- Whether the executing callback contains `drawnow`, `figure`, `getframe`, `pause`, or `waitfor` statements
- The `BusyAction` property of the object whose callback is waiting to execute

If the `Interruptible` property of the object whose callback is executing is `on` (the default), the callback can be interrupted. Whenever the callback calls one of the `drawnow`, `figure`, `getframe`, `pause`, or `waitfor` functions, the function processes any events in the event queue, including the waiting callback, before performing its defined task.

If the `Interruptible` property of the object whose callback is executing is `off`, the callback cannot be interrupted (except by certain callbacks; see the note below). The `BusyAction` property of the object whose callback is waiting to execute determines what happens to the callback.

Note If the interrupting callback is a `DeleteFcn` or `CreateFcn` callback or a figure's `CloseRequest` or `ResizeFcn` callback, it interrupts an executing callback regardless of the value of that object's `Interruptible` property. The interrupting callback starts execution at the next `drawnow`, `figure`, `getframe`, `pause`, or `waitfor` statement. A figure's `WindowButtonDownFcn` callback routine, or an object's `ButtonDownFcn` or `Callback` routine are processed according to the rules described above.

`Parent`

handle

Uitoolbar parent. The handle of the uitoolbar's parent figure. You can move a uitoolbar object to another figure by setting this property to the handle of the new parent.

`Tag`

string

User-specified object identifier. The `Tag` property provides a means to identify graphics objects with a user-specified label. You can define `Tag` as any string.

With the `findobj` function, you can locate an object with a given `Tag` property value. This saves you from defining object handles as global variables. For example, this function call returns the handles of all children (of the specified figures) that have the `Tag` value `'FormatTb'`.

```
h = findobj(figurehandles,'Tag','FormatTb')
```

`Type`
`string` (read-only)

Object class. This property identifies the kind of graphics object. For uitoolbar objects, `Type` is always the string `'uitoolbar'`.

`UIContextMenu`
handle

Associate a context menu with uicontrol. This property has no effect on uitoolbar objects.

`UserData`
array

User specified data. You can specify `UserData` as any array you want to associate with the uitoolbar object. The object does not use this data, but you can access it using the `set` and `get` functions.

`Visible`
`{on} | off`

Uitoolbar visibility. By default, all uitoolbars are visible. When set to `off`, the uitoolbar is not visible, but still exists and you can query and set its properties.

uiwait

Purpose

Block execution and wait for resume

Syntax

```
uiwait
uiwait(h)
uiwait(h,timeout)
```

Description

`uiwait` blocks execution until `uiresume` is called or the current figure is deleted. This syntax is the same as `uiwait(gcf)`.

`uiwait(h)` blocks execution until `uiresume` is called or the figure `h` is deleted.

`uiwait(h,timeout)` blocks execution until `uiresume` is called, the figure `h` is deleted, or `timeout` seconds elapse.

Remarks

The `uiwait` and `uiresume` functions block and resume MATLAB and Simulink program execution. `uiwait` also blocks the execution of Simulink models. The functions `pause` (with no argument) and `waitfor` also block execution in this manner.`uiwait` is a convenient way to use the `waitfor` command. You typically use it in conjunction with a dialog box. It provides a way to block the execution of the M-file that created the dialog, until the user responds to the dialog box. When used in conjunction with a modal dialog, `uiwait` can block the execution of the M-file *and* restrict user interaction to the dialog only.

Example

This example creates a GUI with a **Continue** push button. The example calls `uiwait` to block MATLAB execution until `uiresume` is called. This happens when the user clicks the **Continue** push button because the push button's `Callback` callback, which responds to the click, calls `uiresume`.

```
f = figure;
h = uicontrol('Position',[20 20 200 40],'String','Continue',...
              'Callback','uiresume(gcbf)');
disp('This will print immediately');
uiwait(gcf);
disp('This will print after you click Continue');
```

```
close(f);
```

`gcbf` is the handle of the figure that contains the object whose callback is executing.

"Using a Modal Dialog to Confirm an Operation" is a more complex example for a GUIDE GUI. See "Icon Editor" for an example for a programmatically created GUI.

See Also

`dialog`, `figure`, `uicontrol`, `uimenu`, `uiresume`, `waitfor`

undocheckout

Purpose

Undo previous checkout from source control system (UNIX platforms)

GUI Alternatives

As an alternative to the `undocheckout` function, select **Source Control > Undo Checkout** in the **File** menu of the Editor, Simulink software, or Stateflow software, or in the context menu of the Current Directory browser. For more information, see "Undoing the Checkout on UNIX Platforms".

Syntax

```
undocheckout('filename')
undocheckout({'filename1','filename2', ...,'filenamen'})
```

Description

`undocheckout('filename')` makes the file `filename` available for checkout, where `filename` does not reflect any of the changes you made after you last checked it out. Use the full path for `filename` and include the file extension.

`undocheckout({'filename1','filename2', ...,'filenamen'})` makes `filename1` through `filenamen` available for checkout, where the files do not reflect any of the changes you made after you last checked them out. Use the full paths for the file names and include the file extensions.

Examples

Typing

```
undocheckout({'/myserver/mymfiles/clock.m', ...
'/myserver/mymfiles/calendar.m'})
```

undoes the checkouts of `/myserver/mymfiles/clock.m` and `/myserver/mymfiles/calendar.m` from the source control system.

See Also

`checkin`, `checkout`

For Microsoft Windows platforms, use `verctrl`.

Purpose

Convert Unicode characters to numeric bytes

Syntax

```
bytes = unicode2native(unicodestr)
bytes = unicode2native(unicodestr, encoding)
```

Description

`bytes = unicode2native(unicodestr)` takes a `char` vector of Unicode characters, `unicodestr`, converts it to the MATLAB default character encoding scheme, and returns the bytes as a `uint8` vector, `bytes`. Output vector `bytes` has the same general array shape as the `unicodestr` input. You can save the output of `unicode2native` to a file using the `fwrite` function.

`bytes = unicode2native(unicodestr, encoding)` converts the Unicode characters to the character encoding scheme specified by the string `encoding`. `encoding` must be the empty string (`''`) or a name or alias for an encoding scheme. Some examples are `'UTF-8'`, `'latin1'`, `'US-ASCII'`, and `'Shift_JIS'`. For common names and aliases, see the Web site `http://www.iana.org/assignments/character-sets`. If `encoding` is unspecified or is the empty string (`''`), the MATLAB default encoding scheme is used.

Examples

This example begins with two strings containing Unicode characters. It assumes that string `str1` contains text in a Western European language and string `str2` contains Japanese text. The example writes both strings into the same file, using the ISO-8859-1 character encoding scheme for the first string and the Shift-JIS encoding scheme for the second string. The example uses `unicode2native` to convert the two strings to the appropriate encoding schemes.

```
fid = fopen('mixed.txt', 'w');
bytes1 = unicode2native(str1, 'ISO-8859-1');
fwrite(fid, bytes1, 'uint8');
bytes2 = unicode2native(str2, 'Shift_JIS');
fwrite(fid, bytes2, 'uint8');
fclose(fid);
```

See Also

`native2unicode`

Purpose Find set union of two vectors

Syntax

```
c = union(A, B)
c = union(A, B, 'rows')
[c, ia, ib] = union(...)
```

Description `c = union(A, B)` returns the combined values from `A` and `B` but with no repetitions. In set theoretic terms, `c = A ∪ B`. Inputs `A` and `B` can be numeric or character vectors or cell arrays of strings. The resulting vector is sorted in ascending order.

`c = union(A, B, 'rows')` when `A` and `B` are matrices with the same number of columns returns the combined rows from `A` and `B` with no repetitions. MATLAB ignores the rows flag for all cell arrays.

`[c, ia, ib] = union(...)` also returns index vectors `ia` and `ib` such that `c = a(ia) ∪ b(ib)`, or for row combinations, `c = a(ia,:) ∪ b(ib,:)`. If a value appears in both `a` and `b`, `union` indexes its occurrence in `b`. If a value appears more than once in `b` or in `a` (but not in `b`), `union` indexes the last occurrence of the value.

Remarks Because NaN is considered to be not equal to itself, every occurrence of NaN in `A` or `B` is also included in the result `c`.

Examples

```
a = [-1 0 2 4 6];
b = [-1 0 1 3];
[c, ia, ib] = union(a, b);
c =

    -1     0     1     2     3     4     6

ia =

     3     4     5

ib =
```

1 2 3 4

See Also

`intersect`, `setdiff`, `setxor`, `unique`, `ismember`, `issorted`

unique

Purpose

Find unique elements of vector

Syntax

```
b = unique(A)
b = unique(A, 'rows')
[b, m, n] = unique(...)
[b, m, n] = unique(..., occurrence)
```

Description

`b = unique(A)` returns the same values as in `A` but with no repetitions. `A` can be a numeric or character array or a cell array of strings. If `A` is a vector or an array, `b` is a vector of unique values from `A`. If `A` is a cell array of strings, `b` is a cell vector of unique strings from `A`. The resulting vector `b` is sorted in ascending order and its elements are of the same class as `A`.

`b = unique(A, 'rows')` returns the unique rows of `A`.

`[b, m, n] = unique(...)` also returns index vectors `m` and `n` such that `b = A(m)` and `A = b(n)`. Each element of `m` is the greatest subscript such that `b = A(m)`. For row combinations, `b = A(m,:)` and `A = b(n,:)`.

`[b, m, n] = unique(..., occurrence)`, where `occurrence` can be

- `'first'`, which returns the vector `m` to index the first occurrence of each unique value in `A`, or
- `'last'`, which returns the vector `m` to index the last occurrence.

If you do not specify `occurrence`, it defaults to `'last'`.

You can specify `'rows'` in the same command as `'first'` or `'last'`. The order of appearance in the argument list is not important.

Examples

```
A = [1 1 5 6 2 3 3 9 8 6 2 4]
A =
     1     1     5     6     2     3     3     9     8     6     2     4
```

Get a sorted vector of unique elements of A. Also get indices of the first elements in A that make up vector b, and the first elements in b that make up vector A:

```
[b1, m1, n1] = unique(A, 'first')
b1 =
    1    2    3    4    5    6    8    9
m1 =
    1    5    6   12    3    4    9    8
n1 =
    1    1    5    6    2    3    3    8    7    6    2    4
```

Verify that `b1 = A(m1)` and `A = b1(n1)`:

```
all(b1 == A(m1)) && all(A == b1(n1))
ans =
      1
```

Get a sorted vector of unique elements of A. Also get indices of the last elements in A that make up vector b, and the last elements in b that make up vector A:

```
[b2, m2, n2] = unique(A, 'last')
b2 =
    1    2    3    4    5    6    8    9
m2 =
    2   11    7   12    3   10    9    8
n2 =
    1    1    5    6    2    3    3    8    7    6    2    4
```

Verify that `b2 = A(m2)` and `A = b2(n2)`:

```
all(b2 == A(m2)) && all(A == b2(n2))
ans =
     1
```

Because NaNs are not equal to each other, `unique` treats them as unique elements.

```
unique([1 1 NaN NaN])
ans =
    1 NaN NaN
```

See Also

intersect, ismember, sort, issorted, setdiff, setxor, union

Purpose

Execute UNIX command and return result

Syntax

```
unix command
status = unix('command')
[status, result] = unix('command')
[status,result] = unix('command','-echo')
```

Description

`unix command` calls upon the UNIX[28] operating system to execute the given command.

`status = unix('command')` returns completion status to the `status` variable.

`[status, result] = unix('command')` returns the standard output to the `result` variable, in addition to completion status.

`[status,result] = unix('command','-echo')` displays the results in the Command Window as it executes, and assigns the results to `w`.

Note The MATLAB software uses a shell program to execute the given command. It determines which shell program to use by checking environment variables on your system. MATLAB first checks the `MATLAB_SHELL` variable, and if either empty or not defined, then checks `SHELL`. If `SHELL` is also empty or not defined, MATLAB uses `/bin/sh`.

Examples

List all users that are currently logged in.

```
[s,w] = unix('who');
```

MATLAB returns `0` (success) in `s` and a string containing the list of users in `w`.

In this example

```
[s,w] = unix('why')
s =
     1
w =
why: Command not found.
```

MATLAB returns a nonzero value in `s` to indicate failure, and returns an error message in `w` because `why` is not a UNIX command.

28. UNIX is a registered trademark of The Open Group in the United States and other countries.

See Also

`dos`, `!` (exclamation point), `perl`, `system`

"Running External Programs" in the MATLAB Desktop Tools and Development Environment documentation

unloadlibrary

Purpose

Unload shared library from memory

Syntax

```
unloadlibrary('libname')
unloadlibrary libname
```

Description

`unloadlibrary('libname')` unloads the shared library `libname` from memory. If you need to use functions in this library, you must reload the library using the `loadlibrary` function.

`unloadlibrary libname` is the command format for this function.

If you used an `alias` when initially loading the library, then you must use that alias for the `libname` argument.

Examples

Load the MATLAB sample shared library, `shrlibsample`. Call one of its functions, and then unload the library:

```
addpath([matlabroot '\extern\examples\shrlib'])
loadlibrary shrlibsample shrlibsample.h

s.p1 = 476;   s.p2 = -299;   s.p3 = 1000;
calllib('shrlibsample', 'addStructFields', s)
ans =
    1177

unloadlibrary shrlibsample
```

See Also

`loadlibrary`, `libisloaded`

Purpose

Piecewise polynomial details

Syntax

`[breaks,coefs,l,k,d] = unmkpp(pp)`

Description

`[breaks,coefs,l,k,d] = unmkpp(pp)` extracts, from the piecewise polynomial `pp`, its breaks `breaks`, coefficients `coefs`, number of pieces `l`, order `k`, and dimension `d` of its target. Create `pp` using `spline` or the spline utility `mkpp`.

Examples

This example creates a description of the quadratic polynomial

$$\frac{-x^2}{4} + x$$

as a piecewise polynomial `pp`, then extracts the details of that description.

```
pp = mkpp([-8 -4],[-1/4 1 0]);
[breaks,coefs,l,k,d] = unmkpp(pp)

breaks =
    -8    -4

coefs =
   -0.2500    1.0000         0

l =
     1

k =
     3

d =
     1
```

See Also

`mkpp`, `ppval`, `spline`

unregisterallevents

Purpose Unregister all event handlers for COM object event at run-time

Syntax

```
h.unregisterallevents
unregisterallevents(h)
```

Description `h.unregisterallevents` unregisters all events that have previously been registered with COM object, `h`. After calling `unregisterallevents`, the object no longer responds to any events until you register them again using the `registerevent` function.

`unregisterallevents(h)` is an alternate syntax.

Remarks COM functions are available on Microsoft Windows systems only.

Examples

mwsamp Control Example

Create an `mwsamp` control, registering three events and their respective handler routines. Use the `eventlisteners` function to see the event handler used by each event:

```
f = figure ('position', [100 200 200 200]);
h = actxcontrol('mwsamp.mwsampctrl.2', ...
    [0 0 200 200], f, ...
    {'Click' 'myclick'; 'DblClick' 'my2click'; ...
    'MouseDown' 'mymoused'});
h.eventlisteners
```

MATLAB displays:

```
ans =
    'click'        'myclick'
    'dblclick'     'my2click'
    'mousedown'    'mymoused'
```

Unregister all of these events at once with `unregisterallevents`. Now, calling `eventlisteners` returns an empty cell array, indicating that there are no longer any events registered with the control:

```
h.unregisterallevents;
h.eventlisteners
```

MATLAB displays:

```
ans =
     {}
```

To unregister specific events, use the `unregisterevent` function.

Workbook Events Example

Create a Microsoft Excel `Workbook` object and register some events.

```
myApp = actxserver('Excel.Application');
wbs = myApp.Workbooks;
wb = wbs.Add;
wb.registerevent({'Activate' 'EvtActivateHndlr'; ...
                  'Deactivate' 'EvtDeactivateHndlr'})
wb.eventlisteners
```

MATLAB shows the events registered to their corresponding event handlers.

```
ans =

    'Activate'      'EvtActivateHndlr'
    'Deactivate'    'EvtDeactivateHndlr'
```

Use `unregisterallevents` to clear the events.

```
wb.unregisterallevents
wb.eventlisteners
```

MATLAB displays an empty cell array, showing that no events are registered.

```
ans =
```

```
{}
```

See Also

events (COM), eventlisteners, registerevent, unregisterevent, isevent

Purpose

Unregister event handler for COM object event at run-time

Syntax

```
h.unregisterevent(event_handler)
unregisterevent(h, event_handler)
```

Description

`h.unregisterevent(event_handler)` unregisters certain event handler routines with their corresponding events. Once you unregister an event, the object no longer responds to any further occurrences of the event.

`unregisterevent(h, event_handler)` is an alternate syntax.

You can unregister events at any time after a control has been created. The `event_handler` argument, which is a cell array, specifies both events and event handlers. For example:

```
h.unregisterevent({'event_name',@event_handler});
```

See "Writing Event Handlers" in the External Interfaces documentation.

You must specify events in the `event_handler` argument using the names of the events. Strings used in the `event_handler` argument are not case sensitive. Unlike `actxcontrol` and `registerevent`, `unregisterevent` does not accept numeric event identifiers.

Remarks

COM functions are available on Microsoft Windows systems only.

Examples

Control Example

Create an `mwsamp` control and register all events with the same handler routine, `sampev`. Use `eventlisteners` to see the event handler used by each event. In this case, each event, when fired, calls `sampev.m`:

```
f = figure ('position', [100 200 200 200]);
h = actxcontrol('mwsamp.mwsampctrl.2', ...
                [0 0 200 200], f, ...
                'sampev');
h.eventlisteners
```

MATLAB displays:

```
ans =
    'Click'          'sampev'
    'DblClick'       'sampev'
    'MouseDown'      'sampev'
    'Event_Args'     'sampev'
```

Unregister just the `dblclick` event. Now, when you list the registered events using `eventlisteners`, `dblclick` is no longer registered and the control does not respond when you double-click the mouse over it:

```
h.unregisterevent({'dblclick' 'sampev'});
h.eventlisteners
```

MATLAB displays:

```
ans =
    'Click'          'sampev'
    'MouseDown'      'sampev'
    'Event_Args'     'sampev'
```

This time, register the `click` and `dblclick` events with a different event handler for `myclick` and `my2click`, respectively:

```
h.unregisterallevents;
h.registerevent({'click' 'myclick'; ...
                 'dblclick' 'my2click'});
h.eventlisteners
```

MATLAB displays:

```
ans =
    'click'        'myclick'
    'dblclick'     'my2click'
```

You can unregister these same events by specifying event names and their handler routines in a cell array. `eventlisteners` now returns an empty cell array, meaning no events are registered for the `mwsamp` control:

```
h.unregisterevent({'click' 'myclick'; ...
                   'dblclick' 'my2click'});
h.eventlisteners
```

MATLAB displays:

```
ans =
     {}
```

Workbook Events Example

Create a Microsoft Excel `Workbook` object:

```
myApp = actxserver('Excel.Application');
wbs = myApp.Workbooks;
wb = wbs.Add;
```

Register two events with the your event handler routines, `EvtActivateHndlr` and `EvtDeactivateHndlr`.

```
wb.registerevent({'Activate' 'EvtActivateHndlr'; ...
                  'Deactivate' 'EvtDeactivateHndlr'})
wb.eventlisteners
```

MATLAB shows the events with the corresponding event handlers.

```
ans =

    'Activate'      'EvtActivateHndlr'
    'Deactivate'    'EvtDeactivateHndlr'
```

Next, unregister the `Deactivate` event handler.

```
wb.unregisterevent({'Deactivate' 'EvtDeactivateHndlr'})
wb.eventlisteners
```

MATLAB shows the remaining registered event (`Activate`) with its corresponding event handler.

```
ans =

    'Activate'    'EvtActivateHndlr'
```

See Also

`events (COM)`, `eventlisteners`, `registerevent`, `unregisterallevents`, `isevent`

Purpose Extract contents of tar file

Syntax

```
untar(tarfilename)
untar(tarfilename,outputdir)
untar(url, ...)
filenames = untar(...)
```

Description

`untar(tarfilename)` extracts the archived contents of `tarfilename` into the current directory and sets the files' attributes. It overwrites any existing files with the same names as those in the archive if the existing files' attributes and ownerships permit it. For example, if you rerun `untar` on the same `tarfilename`, MATLAB software does not overwrite files with a read-only attribute; instead, `untar` displays a warning for such files. On Microsoft Windows platforms, the hidden, system, and archive attributes are not set.

`tarfilename` is a string specifying the name of the tar file. `tarfilename` is gunzipped to a temporary directory and deleted if its extension ends in `.tgz` or `.gz`. If an extension is omitted, `untar` searches for `tarfilename` appended with `.tgz`, `.tar.gz`, or `.tar`. `tarfilename` can include the directory name; otherwise, the file must be in the current directory or in a directory on the MATLAB path.

`untar(tarfilename,outputdir)` uncompresses the archive `tarfilename` into the directory `outputdir`. If `outputdir` does not exist, MATLAB creates it.

`untar(url, ...)` extracts the tar archive from an Internet URL. The URL must include the protocol type (for example, `'http://'` or `'ftp://'`). MATLAB downloads the URL is to a temporary directory, and then deletes it.

`filenames = untar(...)` extracts the tar archive and returns the names of the extracted files in the string cell array `filenames`. If `outputdir` specifies a relative path, `filenames` contains the relative path. If `outputdir` specifies an absolute path, `filenames` contains the absolute path.

Examples

Using tar and untar to Copy Files

Copy all .m files in the current directory to the directory backup.

```
tar('mymfiles.tar.gz','*.m');
untar('mymfiles','backup');
```

Using untar with URL

Run untar to list Cleve Moler's "Numerical Computing with MATLAB" examples to the output directory ncm.

```
url ='http://www.mathworks.com/moler/ncm.tar.gz';
ncmFiles = untar(url,'ncm')
```

See Also

gzip, gunzip, tar, unzip, zip

Purpose

Correct phase angles to produce smoother phase plots

Syntax

```
Q = unwrap(P)
Q = unwrap(P,tol)
Q = unwrap(P,[],dim)
Q = unwrap(P,tol,dim)
```

Description

`Q = unwrap(P)` corrects the radian phase angles in a vector `P` by adding multiples of $\pm 2\pi$ when absolute jumps between consecutive elements of `P` are greater than or equal to the default jump tolerance of π radians. If `P` is a matrix, `unwrap` operates columnwise. If `P` is a multidimensional array, `unwrap` operates on the first nonsingleton dimension.

`Q = unwrap(P,tol)` uses a jump tolerance `tol` instead of the default value, π.

`Q = unwrap(P,[],dim)` unwraps along `dim` using the default tolerance.

`Q = unwrap(P,tol,dim)` uses a jump tolerance of `tol`.

Note A jump tolerance less than π has the same effect as a tolerance of π. For a tolerance less than π, if a jump is greater than the tolerance but less than π, adding $\pm 2\pi$ would result in a jump larger than the existing one, so `unwrap` chooses the current point. If you want to eliminate jumps that are less than π, try using a finer grid in the domain.

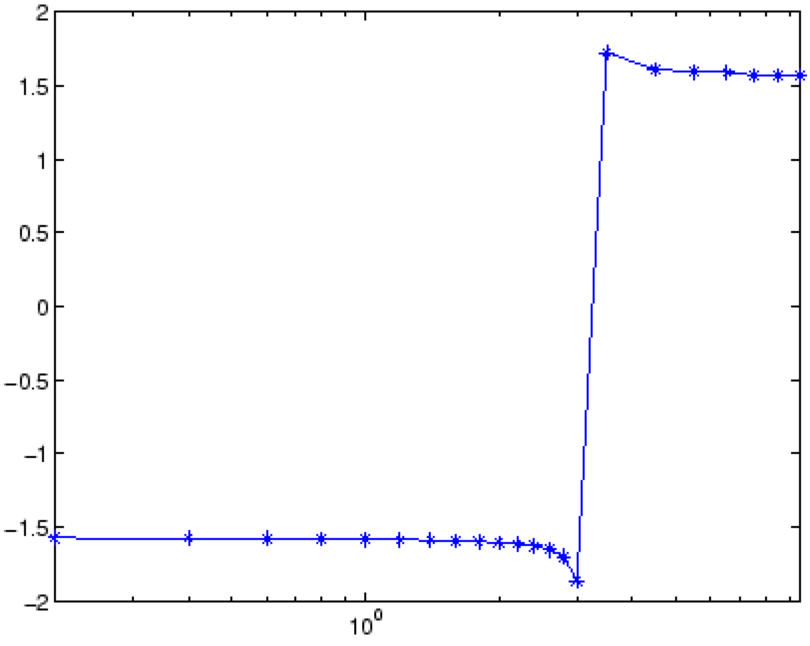
Examples

Example 1

The following phase data comes from the frequency response of a third-order transfer function. The phase curve jumps `3.5873` radians between `w = 3.0` and `w = 3.5`, from `-1.8621` to `1.7252`.

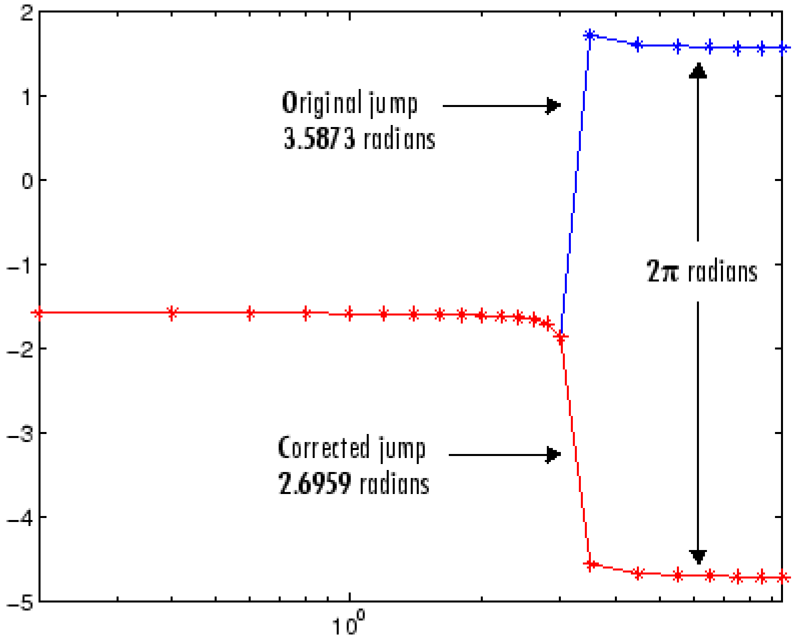
```
w = [0:.2:3,3.5:1:10];
p = [    0
     -1.5728
     -1.5747
     -1.5772
```

```
          -1.5790
          -1.5816
          -1.5852
          -1.5877
          -1.5922
          -1.5976
          -1.6044
          -1.6129
          -1.6269
          -1.6512
          -1.6998
          -1.8621
           1.7252
           1.6124
           1.5930
           1.5916
           1.5708
           1.5708
           1.5708 ];
semilogx(w,p,'b*-'), hold
```



Using `unwrap` to correct the phase angle, the resulting jump is `2.6959`, which is less than the default jump tolerance **π**. This figure plots the new curve over the original curve.

```
semilogx(w,unwrap(p),'r*-')
```



Note If you have the “Control System Toolbox”, you can create the data for this example with the following code.

```
h = freqresp(tf(1,[1 .1 10 0]));
p = angle(h(:));
```

Example 2

Array P features smoothly increasing phase angles except for discontinuities at elements (3,1) and (1,2).

```
P = [      0     7.0686     1.5708     2.3562
      0.1963     0.9817     1.7671     2.5525
      6.6759     1.1781     1.9635     2.7489
      0.5890     1.3744     2.1598     2.9452 ]
```

The function `Q = unwrap(P)` eliminates these discontinuities.

```
Q =
         0    7.0686    1.5708    2.3562
    0.1963    7.2649    1.7671    2.5525
    0.3927    7.4613    1.9635    2.7489
    0.5890    7.6576    2.1598    2.9452
```

See Also

`abs`, `angle`

Purpose

Extract contents of zip file

Syntax

```
unzip(zipfilename)
unzip(zipfilename,outputdir)
unzip(url, ...)
filenames = unzip(...)
```

Description

`unzip(zipfilename)` extracts the archived contents of `zipfilename` into the current directory and sets the files' attributes. It overwrites any existing files with the same names as those in the archive if the existing files' attributes and ownerships permit it. For example, files from rerunning `unzip` on the same zip filename do not overwrite any of those files that have a read-only attribute; instead, `unzip` issues a warning for such files.

`zipfilename` is a string specifying the name of the zip file. The `.zip` extension is appended to `zipfilename` if omitted. `zipfilename` can include the directory name; otherwise, the file must be in the current directory or in a directory on the MATLAB path.

`unzip(zipfilename,outputdir)` extracts the contents of `zipfilename` into the directory `outputdir`.

`unzip(url, ...)` extracts the zipped contents from an Internet URL. The URL must include the protocol type (for example, `http://`). The URL is downloaded to the temp directory and deleted.

`filenames = unzip(...)` extracts the zip archive and returns the names of the extracted files in the string cell array `filenames`. If `outputdir` specifies a relative path, `filenames` contains the relative path. If `outputdir` specifies an absolute path, `filenames` contains the absolute path.

`unzip` does not support password-protected or encrypted zip archives.

Examples

Using zip and unzip to Copy Files

Copy the demos HTML files to the directory `archive`:

```
% Zip the demos html files to demos.zip
```

```
zip('demos.zip','*.html',fullfile(matlabroot,'demos'))
% Unzip demos.zip to the 'directory' archive
unzip('demos','archive')
```

Using unzip with URL

Run `unzip` to list Cleve Moler's "Numerical Computing with MATLAB" examples to the output directory `ncm`.

```
url ='http://www.mathworks.com/moler/ncm.zip';
ncmFiles = unzip(url,'ncm')
```

See Also

`fileattrib`, `gzip`, `gunzip`, `tar`, `untar`, `zip`

Purpose

Convert string to uppercase

Syntax

```
t  = upper('str')
B = upper(A)
```

Description

`t = upper('str')` converts any lowercase characters in the string `str` to the corresponding uppercase characters and leaves all other characters unchanged.

`B = upper(A)` when `A` is a cell array of strings, returns a cell array the same size as `A` containing the result of applying `upper` to each string within `A`.

Examples

`upper('attention!')` is `ATTENTION!`.

Remarks

Character sets supported:

- PC: Windows Latin-1
- Other: ISO Latin-1 (ISO 8859-1)

See Also

`lower`

Purpose Read content at URL

Syntax

```
s = urlread('url')
s = urlread('url','method','params')
[s,status] = urlread(...)
```

Description

`s = urlread('url')` reads the content at a URL into the string `s`. If the server returns binary data, `s` will be unreadable.

`s = urlread('url','`*`method`*`','params')` reads the content at a URL into the string `s`, passing information to the server as part of the request where *`method`* can be `get` or `post`, and `params` is a cell array of parameter name/parameter value pairs.

`[s,status] = urlread(...)` catches any errors and returns the error code.

Note If you need to specify a proxy server to connect to the Internet, select **File -> Preferences -> Web** and enter your proxy information. Use this feature if you have a firewall.

Examples

Download Content from Web Page

Use `urlread` to download the contents of the Authors list at the MATLAB Central File Exchange:

```
urlstring = sprintf('%s%s', ...
   'http://www.mathworks.com/matlabcentral/', ...
   'fileexchange/loadAuthorIndex.do');

s = urlread(urlstring);
```

Download Content from File on FTP Server

```
page = 'ftp://ftp.mathworks.com/pub/doc/';
s=urlread(page);
```

```
s
```

MATLABdisplays:

```
s =

-rw-r--r--   1 ftpuser  ftpusers       448 Nov 15  2004 README
drwxr-xr-x   2 ftpuser  ftpusers       512 Jul 26 13:52 papers
```

Download Content from Local File

```
s = urlread('file:///c:/winnt/matlab.ini')
```

See Also

`urlwrite`

`tcpip` if the Instrument Control Toolbox™ is installed

Purpose

Save contents of URL to file

Syntax

```
urlwrite('url','filename')
f = urlwrite('url','filename')
f = urlwrite('url','method','params')
[f,status] = urlwrite(...)
```

Description

`urlwrite('url','filename')` reads the contents of the specified URL, saving the contents to `filename`. If you do not specify the path for `filename`, the file is saved in the MATLAB current directory.

`f = urlwrite('url','filename')` reads the contents of the specified URL, saving the contents to `filename` and assigning `filename` to `f`.

`f = urlwrite('url','`*`method`*`','params')` saves the contents of the specified URL to `filename`, passing information to the server as part of the request where *`method`* can be `get` or `post`, and `params` is a cell array of parameter name/parameter value pairs.

`[f,status] = urlwrite(...)` catches any errors and returns the error code.

Note If you need to specify a proxy server to connect to the Internet, select **File -> Preferences -> Web** and enter your proxy information. Use this feature if you have a firewall.

Examples

Download the files submitted to the MATLAB Central File Exchange, saving the results to `samples.html` in the MATLAB current directory.

```
urlstring = sprintf('%s%s', ...
'http://www.mathworks.com/matlabcentral/', ...
'fileexchange/Category.jsp?type=category&id=1');

urlwrite(urlstring, 'samples.html');
```

View the file in the Help browser.

```
open('samples.html')
```

See Also

`urlread`

Purpose

Determine whether Sun Java feature is supported in MATLAB software

Syntax

```
usejava(feature)
```

Description

`usejava(feature)` returns 1 if the specified feature is supported and 0 otherwise. Possible `feature` arguments are shown in the following table.

Feature	Description
'awt'	Abstract Window Toolkit components[1] are available
'desktop'	The MATLAB interactive desktop is running
'jvm'	The Java Virtual Machine software (JVM) is running
'swing'	Swing components[2] are available

1. Java GUI components in the Abstract Window Toolkit
2. Java lightweight GUI components in the Java Foundation Classes

Examples

The following conditional code ensures that the AWT's GUI components are available before the M-file attempts to display a Java Frame.

```
if usejava('awt')
   myFrame = java.awt.Frame;
else
   disp('Unable to open a Java Frame');
end
```

The next example is part of an M-file that includes Java code. It fails gracefully when run in a MATLAB session that does not have access to JVM software.

```
if ~usejava('jvm')
   error([mfilename ' requires Java to run.']);
end
```

See Also javachk

Purpose View or change user portion of search path

Syntax

```
userpath
userpath('newpath')
userpath('reset')
userpath('clear')
```

Description `userpath` returns a string specifying the user portion of the search path. The user portion of the search path is the first directory on the search path, above the directories supplied by The MathWorks. The default directory is `My Documents/MATLAB` on Microsoft Windows platforms, and `Documents/MATLAB` on Microsoft Windows Vista™ platforms.

On Apple Macintosh and UNIX[29] platforms, the default value is *userhome*/Documents/MATLAB. If you remove the userpath directory from the search path and save the changes to the path, it also clears the value of userpath. You can define the userpath directory to also be the MATLAB startup directory. On Windows platforms, userpath is the startup directory, unless the startup directory is otherwise specified, such as by the MATLAB shortcut properties **Start in** field. On UNIX and Macintosh platforms, the startup directory is userpath if the value of the environment variable MATLAB_USE_USERPATH is set to 1 prior to startup and if the startup directory is not otherwise specified, such as via a startup.m file. On Macintosh and UNIX platforms, you can automatically add additional subdirectories to the top of the search path upon startup by specifying the path for the subdirectories via the MATLABPATH environment variable.

userpath('newpath') sets the userpath value to newpath. The newpath directory appears at the top of the search path immediately and at startup in future sessions, and MATLAB removes the directory previously specified by userpath from the search path. newpath cannot be a relative path. userpath('newpath') does not work when the -nojvm startup option is used. Upon the next startup, newpath, can become the current directory, as described in the syntax for userpath with no arguments.

userpath('**reset**') sets the userpath value to the default for that platform, creating the Documents/MATLAB (or My Documents/MATLAB) directory if it does not exist. MATLAB immediately adds the default directory to the top of the search path, and also adds it to the path at startup in future sessions; it can become the startup directory as described for the userpath syntax with no arguments. MATLAB removes the directory previously specified by userpath from the search path. userpath('reset') does not work when the -nojvm startup option is used.

userpath('**clear**') clears the value for userpath. MATLAB the directory previously specified by userpath from the search path.

29. UNIX is a registered trademark of The Open Group in the United States and other countries.

This does not work when the -nojvm startup option is used. You can otherwise specify the startup directory—see "Startup Directory for the MATLAB Program".

Examples

- "Viewing userpath" on page 2-3933
- "Setting a New Value for userpath" on page 2-3934
- "Clearing the Value for userpath, and Specifying a New Startup Directory on Windows Platforms" on page 2-3935
- "Removing userpath from the Search Path; Resets the Startup Directory" on page 2-3936
- "Assigning userpath as the Startup Directory on a UNIX or Macintosh Platform" on page 2-3938
- "Adding Directories to the Search Path Upon Startup on a UNIX or Macintosh Platform" on page 2-3939

Viewing userpath

This example assumes `userpath` is set to the default value on the Windows XP platform, `My Documents\MATLAB`. Start MATLAB and run

```
cd
```

MATLAB displays the current directory

```
H:\My Documents\MATLAB
```

where `H` is the drive at which `My Documents` is located for this example. This is the directory specified by `userpath`. To confirm, run

```
userpath
```

and MATLAB returns

```
H:\My Documents\MATLAB;
```

Run

```
path
```

and MATLAB displays the search path; the `userpath` portion is at the top:

```
MATLABPATH

 H:\My Documents\MATLAB
 C:\Program Files\MATLAB\R2008b\toolbox\matlab\general
 C:\Program Files\MATLAB\R2008b\toolbox\matlab\ops
```

Setting a New Value for userpath

This example assumes `userpath` is set to the default value on the Windows XP platform, `My Documents\MATLAB`. To change the value from the default for `userpath` to `C:\Research_Project`, run

```
userpath('C:\Research_Project')
```

To view the effect of the change on the search path, run

```
path
```

and MATLAB displays the search path, with the new value for `userpath` portion at the top:

```
MATLABPATH

 C:\Research_Project
 C:\Program Files\MATLAB\R2008b\toolbox\matlab\general
 C:\Program Files\MATLAB\R2008b\toolbox\matlab\ops
...
```

Note that MATLAB automatically removed the previous value of `userpath`, `H:\My Documents\MATLAB`, from the search path when you assigned a new value to `userpath`. The next time you start MATLAB, the current directory will be `C:\Research_Project` on Windows platforms.

Clearing the Value for userpath, and Specifying a New Startup Directory on Windows Platforms

Assume `userpath` is set to the default value and you do not want any directories to be added to the search path upon startup. To confirm the default is currently set, run

```
userpath
```

and MATLAB returns

```
H:\My Documents\MATLAB
```

Note the `userpath` directory at the top of the search path by running

```
path
```

MATLAB returns

```
MATLABPATH

H:\My Documents\MATLAB
C:\Program Files\MATLAB\R2008b\toolbox\matlab\general
C:\Program Files\MATLAB\R2008b\toolbox\matlab\ops
...
```

To clear the value, run

```
userpath('clear')
```

To verify the result, run

```
userpath
```

MATLAB returns

```
ans =
      ''
```

Confirm the `userpath` directory was removed from the path by running:

```
path
```

MATLAB returns

```
MATLABPATH

C:\Program Files\MATLAB\R2008b\toolbox\matlab\general
C:\Program Files\MATLAB\R2008b\toolbox\matlab\ops
...
```

After clearing the `userpath` value, unless you otherwise specify the startup directory, the startup directory will be the desktop on Windows platforms. There are a number of ways to specify the startup directory. For example, right-click the Windows shortcut icon for MATLAB and select **Properties** from the context menu. In the Properties dialog box **Shortcut** tab, enter the full path to the new startup directory in the **Start in** field, for example, `I\:my_matlab_files\my_mfiles`. The next time you start MATLAB, the current directory will be `I\:my_matlab_files\my_mfiles`, but that directory will *not* be on the search path. Note that you do not have to clear the `userpath` to specify a different startup directory; when you otherwise specify a startup directory, the `userpath` directory is added to the search path upon startup, but is not the startup directory.

Removing userpath from the Search Path; Resets the Startup Directory

In this example, assume `userpath` is set to the default value and you remove the `userpath` directory from the search path, then save the changes. This has the same effect as clearing the value for `userpath`. To confirm the default is currently set, run

```
userpath
```

and MATLAB returns

```
H:\My Documents\MATLAB
```

Note the `userpath` directory at the top of the search path by running

```
path
```

MATLAB returns

```
MATLABPATH

H:\My Documents\MATLAB
C:\Program Files\MATLAB\R2008b\toolbox\matlab\general
C:\Program Files\MATLAB\R2008b\toolbox\matlab\ops
...
```

Remove `H:\My Documents\MATLAB` from the search path and confirm the result by running

```
rmpath('H:\My Documents\MATLAB')
path
```

MATLAB returns

```
MATLABPATH

 C:\Program Files\MATLAB\R2008b\toolbox\matlab\general
 C:\Program Files\MATLAB\R2008b\toolbox\matlab\ops
...
```

Running

```
userpath
```

at this point shows the value is still set

```
H:\My Documents\MATLAB
```

Save changes to the path by running

```
savepath
```

Now when you run

```
userpath
```

MATLAB returns

```
ans =
      ''
```

showing the value is now cleared. Removing the directory from the search path *and* saving the changes to the path has the same effect as clearing the value for `userpath`. At the next startup, the startup directory will *not* be `H:\My Documents\MATLAB`, and `H:\My Documents\MATLAB` will *not* be on the search path.

Assigning userpath as the Startup Directory on a UNIX or Macintosh Platform

This example assumes `userpath` is set to the default value on a Macintosh platform and that you start MATLAB using a bash X11 shell, where `smith` is the home directory. Set the `MATLAB_USE_USERPATH` environment variable so that `userpath` will be used as the startup directory:

```
export MATLAB_USE_USERPATH=1
```

From that shell, start MATLAB. After MATLAB starts, verify its current directory by running

```
pwd
```

MATLAB returns

```
/Users/smith/Documents/MATLAB
```

That is the value defined for `userpath`, which you can confirm by running

```
userpath
```

MATLAB returns

```
/Users/smith/Documents/MATLAB
```

The `userpath` is at the top of the search path, which you can confirm by running

```
path
```

MATLAB returns

```
/Users/smith/Documents/MATLAB
/Users/smith/Applications/MATLAB/R2008b/toolbox/matlab/general
/Users/smith/Applications/MATLAB/R2008b/toolbox/matlab/ops

...
```

Adding Directories to the Search Path Upon Startup on a UNIX or Macintosh Platform

This example assumes `userpath` is set to the default value on a UNIX platform with a csh shell, where `j` is the user's home directory.

To add additional directories to the search path upon startup, for example, `/home/j/Documents/MATLAB/mine` and `/home/j/Documents/MATLAB/mine/research`, run the following in an X11 terminal:

```
setenv MATLABPATH '/home/j/Documents/MATLAB/mine':'/home/j/Documents/MATLAB/mine/research'
```

Separate multiple directories using a : (colon).

MATLAB displays

```
MATLABPATH

home/j/Documents/MATLAB
home/j/Documents/MATLAB/mine
home/j/Documents/MATLAB/mine/research
home/j/Applications/MATLAB/R2008b/toolbox/matlab/general
home/j/Applications/MATLAB/R2008b/toolbox/matlab/ops
...
```

See Also

`addpath`, `path`, `pathtool`, `rmpath`, `savepath`, `startup`,

"Startup and Shutdown" and "Search Path" in the MATLAB Desktop Tools and Development Environment documentation

Purpose

Check validity of array

Syntax

```
validateattributes(A, classes, attributes)
validateattributes(A, classes, attributes, position)
validateattributes(A, classes, attributes, funname)
validateattributes(A, classes, attributes, funname, varname)
validateattributes(A, classes, attributes, funname, varname,
   position)
```

Description

`validateattributes(A, classes, attributes)` validates that array `A` belongs to at least one of the classes specified by the `classes` input and has at least one of the attributes specified by the `attributes` input. If the validation succeeds, the command completes without displaying any output and without throwing an error. If the validation does not succeed, MATLAB issues a formatted error message.

The `classes` input is a cell array of one or more strings, each string containing the name of a MATLAB class (i.e., one of the 15 MATLAB data types), the name of a MATLAB class, or the keyword `numeric`. (See the table Class Values on page 2-3942.)

The `attributes` input is a cell array of one or more strings, each string describing an array attribute. (See the table Attribute Values on page 2-3943.)

`validateattributes(A, classes, attributes, position)` validates array `A` and, if the validation fails, displays an error message that includes the position of the failing variable in the function argument list. The `position` input must be a positive integer.

`validateattributes(A, classes, attributes, funname)` validates array `A` and, if the validation fails, displays an error message that includes the name of the function performing the validation (`funname`). The `funname` input must be a string enclosed in single quotation marks.

`validateattributes(A, classes, attributes, funname, varname)` validates array `A` and, if the validation fails, displays an error message that includes the name of the function performing the validation (`funname`), and the name of the variable being validated (`varname`). The `funname` and `varname` inputs must be strings enclosed in single quotation marks.

`validateattributes(A, classes, attributes, funname, varname, position)` validates array `A` and, if the validation fails, displays an error message that includes the name of the function performing the validation (`funname`), the name of the variable being validated (`varname`), and the position of this variable in the function argument list (`position`). The `funname` and `varname` inputs must be strings enclosed in single quotation marks. The `position` input must be a positive integer.

Class Values

`classes` Argument	Contents of Array `A`
`'numeric'`	Any numeric value
`'single'`	Single-precision number
`'double'`	Double-precision number
`'int8'`	Signed 8-bit integer
`'int16'`	Signed 16-bit integer
`'int32'`	Signed 32-bit integer
`'int64'`	Signed 64-bit integer
`'uint8'`	Unsigned 8-bit integer
`'uint16'`	Unsigned 16-bit integer
`'uint32'`	Unsigned 32-bit integer
`'uint64'`	Unsigned 64-bit integer
`'logical'`	Logical `true` or `false`
’`'char'`	Character or string
`'struct'`	MATLAB structure
`'cell'`	Cell array

Class Values (Continued)

classes Argument	Contents of Array A
'function_handle'	Scalar function handle
class name	Object of any MATLAB class

Attribute Values

attributes Argument	Description of array A
'2d'	Array having dimensions M-by-N (includes scalars, vectors, 2-D matrices, and empty arrays)
'column'	Array having dimensions N-by-1
'even'	Numeric or logical array in which all elements are even (includes zero)
'finite'	Numeric array in which all elements are finite
'integer'	Numeric array in which all elements are integer-valued
'nonempty'	Array having no dimension equal to zero
'nonnan'	Numeric array in which there are no elements equal to NaN (Not a Number)
'nonnegative'	Numeric array in which all elements are zero or greater than zero
'nonsparse'	Array that is not sparse
'nonzero'	Numeric or logical array in which all elements are less than or greater than zero
'odd'	Numeric or logical array in which all elements are odd integers
'positive'	Numeric or logical array in which all elements are greater than zero

Attribute Values (Continued)

attributes Argument	Description of array A
'real'	Numeric array in which all elements are real
'row'	Array having dimensions 1-by-N
'scalar'	Array having dimensions 1-by-1
'vector'	Array having dimensions N-by-1 or 1-by-N (includes scalar arrays)

Numeric properties, such as `positive` and `nonnan`, do not apply to strings. If you attempt to validate numeric properties on a string, `validateattributes` generates an error.

Examples

Example 1

In this example, the `empl_profile1` function compares the values passed in each argument to the specified classes and attributes and throws an error if they are not correct:

```
function empl_profile1(empl_id, empl_info, healthplan, ...
   vacation)
validateattributes(empl_id, {'numeric'}, ...
   {'integer', 'nonempty'});
validateattributes(empl_info, {'struct'}, {'vector'});
validateattributes(healthplan, {'cell', 'char'}, ...
   {'vector'});
validateattributes(vacation, {'numeric'}, ...
   {'nonnegative', 'scalar'});
```

Call the `empl_profile1` function, passing the expected argument types, and the example completes without error:

```
empl_id = 51723;
empl_info.name = 'John Miller';
empl_info.address = '128 Forsythe St.';
```

```
empl_info.town = 'Duluth';  empl_info.state='MN';

empl_profile1(empl_id, empl_info, 'HCP Medical Plus', 14.3)
```

If you accidentally pass the argument values out of their correct sequence, MATLAB throws an error in response to the first argument that is not a match:

```
empl_profile1(empl_id, empl_info, 14.3, 'HCP Medical Plus')

??? Error using ==> empl_profile1 at 6
Expected input to be one of these types:

  cell, char

Instead its type was double.
```

Example 2

Write a new function `empl_profile2` that displays the function name, variable name, and position of the argument:

```
function empl_profile2(empl_id, empl_info, healthplan, ...
   vacation)

validateattributes(empl_id, ...
   {'numeric'}, {'integer', 'nonempty'}, ...
   mfilename, 'Employee Identification', 1);

validateattributes(empl_info, ...
   {'struct'}, {'vector'}, ...
   mfilename, 'Employee Info', 2);

validateattributes(healthplan, ...
   {'cell', 'char'}, {'vector'}, ...
   mfilename, 'Health Plan', 3);
```

```
validateattributes(vacation, ...
   {'numeric'}, {'nonnegative', 'scalar'}, ...
   mfilename, 'Vacation Accrued', 4);
```

Call `empl_profile2` with the argument values out of sequence. MATLAB throws an error that includes the name of the function validating the attributes, the name of the variable that was in error, and its position in the input argument list:

```
??? Error using ==> empl_profile2
Expected input number 3, Health Plan, to be one of
these types:

  cell, char

Instead its type was double.

Error in ==> empl_profile2 at 12
validateattributes(healthplan, ...
```

Example 3

Write a new function `empl_profile2` that checks the input parameters with `inputParser`. Use `validateattributes` as the validating function for the `inputParser` methods:

```
function empl_profile3(empl_id, varargin)
p = inputParser;

% Validate the input arguments.
addRequired(p, 'empl_id', ...
   @(x)validateattributes(x, {'numeric'}, {'integer'}));
addOptional(p, 'empl_info', '', ...
   @(x)validateattributes(x, {'struct'}, {'nonempty'}));
addParamValue(p, 'health', 'HCP Medical Plus', ...
   @(x)validateattributes(x, {'cell', 'char'}, ...
   {'vector'}));
```

```
addParamValue(p, 'vacation', [], ...
   @(x)validateattributes(x, {'numeric'}, ...
   {'nonnegative', 'scalar'}));
parse(p, empl_id, varargin{:});
p.Results
```

Call `empl_profile` using appropriate input arguments:

```
empl_info.name = 'John Miller';
empl_info.address = '128 Forsythe St.';
empl_info.town = 'Duluth';  empl_info.state='MN';

empl_profile(51723, empl_info, 'vacation', 14.3)

ans =
     empl_id: 51723
   empl_info: [1x1 struct]
      health: 'HCP Medical Plus'
    vacation: 14.3000
```

Call `empl_profile` using a character string where a structure is expected:

```
empl_profile(51723, empl_info.name,  'vacation', 14.3)

??? Error using ==> empl_profile at 12
Argument 'empl_info' failed validation with error:
Expected input to be one of these types:

  struct

Instead its type was char.
```

See Also

`validatestring`, `is*`, `isa`, `inputParser`

validatestring

Purpose

Check validity of text string

Syntax

```
validstr = validatestring(str, strarray)
validstr = validatestring(str, strarray, position)
validstr = validatestring(str, strarray, funname)
validstr = validatestring(str, strarray, funname, varname)
validstr = validatestring(str, strarray, funname, varname,
   position)
```

Description

`validstr = validatestring(str, strarray)` checks the validity of text string `str`. If `str` matches one or more of the text strings in the cell array `strarray`, MATLAB returns the matching string in `validstr`. If `str` does not match any of the strings in `strarray`, MATLAB issues a formatted error message. MATLAB compares the strings without respect to letter case.

This table shows how `validatestring` determines what value to return. If multiple matches are found, `validatestring` returns the shortest matching string.

Type of Match	Example — Match 'ball' with . . .	Return Value
Exact match	`ball`, `barn`, `bell`	`ball`
Partial match (leading characters)	`balloon`, `barn`	`balloon`
Multiple partial matches where each string is a subset of another	`ball`, `ballo`, `balloo`, `balloon`	`ball`
Multiple partial matches where strings are unique	`balloon`, `ballet`	Error
No match	`barn`, `bell`	Error

`validstr = validatestring(str, strarray, position)` checks the validity of text string `str` and, if the validation fails, displays an error message that includes the position of the failing variable in the function argument list. The `position` input must be a positive integer.

`validstr = validatestring(str, strarray, funname)` checks the validity of text string `str` and, if the validation fails, displays an error message that includes the name of the function performing the validation (`funname`). The `funname` input must be a string enclosed in single quotation marks.

`validstr = validatestring(str, strarray, funname, varname)` checks the validity of text string `str` and, if the validation fails, displays an error message that includes the name of the function performing the validation (`funname`) and the name of the variable being validated (`varname`). The `funname` and `varname` inputs must be strings enclosed in single quotation marks.

`validstr = validatestring(str, strarray, funname, varname, position)` checks the validity of text string `str` and, if the validation fails, displays an error message that includes the name of the function performing the validation (`funname`), the name of the variable being validated (`varname`), and the position of this variable in the function argument list (`position`). The `funname` and `varname` inputs must be strings enclosed in single quotation marks. The `position` input must be a positive integer.

Examples

Example 1

Use `validatestring` to find the word `won` in the cell array of strings:

```
validatestring('won', {'wind', 'won', 'when'})
ans =
   won
```

Replace the word `won` with `wonder` in the string array. Because the leading characters of the input string and `wonder` are the same, `validatestring` finds a partial match between the two words and returns the full word `wonder`:

```
validatestring('won', {'wind', 'wonder', 'when'})
ans =
   wonder
```

If there is more than one partial match, and each string in the array is a subset or superset of the others, `validatestring` returns the shortest matching string:

```
validatestring('wond', {'won', 'wonder', 'wonderful'})
ans =
   wonder
```

However, if each string in the array is not subset or superset of each other, MATLAB throws an error because there is no exact match and it is not clear which of the two partial matches should be returned:

```
validatestring('wond', {'won', 'wonder', 'wondrous'})
??? Error using ==> validatestring at 89
Function VALIDATESTRING expected its input argument to
   match one of these strings:

  won, wonder, wondrous

The input, 'wond', matched more than one valid string.
```

Example 2

In this example, the `get_flight_numbers` function returns the flight numbers for routes between two cities: a point of origin and point of destination. The function uses `validatestring` to see if the origin and destination are among those covered by the airline. If not, an error message is displayed:

```
function get_flight_numbers(origin, destination)
% Only part of the airline's flight data is shown here.
   flights.chi2rio = [503, 196, 331, 373, 1475];
   flights.chi2par = [718, 9276, 172, 903, 7724 992, 1158];
   flights.chi2hon = [9193, 880, 471, 391];

   routes = {'Athens', 'Paris', 'Chicago', 'Sydney', ...
      'Cancun', 'London', 'Rio de Janeiro', 'Honolulu', ...
      'Rome', 'New York City'};
   orig = '';  dest = '';
```

```
    % Does the airline cover these cities?
    try
       orig = validatestring(origin, routes);
       dest = validatestring(destination, routes);
    catch
       % If not covered, then display error message.
       if isempty(orig)
          fprintf(...
             'We have no flights with origin: %s.\n', ...
             origin)
       elseif isempty(dest)
          fprintf('%s%s%s.\n', 'We have no flights ', ...
                  'with destination: ', destination)
       end
    return
    end

 % If covered, display the flights from 'orig' to 'dest'.
 fprintf(...
    'Flights available from %s to %s are:\n', orig, dest)
 reply = eval(...
   ['flights.' lower(orig(1:3)) '2' lower(dest(1:3))])';
 fprintf('   Flight %d\n', reply)
```

Enter a point of origin that is not covered by this airline:

```
get_flight_numbers('San Diego', 'Rio de Janeiro')
ans =
We have no flights with origin: San Diego.
```

Enter a destination that is misspelled:

```
get_flight_numbers('Chicago', 'Reo de Janeiro')
ans =
We have no flights with destination: Reo de Janeiro.
```

Enter a route that is covered:

```
get_flight_numbers('Chicago', 'Rio de Janeiro')
ans =
Flights available from Chicago to Rio de Janeiro are:
   Flight 503
   Flight 196
   Flight 331
   Flight 373
   Flight 1475
```

Example 3

Rewrite the try-catch block of Example 2 by adding funname, varname, and position arguments to the call to validatestring and replacing the return statement with rethrow:

```
% See if the cities entered are covered by this airline.
try
   orig = validatestring(...
      origin, routes, mfilename, 'Flight Origin', 1);
   dest = validatestring(...
      destination, routes, mfilename, ...
        'Flight Destination', 2);
catch e
   % If not covered, then display error message.
   if isempty(orig)
       fprintf(...
          'We have no flights with origin: %s.\n', ...
          origin)
   elseif isempty(dest)
       fprintf('%s%s%s.\n', 'We have no flights ', ...
                 'with destination: ', destination)
   end
   rethrow(e);
end
```

In response to the rethrow command, MATLAB displays an error message that includes the function name get_flight_numbers, the failing variable name Flight Destination', and its position in the argument list, 2:

```
get_flight_numbers('Chicago', 'Reo de Janeiro')
We have no flights with destination: Reo de Janeiro.

??? Error using ==> validatestring at 89
Function GET_FLIGHT_NUMBERS expected its input argument
    number 2, Flight Destination, to match one of these
    strings:

  Athens, Paris, Chicago, Sydney, Cancun, London, Rio de
Janeiro, Honolulu, Rome

The input, 'Reo de Janeiro', did not match any of the valid
   strings.

Error in ==> get_flight_numbers at 17
   dest = validatestring(destination, routes, mfilename,
   'destination', 2);
```

See Also

validateattributes, is*, isa, inputParser

values (Map)

Purpose

Return values of `containers.Map` object

Syntax

```
v = values(M)
v = values(M, keys)
```

Description

`v = values(M)` returns in cell array `v` the values that correspond to all keys in `Map` object `M`.

`v = values(M, keys)` returns in cell array `v`, those values in `Map` object `M` that correspond to the keys specified by the `keys` argument.

Read more about Map Containers in the MATLAB Programming Fundamentals documentation.

Examples

Create a `Map` object of four US states and their capital cities:

```
US_Capitals = containers.Map( ...
   {'Georgia', 'Alaska', 'Vermont', 'Oregon'}, ...
   {'Atlanta', 'Juneau', 'Montpelier', 'Salem'})
```

Find the capital cities of all states contained in the map:

```
v = values(US_Capitals)
v =
    'Juneau'    'Atlanta'    'Salem'    'Montpelier'
```

Find the capital cities of selected states:

```
 = values(US_Capitals, {'Oregon', 'Alaska'})
v =
    'Salem'    'Juneau'
```

See Also

`containers.Map`, `keys(Map)`, `size(Map)`, `length(Map)`, `isKey(Map)`, `remove(Map)`, `handle`

Purpose

Vandermonde matrix

Syntax

```
A = vander(v)
```

Description

`A = vander(v)` returns the Vandermonde matrix whose columns are powers of the vector `v`, that is, `A(i,j) = v(i)^(n-j)`, where `n = length(v)`.

Examples

```
vander(1:.5:3)

ans =

    1.0000    1.0000    1.0000    1.0000    1.0000
    5.0625    3.3750    2.2500    1.5000    1.0000
   16.0000    8.0000    4.0000    2.0000    1.0000
   39.0625   15.6250    6.2500    2.5000    1.0000
   81.0000   27.0000    9.0000    3.0000    1.0000
```

See Also

`gallery`

Purpose Variance

Syntax

```
V = var(X)
V = var(X,1)
V = var(X,w)
V = var(X,w,dim)
```

Description

V = var(X) returns the variance of X for vectors. For matrices, var(X)is a row vector containing the variance of each column of X. For N-dimensional arrays, var operates along the first nonsingleton dimension of X. The result V is an unbiased estimator of the variance of the population from which X is drawn, as long as X consists of independent, identically distributed samples.

var normalizes V by N-1 if N>1, where N is the sample size. This is an unbiased estimator of the variance of the population from which X is drawn, as long as X consists of independent, identically distributed samples. For N=1, V is normalized by N.

V = var(X,1) normalizes by N and produces the second moment of the sample about its mean.var(X,0) is equivalent to var(X).

V = var(X,w) computes the variance using the weight vector w. The length of w must equal the length of the dimension over which var operates, and its elements must be nonnegative. The elements of w must be positive. var normalizes w to sum of 1.

V = var(X,w,dim) takes the variance along the dimension dim of X. Pass in 0 for w to use the default normalization by N-1, or 1 to use N.

The variance is the square of the standard deviation (STD).

See Also corrcoef, cov, mean, median, std

Purpose

Variance of `timeseries` data

Syntax

```
ts_var = var(ts)
ts_var = var(ts,'PropertyName1',PropertyValue1,...)
```

Description

`ts_var = var(ts)` returns the variance of `ts.data`. When `ts.Data` is a vector, ts_var is the variance of `ts.Data` values. When `ts.Data` is a matrix, ts_var is a row vector containing the variance of each column of `ts.Data` (when `IsTimeFirst` is `true` and the first dimension of `ts` is aligned with time). For the N-dimensional `ts.Data` array, `var` always operates along the first nonsingleton dimension of `ts.Data`.

`ts_var = var(ts,'PropertyName1',PropertyValue1,...)` specifies the following optional input arguments:

- `'MissingData'` property has two possible values, `'remove'` (default) or `'interpolate'`, indicating how to treat missing data during the calculation.
- `'Quality'` values are specified by an integer vector, indicating which quality codes represent missing samples (for vector data) or missing observations (for data arrays with two or more dimensions).
- `'Weighting'` property has two possible values, `'none'` (default) or `'time'`.
  When you specify `'time'`, larger time values correspond to larger weights.

Examples

The following example shows how to calculate the variance values of a multi-variate `timeseries` object.

1 Load a 24-by-3 data array.

```
load count.dat
```

2 Create a `timeseries` object with 24 time values.

```
count_ts = timeseries(count,[1:24],'Name','CountPerSecond')
```

3 Calculate the variance of each data column for this `timeseries` object.

```
var(count_ts)
ans =

  1.0e+003 *

    0.6437    1.7144    4.6278
```

The variance is calculated independently for each data column in the `timeseries` object.

See Also

`iqr (timeseries)`, `mean (timeseries)`, `median (timeseries)`, `std (timeseries)`, `timeseries`

Purpose

Variable length input argument list

Syntax

```
function y = bar(varargin)
```

Description

`function y = bar(varargin)` accepts a variable number of arguments into function `bar.m`.

The `varargin` statement is used only inside a function M-file to contain optional input arguments passed to the function. The `varargin` argument must be declared as the last input argument to a function, collecting all the inputs from that point onwards. In the declaration, `varargin` must be lowercase.

Examples

Example 1

Write an M-file function that displays the expected and optional arguments you pass to it

```
function vartest(argA, argB, varargin)

optargin = size(varargin,2);
stdargin = nargin - optargin;

fprintf('Number of inputs = %d\n', nargin)

fprintf('  Inputs from individual arguments(%d):\n', ...
        stdargin)
if stdargin >= 1
    fprintf('     %d\n', argA)
end
if stdargin == 2
    fprintf('     %d\n', argB)
end

fprintf('  Inputs packaged in varargin(%d):\n', optargin)
 for k= 1 : size(varargin,2)
     fprintf('     %d\n', varargin{k})
 end
```

Call this function and observe that the MATLAB software extracts those arguments that are not individually-specified from the `varargin` cell array:

```
vartest(10,20,30,40,50,60,70)
Number of inputs = 7
  Inputs from individual arguments(2):
     10
     20
  Inputs packaged in varargin(5):
     30
     40
     50
     60
     70
```

Example 2

The function

```
function myplot(x,varargin)
plot(x,varargin{:})
```

collects all the inputs starting with the second input into the variable `varargin`. `myplot` uses the comma-separated list syntax `varargin{:}` to pass the optional parameters to `plot`. The call

```
myplot(sin(0:.1:1),'color',[.5 .7 .3],'linestyle',':')
```

results in `varargin` being a 1-by-4 cell array containing the values `'color'`, `[.5 .7 .3]`, `'linestyle'`, and `':'`.

See Also

`varargout`, `nargin`, `nargout`, `nargchk`, `nargoutchk`, `inputname`

Purpose

Variable length output argument list

Syntax

`function varargout = foo(n)`

Description

`function varargout = foo(n)` returns a variable number of arguments from function `foo.m`.

The `varargout` statement is used only inside a function M-file to contain the optional output arguments returned by the function. The `varargout` argument must be declared as the last output argument to a function, collecting all the outputs from that point onwards. In the declaration, `varargout` must be lowercase.

Examples

The function

```
function [s,varargout] = mysize(x)
nout = max(nargout,1)-1;
s = size(x);
for k=1:nout, varargout(k) = {s(k)}; end
```

returns the size vector and, optionally, individual sizes. So

```
[s,rows,cols] = mysize(rand(4,5));
```

returns `s = [4 5], rows = 4, cols = 5`.

See Also

`varargin`, `nargin`, `nargout`, `nargchk`, `nargoutchk`, `inputname`

Purpose

Vectorize expression

Syntax

```
vectorize(s)
vectorize(fun)
```

Description

`vectorize(s)` where `s` is a string expression, inserts a `.` before any `^`, `*` or `/` in `s`. The result is a character string.

`vectorize(fun)` when `fun` is an inline function object, vectorizes the formula for `fun`. The result is the vectorized version of the inline function.

See Also

`inline`, `cd`, `dbtype`, `delete`, `dir`, `partialpath`, `path`, `what`, `who`

Purpose

Version information for MathWorks products

GUI Alternatives

As an alternative to the `ver` function, select **Help > About** in any tool that has a **Help** menu.

Syntax

```
ver
ver product
v = ver('product')
```

Description

`ver` displays a header containing the current MathWorks product family version number, license number, operating system, and version of Sun Microsystems JVM software for the MATLAB product. This is followed by the version numbers for MATLAB, Simulink, if installed, and all other installed MathWorks products.

`ver product` displays the MathWorks product family header information followed by the current version number for `product`. The name `product` corresponds to the directory name that holds the `Contents.m` file for that product. For example, `Contents.m` for the Control System Toolbox product resides in the `control` directory. You therefore use `ver control` to obtain the version of this toolbox.

`v = ver('product')` returns the version information to structure array, `v`, having fields `Name`, `Version`, `Release`, and `Date`.

Remarks

To use `ver` with your own product, the first two lines of the `Contents.m` file for the product must be of the form

```
% Toolbox Description
% Version xxx dd-mmm-yyyy
```

Do not include any spaces in the date and use a two-character day; that is, use `02-Sep-2008` instead of `2-Sep-2008`.

Examples

Using R2008b, return version information for MathWorks products, and specifically the Control System Toolbox product by typing

```
ver control
```

MATLAB returns

```
-------------------------------------------------------------------------------------
MATLAB Version 7.7.0.31532 (R2008b)
MATLAB License Number: [not shown]
Operating System: Microsoft Windows XP Version 5.1 (Build 2600: Service Pack 2)
Java VM Version: Java 1.6.0_04 with Sun Microsystems Inc. Java HotSpot(TM) Client VM mixed mode
-------------------------------------------------------------------------------------
Control System Toolbox                                Version 8.2        (R2008b)
```

Return version information for the Control System Toolbox product in a structure array, v.

```
v = ver('control')
v =

       Name: 'Control System Toolbox'
    Version: '8.2'
    Release: '(R2008b)'
       Date: '24-Sep-2008'
```

Display version information for MathWorks 'Real-Time' products:

```
v = ver;
for k=1:length(v)
   if strfind(v(k).Name, 'Real-Time')
      disp(sprintf('%s, Version %s', ...
                   v(k).Name, v(k).Version))
   end
end

Real-Time Windows Target, Version 3.2
Real-Time Workshop, Version 7.2
Real-Time Workshop Embedded Coder, Version 5.2
```

See Also

help, hostid, license, verlessthan, version, whatsnew

Help > Check for Updates in the MATLAB desktop.

Purpose

Source control actions (Windows platforms)

GUI Alternatives

As an alternative to the `verctrl` function, use **Source Control** in the **File** menu of the Editor, the Simulink product, or the Stateflow product, or in the context menu of the Current Directory browser.

Syntax

```
verctrl('action',{'filename1','filename2',....},0)
result=verctrl('action',{'filename1','filename2',....},0)
verctrl('action','filename',0)
result=verctrl('isdiff','filename',0)
list = verctrl('all_systems')
```

Description

`verctrl('action',{'filename1','filename2',....},0)` performs the source control operation specified by `'action'` for a single file or multiple files. Enter one file as a string; specify multiple files using a cell array of strings. Use the full paths for each filename and include the extensions. Specify `0` as the last argument. Complete the resulting dialog box to execute the operation; for details about the dialog boxes, see the topic "Source Control Interface on Microsoft Windows" in the MATLAB Desktop Tools and Development Environment documentation. Available values for `'action'` are as follows:

action Argument	Purpose
`'add'`	Adds files to the source control system. Files can be open in the Editor or closed when added.
`'checkin'`	Checks files into the source control system, storing the changes and creating a new version.
`'checkout'`	Retrieves files for editing.
`'get'`	Retrieves files for viewing and compiling, but not editing. When you open the files, they are labeled as read-only.
`'history'`	Displays the history of files.

action Argument	Purpose
'remove'	Removes files from the source control system. It does not delete the files from disk, but only from the source control system.
'runscc'	Starts the source control system. The filename can be an empty string.
'uncheckout'	Cancels a previous checkout operation and restores the contents of the selected files to the precheckout version. All changes made to the files since the checkout are lost.

`result=verctrl('action',{'filename1','filename2',....},0)` performs the source control operation specified by `'action'` on a single file or multiple files. The action can be any one of: `'add'`, `'checkin'`, `'checkout'`, `'get'`, `'history'`, or `'undocheckout'`. `result` is a logical `1` (true) when you complete the operation by clicking **OK** in the resulting dialog box, and is a logical `0` (false) when you abort the operation by clicking **Cancel** in the resulting dialog box.

`verctrl('action','filename',0)` performs the source control operation specified by `'action'` for a single file. Use the full pathname for `'filename'`. Specify `0` as the last argument. Complete any resulting dialog boxes to execute the operation. Available values for `'action'` are as follows:

action Argument	Purpose
'showdiff'	Displays the differences between a file and the latest checked in version of the file in the source control system.
'properties'	Displays the properties of a file.

`result=verctrl('isdiff','filename',0)` compares `filename` with the latest checked in version of the file in the source control system. `result` is a logical `1` (true) when the files are different, and is a logical `0` (false) when the files are identical. Use the full path for `'filename'`. Specify `0` as the last argument.

`list = verctrl('all_systems')` displays in the Command Window a list of all source control systems installed on your computer.

Examples

Check In a File

Check in `D:\file1.ext` to the source control system.

```
result = verctrl('checkin','D:\file1.ext', 0)
```

This opens the **Check in file(s)** dialog box. Click **OK** to complete the check in. MATLAB displays `result = 1`, indicating the checkin was successful.

Add Files to the Source Control System

Add `D:\file1.ext` and `D:\file2.ext` to the source control system.

```
verctrl('add',{'D:\file1.ext','D:\file2.ext'}, 0)
```

This opens the **Add to source control** dialog box. Click **OK** to complete the operation.

Display the Properties of a File

Display the properties of `D:\file1.ext`.

```
verctrl('properties','D:\file1.ext', 0)
```

This opens the source control properties dialog box for your source control system. The function is complete when you close the properties dialog box.

Show Differences for a File

To show the differences between the version of `file1.ext` that you just edited and saved, with the last version in source control, run

```
verctrl('showdiff','D:\file1.ext',0)
```

MATLAB displays differences dialog boxes and results specific to your source control system. After checking in the file, if you run this statement again, MATLAB displays

```
??? The file is identical to latest version under source control.
```

List All Installed Source Control Systems

To view all of the source control systems installed on your computer, type

```
list = verctrl ('all_systems')
```

MATLAB displays all the source control systems currently installed on your computer. For example:

```
list =
'Microsoft Visual SourceSafe'
'ComponentSoftware RCS'
```

See Also

`checkin`, `checkout`, `undocheckout`, `cmopts`

"Source Control Interface on Microsoft Windows" in MATLAB Desktop Tools and Development Environment documentation

Purpose

Compare toolbox version to specified version string

Syntax

```
verLessThan(toolbox, version)
```

Description

`verLessThan(toolbox, version)` returns logical 1 (`true`) if the version of the toolbox specified by the string `toolbox` is older than the version specified by the string `version`, and logical 0 (`false`) otherwise. Use this function when you want to write code that can run across multiple versions of the MATLAB software, when there are differences in the behavior of the code in the different versions.

The `toolbox` argument is a string enclosed within single quotation marks that contains the name of a MATLAB toolbox directory. The `version` argument is a string enclosed within single quotation marks that contains the version to compare against. This argument must be in the form `major[.minor[.revision]]`, such as `7`, `7.1`, or `7.0.1`. If `toolbox` does not exist, MATLAB generates an error.

To specify `toolbox`, find the directory that holds the `Contents.m` file for the toolbox and use that directory name. To see a list of all toolbox directory names, enter the following statement in the MATLAB Command Window:

```
dir([matlabroot '/toolbox'])
```

Remarks

The `verLessThan` function is available with MATLAB Version 7.4 and subsequent versions. If you are running a version of MATLAB prior to 7.4, you can download the `verLessThan` M-file from the following MathWorks Technical Support solution. You must be running MATLAB Version 6.0 or higher to use this M-file:

`http://www.mathworks.com/support/solutions/data/1-38LI61.html?solution`

Examples

These examples illustrate usage of the `verLessThan` function.

Example 1 – Checking For the Minimum Required Version

```
if verLessThan('simulink', '4.0')
    error('Simulink 4.0 or higher is required.');
```

```
end
```

Example 2 – Choosing Which Code to Run

```
if verLessThan('matlab', '7.0.1')
% -- Put code to run under MATLAB 7.0.0 and earlier here --
else
% -- Put code to run under MATLAB 7.0.1 and later here --
end
```

Example 3 – Looking Up the Directory Name

Find the name of the Data Acquisition Toolbox directory:

```
dir([matlabroot '/toolbox/d*'])

   daq        database   des      distcomp   dotnetbuilder
   dastudio   datafeed   dials    dml        dspblks
```

Use the toolbox directory name, `daq`, to compare the Data Acquisition Toolbox software version that MATLAB is currently running against version number `3`:

```
verLessThan('daq', '3')
ans =
     1
```

See Also

`ver`, `version`, `license`, `ispc`, `isunix`, `ismac`, `dir`

Purpose

Version number for the MATLAB software

GUI Alternatives

As an alternative to the `version` function, select **Help > About** in the MATLAB desktop.

Syntax

```
version
v = version
version option
v = version('option')
```

Description

`version` displays the MathWorks product family version.

`v = version` returns the MathWorks product family version number in string `v`.

`version` *`option`* displays the following additional information about the version. You can specify no more than one option in a `version` command.

Option	Description
`-date`	Release date
`-description`	Release description. Mostly used for Service Pack releases.
`-java`	Sun Microsystems JVM software version used by MATLAB
`-release`	Release number

`v = version('`*`option`*`')` returns in string `v` the information displayed in response to the syntax shown above. You can only specify no more than one option when using this syntax.

Remarks

On Microsoft Windows and UNIX[30] platforms, MATLAB includes JVM software and uses that version. If you use the MATLAB interface to Sun Microsystems Java software and the Java classes you want to use require a different version of the JVM software than that provided with MATLAB, it is possible to run MATLAB with a different version of JVM software. For details, see "Using a Different Version of JVM Software".

On the Apple Macintosh platform, MATLAB does not include JVM software, but uses whatever JVM software is currently running on the machine.

Examples

```
d = version('-date')
d =
   September 24, 2008
```

Run the following command in MATLAB Version 7.7 (R2008b):

```
['Release R' version('-release') ', '  version('-description')]

ans =
   Release R2008b,
```

See Also

`ver`, `verlessthan`, `whatsnew`

Help > Check for Updates in the MATLAB desktop.

30. UNIX is a registered trademark of The Open Group in the United States and other countries.

Purpose

Concatenate arrays vertically

Syntax

```
C = vertcat(A1, A2, ...)
```

Description

`C = vertcat(A1, A2, ...)` vertically concatenates matrices `A1`, `A2`, and so on. All matrices in the argument list must have the same number of columns.

`vertcat` concatenates N-dimensional arrays along the first dimension. The remaining dimensions must match.

MATLAB calls `C = vertcat(A1, A2, ...)` for the syntax `C = [A1; A2; ...]` when any of `A1`, `A2`, etc. is an object.

Examples

Create a 5-by-3 matrix, `A`, and a 3-by-3 matrix, `B`. Then vertically concatenate `A` and `B`.

```
A = magic(5);            % Create 5-by-3 matrix, A
A(:, 4:5) = []

A =

    17    24     1
    23     5     7
     4     6    13
    10    12    19
    11    18    25


B = magic(3)*100         % Create 3-by-3 matrix, B

B =

   800   100   600
   300   500   700
   400   900   200
```

```
C = vertcat(A,B)        % Vertically concatenate A and B

C =

    17    24     1
    23     5     7
     4     6    13
    10    12    19
    11    18    25
   800   100   600
   300   500   700
   400   900   200
```

See Also

horzcat, cat

Purpose Vertical concatenation of `timeseries` objects

Syntax

```
ts = vertcat(ts1,ts2,...)
```

Description `ts = vertcat(ts1,ts2,...)` performs

```
ts = [ts1;ts2;...]
```

This operation appends `timeseries` objects. The time vectors must not overlap. The last time in ts1 must be earlier than the first time in ts2. The data sample size of the `timeseries` objects must agree.

See Also `timeseries`

vertcat (tscollection)

Purpose Vertical concatenation for `tscollection` objects

Syntax

```
tsc = vertcat(tsc1,tsc2,...)
```

Description `tsc = vertcat(tsc1,tsc2,...)` performs

```
tsc = [tsc1;tsc2;...]
```

This operation appends `tscollection` objects. The time vectors must not overlap. The last time in tsc1 must be earlier than the first time in tsc2. All `tscollection` objects to be concatenated must have the same `timeseries` members.

See Also `horzcat (tscollection)`, `tscollection`

Purpose Viewpoint specification

Syntax

```
view(az,el)
view([x,y,z])
view(2)
view(3)
view(ax,...)
view(T)
[az,el] = view
T = view
```

Description The position of the viewer (the viewpoint) determines the orientation of the axes. You specify the viewpoint in terms of azimuth and elevation, or by a point in three-dimensional space.

`view(az,el)` and view([az,el]) set the viewing angle for a three-dimensional plot. The azimuth, `az`, is the horizontal rotation about the *z*-axis as measured in degrees from the negative *y*-axis. Positive values indicate counterclockwise rotation of the viewpoint. `el` is the vertical elevation of the viewpoint in degrees. Positive values of elevation correspond to moving above the object; negative values correspond to moving below the object.

`view([x,y,z])` sets the viewpoint to the Cartesian coordinates `x`, `y`, and `z`. The magnitude of `(x,y,z)` is ignored.

`view(2)` sets the default two-dimensional view, `az = 0`, `el = 90`.

`view(3)` sets the default three-dimensional view, `az =  37.5`, `el = 30`.

`view(ax,...)` uses axes `ax` instead of the current axes.

`view(T)` sets the view according to the transformation matrix `T`, which is a 4-by-4 matrix such as a perspective transformation generated by `viewmtx`.

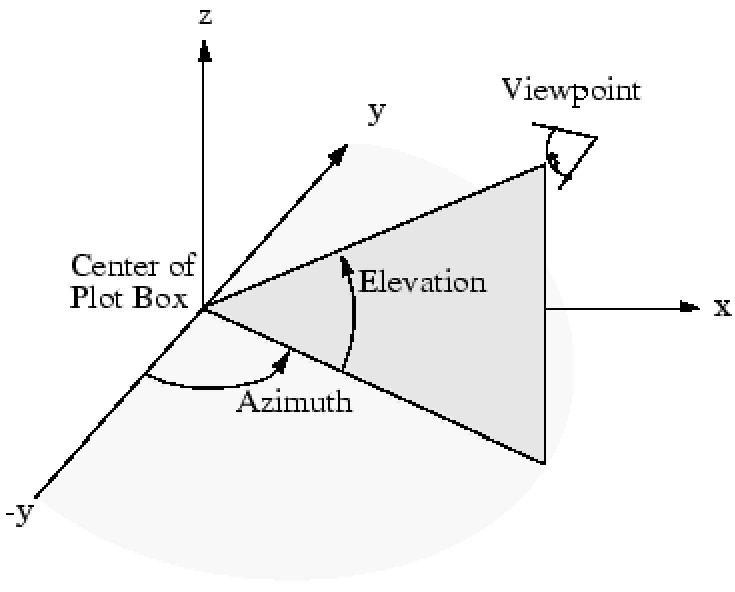
`[az,el] = view` returns the current azimuth and elevation.

`T = view` returns the current 4-by-4 transformation matrix.

Remarks

Azimuth is a polar angle in the *x-y* plane, with positive angles indicating counterclockwise rotation of the viewpoint. Elevation is the angle above (positive angle) or below (negative angle) the *x-y* plane.

This diagram illustrates the coordinate system. The arrows indicate positive directions.



Examples

View the object from directly overhead.

```
az = 0;
el = 90;
view(az, el);
```

Set the view along the *y*-axis, with the *x*-axis extending horizontally and the *z*-axis extending vertically in the figure.

```
view([0 0]);
```

Rotate the view about the *z*-axis by 180º.

```
az = 180;
el = 90;
view(az, el);
```

See Also

`viewmtx`, `hgtransform`, `rotate3d`

"Camera Viewpoint" on page 1-103 for related functions

Axes graphics object properties `CameraPosition`, `CameraTarget`, `CameraViewAngle`, `Projection`

Defining the View for more information on viewing concepts and techniques

Transforming Objects for information on moving and scaling objects in groups

viewmtx

Purpose

View transformation matrices

Syntax

```
viewmtx
T = viewmtx(az,el)
T = viewmtx(az,el,phi)
T = viewmtx(az,el,phi,xc)
```

Description

`viewmtx` computes a 4-by-4 orthographic or perspective transformation matrix that projects four-dimensional homogeneous vectors onto a two-dimensional view surface (e.g., your computer screen).

`T = viewmtx(az,el)` returns an *orthographic* transformation matrix corresponding to azimuth `az` and elevation `el`. `az` is the azimuth (i.e., horizontal rotation) of the viewpoint in degrees. `el` is the elevation of the viewpoint in degrees. This returns the same matrix as the commands

```
view(az,el)
T = view
```

but does not change the current view.

`T = viewmtx(az,el,phi)` returns a *perspective* transformation matrix. `phi` is the perspective viewing angle in degrees. `phi` is the subtended view angle of the normalized plot cube (in degrees) and controls the amount of perspective distortion.

Phi	Description
0 degrees	Orthographic projection
10 degrees	Similar to telephoto lens
25 degrees	Similar to normal lens
60 degrees	Similar to wide-angle lens

You can use the matrix returned to set the view transformation with `view(T)`. The 4-by-4 perspective transformation matrix transforms four-dimensional homogeneous vectors into unnormalized vectors of the form (x,y,z,w), where w is not equal to 1. The x- and y-components of the normalized vector (x/w, y/w, z/w, 1) are the desired two-dimensional components (see example below).

`T = viewmtx(az,el,phi,xc)` returns the perspective transformation matrix using `xc` as the target point within the normalized plot cube (i.e., the camera is looking at the point `xc`). `xc` is the target point that is the center of the view. You specify the point as a three-element vector, `xc = [xc,yc,zc]`, in the interval [0,1]. The default value is `xc = [0,0,0]`.

Remarks

A four-dimensional homogenous vector is formed by appending a 1 to the corresponding three-dimensional vector. For example, `[x,y,z,1]` is the four-dimensional vector corresponding to the three-dimensional point `[x,y,z]`.

Examples

Determine the projected two-dimensional vector corresponding to the three-dimensional point (0.5,0.0,-3.0) using the default view direction. Note that the point is a column vector.

```
A = viewmtx(-37.5,30);
x4d = [.5  0  -3  1]';
x2d = A*x4d;
x2d = x2d(1:2)
x2d =
     0.3967
    -2.4459
```

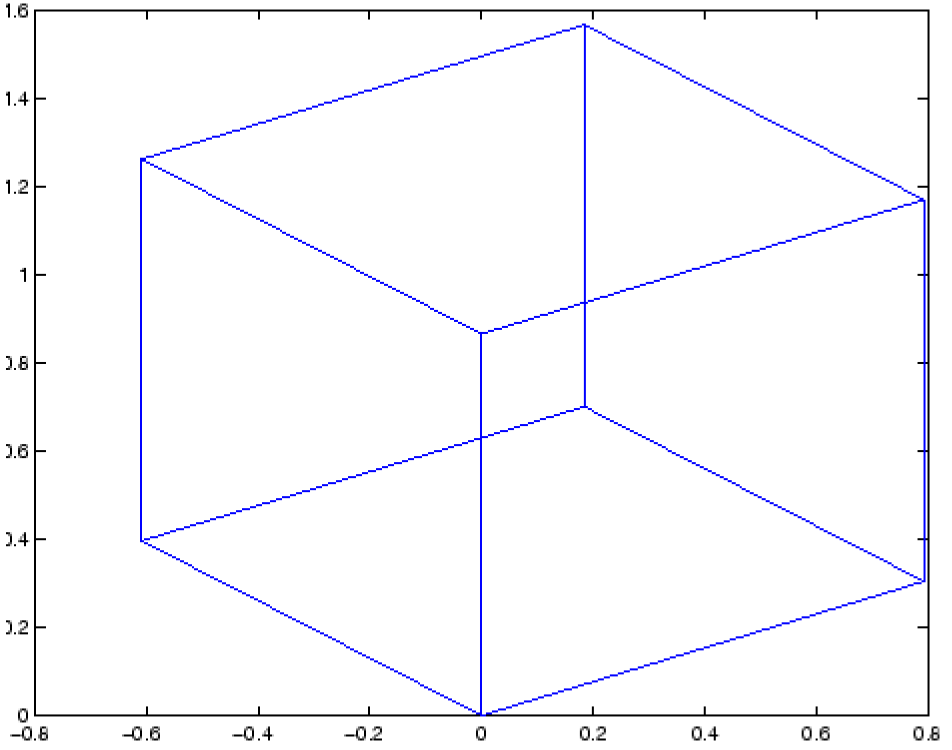
Vectors that trace the edges of a unit cube are

```
x = [0  1  1  0  0  0  1  1  0  0  1  1  1  1  0  0];
y = [0  0  1  1  0  0  0  1  1  0  0  0  1  1  1  1];
z = [0  0  0  0  0  1  1  1  1  1  1  0  0  1  1  0];
```

Transform the points in these vectors to the screen, then plot the object.

```
A = viewmtx(-37.5,30);
[m,n] = size(x);
x4d = [x(:),y(:),z(:),ones(m*n,1)]';
```

```
x2d = A*x4d;
x2 = zeros(m,n); y2 = zeros(m,n);
x2(:) = x2d(1,:);
y2(:) = x2d(2,:);
plot(x2,y2)
```



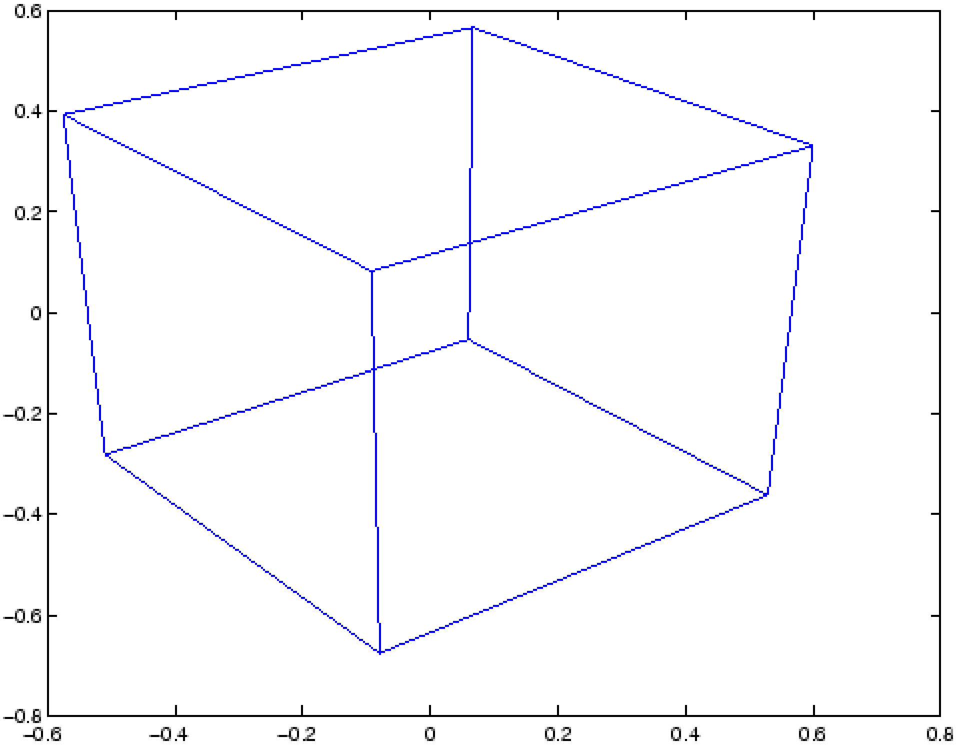
Use a perspective transformation with a 25 degree viewing angle:

```
A = viewmtx(-37.5,30,25);
x4d = [.5  0  -3  1]';
x2d = A*x4d;
x2d = x2d(1:2)/x2d(4)   % Normalize
x2d =
```

```
  0.1777
 -1.8858
```

Transform the cube vectors to the screen and plot the object:

```
A = viewmtx(-37.5,30,25);
[m,n] = size(x);
x4d = [x(:),y(:),z(:),ones(m*n,1)]';
x2d = A*x4d;
x2 = zeros(m,n); y2 = zeros(m,n);
x2(:) = x2d(1,:)./x2d(4,:);
y2(:) = x2d(2,:)./x2d(4,:);
plot(x2,y2)
```



See Also `view`, `hgtransform`

"Camera Viewpoint" on page 1-103 for related functions

Defining the View for more information on viewing concepts and techniques

Purpose

Compare two text files, MAT-Files, or binary files

GUI Alternative

As an alternative to the `visdiff` function, select **Desktop > File and Directory Comparisons**, and then in the File and Directory Comparisons tool select **File > New File Comparison**.

Syntax

```
visdiff('fname1', 'fname2')
visdiff('fname1', 'fname2', showchars)
S = visdiff('fname1', 'fname2')
```

Description

`visdiff('fname1', 'fname2')` opens the File and Directory Comparisons tool and presents the differences between the two files. The two files must be on the MATLAB path, or you must provide the full path for each file.

`visdiff('fname1', 'fname2', showchars)` opens the File and Directory Comparisons tool with the width of each column in the display set to `showchars` characters wide. MATLAB ignores the `showchars` option when you compare two binary files or two MAT-Files.

`S = visdiff('fname1', 'fname2')` creates an HTML report describing the differences between the two files and returns it in the string `S`.

Remarks

MATLAB supports displaying the differences in the File and Directory Comparisons tool only if Java software is installed. However, MATLAB supports assigning the HTML report to a string, even if the Java software is not installed.

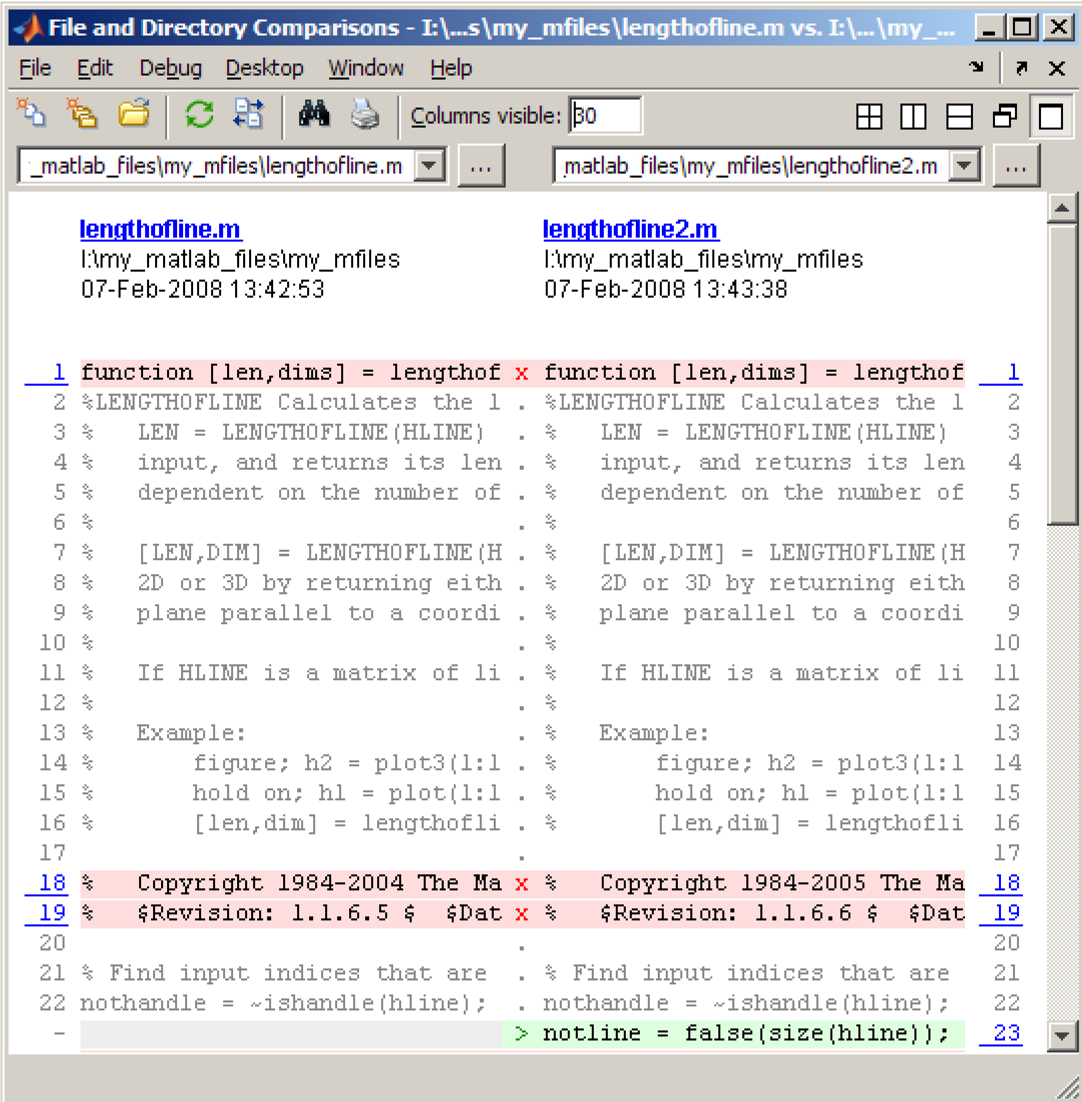
Examples

Compare Two Text Files in the Current Directory

For this example, copy the sample files, `lengthofline.m` and `lengthofline2.m` to your current directory as described in "Comparing Files and Directories", and then type:

```
visdiff('lengthofline.m', 'lengthofline2.m', 30)
```

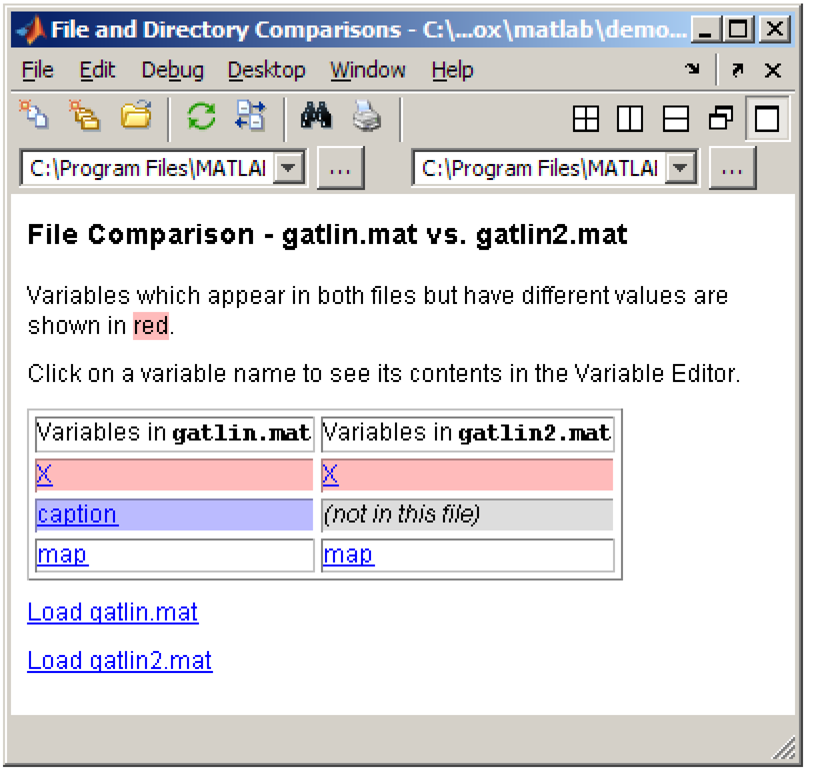
The File and Directory Comparisons tool opens and presents the differences between the two text files with the width of the left column set to 30.


File and Directory Comparisons - I:\...s\my_mfiles\lengthofline.m vs. I:\...\my_...
File Edit Debug Desktop Window Help
Columns visible: 30
_matlab_files\my_mfiles\lengthofline.m
matlab_files\my_mfiles\lengthofline2.m
lengthofline.m
I:\my_matlab_files\my_mfiles
07-Feb-2008 13:42:53
lengthofline2.m
I:\my_matlab_files\my_mfiles
07-Feb-2008 13:43:38
1 function [len,dims] = lengthof x function [len,dims] = lengthof 1
2 %LENGTHOFLINE Calculates the l . %LENGTHOFLINE Calculates the l 2
3 % LEN = LENGTHOFLINE(HLINE) . % LEN = LENGTHOFLINE(HLINE) 3
4 % input, and returns its len . % input, and returns its len 4
5 % dependent on the number of . % dependent on the number of 5
6 % . % 6
7 % [LEN,DIM] = LENGTHOFLINE(H . % [LEN,DIM] = LENGTHOFLINE(H 7
8 % 2D or 3D by returning eith . % 2D or 3D by returning eith 8
9 % plane parallel to a coordi . % plane parallel to a coordi 9
10 % . % 10
11 % If HLINE is a matrix of li . % If HLINE is a matrix of li 11
12 % . % 12
13 % Example: . % Example: 13
14 % figure; h2 = plot3(1:1 . % figure; h2 = plot3(1:1 14
15 % hold on; h1 = plot(1:1 . % hold on; h1 = plot(1:1 15
16 % [len,dim] = lengthofli . % [len,dim] = lengthofli 16
17 . 17
18 % Copyright 1984-2004 The Ma x % Copyright 1984-2005 The Ma 18
19 % $Revision: 1.1.6.5 $ $Dat x % $Revision: 1.1.6.6 $ $Dat 19
20 . 20
21 % Find input indices that are . % Find input indices that are 21
22 nothandle = ~ishandle(hline); . nothandle = ~ishandle(hline); 22
- > notline = false(size(hline)); 23

Compare Two MAT-Files Off the MATLAB Path

If you enter the following command, the File and Directory Comparisons tool opens and presents the differences between the two MAT-Files.

```
visdiff('C:\Program Files\MATLAB\R2008b\toolbox\matlab\demos\gatlin.mat', ...
'C:\Program Files\MATLAB\R2008b\toolbox\matlab\demos\gatlin2.mat')
```



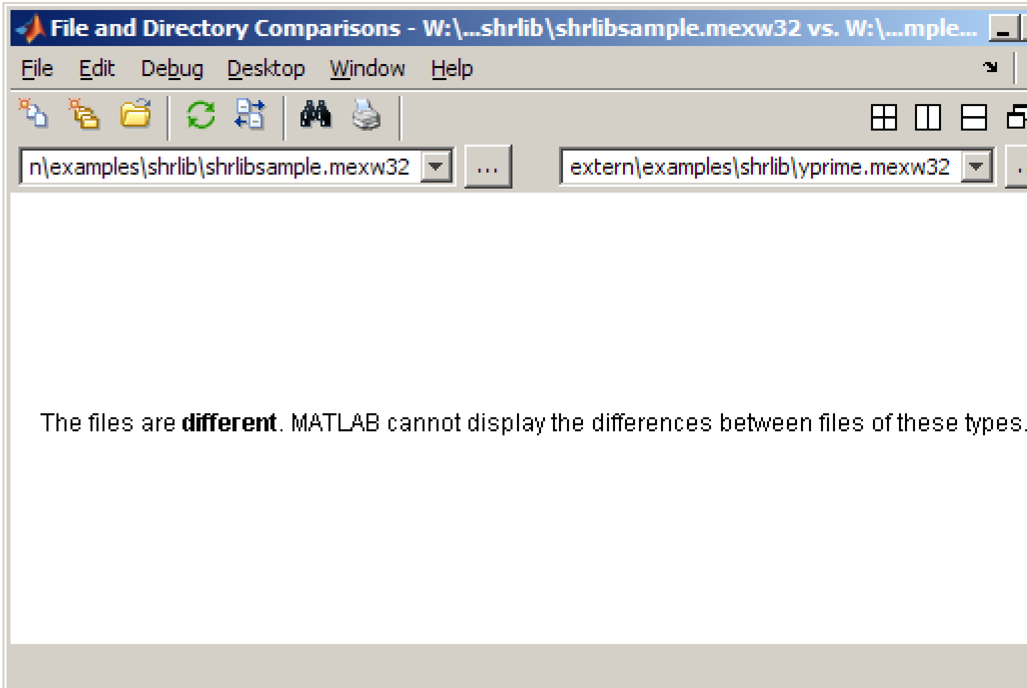
Compare Two Binary Files on the MATLAB Path

Add the directory containing two MEX-files to the MATLAB path, and then compare the files, by issuing the following commands:

```
addpath([matlabroot '\extern\examples\shrlib'])
```

```
visdiff('shrlibsample.mexw32', 'yprime.mexw32')
```

The File and Directory Comparisons tool opens and indicates that the files are different, but does not provide details about the differences.



See Also

"Comparing Files and Directories"

volumebounds

Purpose

Coordinate and color limits for volume data

Syntax

```
lims = volumebounds(X,Y,Z,V)
lims = volumebounds(X,Y,Z,U,V,W)
lims = volumebounds(V), lims = volumebounds(U,V,W)
```

Description

`lims = volumebounds(X,Y,Z,V)` returns the x, y, z, and color limits of the current axes for scalar data. `lims` is returned as a vector:

```
[xmin xmax ymin ymax zmin zmax cmin cmax]
```

You can pass this vector to the `axis` command.

`lims = volumebounds(X,Y,Z,U,V,W)` returns the x, y, and z limits of the current axes for vector data. `lims` is returned as a vector:

```
[xmin xmax ymin ymax zmin zmax]
```

`lims = volumebounds(V), lims = volumebounds(U,V,W)` assumes `X`, `Y`, and `Z` are determined by the expression

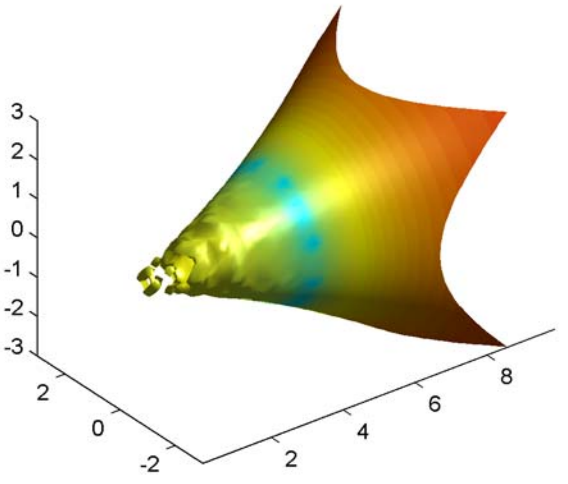
```
[X Y Z] = meshgrid(1:n,1:m,1:p)
```

where `[m n p] = size(V)`.

Examples

This example uses `volumebounds` to set the axis and color limits for an `isosurface` generated by the `flow` function.

```
[x y z v] = flow;
p = patch(isosurface(x,y,z,v,-3));
isonormals(x,y,z,v,p)
daspect([1 1 1])
isocolors(x,y,z,flipdim(v,2),p)
shading interp
axis(volumebounds(x,y,z,v))
view(3)
camlight
lighting phong
```



See Also

`isosurface`, `streamslice`

"Volume Visualization" on page 1-106 for related functions

voronoi

Purpose

Voronoi diagram

Syntax

```
voronoi(x,y)
voronoi(x,y,TRI)
voronoi(X,Y,options)
voronoi(AX,...)
voronoi(...,'LineSpec')
h = voronoi(...)
[vx,vy] = voronoi(...)
```

Definition

Consider a set of coplanar points P. For each point P_x in the set P, you can draw a boundary enclosing all the intermediate points lying closer to P_x than to other points in the set P. Such a boundary is called a *Voronoi polygon*, and the set of all Voronoi polygons for a given point set is called a *Voronoi diagram*.

Description

`voronoi(x,y)` plots the bounded cells of the Voronoi diagram for the points `x`,`y`. Lines-to-infinity are approximated with an arbitrarily distant endpoint.

`voronoi(x,y,TRI)` uses the triangulation `TRI` instead of computing it via `delaunay`.

`voronoi(X,Y,options)` specifies a cell array of strings to be used as options in Qhull via `delaunay`.

If `options` is `[]`, the default `delaunay` options are used. If `options` is `{''}`, no options are used, not even the default.

`voronoi(AX,...)` plots into `AX` instead of `gca`.

`voronoi(...,'LineSpec')` plots the diagram with color and line style specified.

`h = voronoi(...)` returns, in `h`, handles to the line objects created.

`[vx,vy] = voronoi(...)` returns the finite vertices of the Voronoi edges in `vx` and `vy` so that `plot(vx,vy,'-',x,y,'.')` creates the Voronoi diagram. The lines-to-infinity are the last columns of `vx` and vy. To ensure the lines-to-infinity do not affect the settings of the axis limits, use the commands:

```
h = plot(VX,VY,'-',X,Y,'.');
set(h(1:end-1),'xliminclude','off','yliminclude','off')
```

Note For the topology of the Voronoi diagram, i.e., the vertices for each Voronoi cell, use voronoin.

```
[v,c] = voronoin([x(:) y(:)])
```

Visualization

Use one of these methods to plot a Voronoi diagram:

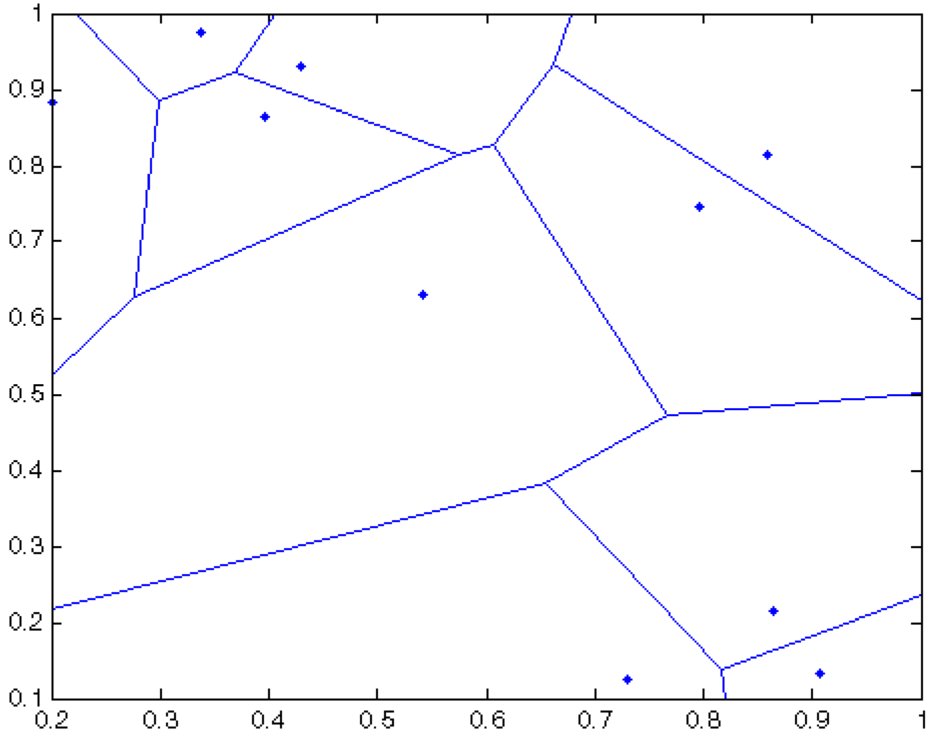
- If you provide no output argument, voronoi plots the diagram. See Example 1.
- To gain more control over color, line style, and other figure properties, use the syntax [vx,vy] = voronoi(...). This syntax returns the vertices of the finite Voronoi edges, which you can then plot with the plot function. See Example 2.
- To fill the cells with color, use voronoin with n = 2 to get the indices of each cell, and then use patch and other plot functions to generate the figure. Note that patch does not fill unbounded cells with color. See Example 3.

Examples

Example 1

This code uses the voronoi function to plot the Voronoi diagram for 10 randomly generated points.

```
rand('state',5);
x = rand(1,10); y = rand(1,10);
voronoi(x,y)
```



Example 2

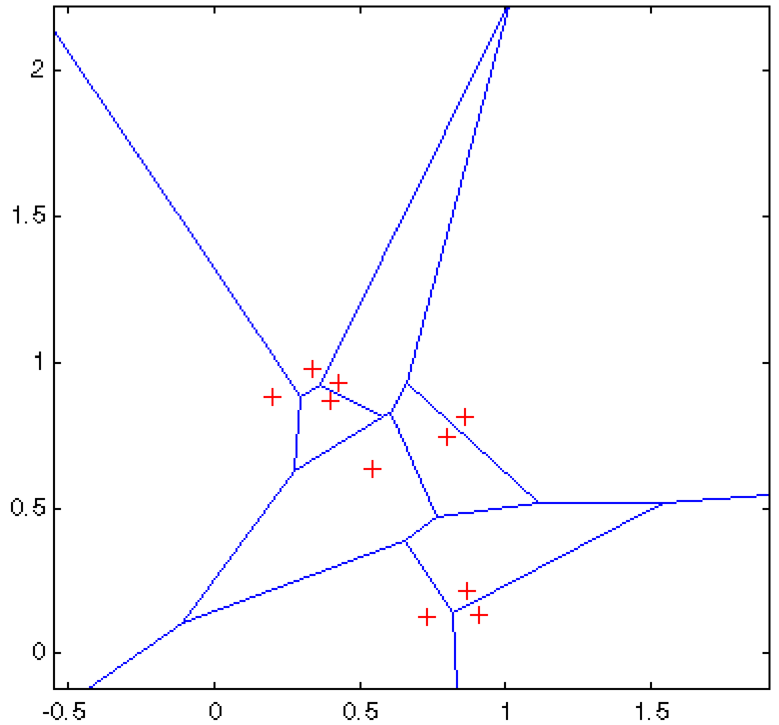
This code uses the vertices of the finite Voronoi edges to plot the Voronoi diagram for the same 10 points.

```
rand('state',5);
x = rand(1,10); y = rand(1,10);
[vx, vy] = voronoi(x,y);
plot(x,y,'r+',vx,vy,'b-'); axis equal
```

Note that you can add this code to get the figure shown in Example 1.

```
xlim([min(x) max(x)])
```

```
ylim([min(y) max(y)])
```

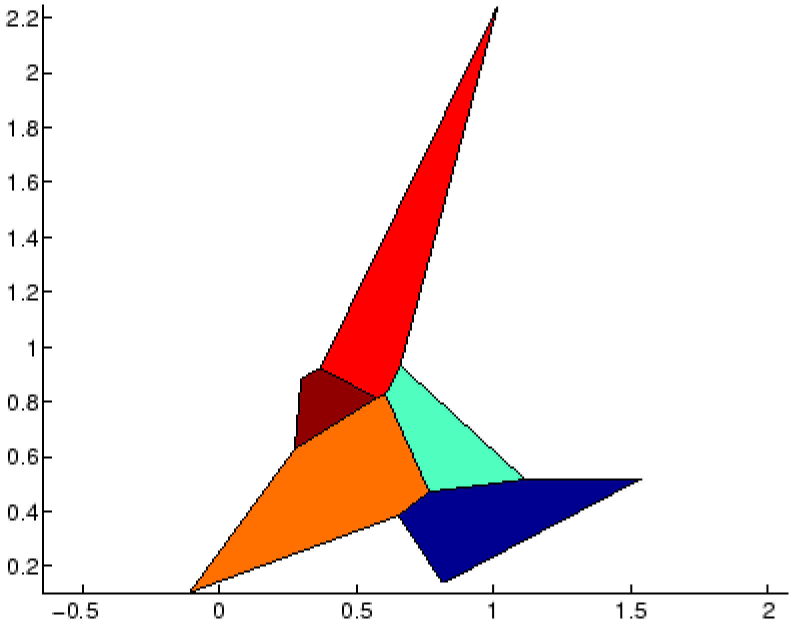


Example 3

This code uses `voronoin` and `patch` to fill the bounded cells of the same Voronoi diagram with color.

```
rand('state',5);
x=rand(10,2);
[v,c]=voronoin(x);
for i = 1:length(c)
if all(c{i}~=1)   % If at least one of the indices is 1,
                  % then it is an open region and we can't
                  % patch that.
```

```
patch(v(c{i},1),v(c{i},2),i); % use color i.
end
end
axis equal
```



Algorithm

If you supply no triangulation `TRI`, the `voronoi` function performs a Delaunay triangulation of the data that uses Qhull [1]. For information about Qhull, see `http://www.qhull.org/`. For copyright information, see `http://www.qhull.org/COPYING.txt`.

See Also

`convhull`, `delaunay`, `LineSpec`, `plot`, `voronoin`

Reference

[1] Barber, C. B., D.P. Dobkin, and H.T. Huhdanpaa, “The Quickhull Algorithm for Convex Hulls,” *ACM Transactions on Mathematical Software*, Vol. 22, No. 4, Dec. 1996, p. 469-483. Available in PDF

format at `http://www.acm.org/pubs/citations/journals/toms/1996-22-4/p469-barber/`.

voronoin

Purpose

N-D Voronoi diagram

Syntax

```
[V,C] = voronoin(X)
[V,C] = voronoin(X,options)
```

Description

`[V,C] = voronoin(X)` returns Voronoi vertices `V` and the Voronoi cells `C` of the Voronoi diagram of `X`. `V` is a `numv`-by-`n` array of the `numv` Voronoi vertices in n-dimensional space, each row corresponds to a Voronoi vertex. `C` is a vector cell array where each element contains the indices into `V` of the vertices of the corresponding Voronoi cell. `X` is an `m`-by-`n` array, representing `m` n-dimensional points, where `n > 1` and `m >= n+1`.

The first row of `V` is a point at infinity. If any index in a cell of the cell array is `1`, then the corresponding Voronoi cell contains the first point in `V`, a point at infinity. This means the Voronoi cell is unbounded.

`voronoin` uses Qhull.

`[V,C] = voronoin(X,options)` specifies a cell array of strings `options` to be used in Qhull. The default options are

- `{'Qbb'}` for 2- and 3-dimensional input
- `{'Qbb','Qx'}` for 4 and higher-dimensional input

If `options` is `[]`, the default options are used. If `code` is `{''}`, no options are used, not even the default. For more information on Qhull and its options, see `http://www.qhull.org`.

Visualization

You can plot individual bounded cells of an n-dimensional Voronoi diagram. To do this, use `convhulln` to compute the vertices of the facets that make up the Voronoi cell. Then use `patch` and other plot functions to generate the figure.

Examples

Example 1

Let

```
x = [ 0.5    0
```

```
     0      0.5
    -0.5   -0.5
    -0.2   -0.1
    -0.1    0.1
     0.1   -0.1
     0.1    0.1 ]
```

then

```
[V,C] = voronoin(x)

V =
       Inf        Inf
       0.3833     0.3833
       0.7000    -1.6500
       0.2875     0.0000
      -0.0000     0.2875
      -0.0000    -0.0000
      -0.0500    -0.5250
      -0.0500    -0.0500
      -1.7500     0.7500
      -1.4500     0.6500
C =

    [1x4 double]
    [1x5 double]
    [1x4 double]
    [1x4 double]
    [1x4 double]
    [1x5 double]
    [1x4 double]
```

Use a `for` loop to see the contents of the cell array `C`.

```
for i=1:length(C), disp(C{i}), end

     4     2     1     3
    10     5     2     1     9
```

```
  9     1     3     7
 10     8     7     9
 10     5     6     8
  8     6     4     3     7
  6     4     2     5
```

In particular, the fifth Voronoi cell consists of 4 points: `V(10,:)`, `V(5,:)`, `V(6,:)`, `V(8,:)`.

Example 2

The following example illustrates the `options` input to `voronoin`. The commands

```
X = [-1 -1; 1 -1; 1 1; -1 1];
[V,C] = voronoin(X)
```

return an error message.

```
? qhull input error: can not scale last coordinate. Input is
cocircular
   or cospherical. Use option 'Qz' to add a point at infinity.
```

The error message indicates that you should add the option `'Qz'`. The following command passes the option `'Qz'`, along with the default `'Qbb'`, to `voronoin`.

```
[V,C] = voronoin(X,{'Qbb','Qz'})
V =

   Inf   Inf
     0     0


C =

    [1x2 double]
    [1x2 double]
    [1x2 double]
```

```
[1x2 double]
```

Algorithm

`voronoin` is based on Qhull [1]. For information about Qhull, see `http://www.qhull.org/`. For copyright information, see `http://www.qhull.org/COPYING.txt`.

See Also

`convhull`, `convhulln`, `delaunay`, `delaunayn`, `voronoi`

Reference

[1] Barber, C. B., D.P. Dobkin, and H.T. Huhdanpaa, “The Quickhull Algorithm for Convex Hulls,” *ACM Transactions on Mathematical Software*, Vol. 22, No. 4, Dec. 1996, p. 469-483. Available in PDF format at `http://www.acm.org/pubs/citations/journals/toms/1996-22-4/p469-barber/`.

Purpose

Wait until timer stops running

Syntax

```
wait(obj)
```

Description

`wait(obj)` blocks the MATLAB command line and waits until the timer, represented by the timer object `obj`, stops running. When a timer stops running, the value of the timer object's `Running` property changes from `'on'` to `'off'`.

If `obj` is an array of timer objects, `wait` blocks the MATLAB command line until all the timers have stopped running.

If the timer is not running, `wait` returns immediately.

See Also

`timer`, `start`, `stop`

Purpose Open waitbar

Syntax

```
h = waitbar(x,'message')
waitbar(x,'message','CreateCancelBtn','button_callback')
waitbar(...,property_name,property_value,...)
waitbar(x)
waitbar(x,h)
waitbar(x,h,'updated message')
```

Description A waitbar shows what percentage of a calculation is complete, as the calculation proceeds.

`h = waitbar(x,'message')` displays a waitbar of fractional length `x`. The waitbar figure is modal. Its handle is returned in `h`. The argument`x` must be between `0` and `1`.

Note A modal figure prevents the user from interacting with other windows before responding. For more information, see `WindowStyle` in the MATLAB Figure Properties.

`waitbar(x,'message','`**`CreateCancelBtn`**`','button_callback')` specifying **`CreateCancelBtn`** adds a cancel button to the figure that executes the MATLAB commands specified in `button_callback` when the user clicks the cancel button or the close figure button. `waitbar` sets both the cancel button callback and the figure `CloseRequestFcn` to the string specified in `button_callback`.

`waitbar(...,property_name,property_value,...)` optional arguments `property_name` and `property_value` enable you to set figure properties for the `waitbar`.

`waitbar(x)` subsequent calls to `waitbar(x)` extend the length of the bar to the new position `x`.

`waitbar(x,h)` extends the length of the bar in the waitbar `h` to the new position `x`.

`waitbar(x,h,'updated message')` updates the message text in the waitbar figure, in addition to setting the fractional length to `x`.

Example

`waitbar` is typically used inside a `for` loop that performs a lengthy computation. For example,

```
h = waitbar(0,'Please wait...');
for i=1:100, % computation here %
waitbar(i/100)
end
close(h)
```

See Also

"Predefined Dialog Boxes" on page 1-108 for related functions

Purpose

Wait for condition before resuming execution

Syntax

```
waitfor(h)
waitfor(h,'PropertyName')
waitfor(h,'PropertyName',PropertyValue)
```

Description

The `waitfor` function blocks the caller's execution stream so that command-line expressions, callbacks, and statements in the blocked M-file do not execute until a specified condition is satisfied. It also blocks Simulink models from executing.

`waitfor(h)` returns when the graphics object identified by `h` is deleted or when a **Ctrl+C** is typed in the Command Window. If `h` does not exist, `waitfor` returns immediately without processing any events.

`waitfor(h,'PropertyName')`, in addition to the conditions in the previous syntax, returns when the value of `'PropertyName'` for the graphics object `h` changes. If `'PropertyName'` is not a valid property for the object, `waitfor` returns immediately without processing any events.

`waitfor(h,'PropertyName',PropertyValue)`, in addition to the conditions in the previous syntax, `waitfor` returns when the value of `'PropertyName'` for the graphics object `h` changes to `PropertyValue`. `waitfor` returns immediately without processing any events if `'PropertyName'` is set to `PropertyValue`.

Remarks

While `waitfor` blocks an execution stream, other execution streams in the form of callbacks may execute as a result of various events (e.g., pressing a mouse button). The functions `pause` (with no argument) and `uiwait` also block execution of MATLAB and Simulink in this manner.

`waitfor` can block nested execution streams. For example, a callback invoked during a `waitfor` statement can itself invoke `waitfor`.

See Also

`keyboard`, `pause`, `uiresume`, `uiwait`

"User Interface Development" on page 1-109 for related functions

waitforbuttonpress

Purpose

Wait for key press or mouse-button click

Syntax

```
k = waitforbuttonpress
```

Description

`k = waitforbuttonpress` blocks the caller's execution stream until the function detects that the user has clicked a mouse button or pressed a key while the figure window is active. The function returns

- `0` if it detects a mouse button click
- `1` if it detects a key press

Additional information about the event that causes execution to resume is available through the figure's `CurrentCharacter`, `SelectionType`, and `CurrentPoint` properties.

If a `WindowButtonDownFcn` is defined for the figure, its callback is executed before `waitforbuttonpress` returns a value.

You can interrupt `waitforbuttonpress` by typing **Ctrl**+C, but an error results unless the function is called from within a `try-catch` block.

Example

These statements display text in the Command Window when the user either clicks a mouse button or types a key in the figure window:

```
w = waitforbuttonpress;
if w == 0
    disp('Button click')
else
    disp('Key press')
end
```

See Also

`dragrect`, `ginput`, `rbbox`, `waitfor`

"User Interface Development" on page 1-109 for related functions

Purpose

Open warning dialog box

Syntax

```
h = warndlg
h = warndlg(warningstring)
h = warndlg(warningstring,dlgname)
h = warndlg(warningstring,dlgname,createmode)
```

Description

`h = warndlg` displays a dialog box named `Warning Dialog` containing the string `This is the default warning string.` The `warndlg` function returns the handle of the dialog box in `h`. The warning dialog box disappears after the user clicks **OK**.

`h = warndlg(warningstring)` displays a dialog box with the title `Warning Dialog` containing the string specified by `warningstring`. The `warningstring` argument can be any valid string format – cell arrays are preferred.

To use multiple lines in your warning, define `warningstring` using either of the following:

- `sprintf` with `newline` characters separating the lines

  ```
  warndlg(sprintf('Message line 1 \n Message line 2'))
  ```

- Cell arrays of strings

  ```
  warndlg({'Message line 1';'Message line 2'})
  ```

`h = warndlg(warningstring,dlgname)` displays a dialog box with title `dlgname`.

`h = warndlg(warningstring,dlgname,`*`createmode`*`)` specifies whether the warning dialog box is modal or nonmodal. Optionally, it can also specify an interpreter for `warningstring` and `dlgname`. The *`createmode`* argument can be a string or a structure.

If *`createmode`* is a string, it must be one of the values shown in the following table.

createmode Value	Description
modal	Replaces the warning dialog box having the specified Title, that was last created or clicked on, with a modal warning dialog box as specified. All other warning dialog boxes with the same title are deleted. The dialog box which is replaced can be either modal or nonmodal.
non-modal (default)	Creates a new nonmodal warning dialog box with the specified parameters. Existing warning dialog boxes with the same title are not deleted.
replace	Replaces the warning dialog box having the specified Title, that was last created or clicked on, with a nonmodal warning dialog box as specified. All other warning dialog boxes with the same title are deleted. The dialog box which is replaced can be either modal or nonmodal.

Note A modal dialog box prevents the user from interacting with other windows before responding. To block MATLAB program execution as well, use the uiwait function.

If you open a dialog with errordlg, msgbox, or warndlg using 'CreateMode','modal' and a non-modal dialog created with any of these functions is already present and *has the same name as the modal dialog*, the non-modal dialog closes when the modal one opens.

For more information about modal dialog boxes, see 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'`.

Examples

The statement

```
warndlg('Pressing OK will clear memory','!! Warning !!')
```

displays this dialog box:

See Also

`dialog`, `errordlg`, `helpdlg`, `inputdlg`, `listdlg`, `msgbox`, `questdlg`

`figure`, `uiwait`, `uiresume`, `warning`

"Predefined Dialog Boxes" on page 1-108 for related functions

Purpose

Warning message

Syntax

```
warning('message')
warning('message', a1, a2,...)
warning('message_id', 'message')
warning('message_id', 'message', a1, a2, ..., an)
s = warning(state, 'message_id')
s = warning(state, mode)
```

Description

`warning('message')` displays the text `'message'` like the `disp` function, except that with `warning`, message display can be suppressed.

`warning('message', a1, a2,...)` displays a message string that contains formatting conversion characters, such as those used with the MATLAB `sprintf` function. Each conversion character in `message` is converted to one of the values `a1`, `a2`, `...` in the argument list.

Note MATLAB converts special characters (like `\n` and `%d`) in the warning message string only when you specify more than one input argument with `warning`. See Example 4 below.

`warning('message_id', 'message')` attaches a unique identifier, or `message_id`, to the warning message. The identifier enables you to single out certain warnings during the execution of your program, controlling what happens when the warnings are encountered. See "Message Identifiers" and "Warning Control" in the MATLAB Programming Fundamentals documentation for more information on the `message_id` argument and how to use it.

`warning('message_id', 'message', a1, a2, ..., an)` includes formatting conversion characters in `message`, and the character translations in arguments `a1, a2, ..., an`.

`s = warning(state, 'message_id')` is a warning control statement that enables you to indicate how you want MATLAB to act on certain warnings. The `state` argument can be `'on'`, `'off'`, or `'query'`. The message_id argument can be a message identifier string, 'all', or 'last'. See "Warning Control Statements" in the MATLAB Programming Fundamentals documentation for more information.

Output s is a structure array that indicates the previous state of the selected warnings. The structure has the fields identifier and state. See "Output from Control Statements" in the MATLAB Programming Fundamentals documentation for more.

s = warning(state, mode) is a warning control statement that enables you to display an M-stack trace or display more information with each warning. The state argument can be 'on', 'off', or 'query'. The mode argument can be 'backtrace' or 'verbose'. See "Backtrace and Verbose Modes" in the MATLAB Programming Fundamentals documentation for more information.

Examples

Example 1

Generate a warning that displays a simple string:

```
if ~ischar(p1)
   warning('Input must be a string')
end
```

Example 2

Generate a warning string that is defined at run-time. The first argument defines a message identifier for this warning:

```
warning('MATLAB:paramAmbiguous', ...
        'Ambiguous parameter name, "%s".', param)
```

Example 3

Using a message identifier, enable just the actionNotTaken warning from Simulink by first turning off all warnings and then setting just that warning to on:

```
warning off all
warning on Simulink:actionNotTaken
```

Use query to determine the current state of all warnings. It reports that you have set all warnings to off with the exception of Simulink:actionNotTaken:

```
warning query all
The default warning state is 'off'. Warnings not set to the default are

  State  Warning Identifier

     on  Simulink:actionNotTaken
```

Example 4

MATLAB converts special characters (like \n and %d) in the warning message string only when you specify more than one input argument with warning. In the single argument case shown below, \n is taken to mean backslash-n. It is not converted to a newline character:

```
warning('In this case, the newline \n is not converted.')
Warning: In this case, the newline \n is not converted.
```

But, when more than one argument is specified, MATLAB does convert special characters. This is true regardless of whether the additional argument supplies conversion values or is a message identifier:

```
warning('WarnTests:convertTest', ...
      'In this case, the newline \n is converted.')
Warning: In this case, the newline
 is converted.
```

Example 5

Turn on one particular warning, saving the previous state of this one warning in s. Remember that this nonquery syntax performs an implicit query prior to setting the new state:

```
s = warning('on', 'Control:parameterNotSymmetric');
```

After doing some work that includes making changes to the state of some warnings, restore the original state of all warnings:

```
warning(s)
```

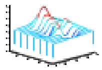
See Also

`lastwarn`, `warndlg`, `error`, `lasterror`, `errordlg`, `dbstop`, `disp`, `sprintf`

waterfall

Purpose

Waterfall plot



GUI Alternatives

To graph selected variables, use the Plot Selector in the Workspace Browser, or use the Figure Palette Plot Catalog. Manipulate graphs in *plot edit* mode with the Property Editor. For details, see Plotting Tools — Interactive Plotting in the MATLAB Graphics documentation and Creating Graphics from the Workspace Browser in the MATLAB Desktop Tools documentation.

Syntax

```
waterfall(Z)
waterfall(X,Y,Z)
waterfall(...,C)
waterfall(axes_handles,...)
h = waterfall(...)
```

Description

The `waterfall` function draws a mesh similar to the `meshz` function, but it does not generate lines from the columns of the matrices. This produces a “waterfall” effect.

`waterfall(Z)` creates a waterfall plot using `x = 1:size(Z,1)` and `y = 1:size(Z,1)`. `Z` determines the color, so color is proportional to surface height.

`waterfall(X,Y,Z)` creates a waterfall plot using the values specified in `X`, `Y`, and `Z`. `Z` also determines the color, so color is proportional to the surface height. If `X` and `Y` are vectors, `X` corresponds to the columns of `Z`, and `Y` corresponds to the rows, where `length(x) = n`, `length(y) = m`, and `[m,n] = size(Z)`. `X` and `Y` are vectors or matrices that define the *x*- and *y*-coordinates of the plot. `Z` is a matrix that defines the *z*-coordinates of the plot (i.e., height above a plane). If `C` is omitted, color is proportional to `Z`.

`waterfall(...,C)` uses scaled color values to obtain colors from the current colormap. Color scaling is determined by the range of `C`, which must be the same size as Z. MATLAB performs a linear transformation on C to obtain colors from the current colormap.

waterfall(axes_handles,...) plots into the axes with handle axes_handle instead of the current axes (gca).

h = waterfall(...) returns the handle of the patch graphics object used to draw the plot.

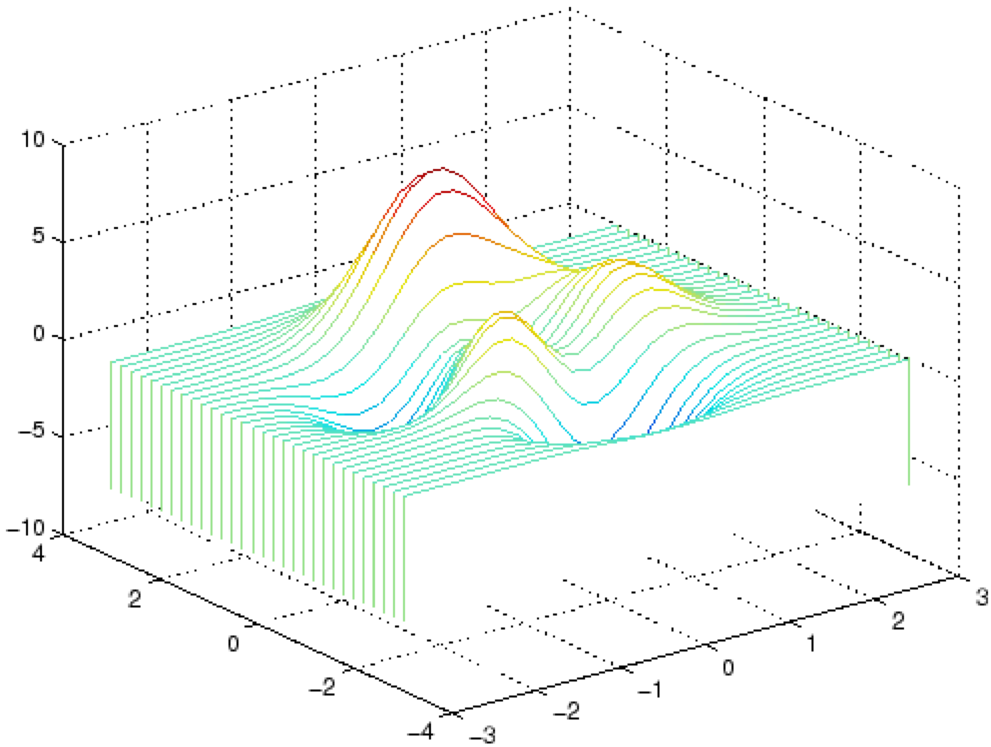
Remarks

For column-oriented data analysis, use waterfall(Z') or waterfall(X',Y',Z').

Examples

Produce a waterfall plot of the peaks function.

```
[X,Y,Z] = peaks(30);
waterfall(X,Y,Z)
```



Algorithm

The range of X, Y, and Z, or the current setting of the axes Llim, YLim, and ZLim properties, determines the range of the axes (also set by axis). The range of C, or the current setting of the axes CLim property, determines the color scaling (also set by caxis).

The CData property for the patch graphics objects specifies the color at every point along the edge of the patch, which determines the color of the lines.

The waterfall plot looks like a mesh surface; however, it is a patch graphics object. To create a surface plot similar to waterfall, use the meshz function and set the MeshStyle property of the surface to 'Row'.

For a discussion of parametric surfaces and related color properties, see `surf`.

See Also

`axes`, `axis`, `caxis`, `meshz`, `ribbon`, `surf`

Properties for patch graphics objects

Purpose Information about Microsoft WAVE (.wav) sound file

Syntax

```
[m d] = wavfinfo(filename)
```

Description

`[m d] = wavfinfo(filename)` returns information about the contents of the WAVE sound file specified by the string `filename`. Enclose the `filename` input in single quotes.

`m` is the string `'Sound (WAV) file'`, if `filename` is a WAVE file. Otherwise, it contains an empty string (`''`).

`d` is a string that reports the number of samples in the file and the number of channels of audio data. If `filename` is not a WAVE file, it contains the string `'Not a WAVE file'`.

See Also `wavplay`, `wavread`, `wavrecord`, `wavwrite`

Purpose

Play recorded sound on PC-based audio output device

Syntax

```
wavplay(y,Fs)
wavplay(..., mode')
```

Description

`wavplay(y,Fs)` plays the audio signal stored in the vector `y` on a PC-based audio output device. You specify the audio signal sampling rate with the integer `Fs` in samples per second. The default value for `Fs` is 11025 Hz (samples per second). `wavplay` supports only 1- or 2-channel (mono or stereo) audio signals.

`wavplay(..., mode')` specifies how `wavplay` interacts with the command line, according to the string `'mode'`. The string `'mode'` can be

- `'async'`: You have immediate access to the command line as soon as the sound begins to play on the audio output device (a nonblocking device call).
- `'sync'` (default value): You don't have access to the command line until the sound has finished playing (a blocking device call).

The audio signal `y` can be one of four data types. The number of bits used to quantize and play back each sample depends on the data type.

Data Types for wavplay

Data Type	Quantization
Double-precision (default value)	16 bits/sample
Single-precision	16 bits/sample
16-bit signed integer	16 bits/sample
8-bit unsigned integer	8 bits/sample

Remarks

You can play your signal in stereo if `y` is a two-column matrix.

Examples

The MAT-files `gong.mat` and `chirp.mat` both contain an audio signal `y` and a sampling frequency `Fs`. Load and play the gong and the chirp audio signals. Change the names of these signals in between `load` commands and play them sequentially using the `'sync'` option for `wavplay`.

```
load chirp;
y1 = y; Fs1 = Fs;
load gong;
wavplay(y1,Fs1,'sync') % The chirp signal finishes before the
wavplay(y,Fs)          % gong signal begins playing.
```

See Also

`wavfinfo`, `wavread`, `wavrecord`, `wavwrite`

Purpose Read Microsoft WAVE (.wav) sound file

Graphical Interface As an alternative to wavread, use the Import Wizard. To activate the Import Wizard, select **Import Data** from the **File** menu.

Syntax

```
y = wavread(filename)
[y, Fs, nbits] = wavread(filename)
[...] = wavread(filename, N)
[...] = wavread(filename,[N1 N2])
y = wavread(filename, fmt)
siz = wavread(filename,'size')
[y, fs, nbits, opts] = wavread(...)
```

Description

y = wavread(filename) loads a WAVE file specified by filename, returning the sampled data in y. The filename input is a string enclosed in single quotes. The .wav extension is appended if no extension is given.

[y, Fs, nbits] = wavread(filename) returns the sample rate (Fs) in Hertz and the number of bits per sample (nbits) used to encode the data in the file.

[...] = wavread(filename, N) returns only the first N samples from each channel in the file.

[...] = wavread(filename,[N1 N2]) returns only samples N1 through N2 from each channel in the file.

y = wavread(filename, *fmt*) specifies the data type format of y used to represent samples read from the file. *fmt* can be either of the following values.

Value	Description
'double'	y contains double-precision normalized samples. This is the default value, if *fmt* is omitted.
'native'	y contains samples in the native data type found in the file. Interpretation of *fmt* is case-insensitive, and partial matching is supported.

`siz = wavread(filename,'size')` returns the size of the audio data contained in `filename` in place of the actual audio data, returning the vector `siz = [samples channels]`.

`[y, fs, nbits, opts] = wavread(...)` returns a structure `opts` of additional information contained in the WAV file. The content of this structure differs from file to file. Typical structure fields include `opts.fmt` (audio format information) and `opts.info` (text which may describe title, author, etc.).

Output Scaling

The range of values in `y` depends on the data format *fmt* specified. Some examples of output scaling based on typical bit-widths found in a WAV file are given below for both `'double'` and `'native'` formats.

Native Formats

Number of Bits	MATLAB Data Type	Data Range
8	`uint8` (unsigned integer)	0 <= y <= 255
16	`int16` (signed integer)	-32768 <= y <= +32767
24	`int32` (signed integer)	-2^23 <= y <= 2^23-1
32	`single` (floating point)	-1.0 <= y < +1.0

Double Formats

Number of Bits	MATLAB Data Type	Data Range
N<32	double	-1.0 <= y < +1.0
N=32	double	-1.0 <= y <= +1.0 Note: Values in y might exceed -1.0 or +1.0 for the case of N=32 bit data samples stored in the WAV file.

wavread supports multi-channel data, with up to 32 bits per sample.

wavread supports Pulse-code Modulation (PCM) data format only.

See Also

aureado, auwrite, wavfinfo, wavplay, wavrecord, wavwrite

wavrecord

Purpose

Record sound using PC-based audio input device

Syntax

```
y = wavrecord(n,Fs)
y = wavrecord(...,ch)
y = wavrecord(...,'dtype')
```

Description

`y = wavrecord(n,Fs)` records `n` samples of an audio signal, sampled at a rate of `Fs` Hz (samples per second). The default value for `Fs` is 11025 Hz.

`y = wavrecord(...,ch)` uses `ch` number of input channels from the audio device. `ch` can be either 1 or 2, for mono or stereo, respectively. The default value for `ch` is 1.

`y = wavrecord(...,'dtype')` uses the data type specified by the string `'dtype'` to record the sound. The following table lists the string values for `'dtype'` along with the corresponding bits per sample and acceptable data range for `y`.

dtype	Bits/sample	y Data Range
`'double'`	16	–1.0 <= `y` < +1.0
`'single'`	16	–1.0 <= `y` < +1.0
`'int16'`	16	–32768 <= `y` <= +32767
`'uint8'`	8	0 <= `y` <= 255

Remarks

Standard sampling rates for PC-based audio hardware are 8000, 11025, 2250, and 44100 samples per second. Stereo signals are returned as two-column matrices. The first column of a stereo audio matrix corresponds to the left input channel, while the second column corresponds to the right input channel.

The `wavrecord` function is for use only with 32-bit Microsoft Windows operating systems. To record audio data from audio input devices on other platforms, use `audiorecorder`.

Examples

Record 5 seconds of 16-bit audio sampled at 11025 Hz. Play back the recorded sound using wavplay. Speak into your audio device (or produce your audio signal) while the wavrecord command runs.

```
Fs = 11025;
y = wavrecord(5*Fs,Fs,'int16');
wavplay(y,Fs);
```

See Also

audiorecorder, wavfinfo, wavplay, wavread, wavwrite

Purpose

Write Microsoft WAVE (`.wav`) sound file

Syntax

```
wavwrite(y,filename)
wavwrite(y,Fs,filename)
wavwrite(y,Fs,N,filename)
```

Description

`wavwrite(y,filename)` writes the data stored in the variable `y` to a WAVE file called `filename`. The `filename` input is a string enclosed in single quotes. The data has a sample rate of 8000 Hz and is assumed to be 16-bit. Each column of the data represents a separate channel. Therefore, stereo data should be specified as a matrix with two columns.

`wavwrite(y,Fs,filename)` writes the data stored in the variable `y` to a WAVE file called `filename`. The data has a sample rate of `Fs` Hz and is assumed to be 16-bit.

`wavwrite(y,Fs,N,filename)` writes the data stored in the variable `y` to a WAVE file called `filename`. The data has a sample rate of `Fs` Hz and is `N`-bit, where `N` is 8, 16, 24, or 32.

Input Data Ranges

The range of values in `y` depends on the number of bits specified by `N` and the data type of `y`. The following tables list the valid input ranges based on the value of `N` and the data type of `y`.

If `y` contains integer data:

N Bits	y Data Type	y Data Range	Output Format
8	`uint8`	0 <= `y` <= 255	`uint8`
16	`int16`	–32768 <= `y` <= +32767	`int16`
24	`int32`	–2^23 <= `y` <= 2^23 – 1	`int32`

If y contains floating-point data:

N Bits	y Data Type	y Data Range	Output Format
8	single or double	–1.0 <= y < +1.0	uint8
16	single or double	–1.0 <= y < +1.0	int16
24	single or double	–1.0 <= y < +1.0	int32
32	single or double	–1.0 <= y <= +1.0	single

For floating point data where N < 32, amplitude values are clipped to the range –1.0 <= y < +1.0.

Note 8-, 16-, and 24-bit files are type 1 integer pulse code modulation (PCM). 32-bit files are written as type 3 normalized floating point.

See Also

auwrite, wavfinfo, wavplay, wavread, wavrecord

Purpose

Open Web site or file in Web browser or Help browser

Syntax

```
web
web url
web url -new
web url -notoolbar
web url -noaddressbox
web url -helpbrowser
web url -browser
web(...)
stat = web('url', '-browser')
[stat, h1] = web
[stat, h1, url] = web
```

Description

`web` opens an empty MATLAB "Web Browser". The MATLAB Web browser includes an address field where you can enter a URL, for example, to a Web site or file, a toolbar with common browser buttons, and a MATLAB desktop menu.

`web url` displays the specified URL, `url`, in the MATLAB Web browser. If any MATLAB Web browsers are already open, it displays the page in the browser that last had focus. Files up to 1.5 MB in size display in the MATLAB Web browser, while larger files instead display in the default Web browser for your system. If `url` is located in the directory returned when you run `docroot` (an unsupported utility), the URL displays in the MATLAB Help browser instead of the MATLAB Web browser.

`web url -`**`new`** displays the specified URL, `url`, in a new MATLAB Web browser.

`web url -`**`notoolbar`** displays the specified URL, `url`, in a MATLAB Web browser that does not include the toolbar and address field. If any MATLAB Web browsers are already open, also use the **`-new`** option; otherwise `url` displays in the browser that last had focus, regardless of its toolbar status.

`web url -`**`noaddressbox`** displays the specified URL, `url`, in a MATLAB Web browser that does not include the address field. If any MATLAB Web browsers are already open, also use the **`-new`** option; otherwise `url` displays in the browser that last had focus, regardless of its address field status.

`web url -helpbrowser` displays the specified URL, `url`, in the MATLAB Help browser.

`web url -browser` displays the default Web browser for your system and loads the file or Web site specified by the URL `url` in it. Generally, `url` specifies a local file or a Web site on the Internet. The URL can be in any form that the browser supports. On Microsoft Windows and Apple Macintosh platforms, the default Web browser is determined by the operating system. On UNIX[31] platforms, the Web browser used is specified via `docopt` in the `doccmd` string.

`web(...)` is the functional form of `web`.

`stat = web('url', '-browser')` runs `web` and returns the status of `web` to the variable `stat`.

Value of `stat`	Description
0	Browser was found and launched.
1	Browser was not found.
2	Browser was found but could not be launched.

`[stat, h1] = web` returns the status of `web` to the variable `stat`, and returns a handle to the Sun Microsystems Java class, `h1`, for the last active browser. Run `methods(h1)` to view allowable methods for the class. The browser, `h1`, could have been opened when the `web` function was previously executed, or when a tool ran the `web` function. For example, clicking a link to an external link from the Help browser runs `web` to open the Web site in a system browser, and `h1` would be the handle for that browser instance.

`[stat, h1, url] = web` returns the status of `web` to the variable `stat`, returns a handle to the Java class `h1`, for the last active browser, and returns its current URL to `url`. Run `methods(h1)` to view allowable methods for the class.

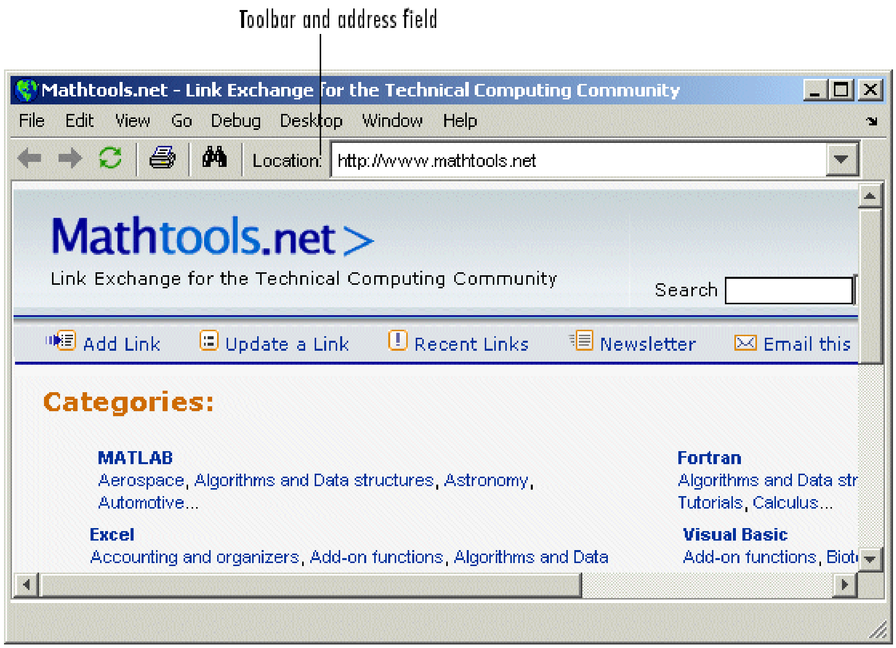
Examples

Run

```
web http://www.mathtools.net
```

and MATLAB displays

31. UNIX is a registered trademark of The Open Group in the United States and other countries.



web http://www.mathworks.com loads the MathWorks Web site home page into the MATLAB Web browser.

web file:///disk/dir1/dir2/foo.html opens the file foo.html in the MATLAB Web browser.

web(['file:///' which('foo.html')])opens foo.html if the file is on the search path or in the current directory for MATLAB.

web('text://<html><h1>Hello World</h1></html>') displays the HTML-formatted text Hello World.

web('http://www.mathworks.com', '-new', '-notoolbar') loads the MathWorks Web site home page into a new MATLAB Web browser that does not include a toolbar or address field.

web file:///disk/dir1/foo.html -helpbrowser opens the file foo.html in the MATLAB Help browser.

`web file:///disk/dir1/foo.html -browser` opens the file `foo.html` in the system Web browser.

`web mailto:email_address` uses your system browser's default e-mail application to send a message to `email_address`.

`web http://www.mathtools.net -browser` opens a browser to `mathtools.net`.

`[stat,h1,url]=web` for that `web` statement returns

```
stat =
     0

h1 =
com.mathworks.mde.webbrowser.WebBrowser[,0,0,591x140,
layout=java.awt.BorderLayout,alignmentX=null,alignmentY=null,
border=,flags=9,maximumSize=,minimumSize=,preferredSize=]

url =
http://www.mathtools.net/
```

As an example, you can use the method `setCurrentLocation` to change the URL displayed in `h1`, as in

```
setCurrentLocation(h1,'http://www.mathworks.com')
```

`[stat,h1]=web('http://www.mathworks.com')` opens `mathworks.com` in a browser. Then `close(h1)` clears the displayed URL, `mathworks.com`, from the browser window.

See Also

`doc`, `docopt`, `helpbrowser`, `matlabcolon`

"Web Browser" in the MATLAB Desktop Tools and Development Environment documentation

Purpose

Day of week

Syntax

```
[N, S] = weekday(D)
[N, S] = weekday(D, form)
[N, S] = weekday(D, locale)
[N, S] = weekday(D, form, locale)
```

Description

`[N, S] = weekday(D)` returns the day of the week in numeric (`N`) and string (`S`) form for a given serial date number or date string `D`. Input argument `D` can represent more than one date in an array of serial date numbers or a cell array of date strings.

`[N, S] = weekday(D, form)` returns the day of the week in numeric (`N`) and string (`S`) form, where the content of `S` depends on the `form` argument. If `form` is '**`long`**', then `S` contains the full name of the weekday (e.g., `Tuesday`). If `form` is '**`short`**', then `S` contains an abbreviated name (e.g., `Tues`) from this table.

The days of the week are assigned these numbers and abbreviations.

N	S (short)	S (long)
1	Sun	Sunday
2	Mon	Monday
3	Tue	Tuesday
4	Wed	Wednesday
5	Thu	Thursday
6	Fri	Friday
7	Sat	Saturday

`[N, S] = weekday(D, locale)` returns the day of the week in numeric (`N`) and string (`S`) form, where the format of the output depends on the `locale` argument. If `locale` is '**`local`**', then `weekday` uses local format for its output. If `locale` is '**`en_US`**', then `weekday` uses US English.

`[N, S] = weekday(D, form, locale)` returns the day of the week using the formats described above for `form` and `locale`.

Examples

Either

```
[n, s] = weekday(728647)
```

or

```
[n, s] = weekday('19-Dec-1994')
```

returns `n = 2` and `s = Mon`.

See Also

`datenum`, `datevec`, `eomday`

Purpose

List MATLAB files in current directory

Graphical Interface

As an alternative to the `what` function, use the Current Directory browser.

Syntax

```
what
what dirname
what classname
what packagename
s = what('dirname')
```

Description

`what` lists the path for the current working directory, and all files and directories related to MATLAB found in the working directory. Files listed are M, MAT, MEX, MDL, and P-files. Directories listed are all class and package directories.

`what` *`dirname`* lists path, file, and directory information for directory *`dirname`*. If this directory is on the MATLAB search path, it is not necessary to enter the full path to *`dirname`*. The last one or two components of the path are sufficient.

`what` *`classname`* lists path, file, and directory information for method directory `@`*`classname`*. For example, `what cfit` lists the MATLAB files and directories in `toolbox/curvefit/curvefit/@cfit`.

`what` *`packagename`* lists path, file, and directory information for package directory `+`*`packagename`*. For example, `what commsrc` lists the MATLAB files and directories in `toolbox/comm/comm/+commsrc`.

`s = what('`*`dirname`*`')` returns the results in a structure array with the fields shown in the following table.

Field	Description
`path`	Path to directory
`m`	Cell array of M-file names
`mat`	Cell array of MAT-file names

Field	Description
mex	Cell array of MEX-file names
mdl	Cell array of MDL-file names
p	Cell array of P-file names
classes	Cell array of class directories
packages	Cell array of package directories

Examples

List MATLAB Files in a Directory

List the files in `toolbox/matlab/audiovideo`:

```
what audiovideo

M-files in directory matlabroot\toolbox\matlab\audiovideo

Contents            avifinfo            sound
audiodevinfo        aviinfo             soundsc
audioplayerreg      aviread             wavfinfo
audiorecorderreg    lin2mu              wavplay
audiouniquename     mmcompinfo          wavread
aufinfo             mmfileinfo          wavrecord
auread              movie2avi           wavwrite
auwrite             mu2lin
avgate              prefspanel

MAT-files in directory matlabroot\toolbox\matlab\audiovideo

chirp         handel        splat
gong          laughter      train

MEX-files in directory matlabroot\toolbox\matlab\audiovideo

winaudioplayer
winaudiorecorder
```

```
Classes in directory matlabroot\toolbox\matlab\audiovideo

audioplayer    avifile
audiorecorder  mmreader
```

Return File Names to Structure

Obtain a structure array containing the MATLAB file names in `toolbox/matlab/general`:

```
s = what('general')
s =
       path: 'matlabroot:\toolbox\matlab\general'
          m: {89x1 cell}
        mat: {0x1 cell}
        mex: {2x1 cell}
        mdl: {0x1 cell}
          p: {'callgraphviz.p'}
    classes: {'char'}
   packages: {0x1 cell}
```

List M-Files in a Package

Find the supporting M-files for one of the packages in the Communications Toolbox product:

```
p1 = what('comm');
p1.packages
ans =
    'commdevice'
    'crc'
    'commsrc'

p2 = what('commsrc');
p2.m
ans =
    'abstractJitter.m'
```

```
'abstractPulse.m'
'combinedjitter.m'
'diracjitter.m'
'periodicjitter.m'
'randomjitter.m'
```

See Also

`dir`, `exist`, `lookfor`, `mfilename`, `path`, `which`, `who`

"Managing Files and Working with the Current Directory"

Purpose Release Notes for MathWorks products

Syntax `whatsnew`

Description `whatsnew` displays the Release Notes in the Help browser, presenting information about new features, problems from previous releases that have been fixed in the current release, and compatibility issues, all organized by product.

See Also `help`, `version`

Purpose

Locate functions and files

Graphical Interface

As an alternative to the `which` function, you can use the Current Directory browser to find files. You can find functions using the Function Browser in the Command Window or Editor.

Syntax

```
which fun
which classname/fun
which private/fun
which classname/private/fun
which fun1 in fun2
which fun(a,b,c,...)
which file.ext
which fun -all
s = which('fun',...)
```

Description

`which fun` displays the full pathname for the argument `fun`. If `fun` is a

- MATLAB function or Simulink model in an M, P, or MDL file on the MATLAB path, then `which` displays the full pathname for the corresponding file
- Workspace variable, then `which` displays a message identifying `fun` as a variable
- Method in a loaded Java class, then `which` displays the package, class, and method name for that method

If `fun` is an overloaded function or method, then `which fun` returns only the pathname of the first function or method found.

`which classname/fun` displays the full pathname for the M-file defining the `fun` method in MATLAB class, `classname`. For example, `which serial/fopen` displays the path for `fopen.m` in the MATLAB class directory, `@serial`.

`which private/fun` limits the search to private functions. For example, `which private/orthog` displays the path for `orthog.m` in the `/private` subdirectory of `toolbox/matlab/elmat`.

`which classname/private/fun` limits the search to private methods defined by the MATLAB class, `classname`. For example, `which dfilt/private/todtf` displays the path for `todtf.m` in the `private` directory of the `dfilt` class.

`which fun1 in fun2` displays the pathname to function `fun1` in the context of the M-file `fun2`. You can use this form to determine whether a subfunction is being called instead of a function on the path. For example, `which get in editpath` tells you which `get` function is called by `editpath.m`.

During debugging of `fun2`, using `which fun1` gives the same result.

`which fun(a,b,c,...)` displays the path to the specified function with the given input arguments. For example, `which feval(g)`, when `g=inline('sin(x)')`, indicates that `inline/feval.m` would be invoked. `which toLowerCase(s)`, when `s=java.lang.String('my Java string')`, indicates that the `toLowerCase` method in `class java.lang.String` would be invoked.

`which file.ext` displays the full pathname of the specified file if that file is in the current working directory or on the MATLAB path. To display the path for a file that has no file extension, type "`which file.`" (the period following the filename is required). Use `exist` to check for the existence of files anywhere else.

`which fun -all` d isplays the paths to all items on the MATLAB path with the name `fun`. You may use the **`-all`** qualifier with any of the above formats of the `which` function.

`s = which('fun',...)` returns the results of `which` in the string `s`. For workspace variables, `s` is the string '`variable`'. You may specify an output variable in any of the above formats of the `which` function.

If **`-all`** is used with this form, the output `s` is always a cell array of strings, even if only one string is returned.

Examples

The statement below indicates that `pinv` is in the `matfun` directory of MATLAB.

```
which pinv
matlabroot\toolbox\matlab\matfun\pinv.m
```

To find the `fopen` function used on MATLAB `serial` class objects

```
which serial/fopen
matlabroot\toolbox\matlab\iofun\@serial\fopen.m  % serial method
```

To find the `setMonth` method used on objects of the Java `Date` class, the class must first be loaded into MATLAB. The class is loaded when you create an instance of the class:

```
myDate = java.util.Date;
which setMonth
```

MATLAB displays:

```
setMonth is a Java method  % java.util.Date method
```

When you specify an output variable, `which` returns a cell array of strings to the variable. You must use the *function* form of `which`, enclosing all arguments in parentheses and single quotes:

```
s = which('private/stradd','-all');
whos s
  Name      Size         Bytes  Class
  s         3x1            562  cell array
Grand total is 146 elements using 562 bytes
```

See Also

`dir`, `doc`, `exist`, `lookfor`, `mfilename`, `path`, `type`, `what`, `who`

Purpose Repeatedly execute statements while condition is true

Syntax `while expression, statements, end`

Description `while` *`expression`*, *`statements`*, `end` repeatedly executes one or more MATLAB *`statements`* in a loop, continuing until *`expression`* no longer holds true or until MATLAB encounters a `break`, or `return` instruction. thus forcing an immediately exit of the loop. If MATLAB encounters a `continue` statement in the loop code, it immediately exits the current pass at the location of the `continue` statement, skipping any remaining code in that pass, and begins another pass at the start of the loop *`statements`* with the value of the loop counter incremented by 1.

`expression` is a MATLAB expression that evaluates to a result of logical 1 (`true`) or logical 0 (`false`). *`expression`* can be scalar or an array. It must contain all real elements, and the statement `all(A(:))` must be equal to logical 1 for the expression to be true.

`expression` usually consists of variables or smaller expressions joined by relational operators (e.g., `count < limit`) or logical functions (e.g., `isreal(A)`). Simple expressions can be combined by logical operators (`&&`, `||`, `~`) into compound expressions such as the following. MATLAB evaluates compound expressions from left to right, adhering to "Operator Precedence" rules.

```
(count < limit) && ((height - offset) >= 0)
```

`statements` is one or more MATLAB statements to be executed only while the *`expression`* is `true` or nonzero.

The scope of a `while` statement is always terminated with a matching `end`.

See "Program Control Statements" in the MATLAB Programming Fundamentals documentation for more information on controlling the flow of your program code.

Remarks

Nonscalar Expressions

If the evaluated `expression` yields a nonscalar value, then every element of this value must be `true` or nonzero for the entire expression to be considered `true`. For example, the statement `while (A < B)` is `true` only if each element of matrix `A` is less than its corresponding element in matrix `B`. See "Example 2 – Nonscalar Expression" on page 2-4045, below.

Partial Evaluation of the Expression Argument

Within the context of an `if` or `while` expression, MATLAB does not necessarily evaluate all parts of a logical expression. In some cases it is possible, and often advantageous, to determine whether an expression is `true` or `false` through only partial evaluation.

For example, if `A` equals zero in statement 1 below, then the expression evaluates to `false`, regardless of the value of `B`. In this case, there is no need to evaluate `B` and MATLAB does not do so. In statement 2, if `A` is nonzero, then the expression is `true`, regardless of `B`. Again, MATLAB does not evaluate the latter part of the expression.

```
1)   while (A && B)              2)   while (A || B)
```

You can use this property to your advantage to cause MATLAB to evaluate a part of an expression only if a preceding part evaluates to the desired state. Here are some examples.

```
while (b ~= 0) && (a/b > 18.5)
if exist('myfun.m') && (myfun(x) >= y)
if iscell(A) && all(cellfun('isreal', A))
```

Empty Arrays

In most cases, using `while` on an empty array returns `false`. There are some conditions however under which `while` evaluates as `true` on an empty array. Two examples of this are

```
A = [];
while all(A), do_something, end
while 1|A, do_something, end
```

Short-Circuiting Behavior

When used in the context of a `while` or `if` expression, and only in this context, the element-wise `|` and `&` operators use short-circuiting in evaluating their expressions. That is, `A|B` and `A&B` ignore the second operand, `B`, if the first operand, `A`, is sufficient to determine the result.

See "Short-Circuiting in Elementwise Operators" for more information on this.

Examples

Example 1 – Simple while Statement

The variable `eps` is a tolerance used to determine such things as near singularity and rank. Its initial value is the *machine epsilon*, the distance from 1.0 to the next largest floating-point number on your machine. Its calculation demonstrates `while` loops.

```
eps = 1;
while (1+eps) > 1
    eps = eps/2;
end
eps = eps*2
```

This example is for the purposes of illustrating `while` loops only and should not be executed in your MATLAB session. Doing so will disable the `eps` function from working in that session.

Example 2 – Nonscalar Expression

Given matrices `A` and `B`,

```
A =                  B =
      1     0              1     1
      2     3              3     4
```

Expression	Evaluates As	Because
`A < B`	`false`	A(1,1) is not less than B(1,1).

Expression	Evaluates As	Because
`A < (B + 1)`	`true`	Every element of A is less than that same element of B with 1 added.
`A & B`	`false`	A(1,2) is false, and B is ignored due to short-circuiting.
`B < 5`	`true`	Every element of B is less than 5.

See Also

`end`, `for`, `break`, `continue`, `return`, `all`, `any`, `if`, `switch`

Purpose

Change axes background color

Syntax

```
whitebg
whitebg(fig)
whitebg(ColorSpec)
whitebg(fig, ColorSpec)
whitebg(fig, ColorSpec)
whitebg(fig)
```

Description

`whitebg` complements the colors in the current figure.

`whitebg(fig)` complements colors in all figures specified in the vector `fig`.

`whitebg(ColorSpec)` and `whitebg(fig, ColorSpec)` change the color of the axes, which are children of the figure, to the color specified by `ColorSpec`. Without a figure specification, `whitebg` or `whitebg(ColorSpec)` affects the current figure and the root's default properties so subsequent plots and new figures use the new colors.

`whitebg(fig, ColorSpec)` sets the default axes background color of the figures in the vector `fig` to the color specified by `ColorSpec`. Other axes properties and the figure background color can change as well so that graphs maintain adequate contrast. `ColorSpec` can be a 1-by-3 RGB color or a color string such as `'white'` or `'w'`.

`whitebg(fig)` complements the colors of the objects in the specified figures. This syntax is typically used to toggle between black and white axes background colors, and is where `whitebg` gets its name. Include the root window handle `(0)` in `fig` to affect the default properties for new windows or for `clf reset`.

Remarks

`whitebg` works best in cases where all the axes in the figure have the same background color.

`whitebg` changes the colors of the figure's children, with the exception of shaded surfaces. This ensures that all objects are visible against the new background color. `whitebg` sets the default properties on the root such that all subsequent figures use the new background color.

Examples

Set the background color to blue-gray.

```
whitebg([0 .5 .6])
```

Set the background color to blue.

```
whitebg('blue')
```

See Also

`ColorSpec`, `colordef`

The figure graphics object property `InvertHardCopy`

“Color Operations” on page 1-102 for related functions

Purpose List variables in workspace

Graphical Interface As an alternative to whos, use the Workspace browser. Or use the Current Directory browser to view the contents of MAT-files without loading them.

Syntax

```
who
whos
who(variable_list)
whos(variable_list)
who(variable_list, qualifiers)
whos(variable_list, qualifiers)
s = who(variable_list, qualifiers)
s = whos(variable_list, qualifiers)
who variable_list qualifiers
whos variable_list qualifiers
```

Each of these syntaxes applies to both who and whos:

Description

who lists in alphabetical order all variables in the currently active workspace.

whos lists in alphabetical order all variables in the currently active workspace along with their sizes and types. It also reports the totals for sizes.

Note If who or whos is executed within a nested function, the MATLAB software lists the variables in the workspace of that function and in the workspaces of all functions containing that function. See the Remarks section, below.

---

who(variable_list) and whos(variable_list) list only those variables specified in variable_list, where variable_list is a comma-delimited list of quoted strings: 'var1', 'var2', ..., 'varN'. You can use the wildcard character * to display variables that match a pattern. For example, `who('A*')` finds all variables in the current workspace that start with `A`.

`who(variable_list, qualifiers)` and `whos(variable_list, qualifiers)` list those variables in `variable_list` that meet all qualifications specified in `qualifiers`. You can specify any or all of the following qualifiers, and in any order.

Qualifier Syntax	Description	Example
`global`	List variables in the global workspace.	`whos('global')`
`-file` , `filename`	List variables in the specified MAT-file. Use the full path for `filename`.	`whos('-file', 'mydata')`
`-regexp` , `exprlist`	List variables that match any of the regular expressions in `exprlist`.	`whos('-regexp', '[AB].', '\w\d')`

`s = who(variable_list, qualifiers)` returns cell array `s` containing the names of the variables specified in `variable_list` that meet the conditions specified in `qualifiers`.

`s = whos(variable_list, qualifiers)` returns structure `s` containing the following fields for the variables specified in `variable_list` that meet the conditions specified in `qualifiers`:

Field Name	Description
`name`	Name of the variable
`size`	Dimensions of the variable array
`bytes`	Number of bytes allocated for the variable array
`class`	Class of the variable. Set to the string `'(unassigned)'` if the variable has no value.

Field Name	Description
`global`	True if the variable is global; otherwise false
`sparse`	True if the variable is sparse; otherwise false
`complex`	True if the variable is complex; otherwise false
`nesting`	Structure having the following fields: • `function` — Name of the nested or outer function that defines the variable • `level` — Nesting level of that function
`persistent`	True if the variable is persistent; otherwise false

`who variable_list qualifiers` and `whos variable_list qualifiers` are the unquoted forms of the syntax. Both `variable_list` and `qualifiers` are space-delimited lists of unquoted strings.

Remarks

Nested Functions. When you use `who` or `whos` inside of a nested function, MATLAB returns or displays all variables in the workspace of that function, and in the workspaces of all functions in which that function is nested. This applies whether you include calls to `who` or `whos` in your M-file code or if you call `who` or `whos` from the MATLAB debugger.

If your code assigns the output of `whos` to a variable, MATLAB returns the information in a structure array containing the fields described above. If you do not assign the output to a variable, MATLAB displays the information at the Command Window, grouped according to workspace.

If your code assigns the output of `who` to a variable, MATLAB returns the variable names in a cell array of strings. If you do not assign the output, MATLAB displays the variable names at the Command Window, but not grouped according to workspace.

Compressed Data. Information returned by the command `whos -file` is independent of whether the data in that file is compressed or not. The byte counts returned by this command represent the number of bytes data occupies in the MATLAB workspace, and not in the file the data was saved to. See the function reference for `save` for more information on data compression.

MATLAB Objects. `whos -file` *`filename`* does not return the sizes of any MATLAB objects that are stored in file *`filename`*.

Examples

Example 1

Show variable names starting with the letter `a`:

```
who a*
```

Show variables stored in MAT-file `mydata.mat`:

```
who -file mydata
```

Example 2

Return information on variables stored in file `mydata.mat` in structure array `s`:

```
s = whos('-file', 'mydata1')
s =
6x1 struct array with fields:
    name
    size
    bytes
    class
    global
    sparse
    complex
    nesting
    persistent
```

Display the name, size, and class of each of the variables returned by `whos`:

```
for k=1:length(s)
disp(['  ' s(k).name '  ' mat2str(s(k).size) '  ' s(k).class])
end
  A   [1 1]   double
  spArray   [5 5]   double
  strArray   [2 5]   cell
  x   [3 2 2]   double
  y   [4 5]   cell
```

Example 3

Show variables that start with `java` and end with `Array`. Also show their dimensions and class name:

```
whos -file mydata2 -regexp \<java.*Array\>
  Name               Size        Bytes  Class

  javaChrArray        3x1               java.lang.String[][][]
  javaDblArray        4x1               java.lang.Double[][]
  javaIntArray       14x1               java.lang.Integer[][]
```

Example 4

The function shown here uses variables with persistent, global, sparse, and complex attributes:

```
function show_attributes
persistent p;
global g;
o = 1;   g = 2;
s = sparse(eye(5));
c = [4+5i 9-3i 7+6i];
whos
```

When the function is run, `whos` displays these attributes:

```
show_attributes
```

```
  Name      Size           Bytes  Class      Attributes

c           1x3               48  double     complex
g           1x1                8  double     global
p           1x1                8  double     persistent
s           5x5               84  double     sparse
```

Example 5

Function whos_demo contains two nested functions. One of these functions calls whos; the other calls who:

```
function whos_demo
date_time = datestr(now);

[str pos] = textscan(date_time, '%s%s%s', ...
                     1, 'delimiter', '- :');
get_date(str);

str = textscan(date_time(pos+1:end), '%s%s%s', ...
               1, 'delimiter', '- :');
get_time(str);

   function get_date(d)
      day = d{1};   mon = d{2};   year = d{3};
      whos
   end
   function get_time(t)
      hour = t{1};   min = t{2};   sec = t{3};
      who
   end
end
```

When nested function get_date calls whos, MATLAB displays information on the variables in all workspaces that are in scope at the time. This includes nested function get_date and also the function in which it is nested, whos_demo. The information is grouped by workspace:

```
whos_demo
  Name            Size                Bytes  Class

  ---- get_date ----------------------------------------
  d               1x3                   378  cell
  day             1x1                    64  cell
  mon             1x1                    66  cell
  year            1x1                    68  cell

  ---- whos_demo ---------------------------------------
  ans             0x0                     0  (unassigned)
  date_time       1x20                   40  char
  pos             1x1                     8  double
  str             1x3                   378  cell
```

When nested function `get_time` calls `who`, MATLAB displays names of the variables in the workspaces that are in scope at the time. This includes nested function `get_time` and also the function in which it is nested, `whos_demo`. The information is not grouped by workspace in this case:

```
Your variables are:

hour       min        sec        t        ans        date_time
pos        str
```

See Also

`assignin`, `clear`, `computer`, `dir`, `evalin`, `exist`, `inmem`, `load`, `save`, `what`, `workspace`

"MATLAB Workspace" in the Desktop Tools and Development Environment documentation

Purpose

Wilkinson's eigenvalue test matrix

Syntax

```
W = wilkinson(n)
```

Description

`W = wilkinson(n)` returns one of J. H. Wilkinson's eigenvalue test matrices. It is a symmetric, tridiagonal matrix with pairs of nearly, but not exactly, equal eigenvalues.

Examples

```
wilkinson(7)

ans =

     3     1     0     0     0     0     0
     1     2     1     0     0     0     0
     0     1     1     1     0     0     0
     0     0     1     0     1     0     0
     0     0     0     1     1     1     0
     0     0     0     0     1     2     1
     0     0     0     0     0     1     3
```

The most frequently used case is `wilkinson(21)`. Its two largest eigenvalues are both about 10.746; they agree to 14, but not to 15, decimal places.

See Also

`eig`, `gallery`, `pascal`

Purpose

Open file in appropriate application (Windows)

Syntax

`winopen(filename)`

Description

`winopen(filename)` opens `filename` in the appropriate Microsoft Windows application. The `filename` input is a string enclosed in single quotes. The `winopen` function uses the appropriate Windows shell command, and performs the same action as if you double-click the file in the Windows Explorer program. If `filename` is not in the current directory, specify the absolute path for `filename`.

Examples

Open the file `thesis.doc`, located in the current directory, in the Microsoft Word program:

```
winopen('thesis.doc')
```

Open `myresults.html` in your system's default Web browser:

```
winopen('D:/myfiles/myresults.html')
```

See Also

`dos`, `open`, `web`

winqueryreg

Purpose

Item from Windows registry

Syntax

```
valnames = winqueryreg('name', 'rootkey', 'subkey')
value = winqueryreg('rootkey', 'subkey', 'valname')
value = winqueryreg('rootkey', 'subkey')
```

Description

`valnames = winqueryreg('name', 'rootkey', 'subkey')` returns all value names in `rootkey\subkey` of Microsoft Windows operating system registry to a cell array of strings. The first argument is the literal quoted string, `'name'`.

`value = winqueryreg('rootkey', 'subkey', 'valname')` returns the value for value name `valname` in `rootkey\subkey`.

If the value retrieved from the registry is a string, `winqueryreg` returns a string. If the value is a 32-bit integer, `winqueryreg` returns the value as an integer of the MATLAB software type `int32`.

`value = winqueryreg('rootkey', 'subkey')` returns a value in `rootkey\subkey` that has no value name property.

Note The literal **`name`** argument and the `rootkey` argument are case-sensitive. The `subkey` and `valname` arguments are not.

Remarks

This function works only for the following registry value types:

- strings (REG_SZ)
- expanded strings (REG_EXPAND_SZ)
- 32-bit integer (REG_DWORD)

Examples

Example 1

Get the value of `CLSID` for the MATLAB sample Microsoft COM control `mwsampctrl.2`:

```
winqueryreg 'HKEY_CLASSES_ROOT' 'mwsamp.mwsampctrl.2\clsid'
```

```
ans =
   {5771A80A-2294-4CAC-A75B-157DCDDD3653}
```

Example 2

Get a list in variable `mousechar` for registry subkey `Mouse`, which is under subkey `Control Panel`, which is under root key `HKEY_CURRENT_USER`.

```
mousechar = winqueryreg('name', 'HKEY_CURRENT_USER', ...
   'control panel\mouse');
```

For each name in the `mousechar` list, get its value from the registry and then display the name and its value:

```
for k=1:length(mousechar)
   setting = winqueryreg('HKEY_CURRENT_USER', ...
      'control panel\mouse', mousechar{k});
   str = sprintf('%s = %s', mousechar{k}, num2str(setting));
   disp(str)
   end

ActiveWindowTracking = 0
DoubleClickHeight = 4
DoubleClickSpeed = 830
DoubleClickWidth = 4
MouseSpeed = 1
MouseThreshold1 = 6
MouseThreshold2 = 10
SnapToDefaultButton = 0
SwapMouseButtons = 0
```

wk1finfo

Purpose Determine whether file contains 1-2-3 WK1 worksheet

Syntax `[extens, typ] = wk1finfo(filename)`

Description `[extens, typ] = wk1finfo(filename)` returns the string 'WK1' in `extens`, and ' `1-2-3 Spreadsheet`' in `typ` if the file `filename` contains a readable worksheet. The `filename` input is a string enclosed in single quotes.

Examples This example returns information on spreadsheet file `matA.wk1`:

```
[extens, typ] = wk1finfo('matA.wk1')

extens =
   WK1
typ =
    123 Spreadsheet
```

See Also `wk1read`, `wk1write`, `csvread`, `csvwrite`

Purpose

Read Lotus 1-2-3 WK1 spreadsheet file into matrix

Syntax

```
M = wk1read(filename)
M = wk1read(filename,r,c)
M = wk1read(filename,r,c,range)
```

Description

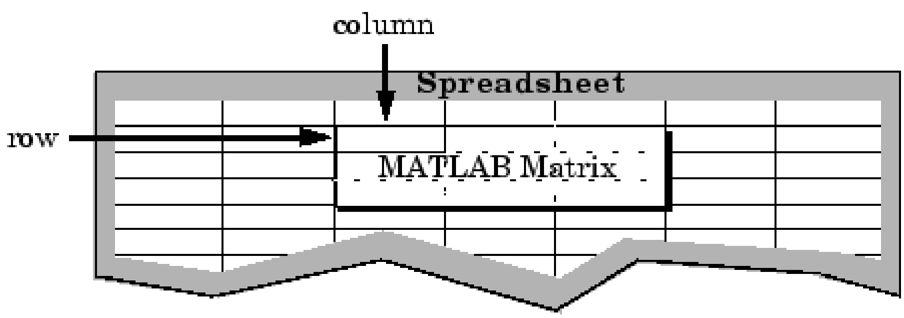
`M = wk1read(filename)` reads a Lotus1-2-3 WK1 spreadsheet file into the matrix `M`. The `filename` input is a string enclosed in single quotes.

`M = wk1read(filename,r,c)` starts reading at the row-column cell offset specified by `(r,c)`. `r` and `c` are zero based so that `r=0`, `c=0` specifies the first value in the file.

`M = wk1read(filename,r,c,range)` reads the range of values specified by the parameter `range`, where `range` can be

- A four-element vector specifying the cell range in the format

```
[upper_left_row upper_left_col lower_right_row lower_right_col]
```



- A cell range specified as a string, for example, `'A1...C5'`
- A named range specified as a string, for example, `'Sales'`

Examples

Create a 8-by-8 matrix `A` and export it to Lotus spreadsheet `matA.wk1`:

```
A = [1:8; 11:18; 21:28; 31:38; 41:48; 51:58; 61:68; 71:78]
A =
```

```
     1     2     3     4     5     6     7     8
    11    12    13    14    15    16    17    18
    21    22    23    24    25    26    27    28
    31    32    33    34    35    36    37    38
    41    42    43    44    45    46    47    48
    51    52    53    54    55    56    57    58
    61    62    63    64    65    66    67    68
    71    72    73    74    75    76    77    78

wk1write('matA.wk1', A);
```

To read in a limited block of the spreadsheet data, specify the upper left row and column of the block using zero-based indexing:

```
M = wk1read('matA.wk1', 3, 2)
M =
    33    34    35    36    37    38
    43    44    45    46    47    48
    53    54    55    56    57    58
    63    64    65    66    67    68
    73    74    75    76    77    78
```

To select a more restricted block of data, you can specify both the upper left and lower right corners of the block you want imported. Read in a range of values from row 4, column 3 (defining the upper left corner) to row 6, column 6 (defining the lower right corner). Note that, unlike the second and third arguments, the range argument `[4 3 6 6]` is one-based:

```
M = wk1read('matA.wk1', 3, 2, [4 3 6 6])
M =
    33    34    35    36
    43    44    45    46
    53    54    55    56
```

See Also

`wk1write`

Purpose

Write matrix to Lotus 1-2-3 WK1 spreadsheet file

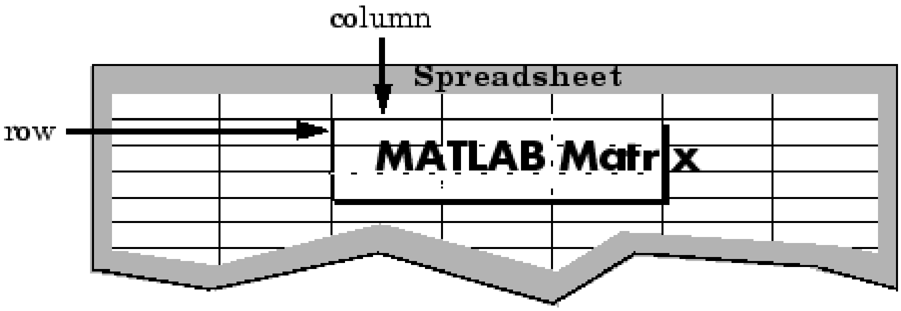
Syntax

```
wk1write(filename,M)
wk1write(filename,M,r,c)
```

Description

`wk1write(filename,M)` writes the matrix `M` into a Lotus1-2-3 WK1 spreadsheet file named `filename`. The `filename` input is a string enclosed in single quotes.

`wk1write(filename,M,r,c)` writes the matrix starting at the spreadsheet location `(r,c)`. `r` and `c` are zero based so that `r=0`, `c=0` specifies the first cell in the spreadsheet.



Examples

Write a 4-by-5 matrix A to spreadsheet file matA.wk1. Place the matrix with its upper left corner at row 2, column 3 using zero-based indexing:

```
A = [1:5; 11:15; 21:25; 31:35]
A =
     1     2     3     4     5
    11    12    13    14    15
    21    22    23    24    25
    31    32    33    34    35

wk1write('matA.wk1', A, 2, 3)

M = wk1read('matA.wk1')
M =
```

```
0     0     0     0     0     0     0     0
0     0     0     0     0     0     0     0
0     0     0     1     2     3     4     5
0     0     0    11    12    13    14    15
0     0     0    21    22    23    24    25
0     0     0    31    32    33    34    35
```

See Also

`wk1read`, `dlmwrite`, `dlmread`, `csvwrite`, `csvread`

Purpose

Open Workspace browser to manage workspace

GUI Alternatives

As an alternative to the `workspace` function, select **Desktop > Workspace** in the MATLAB desktop.

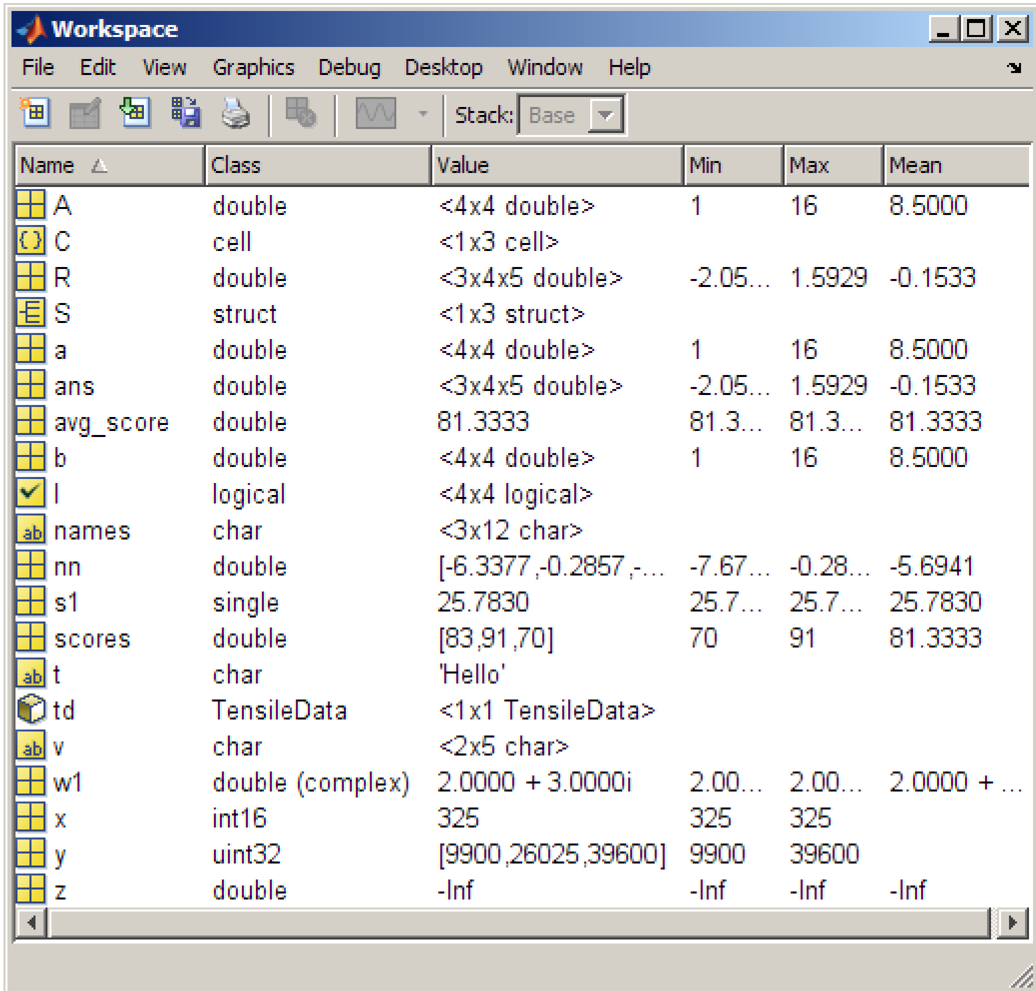
Syntax

`workspace`

Description

`workspace` displays the Workspace browser, a graphical user interface that allows you to view and manage the contents of the workspace in MATLAB. It provides a graphical representation of the `whos` display, and allows you to perform the equivalent of the `clear`, `load`, `open`, and `save` functions.

The Workspace browser also displays and automatically updates statistical calculations for each variable, which you can choose to show or hide.



You can edit a value directly in the Workspace browser for small numeric and character arrays. To see and edit a graphical representation of larger variables and for other classes, double-click the variable in the Workspace browser. The variable displays in the Variable Editor, where you can view the full contents and make changes.

See Also

`openvar`, `who`

"MATLAB Workspace"

xlabel, ylabel, zlabel

Purpose Label *x*-, *y*-, and *z*-axis

GUI Alternative To control the presence and appearance of axis labels on a graph, use the Property Editor, one of the plotting tools . For details, see The Property Editor in the MATLAB Graphics documentation.

Syntax

```
xlabel('string')
xlabel(fname)
xlabel(...,'PropertyName',PropertyValue,...)
xlabel(axes_handle,...)
h = xlabel(...)

ylabel(...)
ylabel(axes_handle,...)
h = ylabel(...)

zlabel(...)
zlabel(axes_handle,...)
h = zlabel(...)
```

Description Each axes graphics object can have one label for the *x*-, *y*-, and *z*-axis. The label appears beneath its respective axis in a two-dimensional plot and to the side or beneath the axis in a three-dimensional plot.

`xlabel('string')` labels the *x*-axis of the current axes.

`xlabel(fname)` evaluates the function `fname`, which must return a string, then displays the string beside the *x*-axis.

`xlabel(...,'PropertyName',PropertyValue,...)` specifies property name and property value pairs for the `text` graphics object created by `xlabel`.

`xlabel(axes_handle,...)`, ylabel(axes_handle,...), and zlabel(axes_handle,...) plot into the axes with handle `axes_handle` instead of the current axes (`gca`).

`h = xlabel(...)`, h = ylabel(...), and h = zlabel(...) return the handle to the text object used as the label.

`ylabel(...)` and zlabel(...) label the *y*-axis and *z*-axis, respectively, of the current axes.

Remarks

Reissuing an `xlabel`, `ylabel`, or `zlabel` command causes the new label to replace the old label.

For three-dimensional graphics, MATLAB puts the label in the front or side, so that it is never hidden by the plot.

Examples

Create a multiline label for the *x*-axis using a multiline cell array:

```
xlabel({'first line';'second line'})
```

Create a bold label for the *y*-axis that contains a single quote:

```
ylabel('George''s Popularity','fontsize',12,'fontweight','b')
```

See Also

`strings`, `text`, `title`

"Annotating Plots" on page 1-91 for related functions

"Adding Axis Labels to Graphs" for more information about labeling axes

xlim, ylim, zlim

Purpose

Set or query axis limits

GUI Alternative

To control the upper and lower axis limits on a graph, use the Property Editor, one of the plotting tools . For details, see The Property Editor in the MATLAB Graphics documentation.

Syntax

```
xlim
xlim([xmin xmax])
xlim('mode')
xlim('auto')
xlim('manual')
xlim(axes_handle,...)
```

Note that the syntax for each of these three functions is the same; only the `xlim` function is used for simplicity. Each operates on the respective *x*-, *y*-, or *z*-axis.

Description

`xlim` with no arguments returns the respective limits of the current axes.

`xlim([xmin xmax])` sets the axis limits in the current axes to the specified values.

`xlim('mode')` returns the current value of the axis limits mode, which can be either `auto` (the default) or `manual`.

`xlim('auto')` sets the axis limit mode to `auto`.

`xlim('manual')` sets the respective axis limit mode to `manual`.

`xlim(axes_handle,...)` performs the set or query on the axes identified by the first argument, `axes_handle`. When you do not specify an axes handle, these functions operate on the current axes.

Remarks

`xlim`, `ylim`, and `zlim` set or query values of the axes object `XLim`, `YLim`, `ZLim`, and `XLimMode`, `YLimMode`, `ZLimMode` properties.

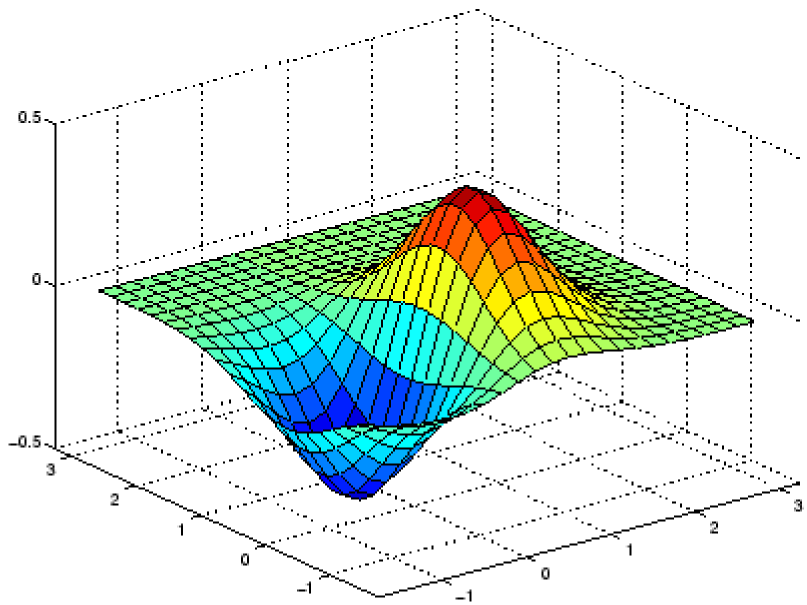
When the axis limit modes are `auto` (the default), MATLAB uses limits that span the range of the data being displayed and are round numbers.

Setting a value for any of the limits also sets the corresponding mode to `manual`. Note that high-level plotting functions like `plot` and `surf` reset both the modes and the limits. If you set the limits on an existing graph and want to maintain these limits while adding more graphs, use the `hold` command.

Examples

This example illustrates how to set the *x*- and *y*-axis limits to match the actual range of the data, rather than the rounded values of `[-2 3]` for the *x*-axis and `[-2 4]` for the *y*-axis originally selected by MATLAB.

```
[x,y] = meshgrid([-1.75:.2:3.25]);
z = x.*exp(-x.^2-y.^2);
surf(x,y,z)
xlim([-1.75 3.25])
ylim([-1.75 3.25])
```



See Also

`axis`

The axes properties `XLim`, `YLim`, `ZLim`

"Aspect Ratio and Axis Limits" on page 1-104 for related functions

Understanding Axes Aspect Ratio for more information on how axis limits affect the axes

Purpose

Determine whether file contains Microsoft Excel (.xls) spreadsheet

Syntax

```
typ = xlsfinfo(filename)
[typ, desc] = xlsfinfo(filename)
[typ, desc, fmt] = xlsfinfo(filename)
xlsfinfo filename
```

Description

`typ = xlsfinfo(filename)` returns the string `'Microsoft Excel Spreadsheet'` if the file specified by `filename` is an XLS file that can be read by the MATLAB `xlsread` function. Otherwise, `typ` is the empty string, (`''`). The `filename` input is a string enclosed in single quotes.

`[typ, desc] = xlsfinfo(filename)` returns in `desc` a cell array of strings containing the names of each spreadsheet in the file. If a spreadsheet is unreadable, the cell in `desc` that represents that spreadsheet contains an error message.

`[typ, desc, fmt] = xlsfinfo(filename)` returns in the `fmt` output a string containing the actual format of the file as obtained from the Microsoft Excel COM server. On UNIX systems, or on Windows when the COM server is not available, `fmt` is returned as an empty string, (`''`).

Note In the case where an Excel COM server cannot be started, functionality is limited in that some Excel files might not be readable.

`xlsfinfo filename` is the command format for `xlsfinfo`. It returns only the first output, `typ`, assigning it to the MATLAB default variable `ans`.

Examples

Get information about an `.xls` file:

```
[typ, desc, fmt] = xlsfinfo('myaccount.xls')

typ =
    Microsoft Excel Spreadsheet
```

```
desc =
    'Sheet1'    'Income'    'Expenses'

fmt =
    xlWorkbookNormal
```

Export the `.xls` file to comma-separated value (CSV) format. Use `xlsfinfo` to see the format of the exported file:

```
[typ, desc, fmt] = xlsfinfo('myaccount.csv');
fmt

fmt =
    xlCSV
```

Export the `.xls` file to HTML format. `xlsfinfo` returns the following format string:

```
[typ, desc, fmt] = xlsfinfo('myaccount.html');
fmt

fmt =
    xlHtml
```

Export the `.xls` file to XML format. `xlsfinfo` returns the following format string:

```
[typ, desc, fmt] = xlsfinfo('myaccount.xml');
fmt

fmt =
    xlXMLSpreadsheet
```

See Also

`xlsread`, `xlswrite`

Purpose

Read Microsoft Excel spreadsheet file (`.xls`)

Syntax

```
num = xlsread(filename)
num = xlsread(filename, -1)
num = xlsread(filename, sheet)
num = xlsread(filename, 'range')
num = xlsread(filename, sheet, 'range')
num = xlsread(filename, sheet, 'range', 'basic')
num = xlsread(filename, ..., functionhandle)
[num, txt]= xlsread(filename, ...)
[num, txt, raw] = xlsread(filename, ...)
[num, txt, raw, X] = xlsread(filename, ..., functionhandle)
xlsread filename sheet range basic
```

Description

`num = xlsread(filename)` returns numeric data in `double` array `num` from the first sheet in the Microsoft Excel spreadsheet file named `filename`. The `filename` argument is a string enclosed in single quotes.

`xlsread` ignores any *outer* rows or columns of the spreadsheet that contain no numeric data. If there are single or multiple nonnumeric rows at the top or bottom, or single or multiple nonnumeric columns to the left or right, `xlsread` does not include these rows or columns in the output. For example, one or more header lines appearing at the top of a spreadsheet are ignored by `xlsread`. Any *inner* rows or columns in which some or all cells contain nonnumeric data are *not* ignored. The nonnumeric cells are instead assigned a value of `NaN`.

The full functionality of `xlsread` depends on the ability to start Excel as a COM server from MATLAB. If your system does not have this capability, the `xlsread` syntax that passes the **`basic`** keyword is recommended. As long as the COM server is available, you can use `xlsread` on Excel files having formats other than XLS (for example, HTML).

Note `xlsread` on the UNIX platform is being grandfathered. If the Excel COM server is not available, `xlsread` reads only strictly XLS files. It cannot read Excel files saved in HTML or other formats.

`num = xlsread(filename, -1)` opens the file `filename` in an Excel window, enabling you to interactively select the worksheet to be read and the range of data on that worksheet to import. To import an entire worksheet, first select the sheet in the Excel window and then click the **OK** button in the Data Selection Dialog box. To import a certain range of data from the sheet, select the worksheet in the Excel window, drag and drop the mouse over the desired range, and then click **OK**. (See "COM Server Requirements" on page 2-4079 below.)

`num = xlsread(filename, sheet)` reads the specified worksheet, where `sheet` is either a positive, double scalar value or a quoted string containing the sheet name. To determine the names of the sheets in a spreadsheet file, use `xlsfinfo`.

`num = xlsread(filename, 'range')` reads data from a specific rectangular region of the default worksheet (`Sheet1`). Specify `range` using the syntax `'C1:C2'`, where `C1` and `C2` are two opposing corners that define the region to be read. For example, `'D2:H4'` represents the 3-by-5 rectangular region between the two corners `D2` and `H4` on the worksheet. The `range` input is not case sensitive and uses Excel A1 notation. (See help in Excel for more information on this notation.) (Also, see "COM Server Requirements" on page 2-4079 below.)

`num = xlsread(filename, sheet, 'range')` reads data from a specific rectangular region (`range`) of the worksheet specified by `sheet`. See the previous two syntax formats for further explanation of the `sheet` and `range` inputs. (See "COM Server Requirements" on page 2-4079 below.)

`num = xlsread(filename, sheet, 'range', 'basic')` imports data from the spreadsheet in basic import mode. This is the mode used on UNIX platforms as well as on Windows platforms when Excel is not available as a COM server. In this mode, `xlsread` does not use Excel as a COM server, and this limits import ability. Without Excel as a COM server, `range` is ignored and, consequently, the whole active range of a sheet is imported. (You can set `range` to the empty string (`''`)). Also, in basic mode, `sheet` is case-sensitive and must be a quoted string.

`num = xlsread(filename, ..., functionhandle)` calls the function associated with `functionhandle` just prior to obtaining spreadsheet values. This enables you to operate on the spreadsheet data (for example, convert it to a numeric type) before reading it in. (See "COM Server Requirements" on page 2-4079 below.)

You can write your own custom function and pass a handle to this function to `xlsread`. When `xlsread` executes, it reads from the spreadsheet, executes your function on the data read from the spreadsheet, and returns the final results to you. When `xlsread` calls your function, it passes a range interface from Excel to provide access to the data read from the spreadsheet. Your function must include this interface both as an input and output argument. Example 5 below shows how you might use this syntax.

`[num, txt]= xlsread(filename, ...)` returns numeric data in array `num` and text data in cell array `txt`. All cells in `txt` that correspond to numeric data contain the empty string.

If `txt` includes data that was previously written to the file using `xlswrite`, and the `range` specified for that `xlswrite` operation caused undefined data (`'#N/A'`) to be written to the worksheet, then cells containing that undefined data are represented in the `txt` output as `'ActiveX VT_ERROR: '`.

`[num, txt, raw] = xlsread(filename, ...)` returns numeric and text data in `num` and `txt`, and unprocessed cell content in cell array `raw`, which contains both numeric and text data. (See "COM Server Requirements" on page 2-4079 below.)

`[num, txt, raw, X] = xlsread(filename, ..., functionhandle)` calls the function associated with `functionhandle` just prior to reading from the spreadsheet file. This syntax returns one additional output `X` from the function mapped to by `functionhandle`. Example 6 below shows how you might use this syntax. (See “COM Server Requirements” on page 2-4079 below.)

`xlsread filename sheet range basic` is the command format for `xlsread`, showing its usage with all input arguments specified. When using this format, you must specify `sheet` as a string, (for example, `Income` or `Sheet4`) and not a numeric index. If the `sheet` name contains space characters, then quotation marks are required around the string, (for example, `'Income 2002'`).

Remarks

Handling Excel Date Values

The MATLAB software imports date fields from Excel files in the format in which they were stored in the Excel file. If stored in string or date format, `xlsread` returns the date as a string. If stored in a numeric format, `xlsread` returns a numeric date.

Both Excel and MATLAB represent numeric dates as a number of serial days elapsed from a specific reference date. However, Excel uses January 1, 1900 as the reference date while MATLAB uses January 0, 0000. Due to this difference in the way Excel and MATLAB compute numeric date values, any numeric date imported from Excel into MATLAB must first be converted before being used in the MATLAB application.

You can do this conversion after the `xlsread` completes, as shown below:

```
excelDates = xlsread(filename)
matlabDates = datenum('30-Dec-1899') + excelDates
datestr(matlabDates,2)
```

You can also do this as part of the `xlsread` operation by writing a conversion routine that acts directly on the Excel COM `Range` object, and then passing a function handle for your routine as an input to `xlsread`. The description above for the following syntax, along with Examples 5 and 6, explain how to do this:

```
[num, txt, raw, X] = xlsread(filename, ..., functionhandle)
```

COM Server Requirements

The following six syntax formats are supported only on computer systems capable of starting Excel as a COM server from MATLAB. They are not supported in `basic` mode.

```
num = xlsread(filename, -1)
num = xlsread(filename, 'range')
num = xlsread(filename, sheet, 'range')
[num, txt, raw] = xlsread(filename, ...)
num = xlsread(filename, ..., functionhandle)
[num, txt, raw, opt] = xlsread(filename, ..., functionhandle)
```

Examples

Example 1— Reading Numeric Data

The Microsoft Excel spreadsheet file `testdata1.xls` contains this data:

```
    1     6
    2     7
    3     8
    4     9
    5    10
```

To read this data into MATLAB, use this command:

```
A = xlsread('testdata1.xls')
A =
    1     6
    2     7
    3     8
    4     9
    5    10
```

Example 2 — Handling Text Data

The Microsoft Excel spreadsheet file `testdata2.xls` contains a mix of numeric and text data:

```
    1     6
    2     7
```

```
3    8
4    9
5   text
```

xlsread puts a NaN in place of the text data in the result:

```
A = xlsread('testdata2.xls')
A =
     1     6
     2     7
     3     8
     4     9
     5   NaN
```

Example 3 — Selecting a Range of Data

To import only rows 4 and 5 from worksheet 1, specify the range as 'A4:B5':

```
A = xlsread('testdata2.xls', 1, 'A4:B5')

A =
     4     9
     5   NaN
```

Example 4 — Handling Files with Row or Column Headers

A Microsoft Excel spreadsheet labeled Temperatures in file tempdata.xls contains two columns of numeric data with text headers for each column:

```
Time  Temp
12     98
13     99
14     97
```

If you want to import only the numeric data, use xlsread with a single return argument. Specify the filename and sheet name as inputs.

xlsread ignores any leading row or column of text in the numeric result.

```
ndata = xlsread('tempdata.xls', 'Temperatures')

ndata =
    12    98
    13    99
    14    97
```

To import both the numeric data and the text data, specify two return values for `xlsread`:

```
[ndata, headertext] = xlsread('tempdata.xls', 'Temperatures')

ndata =
    12    98
    13    99
    14    97

headertext =
    'Time'    'Temp'
```

Example 5 — Passing a Function Handle

This example calls `xlsread` twice, the first time as a simple read from a file, and the second time requesting that `xlsread` execute some user-defined modifications on the data prior to returning the results of the read. These modifications are performed by a user-written function, `setMinMax`, that you pass as a function handle in the call to `xlsread`. When `xlsread` executes, it reads from the spreadsheet, executes the function on the data read from the spreadsheet, and returns the final results to you.

Note The function passed to `xlsread` operates on the copy of the data read from the spreadsheet. It does not modify data in the spreadsheet itself.

Read a 10-by-3 numeric array from Excel spreadsheet `testsheet.xls`. with a simple `xlsread` statement that does not pass a function handle. Note that the values returned range from -587 to +4,149:

```
arr = xlsread('testsheet.xls')
arr =
  1.0e+003 *
    1.0020    4.1490    0.2300
    1.0750    0.1220   -0.4550
   -0.0301    3.0560    0.2471
    0.4070    0.1420   -0.2472
    2.1160   -0.0557   -0.5870
    0.4040    2.9280    0.0265
    0.1723    3.4440    0.1112
    4.1180    0.1820    2.8630
    0.9000    0.0573    1.9750
    0.0163    0.2000   -0.0223
```

In preparation for the second part of this example, write a function `setMinMax` that restricts the values returned from the read to be in the range of 0 to 2000. You will need to pass this function in the call to `xlsread` which will then execute the function on the data it has read before returning it to you.

When `xlsread` calls your function, it passes a range interface from Excel to provide access to the data read from the spreadsheet. This is shown as `DataRange` in this example. Your function must include this interface both as an input and output argument. The output argument allows your function to pass modified data back to `xlsread`:

```
function [DataRange] = setMinMax(DataRange)
maxval = 2000;  minval = 0;

for k = 1:DataRange.Count
   v = DataRange.Value{k};
   if v > maxval || v < minval
      if v > maxval
         DataRange.Value{k} = maxval;
```

```
         else
            DataRange.Value{k} = minval;
         end
      end
   end
```

Now call `xlsread`, passing a function handle for the `setMinMax` function as the final argument. Note the changes from the values returned from the last call to `xlsread`:

```
arr = xlsread('testsheet.xls', '', '', '', @setMinMax)
arr =
  1.0e+003 *
    1.0020    2.0000    0.2300
    1.0750    0.1220         0
         0    2.0000    0.2471
    0.4070    0.1420         0
    2.0000         0         0
    0.4040    2.0000    0.0265
    0.1723    2.0000    0.1112
    2.0000    0.1820    2.0000
    0.9000    0.0573    1.9750
    0.0163    0.2000         0
```

Example 6 — Passing a Function Handle with Additional Output

This example adds onto the previous one by returning an additional output from the call to `setMinMax`. Modify the function so that it not only limits the range of values returned, but also reports which elements of the spreadsheet matrix have been altered. Return this information in a new output argument, `indices`:

```
function [DataRange, indices] = setMinMax(DataRange)
maxval = 2000;  minval = 0;
indices = [];

for k = 1:DataRange.Count
   v = DataRange.Value{k};
```

```
    if v > maxval || v < minval
       if v > maxval
          DataRange.Value{k} = maxval;
       else
          DataRange.Value{k} = minval;
       end
    indices = [indices k];
    end
end
```

When you call `xlsread` this time, account for the three initial outputs, and add a fourth called `idx` to accept the indices returned from `setMinMax`. Call `xlsread` again, and you will see just where the returned matrix has been modified:

```
[arr txt raw idx] = xlsread('testsheet.xls', ...
                            '', '', '', @setMinMax);

idx
idx =
    3    5    8   11   13   15   16   17   22   24   25   28   30
arr
arr =
  1.0e+003 *
    1.0020    2.0000    0.2300
    1.0750    0.1220         0
         0    2.0000    0.2471
    0.4070    0.1420         0
    2.0000         0         0
    0.4040    2.0000    0.0265
    0.1723    2.0000    0.1112
    2.0000    0.1820    2.0000
    0.9000    0.0573    1.9750
    0.0163    0.2000         0
```

See Also

`xlswrite`, `xlsfinfo`, `wk1read`, `textread`, `function_handle`

Purpose

Write Microsoft Excel spreadsheet file (.xls)

Syntax

```
xlswrite(filename, M)
xlswrite(filename, M, sheet)
xlswrite(filename, M, range)
xlswrite(filename, M, sheet, range)
status = xlswrite(filename, ...)
[status, message] = xlswrite(filename, ...)
xlswrite filename M sheet range
```

Description

xlswrite(filename, M) writes matrix M to the Excel file filename. The filename input is a string enclosed in single quotes. The input matrix M is an m-by-n numeric, character, or cell array, where m < 65536 and n < 256. The matrix data is written to the first worksheet in the file, starting at cell A1.

Note To specify sheet or range, but not both, call xlswrite with just three inputs. If the third input is a string that includes a colon character (e.g., 'D2:H4'), it specifies range. If it is not (e.g.,'sales'), it specifies the worksheet to write to. See the next two syntaxes below.

---

xlswrite(filename, M, sheet) writes matrix M to the specified worksheet sheet in the file filename. The sheet argument can be either a positive, double scalar value representing the worksheet index, or a quoted string containing the sheet name. The sheet argument cannot contain a colon.

If sheet does not exist, a new sheet is added at the end of the worksheet collection. If sheet is an index larger than the number of worksheets, empty sheets are appended until the number of worksheets in the workbook equals sheet. In either case, the MATLAB software generates a warning indicating that it has added a new worksheet.

xlswrite(filename, M, range) writes matrix M to a rectangular region specified by range in the first worksheet of the file filename. Specify range using two cell designations separated by a colon, such as `'D2:H4'`, to indicate two opposing corners of the region to receive the matrix data. The range `'D2:H4'` represents the 3-by-5 rectangular region between the two corners `D2` and `H4` on the worksheet.

The `range` input is not case sensitive and uses Excel A1 notation. (See help in Excel for more information on this notation.)

The size defined by `range` should fit the size of `M` or contain only the first cell, (e.g., `'A2'`). If `range` is larger than the size of `M`, Excel fills the remainder of the region with `#N/A`. If `range` is smaller than the size of `M`, only the submatrix that fits into `range` is written to the file specified by `filename`.

`xlswrite(filename, M, sheet, range)` writes matrix `M` to a rectangular region specified by `range` in worksheet `sheet` of the file `filename`. See the previous two syntax formats for further explanation of the `sheet` and `range` inputs.

`status = xlswrite(filename, ...)` returns the completion status of the write operation in `status`. If the write completed successfully, `status` is equal to logical `1` (`true`). Otherwise, `status` is logical `0` (`false`). Unless you specify an output for `xlswrite`, no status is displayed in the Command Window.

`[status, message] = xlswrite(filename, ...)` returns any warning or error message generated by the write operation in the MATLAB structure `message`. The `message` structure has two fields:

- `message` — String containing the text of the warning or error message
- `identifier` — String containing the message identifier for the warning or error

`xlswrite filename M sheet range` is the command format for `xlswrite`, showing its usage with all input arguments specified. When using this format, you must specify `sheet` as a string (for example, `Income` or `Sheet4`). If the `sheet` name contains space characters, then quotation marks are required around the string (for example, `'Income 2002'`).

Note The above functionality depends upon having Microsoft Excel as a COM server. In absence of Excel, matrix `M` is written as a text file in Comma-Separated Value (CSV) format. In this mode, the `sheet` and `range` arguments are ignored.

Examples

Example 1 — Writing Numeric Data to the Default Worksheet

Write a 7-element vector to Microsoft Excel file `testdata.xls`. By default, the data is written to cells `A1` through `G1` in the first worksheet in the file:

```
xlswrite('testdata', [12.7 5.02 -98 63.9 0 -.2 56])
```

Example 2 — Writing Mixed Data to a Specific Worksheet

This example writes the following mixed text and numeric data to the file `tempdata.xls`:

```
d = {'Time', 'Temp'; 12 98; 13 99; 14 97};
```

Call `xlswrite`, specifying the worksheet labeled `Temperatures`, and the region within the worksheet to write the data to. The 4-by-2 matrix will be written to the rectangular region that starts at cell `E1` in its upper left corner:

```
s = xlswrite('tempdata.xls', d, 'Temperatures', 'E1')
s =
    1
```

The output status `s` shows that the write operation succeeded. The data appears as shown here in the output file:

```
Time   Temp
  12     98
  13     99
  14     97
```

Example 3 — Appending a New Worksheet to the File

Now write the same data to a worksheet that doesn't yet exist in `tempdata.xls`. In this case, MATLAB appends a new sheet to the workbook, calling it by the name you supplied in the `sheets` input argument, `'NewTemp'`. MATLAB displays a warning indicating that it has added a new worksheet to the file:

```
xlswrite('tempdata.xls', d, 'NewTemp', 'E1')
Warning: Added specified worksheet.
```

If you don't want to see these warnings, you can turn them off using the command indicated in the message above:

```
warning off MATLAB:xlswrite:AddSheet
```

Now try the command again, this time creating another new worksheet, `NewTemp2`. Although the message is not displayed this time, you can still retrieve it and its identifier from the second output argument, `m`:

```
[stat msg] = xlswrite('tempdata.xls', d, 'NewTemp2', 'E1');

msg
msg =
       message: 'Added specified worksheet.'
    identifier: 'MATLAB:xlswrite:AddSheet'
```

See Also

`xlsread`, `xlsfinfo`, `wk1read`, `textread`

Purpose

Parse XML document and return Document Object Model node

Syntax

```
DOMnode = xmlread(filename)
```

Description

`DOMnode = xmlread(filename)` reads a URL or `filename` and returns a Document Object Model node representing the parsed document. The `filename` input is a string enclosed in single quotes. The node can be manipulated by using standard DOM functions.

A properly parsed document displays to the screen as

```
xDoc = xmlread(...)
xDoc =
    [#document: null]
```

Remarks

Find out more about the Document Object Model at the World Wide Web Consortium (W3C) Web site, `http://www.w3.org/DOM/`. For specific information on using Java DOM objects, visit the Sun Web site, `http://www.java.sun.com/xml/docs/api`.

Examples

Example 1

All XML files have a single root element. Some XML files declare a preferred schema file as an attribute of this element. Use the `getAttribute` method of the DOM node to get the name of the preferred schema file:

```
xDoc = xmlread(fullfile(matlabroot, ...
               'toolbox/matlab/general/info.xml'));

xRoot = xDoc.getDocumentElement;
schemaURL = ...
   char(xRoot.getAttribute('xsi:noNamespaceSchemaLocation'))

schemaURL =
   http://www.mathworks.com/namespace/info/v1/info.xsd
```

Example 2

Each `info.xml` file on the MATLAB path contains several `listitem` elements with a `label` and `callback` element. This script finds the callback that corresponds to the label `'Plot Tools'`:

```
infoLabel = 'Plot Tools';
infoCbk = '';
itemFound = false;

xDoc = xmlread(fullfile(matlabroot, ...
               'toolbox/matlab/general/info.xml'));

% Find a deep list of all listitem elements.
allListItems = xDoc.getElementsByTagName('listitem');

% Note that the item list index is zero-based.
for k = 0:allListItems.getLength-1
   thisListItem = allListItems.item(k);
   childNode = thisListItem.getFirstChild;

   while ~isempty(childNode)
      %Filter out text, comments, and processing instructions.
      if childNode.getNodeType == childNode.ELEMENT_NODE
         % Assume that each element has a single
         % org.w3c.dom.Text child.
         childText = char(childNode.getFirstChild.getData);

         switch char(childNode.getTagName)
         case 'label';
            itemFound = strcmp(childText, infoLabel);
         case 'callback' ;
            infoCbk = childText;
         end
      end  % End IF
      childNode = childNode.getNextSibling;
   end  % End WHILE
```

```
   if itemFound
      break;
   else
      infoCbk = '';
   end
end  % End FOR

disp(sprintf('Item "%s" has a callback of "%s".', ...
             infoLabel, infoCbk))
```

Example 3

This function parses an XML file using methods of the DOM node returned by `xmlread`, and stores the data it reads in the `Name`, `Attributes`, `Data`, and `Children` fields of a MATLAB structure:

```
function theStruct = parseXML(filename)
% PARSEXML Convert XML file to a MATLAB structure.
try
   tree = xmlread(filename);
catch
   error('Failed to read XML file %s.',filename);
end

% Recurse over child nodes. This could run into problems
% with very deeply nested trees.
try
   theStruct = parseChildNodes(tree);
catch
   error('Unable to parse XML file %s.',filename);
end


% ----- Subfunction PARSECHILDNODES -----
function children = parseChildNodes(theNode)
% Recurse over node children.
children = [];
if theNode.hasChildNodes
```

```
   childNodes = theNode.getChildNodes;
   numChildNodes = childNodes.getLength;
   allocCell = cell(1, numChildNodes);

   children = struct(             ...
      'Name', allocCell, 'Attributes', allocCell,    ...
      'Data', allocCell, 'Children', allocCell);

    for count = 1:numChildNodes
        theChild = childNodes.item(count-1);
        children(count) = makeStructFromNode(theChild);
    end
end

% ----- Subfunction MAKESTRUCTFROMNODE -----
function nodeStruct = makeStructFromNode(theNode)
% Create structure of node info.

nodeStruct = struct(                        ...
   'Name', char(theNode.getNodeName),       ...
   'Attributes', parseAttributes(theNode),  ...
   'Data', '',                              ...
   'Children', parseChildNodes(theNode));

if any(strcmp(methods(theNode), 'getData'))
   nodeStruct.Data = char(theNode.getData);
else
   nodeStruct.Data = '';
end

% ----- Subfunction PARSEATTRIBUTES -----
function attributes = parseAttributes(theNode)
% Create attributes structure.

attributes = [];
if theNode.hasAttributes
   theAttributes = theNode.getAttributes;
```

```
   numAttributes = theAttributes.getLength;
   allocCell = cell(1, numAttributes);
   attributes = struct('Name', allocCell, 'Value', ...
                       allocCell);

   for count = 1:numAttributes
      attrib = theAttributes.item(count-1);
      attributes(count).Name = char(attrib.getName);
      attributes(count).Value = char(attrib.getValue);
   end
end
```

See Also

xmlwrite, xslt

xmlwrite

Purpose

Serialize XML Document Object Model node

Syntax

```
xmlwrite(filename, DOMnode)
str = xmlwrite(DOMnode)
```

Description

`xmlwrite(filename, DOMnode)` serializes the Document Object Model node `DOMnode` to the file specified by `filename`. The `filename` input is a string enclosed in single quotes.

`str = xmlwrite(DOMnode)` serializes the Document Object Model node `DOMnode` and returns the node tree as a string, `s`.

Remarks

Find out more about the Document Object Model at the World Wide Web Consortium (W3C) Web site, `http://www.w3.org/DOM/`.

Example

```
% Create a sample XML document.
docNode = com.mathworks.xml.XMLUtils.createDocument...
    ('root_element')
docRootNode = docNode.getDocumentElement;
for i=1:20
    thisElement = docNode.createElement('child_node');
    thisElement.appendChild...
        (docNode.createTextNode(sprintf('%i',i)));
    docRootNode.appendChild(thisElement);
end
docNode.appendChild(docNode.createComment('this is a comment'));

% Save the sample XML document.
xmlFileName = [tempname,'.xml'];
xmlwrite(xmlFileName,docNode);
edit(xmlFileName);
```

See Also

`xmlread`, `xslt`

Purpose

Logical exclusive-OR

Syntax

```
C = xor(A, B)
```

Description

`C = xor(A, B)` performs an exclusive OR operation on the corresponding elements of arrays `A` and `B`. The resulting element `C(i,j,...)` is logical true (1) if `A(i,j,...)` or `B(i,j,...)`, but not both, is nonzero.

A	B	C
Zero	Zero	0
Zero	Nonzero	1
Nonzero	Zero	1
Nonzero	Nonzero	0

Examples

Given `A = [0 0 pi eps]` and `B = [0 -2.4 0 1]`, then

```
C = xor(A,B)
C =
    0    1    1    0
```

To see where either `A` or `B` has a nonzero element and the other matrix does not,

```
spy(xor(A,B))
```

See Also

`all`, `any`, `find`, Elementwise Logical Operators, Short-Circuit Logical Operators

xslt

Purpose

Transform XML document using XSLT engine

Syntax

```
result = xslt(source, style, dest)
[result,style] = xslt(...)
xslt(...,'-web')
```

Description

`result = xslt(source, style, dest)` transforms an XML document using a stylesheet and returns the resulting document's URL. The function uses these inputs, the first of which is required:

- `source` is the filename or URL of the source XML file. `source` can also specify a DOM node.
- `style` is the filename or URL of an XSL stylesheet.
- `dest` is the filename or URL of the desired output document. If `dest` is absent or empty, the function uses a temporary filename. If `dest` is `'-tostring'`, the function returns the output document as a MATLAB string.

`[result,style] = xslt(...)` returns a processed stylesheet appropriate for passing to subsequent XSLT calls as `style`. This prevents costly repeated processing of the stylesheet.

`xslt(...,'-web')` displays the resulting document in the Help Browser.

Remarks

Find out more about XSL stylesheets and how to write them at the World Wide Web Consortium (W3C) web site, `http://www.w3.org/Style/XSL/`.

Example

This example converts the file `info.xml` using the stylesheet `info.xsl`, writing the output to the file `info.html`. It launches the resulting HTML file in the Help Browser. MATLAB has several `info.xml` files that are used by the **Start** menu.

```
xslt info.xml info.xsl info.html -web
```

See Also

xmlread, xmlwrite

Purpose Create array of all zeros

Syntax

```
B = zeros(n)
B = zeros(m,n)
B = zeros([m n])
B = zeros(m,n,p,...)
B = zeros([m n p ...])
B = zeros(size(A))
zeros(m, n,...,classname)
zeros([m,n,...],classname)
```

Description

`B = zeros(n)` returns an `n`-by-`n` matrix of zeros. An error message appears if `n` is not a scalar.

`B = zeros(m,n)` or `B = zeros([m n])` returns an `m`-by-`n` matrix of zeros.

`B = zeros(m,n,p,...)` or `B = zeros([m n p ...])` returns an `m`-by-`n`-by-`p`-by-`...` array of `zeros`.

Note The size inputs `m`, `n`, `p`, `...` should be nonnegative integers. Negative integers are treated as 0.

`B = zeros(size(A))` returns an array the same size as `A` consisting of all zeros.

`zeros(m, n,...,classname)` or `zeros([m,n,...],classname)` is an `m`-by-`n`-by-... array of zeros of data type `classname`. `classname` is a string specifying the data type of the output. `classname` can have the following values: `'double'`, `'single'`, `'int8'`, `'uint8'`, `'int16'`, `'uint16'`, `'int32'`, `'uint32'`, `'int64'`, or `'uint64'`.

Example

```
x = zeros(2,3,'int8');
```

Remarks

The MATLAB language does not have a dimension statement; MATLAB automatically allocates storage for matrices. Nevertheless, for large matrices, MATLAB programs may execute faster if the `zeros` function is used to set aside storage for a matrix whose elements are to be generated one at a time, or a row or column at a time. For example

```
x = zeros(1,n);
for i = 1:n, x(i) = i; end
```

See Also

`eye`, `ones`, `rand`, `randn`, `complex`

Purpose

Compress files into zip file

Syntax

```
zip(zipfile,files)
zip(zipfile,files,rootdir)
entrynames = zip(...)
```

Description

`zip(zipfile,files)` creates a zip file with the name `zipfile` from the list of files and directories specified in `files`. Relative paths are stored in the zip file, but absolute paths are not. Directories recursively include all of their content.

`zipfile` is a string specifying the name of the zip file. If `zipfile` has no extension, MATLAB appends the `.zip` extension.

`files` is a string or cell array of strings containing the list of files or directories included in `zipfile`. Individual files that are on the MATLAB path can be specified as partial path names. Otherwise an individual file can be specified relative to the current directory or with an absolute path.

Directories must be specified relative to the current directory or with absolute paths. On UNIX[32] systems, directories can also start with `~/` or `~`*`username`*`/`, which expands to the current user's home directory or the specified user's home directory, respectively. The wildcard character `*` can be used when specifying files or directories, except when relying on the MATLAB path to resolve a file name or partial path name.

`zip(zipfile,files,rootdir)` allows the path for `files` to be specified relative to `rootdir` rather than the current directory.

`entrynames = zip(...)` returns a string cell array of the names of the files contained in `zipfile`. If `files` contains a relative path, `entrynames` also contains the relative path.

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Examples

Zip a File

Create a zip file of the file `guide.viewlet`, which is in the MATLAB `demos` directory. It saves the zip file in `d:/mymfiles/viewlet.zip`.

```
file = fullfile(matlabroot,'demos','guide.viewlet');
zip('d:/mymfiles/viewlet.zip',file)
```

Run `zip` for the files `guide.viewlet` and `import.viewlet` and save the zip file in `viewlets.zip`. The source files and zipped file are in the current directory.

```
zip('viewlets.zip',{'guide.viewlet','import.viewlet'})
```

Zip Selected Files

Run `zip` for all `.m` and `.mat` files in the current directory to the file `backup.zip`:

```
zip('backup',{'*.m','*.mat'});
```

Zip a Directory

Run `zip` for the directory `D:/mymfiles` and its contents to the zip file `mymfiles` in the directory one level up from the current directory.

```
zip('../mymfiles','D:/mymfiles')
```

Zip Between Directories

Run `zip` for the files `thesis.doc` and `defense.ppt`, which are located in `d:/PhD`, to the zip file `thesis.zip` in the current directory.

```
zip('thesis.zip',{'thesis.doc','defense.ppt'},'d:/PhD')
```

See Also

`gzip`, `gunzip`, `tar`, `untar`, `unzip`

Purpose

Turn zooming on or off or magnify by factor

GUI Alternatives

Use the **Zoom** tools on the figure toolbar to zoom in or zoom out on a plot, or select **Zoom In** or **Zoom Out** from the figure's **Tools** menu. For details, see "Enlarging the View" in the MATLAB Graphics documentation.

Syntax

```
zoom on
zoom off
zoom out
zoom reset
zoom
zoom xon
zoom yon
zoom(factor)
zoom(fig, option)
h = zoom(figure_handle)
```

Description

`zoom on` turns on interactive zooming. When interactive zooming is enabled in a figure, pressing a mouse button while your cursor is within an axes zooms into the point or out from the point beneath the mouse. Zooming changes the axes limits. When using zoom mode, you

- Zoom in by positioning the mouse cursor where you want the center of the plot to be and either
  - Press the mouse button or
  - Rotate the mouse scroll wheel away from you (upward).
- Zoom out by positioning the mouse cursor where you want the center of the plot to be and either
  - Simultaneously press **Shift** and the mouse button, or
  - Rotate the mouse scroll wheel toward you (downward).

Each mouse click or scroll wheel click zooms in or out by a factor of 2.

Clicking and dragging over an axes when zooming in is enabled draws a rubberband box. When you release the mouse button, the axes zoom in to the region enclosed by the rubberband box.

Double-clicking over an axes returns the axes to its initial zoom setting in both zoom-in and zoom-out modes.

`zoom off` turns interactive zooming off.

`zoom out` returns the plot to its initial zoom setting.

`zoom reset` remembers the current zoom setting as the initial zoom setting. Later calls to `zoom out`, or double-clicks when interactive `zoom` mode is enabled, will return to this zoom level.

`zoom` toggles the interactive zoom status between off and on (restoring the most recently used zoom tool).

`zoom xon` and `zoom yon` set `zoom on` for the *x*- and *y*-axis, respectively.

`zoom(factor)` zooms in or out by the specified zoom factor, without affecting the interactive zoom mode. Values greater than 1 zoom in by that amount, while numbers greater than 0 and less than 1 zoom out by `1/factor`.

`zoom(fig, option)` Any of the preceding options can be specified on a figure other than the current figure using this syntax.

`h = zoom(figure_handle)` returns a zoom *mode object* for the figure `figure_handle` for you to customize the mode's behavior.

Using Zoom Mode Objects

Access the following properties of zoom mode objects via `get` and modify some of them using `set`.

- *`Enable`* `'on'|'off'` — Specifies whether this figure mode is currently enabled on the figure
- `FigureHandle <handle>` — The associated figure handle, a read-only property that cannot be set

- *Motion* 'horizontal'|'vertical'|'both' — The type of zooming enabled for the figure
- *Direction* 'in'|'out' — The direction of the zoom operation
- *RightClickAction* 'InverseZoom'|'PostContextMenu' — The behavior of a right-click action

  A value of 'InverseZoom' causes a right-click to zoom out. A value of 'PostContextMenu' displays a context menu. This setting persists between MATLAB sessions.
- UIContextMenu <handle> — Specifies a custom context menu to be displayed during a right-click action

  This property is ignored if the RightClickAction property has been set to 'on'.

Zoom Mode Callbacks

You can program the following callbacks for zoom mode operations.

- ButtonDownFilter <function_handle> — Function to intercept ButtonDown events

  The application can inhibit the zoom operation under circumstances the programmer defines, depending on what the callback returns. The input function handle should reference a function with two implicit arguments (similar to Handle Graphics object callbacks), as follows:

```
function [res] = myfunction(obj,event_obj)
% obj           handle to the object that has been clicked on
% eventdata     struct for event data (empty in this release)
% res [output]  a logical flag to determine whether the zoom
%               operation should take place or the 'ButtonDownFcn'
%               property of the object should take precedence
```

- ActionPreCallback <function_handle> — Function to execute before zooming

Set this callback if you want to execute code when a zoom operation starts. The input function handle should reference a function with two implicit arguments (similar to Handle Graphics object callbacks), as follows:

```
function myfunction(obj,event_obj)
% obj         handle to the figure that has been clicked on.
% eventdata   struct containing event data
```

The event data has the following field.

Axes	The handle of the axes that is being zoomed

- ActionPostCallback <function_handle> — Function to execute after zooming

  Set this callback if you want to execute code when a zoom operation finishes. The input function handle should reference a function with two implicit arguments (similar to Handle Graphics object callbacks), as follows:

```
function myfunction(obj,eventdata)
% obj         handle to the figure that has been clicked on
% eventdata   struct containing event data (same as the
%             event data of the 'ActionPreCallback' callback)
```

Zoom Mode Utility Functions

The following functions in zoom mode query and set certain of its properties.

- flags = isAllowAxesZoom(h,axes) — Function querying permission to zoom axes

  Calling the function isAllowAxesZoom on the zoom object, h, with a vector of axes handles, axes, as input returns a logical array of the same dimension as the axes handle vector, which indicates whether a zoom operation is permitted on the axes objects.

- `setAllowAxesZoom(h,axes,flag)` — Function to set permission to zoom axes

  Calling the function `setAllowAxesZoom` on the zoom object, `h`, with a vector of axes handles, `axes`, and a logical scalar, `flag`, either allows or disallows a zoom operation on the axes objects.

- `*info* = getAxesZoomMotion(h,axes)` — Function to get style of zoom operations

  Calling the function `getAxesZoomMotion` on the zoom object, `H`, with a vector of axes handles, `axes`, as input returns a character cell array of the same dimension as the axes handle vector, which indicates the type of zoom operation for each axes. Possible values for the type of operation are `'horizontal'`, `'vertical'`, or `'both'`.

- `setAxesZoomMotion(h,axes,style)` — Function to set style of zoom operations

  Calling the function `setAxesZoomMotion` on the zoom object, `h`, with a vector of axes handles, `axes`, and a character array, `style`, ses the style of zooming on each axes.

Examples

Example 1 — Entering Zoom Mode

Plot a graph and turn on Zoom mode:

```
plot(1:10);
zoom on
% zoom in on the plot
```

Example 2 — Constrained Zoom

Create zoom mode object and constrain to *x*-axis zooming:

```
plot(1:10);
 h = zoom;
set(h,'Motion','horizontal','Enable','on');
```

```
% zoom in on the plot in the horizontal direction.
```

Example 3 — Constrained Zoom in Subplots

Create four axes as subplots and set zoom style differently for each by setting a different property for each axes handle:

```
ax1 = subplot(2,2,1);
plot(1:10);
h = zoom;
ax2 = subplot(2,2,2);
plot(rand(3));
setAllowAxesZoom(h,ax2,false);
ax3 = subplot(2,2,3);
plot(peaks);
setAxesZoomMotion(h,ax3,'horizontal');
ax4 = subplot(2,2,4);
contour(peaks);
setAxesZoomMotion(h,ax4,'vertical');
% Zoom in on the plots.
```

Example 4 — Coding a ButtonDown Callback

Create a buttonDown callback for zoom mode objects to trigger. Copy the following code to a new M-file, execute it, and observe zooming behavior:

```
function demo
% Allow a line to have its own 'ButtonDownFcn' callback.
hLine = plot(rand(1,10));
set(hLine,'ButtonDownFcn','disp(''This executes'')');
set(hLine,'Tag','DoNotIgnore');
h = zoom;
set(h,'ButtonDownFilter',@mycallback);
set(h,'Enable','on');
% mouse click on the line
%
```

```
function [flag] = mycallback(obj,event_obj)
% If the tag of the object is 'DoNotIgnore', then return true.
objTag = get(obj,'Tag');
if strcmpi(objTag,'DoNotIgnore')
   flag = true;
else
   flag = false;
end
```

Example 5 — Coding Pre- and Post-Callback Behavior

Create callbacks for pre- and post-buttonDown events for zoom mode objects to trigger. Copy the following code to a new M-file, execute it, and observe zoom behavior:

```
function demo
% Listen to zoom events
plot(1:10);
h = zoom;
set(h,'ActionPreCallback',@myprecallback);
set(h,'ActionPostCallback',@mypostcallback);
set(h,'Enable','on');
%
function myprecallback(obj,evd)
disp('A zoom is about to occur.');
%
function mypostcallback(obj,evd)
newLim = get(evd.Axes,'XLim');
msgbox(sprintf('The new X-Limits are [%.2f %.2f].',newLim));
```

Example 6 — Creating a Context Menu for Zoom Mode

Coding a context menu that lets the user to switch to Pan mode by right-clicking:

```
figure;plot(magic(10))
hCMZ = uicontextmenu;
```

```
hZMenu = uimenu('Parent',hCMZ,'Label','Switch to pan','Callback','p
hZoom = zoom(gcf);
set(hZoom,'UIContextMenu',hCMZ);
zoom('on')
```

You cannot add items to the built-in zoom context menu, but you can replace it with your own.

Remarks

`zoom` changes the axes limits by a factor of 2 (in or out) each time you press the mouse button while the cursor is within an axes. You can also click and drag the mouse to define a zoom area, or double-click to return to the initial zoom level.

You can create a zoom mode object once and use it to customize the behavior of different axes, as Example 3 illustrates. You can also change its callback functions on the fly.

Note Do not change figure callbacks within an interactive mode. While a mode is active (when panning, zooming, etc.), you will receive a warning if you attempt to change any of the figure's callbacks and the operation will not succeed. The one exception to this rule is the figure `WindowButtonMotionFcn` callback, which can be changed from within a mode. Therefore, if you are creating a GUI that updates a figure's callbacks, the GUI should some keep track of which interactive mode is active, if any, before attempting to do this.

When you assign different zoom behaviors to different `subplot` axes via a mode object and then link them using the `linkaxes` function, the behavior of the axes you manipulate with the mouse carries over to the linked axes, regardless of the behavior you previously set for the other axes.

See Also

`linkaxes`, `pan`, `rotate3d`

"Object Manipulation" on page 1-104 for related functions

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