Introduction to Matlab

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What is MATLAB

What is MATLAB

MATrix **LAB**oratory

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MATrix **LAB**oratory

- high-performance language for technical computing

What is MATLAB

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- high-performance language for technical computing
- computational, visualization, and programming environment

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- high-performance language for technical computing
- computational, visualization, and programming environment

Typical Uses:

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- high-performance language for technical computing
- computational, visualization, and programming environment

Typical Uses:

- Math and computation

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Typical Uses:

- Math and computation
- Algorithm development

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Typical Uses:

- Math and computation
- Algorithm development
- Modelling, simulation and prototyping

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- computational, visualization, and programming environment

Typical Uses:

- Math and computation
- Algorithm development
- Modelling, simulation and prototyping
- Data analysis, exploration and visualization

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- high-performance language for technical computing
- computational, visualization, and programming environment

Typical Uses:

- Math and computation
- Algorithm development
- Modelling, simulation and prototyping
- Data analysis, exploration and visualization
- Scientific and engineering graphics

What is MATLAB

MATrix **LAB**oratory

- high-performance language for technical computing
- computational, visualization, and programming environment

Typical Uses:

- Math and computation
- Algorithm development
- Modelling, simulation and prototyping
- Data analysis, exploration and visualization
- Scientific and engineering graphics
- Application development
    - Graphical user interfaces

MATLAB Components

1. MATLAB environment
2. MATLAB language
3. Handle graphics
4. Function library and Toolboxes
5. Application Program Interface (API)

MATLAB Components

1. MATLAB environment
2. MATLAB language
3. Handle graphics
4. Function library and Toolboxes
5. Application Program Interface (API)

The set of tools and facilities that you work as the MATLAB user or programmer, including tools for development, management, debugging and profiling.

MATLAB Components

1. MATLAB environment
2. MATLAB language
3. Handle graphics
4. Function library and Toolboxes
5. Application Program Interface (API)

A high-level matrix/array language with control flow mechanism, functions, data structures, input/output and object-oriented programming features.

MATLAB Components

1. MATLAB environment
2. MATLAB language
3. Handle graphics
4. Function library and Toolboxes
5. Application Program Interface (API)

The graphics system. It includes high-level commands for 2-D and 3-D data visualization, image processing, animation and presentation graphics.

MATLAB Components

1. MATLAB environment
2. MATLAB language
3. Handle graphics
4. Function library and Toolboxes
5. Application Program Interface (API)

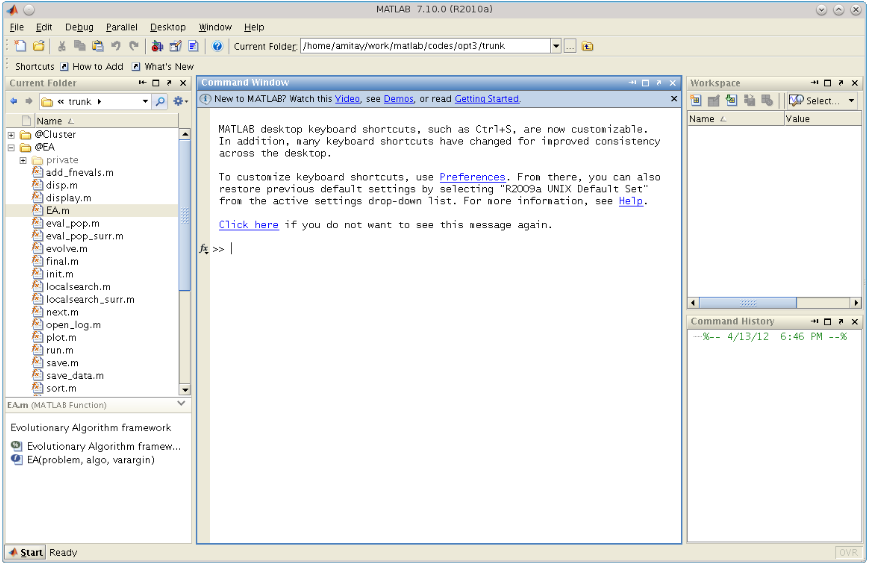
A vast collection of computational algorithms ranging from elementary functions like *sum*, *sine*, and complex arithmetic, to more sophisticated functions like matrix inverse, eigenvalues, Bessel functions and Fast fourier transforms.

MATLAB Components

1. MATLAB environment
2. MATLAB language
3. Handle graphics
4. Function library and Toolboxes
5. Application Program Interface (API)

A library that allows you to write C and Fortran programs that interact with MATLAB. It includes facilities for calling routines from MATLAB, calling MATLAB as a computational engine, and for reading/writing MAT-files.

MATLAB Environment



```
MATLAB desktop keyboard shortcuts, such as Ctrl+S, are now customizable.
In addition, many keyboard shortcuts have changed for improved consistency
across the desktop.

To customize keyboard shortcuts, use Preferences. From there, you can also
restore previous default settings by selecting "R2009a UNIX Default Set"
from the active settings drop-down list. For more information, see Help.

Click here if you do not want to see this message again.

>> 
```

```
%-- 4/13/12  6:46 PM --%
```

Resources

On the Web

- Matlab Website
- Matlab Tutorials and Learning Resources

Online Help

- The help command >> **help**
- The help window >> **doc**

Example

```
>> help clc
 CLC    Clear command window.
    CLC clears the command window and homes the cursor.

    See also home.

    Reference page in Help browser
       doc clc
```

Using the Command Line

- Matlab as a calculator

Using the Command Line

- Matlab as a calculator
  - Expressions

Example

```
>> -5/(4.8+5.32)^2

ans =
   -0.0488
```

Using the Command Line

- Matlab as a calculator
  - Expressions
  - Math functions

Example

```
>> sqrt(23)

ans =
    4.7958
```

Functions

abs sign sqrt
real imag angle
sin cos tan
exp log log10
sinh cosh tanh
asin acos atan
asinh acosh atanh
round floor ceil
rem

Using the Command Line

- Matlab as a calculator
  - Expressions
  - Math functions
  - Constants

Example

```
>> sin(pi/2)

ans =
     1
```

Special Variables

pi
eps
inf
NaN
i, j
nargin
nargout
varargin
varargout
ans

Using the Command Line

- Matlab as a calculator
    - Expressions
    - Math functions
    - Constants
    - Multiple functions

Example

```
>> exp(acos(0.3))

ans =
    3.5470
```

Using the Command Line

- Matlab as a calculator
    - Expressions
    - Math functions
    - Constants
    - Multiple functions
- Using Variables

Using the Command Line

- Matlab as a calculator
  - Expressions
  - Math functions
  - Constants
  - Multiple functions
- Using Variables
  - Assigning values

Example

```
>> a = 2

a =
     2
```

Using the Command Line

- Matlab as a calculator
  - Expressions
  - Math functions
  - Constants
  - Multiple functions
- Using Variables
  - Assigning values
  - Suppressing output

Example

```
>> a = 2

a =
     2


>> b = 5;
```

Using the Command Line

- Matlab as a calculator
  - Expressions
  - Math functions
  - Constants
  - Multiple functions
- Using Variables
  - Assigning values
  - Suppressing output
  - Expressions

Example

```
>> a = 2

a =
     2


>> b = 5;


>> a^b

ans =
    32
```

Using the Command Line

- Matlab as a calculator
  - Expressions
  - Math functions
  - Constants
  - Multiple functions
- Using Variables
  - Assigning values
  - Suppressing output
  - Expressions
  - Assiging with expression

Example

```
>> X = 5/2*pi;
```

Using the Command Line

- Matlab as a calculator
  - Expressions
  - Math functions
  - Constants
  - Multiple functions
- Using Variables
  - Assigning values
  - Suppressing output
  - Expressions
  - Assiging with expression
  - Inspecting variable

Example

```
>> X = 5/2*pi;


>> X

X =
    7.8540
```

Utility Commands

- Working with variables

Utility Commands

- Working with variables
  - Workspace variables

Example

```
>> who

Your variables are:

a     ans   b     X     y
```

Utility Commands

- Working with variables
  - Workspace variables
  - Variable details (size, memory usage, data type)

Example

```
>> who

Your variables are:

a    ans  b    X    y


>> whos
```

Utility Commands

- Working with variables
  - Workspace variables
  - Variable details (size, memory usage, data type)
  - Clearing variables

Example

```
>> who

Your variables are:

a     ans   b     X     y


>> whos


>> clear x
>> clear
>> clear all
```

Utility Commands

- Working with variables
  - Workspace variables
  - Variable details (size, memory usage, data type)
  - Clearing variables
- Working with files/directories

Utility Commands

- Working with variables
  - Workspace variables
  - Variable details (size, memory usage, data type)
  - Clearing variables
- Working with files/directories
  - Listing files

Example

```
>> ls
codes  presentation

>> dir

.             codes
..            presentation

>> what
```

Utility Commands

- Working with variables
  - Workspace variables
  - Variable details (size, memory usage, data type)
  - Clearing variables
- Working with files/directories
  - Listing files
  - Navigating directories

Example

```
>> pwd

ans =
/home/amitay/matlab

>> cd utils

>> pwd

ans =
/home/amitay/matlab/utils
```

Utility Commands

- Working with variables
  - Workspace variables
  - Variable details (size, memory usage, data type)
  - Clearing variables
- Working with files/directories
  - Listing files
  - Navigating directories
  - Identify objects

Example

```
>> a = 2;

>> which a
a is a variable.

>> which sin
built-in (.../@double/sin)
```

Everything in MATLAB is a matrix!

Vectors

Vectors

- Row Vector

Example

```
>> row1 = [ 1 2 3 4 ]

row1 =
     1     2     3     4

>> row2 = 1:4

row2 =
     1     2     3     4

>> row3 = 1:2:6

row3 =
     1     3     5
```

Vectors

- Row Vector
- Column Vector

Example

```
>> col1 = [ 1; 2; 3; 4; ]

col1 =
     1
     2
     3
     4

>> col2 = (3:6)'

col2 =
     3
     4
     5
     6
```

Vectors

- Row Vector
- Column Vector
- Indexing

Example

```
>> row1 = [ 1 2 3 4 ];
>> row1(2)

ans =
     2

>> b = row1(2:3)

b =
     2     3

>> row1(end) = 5

row1 =
     1     2     3     5
```

Vectors

- Row Vector
- Column Vector
- Indexing

Example

```
>> row1(end+1) = 6

row1 =
     1     2     3     5     6

>> row1([3 1 4 2])

ans =

     3     1     5     2

>> row1(1) = []

row1 =
     2     3     5     6
```

Vectors

- Row Vector
- Column Vector
- Indexing
- Operations

Example

```
>> row1 = [ 1 2 3 4 ]; row2 = 2:5;
>> row1 + row2

ans =
     3     5     7     9

>> row1 + 10

ans =
    11    12    13    14

>> row1 * row2'

ans =
    40
```

Vectors

- Row Vector
- Column Vector
- Indexing
- Operations

Example

```
>> row1 = [ 3 8 6 2 5 ];
>> sum(row1)

ans =
    24

>> min(row1)

ans =
     2

>> sort(row1)

ans =
     2     3     5     6     8
}
```

Vectors

- Row Vector
- Column Vector
- Indexing
- Operations
  - Arithmatic

Operators

+	addition
-	subtraction
*	multiplication
/	division
^	power
'	transpose

Vectors

- Row Vector
- Column Vector
- Indexing
- Operations
  - Arithmatic
  - Functions

Functions

length	Length of vector
min	Smallest component
max	Largest component
mean	Average or mean value
median	Median value
norm	Vector norm
sum	Sum of elements
prod	Product of elements
cumsum	Cumulative sum of elements
cumprod	Cumulative product of elements
find	Find indices of non-zero elements
dot	Dot product of two vectors
cross	Cross product of two vectors

Vectors

- Row Vector
- Column Vector
- Indexing
- Operations
  - Arithmatic
  - Functions
- Array Operations

Example

```
>> r1 = [ 1 2 3 ]; r2 = [ 5 6 7 ];
>> r1 .^ 2

ans =
     1     4     9

>> r1 .* r2

ans =

     5    12    21

>> r2 ./ r1

ans =
    5.0000    3.0000    2.3333
```

Vectors

- Row Vector
- Column Vector
- Indexing
- Operations
  - Arithmatic
  - Functions
- Array Operations
  - Arithmatic

Operators

.*	element-by-element multiplication
./	element-by-element division
.^	element-by-element power
.'	transpose

Matrices

Matrices

- Initialization

Example

```
>> m1 = zeros(3,5)

m1 =
     0     0     0     0     0
     0     0     0     0     0
     0     0     0     0     0

>> m2 = ones(6,3);

>> m3 = eye(4)

m3 =
     1     0     0     0
     0     1     0     0
     0     0     1     0
     0     0     0     1
```

Matrices

- Initialization
- Assignment

Example

```
>> mat1 = [ 1 2 3 ; 4 5 6 ; 7 8 9 ]

mat1 =
     1     2     3
     4     5     6
     7     8     9

>> mat2 = [ 2:4 ; ones(1,3); zeros(1,3) ]

mat2 =
     2     3     4
     1     1     1
     0     0     0

>> mat3 = rand(4,4);
```

Matrices

- Initialization
- Assignment
- Indexing

Example

```
>> mat = reshape(1:16, 4, 4)
mat =
     1     5     9    13
     2     6    10    14
     3     7    11    15
     4     8    12    16

>> mat(2,:)

ans =
     2     6    10    14

>> mat(2:3, 2:4)

ans =
     6    10    14
     7    11    15
```

Matrices

- Initialization
- Assignment
- Indexing

Example

```
>> row1(end+1) = 6

row1 =
     1     2     3     5     6

>> row1([3 1 4 2])

ans =

     3     1     5     2

>> row1(1) = []

row1 =
     2     3     5     6
```

Matrices

- Initialization
- Assignment
- Indexing
- Operations

Example

```
mat1 = [ 1     2     3
         4     5     6
         7     8     9 ];

>> mat1 + mat1

ans =
     2     4     6
     8    10    12
    14    16    18

>> mat1 * mat1

ans =
    30    36    42
    66    81    96
   102   126   150
```

Matrices

- Initialization
- Assignment
- Indexing
- Operations

Example

```
mat1 = [ 1     2     3
         4     5     6
         7     8     5 ];

>> inv(mat1)

ans =
   -1.9167    1.1667   -0.2500
    1.8333   -1.3333    0.5000
   -0.2500    0.5000   -0.2500

>> eig(mat1)

ans =
   14.0501
   -0.3119
   -2.7382
```

Matrices

- Initialization
- Assignment
- Indexing
- Operations
    - Arithmatic

Operators

+	addition
-	subtraction
*	multiplication
/	division
^	power
'	transpose
.*	element-by-element multiplication
./	element-by-element division
.^	element-by-element power
.'	transpose

Matrices

- Initialization
- Assignment
- Indexing
- Operations
  - Arithmatic
  - Functions

Functions

size	Size of array
min	Smallest component
max	Largest component
mean	Average or mean value
median	Median value
norm	Vector norm
sum	Sum of elements
prod	Product of elements
find	Find indices of non-zero elements
det	Determinant
inv	Matrix inverse
eig	Eigenvalues and eigenvectors
diag	Diagonal of a matrix
rank	Matrix rank

Matrices

- Initialization
- Assignment
- Indexing
- Operations
  - Arithmatic
  - Functions
- Linear Algebra ($Ax = B$)

Example

```
A =                              B =

     1     2    -1                    2
     3     5     2                   19
    -2     4     3                   15


>> x = inv(A)*B


x =

    1.0000
    2.0000
    3.0000


>> x = A\B


x =

    1.0000
    2.0000
    3.0000
```

Strings

Strings

- Assignment

Example

```
>> var1 = 'hello'

var1 =
hello

>> var2 = [ var1 var1 ]

var2 =
hellohello

>> var3 = [ var1; var1 ]

var3 =
hello
hello
```

Strings

- Assignment
- Indexing

Example

```
>> var1 = 'abcdefghijklmn';
>> var1(1:5)

ans =
abcde

>> var1(end-4:end)

ans =
jklmn

>> length(var1)

ans =
    14
```

Strings

- Assignment
- Indexing
- Operations

Example

```
>> var1 = [ ’h’, ’e’, ’l’, ’l’, ’o’ ];
>> strcmp(var1, ’hello’)

ans =
     1

>> upper(var1)

var1 =
HELLO

>> char(var1 + 4)

ans =
lipps
```

Strings

- Assignment
- Indexing
- Operations

Example

```
>> var1 = 'hello';
>> var2 = 'everyone';
>> msg = [ var1 ; var2 ]
```

Strings

- Assignment
- Indexing
- Operations

Example

```
>> var1 = 'hello';
>> var2 = 'everyone';
>> msg = [ var1 ; var2 ]
??? Error using ==> vertcat
CAT arguments dimensions are not consistent.
```

Strings

- Assignment
- Indexing
- Operations

Example

```
>> var1 = 'hello';
>> var2 = 'everyone';
>> msg = [ var1 ; var2 ]
??? Error using ==> vertcat
CAT arguments dimensions are not consistent.

>> msg = strvcat(var1, var2)
```

Strings

- Assignment
- Indexing
- Operations

Example

```
>> var1 = ’hello’;
>> var2 = ’everyone’;
>> msg = [ var1 ; var2 ]
??? Error using ==> vertcat
CAT arguments dimensions are not consistent.

>> msg = strvcat(var1, var2)
msg =
hello
everyone
```

Strings

- Assignment
- Indexing
- Operations

Example

```
>> var1 = 'hello';
>> var2 = 'everyone';
>> msg = [ var1 ; var2 ]
??? Error using ==> vertcat
CAT arguments dimensions are not consistent.

>> msg = strvcat(var1, var2)
msg =
hello
everyone

>> size(msg)
ans =
     2     8
```

Cell Array

A cell array is a collection of contains called *cells* which can store different types of data. Each cell of a cell array contains some type of MATLAB array.

Cell Array

- Initialization

Example

Cell Array

- Initialization

Example

```
>> a = cell(1, 3)
a =
    []    []    []
```

Cell Array

- Initialization

Example

```
>> a = cell(1, 3)
a =
    []    []    []

>> a{1} = ’hello’;
>> a{2} = ’everyone’;
>> a{3} = [ 1 2 3 ];
>> a

    ’hello’    ’everyone’    [1x3 double]
```

Cell Array

- Initialization

Example

```
>> a = cell(1, 3)
a =
    []    []    []

>> a{1} = ’hello’;
>> a{2} = ’everyone’;
>> a{3} = [ 1 2 3 ];
>> a

    ’hello’    ’everyone’    [1x3 double]

>> b = { ’hello’ ; ’everyone’ }

b =
    ’hello’
    ’everyone’
```

Cell Array

- Initialization
- Indexing

Example

```
>> a = { 'hello',  eye(4);  [1 2 3], 'everyone' }
a =
    'hello'          [4x4 double]
    [1x3 double]     'everyone'
```

Cell Array

- Initialization
- Indexing

Example

```
>> a = { 'hello',  eye(4);  [1 2 3], 'everyone' }
a =
    'hello'         [4x4 double]
    [1x3 double]    'everyone'

>> a{2,1}

ans =
     1     2     3
```

Cell Array

- Initialization
- Indexing

Example

```
>> a = { 'hello',  eye(4);  [1 2 3], 'everyone' }
a =
    'hello'          [4x4 double]
    [1x3 double]     'everyone'

>> a{2,1}

ans =
     1     2     3

>> b = a(2,1)

b =
    [1x3 double]
```

Cell Array

- Initialization
- Indexing
- Concatenation

Example

```
>> C1 = { ’Aug’ ’Sep’ ; ’10’ ’17’ };
>> C2 = { ’Dec’ ’Jan’ ’Feb’ ; ’31’ ’26’ ’12’ };
```

Cell Array

- Initialization
- Indexing
- Concatenation

Example

```
>> C1 = { ’Aug’ ’Sep’ ; ’10’ ’17’ };
>> C2 = { ’Dec’ ’Jan’ ’Feb’ ; ’31’ ’26’ ’12’ };
>> C3 = { C1 C2 }
C3 =

   {2x2 cell}    {2x3 cell}
```

Cell Array

- Initialization
- Indexing
- Concatenation

Example

```
>> C1 = { ’Aug’ ’Sep’ ; ’10’ ’17’ };
>> C2 = { ’Dec’ ’Jan’ ’Feb’ ; ’31’ ’26’ ’12’ };
>> C3 = { C1 C2 }
C3 =

   {2x2 cell}    {2x3 cell}

>> C4 = [ C1 C2 ]

C4 =
    ’Aug’    ’Sep’    ’Dec’    ’Jan’    ’Feb’
    ’10’     ’17’     ’31’     ’26’     ’12’
```

Structures

A structre is a MATLAB data type to store hierarchical data together in a single entity. A structure consists mainly of data containers, called *fields*, and each of these fields stores an array of some MATLAB data type. Each field is assigned a name.

Structures

- Initialization

Example

Structures

- Initialization

Example

```
>> s.length = 10;
>> s.width = 20;
```

Structures

- Initialization

Example

```
>> s.length = 10;
>> s.width = 20;
s =
    length: 10
     width: 20
```

Structures

- Initialization

Example

```
>> s.length = 10;
>> s.width = 20;
s =
    length: 10
     width: 20

>> data = struct('name', 'john', 'age', 28, ...
                 'height', 1.8)

data =
      name: 'john'
       age: 28
    height: 1.8000
```

Structures

- Initialization

Example

```
>> s.length = 10;
>> s.width = 20;
s =
    length: 10
     width: 20

>> data = struct(’name’, ’john’, ’age’, 28, ...
                 ’height’, 1.8)

data =
      name: ’john’
       age: 28
    height: 1.8000

>> data(2).name = ’mary’;
>> data(2).age = 20;
>> data(2).height = 1.5;
```

Structures

- Initialization
- Accessing

Example

```
>> data(1).age
```

Structures

- Initialization
- Accessing

Example

```
>> data(1).age
ans =
    28
```

Structures

- Initialization
- Accessing

Example

```
>> data(1).age
ans =
    28

>> [data.height]
ans =
    1.8000    1.5000
```

Structures

- Initialization
- Accessing

Example

```
>> data(1).age
ans =
    28

>> [data.height]
ans =
    1.8000    1.5000

>> {data.height}

ans =
    [1.8000]    [1.5000]
```

Structures

- Initialization
- Accessing

Example

```
>> data(1).age
ans =
    28

>> [data.height]
ans =
    1.8000    1.5000

>> {data.height}

ans =
    [1.8000]    [1.5000]

>> {data.name}

ans =
    'john'    'mary'
```

Structures

- Initialization
- Accessing
- Operations

Example

```
>> data
data =
1x2 struct array with fields:
    name
    age
    height
```

Structures

- Initialization
- Accessing
- Operations

Example

```
>> data
data =
1x2 struct array with fields:
    name
    age
    height

>> fieldnames(data)
ans =
    ’name’
    ’age’
    ’height’
```

Structures

- Initialization
- Accessing
- Operations

Example

```
>> data
data =
1x2 struct array with fields:
    name
    age
    height

>> fieldnames(data)
ans =
    'name'
    'age'
    'height'

>> data(1) = [];
>> size(data)
ans =
     1     1
```

Things to Remember

- Rows and columns are always numbered starting at 1

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- A single number is really a 1x1 matrix in MATLAB

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- Variable names are case-sensitive

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- [] represents an empty matrix
- {} represents an empty cell array

Things to Remember

- Rows and columns are always numbered starting at 1
- A single number is really a 1x1 matrix in MATLAB
- Variable names are case-sensitive
- [] represents an empty matrix
- {} represents an empty cell array
- struct([]) represents an empty structure

Simple plot

Example

```
>> x = linspace(0, 4*pi);
```

Simple plot

Example

```
>> x = linspace(0, 4*pi);
>> y = sin(x);
```

Simple plot

Example

```
>> x = linspace(0, 4*pi);
>> y = sin(x);
>> plot(x, y);
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Simple plot

Example

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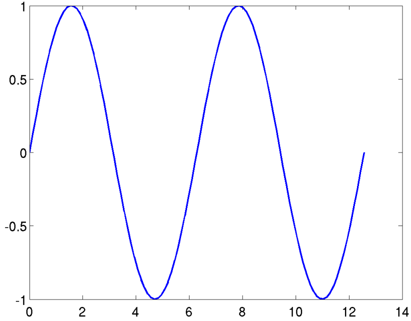

Simple plot

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>> x = linspace(0, 4*pi);
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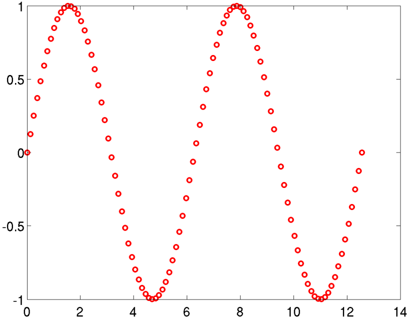

Simple plot

Example

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>> x = linspace(0, 4*pi);
>> y = sin(x);
>> plot(x, y);
>> plot(x, y, 'ro');
>> z = cos(x);
```

Simple plot

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>> x = linspace(0, 4*pi);
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>> plot(x, y);
>> plot(x, y, 'ro');
>> z = cos(x);
>> plot(x, z, 'bs:');
```

Simple plot

Example

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>> x = linspace(0, 4*pi);
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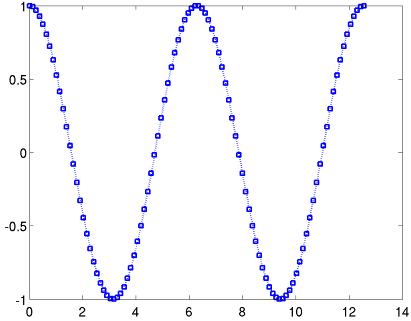
>> plot(x, y);
>> plot(x, y, 'ro');
>> z = cos(x);
>> plot(x, z, 'bs:');
```



Simple plot

Example

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>> y = sin(x);
>> plot(x, y);
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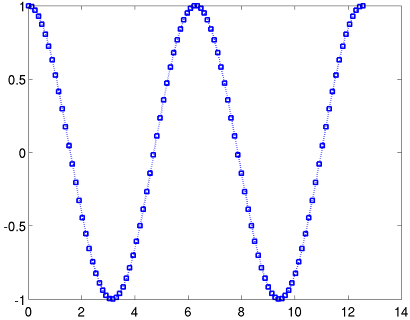
>> z = cos(x);
>> plot(x, z, 'bs:');
>> hold on
```



Simple plot

Example

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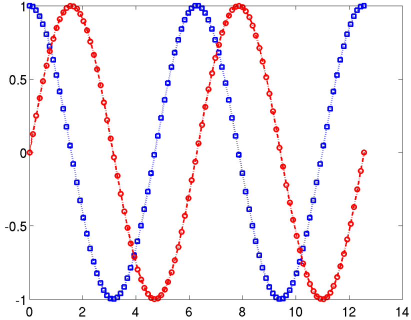
>> x = linspace(0, 4*pi);
>> y = sin(x);
>> plot(x, y);
>> plot(x, y, 'ro');
>> z = cos(x);
>> plot(x, z, 'bs:');
>> hold on
>> plot(x, y, 'ro-.');
```



Simple plot

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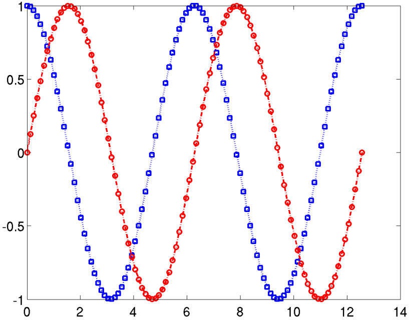

Simple plot

Example

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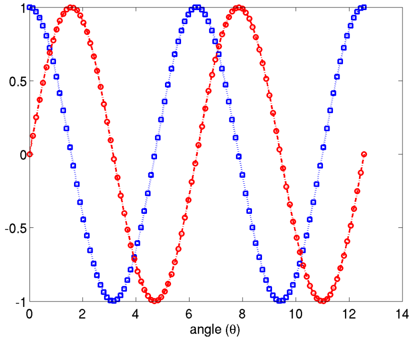
>> y = sin(x);
>> plot(x, y);
>> plot(x, y, 'ro');
>> z = cos(x);
>> plot(x, z, 'bs:');
>> hold on
>> plot(x, y, 'ro-.');
>> hold off
>> xlabel('angle (\theta)');
```



Simple plot

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>> plot(x, y);
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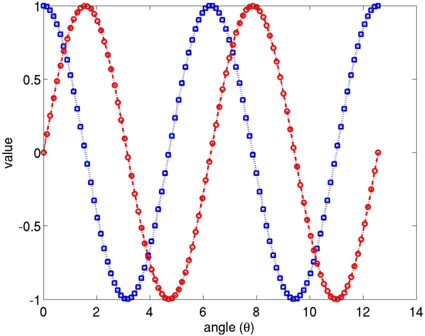
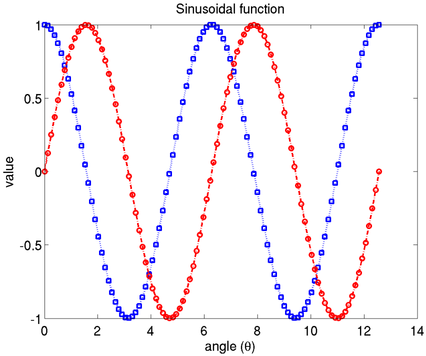
>> z = cos(x);
>> plot(x, z, 'bs:');
>> hold on
>> plot(x, y, 'ro-.');
>> hold off
>> xlabel('angle (\theta)');
>> ylabel('value');
```



Simple plot

Example

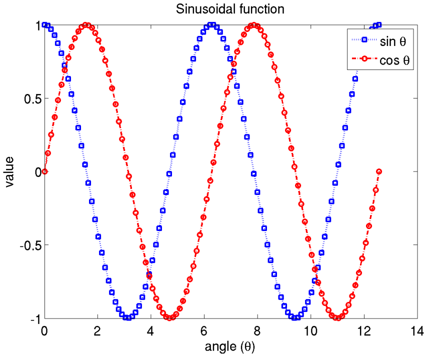
```
>> x = linspace(0, 4*pi);
>> y = sin(x);
>> plot(x, y);
>> plot(x, y, 'ro');
>> z = cos(x);
>> plot(x, z, 'bs:');
>> hold on
>> plot(x, y, 'ro-.');
>> hold off
>> xlabel('angle (\theta)');
>> ylabel('value');
>> title('Sine/Cosine');
```



Simple plot

Example

```
>> x = linspace(0, 4*pi);
>> y = sin(x);
>> plot(x, y);
>> plot(x, y, 'ro');
>> z = cos(x);
>> plot(x, z, 'bs:');
>> hold on
>> plot(x, y, 'ro-.');
>> hold off
>> xlabel('angle (\theta)');
>> ylabel('value');
>> title('Sine/Cosine');
>> legend('sin \theta', ...
          'cos \theta');
```



Multiple plots

Example

```
>> x = linspace(0, 4*pi); y = sin(x); z = cos(x);
```

Multiple plots

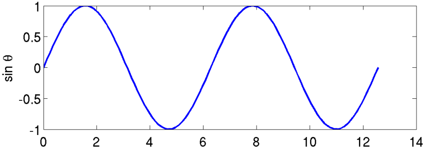
Example

```
>> x = linspace(0, 4*pi); y = sin(x); z = cos(x);
>> subplot(2, 1, 1); plot(x, y); ylabel('sin \theta');
```

Multiple plots

Example

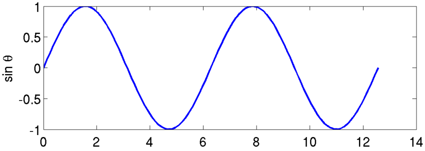
```
>> x = linspace(0, 4*pi); y = sin(x); z = cos(x);
>> subplot(2, 1, 1); plot(x, y); ylabel('sin \theta');
```



Multiple plots

Example

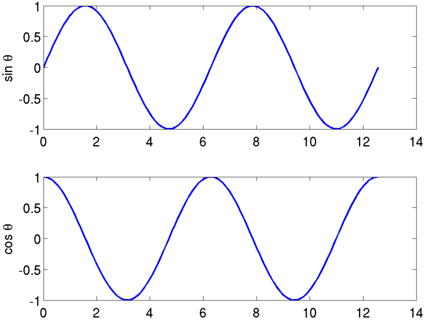
```
>> x = linspace(0, 4*pi); y = sin(x); z = cos(x);
>> subplot(2, 1, 1); plot(x, y); ylabel('sin \theta');
>> subplot(2, 1, 2); plot(x, z); ylabel('cos \theta');
```



Multiple plots

Example

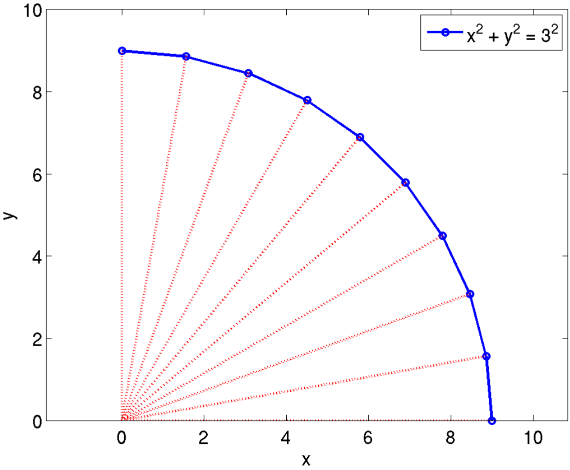
```
>> x = linspace(0, 4*pi); y = sin(x); z = cos(x);
>> subplot(2, 1, 1); plot(x, y); ylabel('sin \theta');
>> subplot(2, 1, 2); plot(x, z); ylabel('cos \theta');
```



Other plots

loglog	Log-log scale plot
semilogy	Semilogarithmic plot
area	Filled area 2-D plot
bar, barh	Plot bar graph (vertical and horizontal)
pie	Pie chart
contour	Contour plot
hist	Histogram plot
plot3	3-D line plot
plotyy	2-D line plots with y-axes on left and right

Exercise: How to create this figure?



Loading and Saving Workspace

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- MATLAB can load and save data in MAT format

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- .MAT files are binary files

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- MATLAB can load and save data in MAT format
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- Save current session

Example

```
>> save mysession
```

Loading and Saving Workspace

- MATLAB can load and save data in MAT format
- .MAT files are binary files
- Save current session
- Load saved session

Example

```
>> save mysession
>> load mysession
```

Loading and Saving Workspace

- MATLAB can load and save data in MAT format
- .MAT files are binary files
- Save current session
- Load saved session
- Save only some variables

Example

```
>> save mysession
>> load mysession
>> save mydata a b c data C1
```

ASCII Files

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- load and save can also read and write ASCII (text) files
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- Write ASCII file

Example

```
>> save data1.dat matrix1 -ascii
>> save data1.dat matrix1 -ascii -double
```

ASCII Files

- load and save can also read and write ASCII (text) files
- The columns are separated by space
- Write ASCII file
- Read ASCII file

Example

```
>> save data1.dat matrix1 -ascii
>> save data1.dat matrix1 -ascii -double
>> load data1.dat -ascii
>> t1 = load('data1.dat', '-ascii');
```

ASCII Files

- load and save can also read and write ASCII (text) files
- The columns are separated by space
- Write ASCII file
- Read ASCII file
- Reading free format text (output of some program)

Example

```
>> save data1.dat matrix1 -ascii
>> save data1.dat matrix1 -ascii -double
>> load data1.dat -ascii
>> t1 = load('data1.dat', '-ascii');
>> help textread
```

Spreadsheets

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- MATLAB can read Excel spreadsheets (on windows)

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- MATLAB can read Excel spreadsheets (on windows)
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- Read/write Excel spreadsheet

Example

```
>> help xlsread
>> help xlswrite
```

Spreadsheets

- MATLAB can read Excel spreadsheets (on windows)
- Supports CSV files
- Read/write Excel spreadsheet
- Read ASCII file

Example

```
>> help xlsread
>> help xlswrite
>> help csvread
>> help csvwrite
```

Spreadsheets

- MATLAB can read Excel spreadsheets (on windows)
- Supports CSV files
- Read/write Excel spreadsheet
- Read ASCII file
- *Import Wizard* can be used to import data

Example

```
>> help xlsread
>> help xlswrite
>> help csvread
>> help csvwrite
```

Saving Graphics

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- MATLAB save graphics in FIG format

Example

```
>> saveas(gcf, 'output', 'fig')
```

Saving Graphics

- MATLAB save graphics in FIG format
- Or save in variety of image formats

Example

```
>> saveas(gcf, 'output', 'fig')
>> saveas(gcf, 'graph1.bmp', 'bmp')
>> saveas(gcf, 'graph1.png', 'png')
>> saveas(gcf, 'graph1.jpg', 'jpg')
>> saveas(gcf, 'graph1.eps', 'eps')
>> saveas(gcf, 'graph1.pdf', 'pdf')
```

Saving Graphics

- MATLAB save graphics in FIG format
- Or save in variety of image formats
- Read/write Images

Example

```
>> saveas(gcf, 'output', 'fig')
>> saveas(gcf, 'graph1.bmp', 'bmp')
>> saveas(gcf, 'graph1.png', 'png')
>> saveas(gcf, 'graph1.jpg', 'jpg')
>> saveas(gcf, 'graph1.eps', 'eps')
>> saveas(gcf, 'graph1.pdf', 'pdf')
>> help imread
>> help imwrite
```

Saving Graphics

- MATLAB save graphics in FIG format
- Or save in variety of image formats
- Read/write Images
- MATAB support file formats

Example

```
>> saveas(gcf, ’output’, ’fig’)
>> saveas(gcf, ’graph1.bmp’, ’bmp’)
>> saveas(gcf, ’graph1.png’, ’png’)
>> saveas(gcf, ’graph1.jpg’, ’jpg’)
>> saveas(gcf, ’graph1.eps’, ’eps’)
>> saveas(gcf, ’graph1.pdf’, ’pdf’)
>> help imread
>> help imwrite
>> help fileformats
```

Reading and Writing formatted data

Reading and Writing formatted data

- Open a file (for reading or writing)

Example

```
>> fd = fopen('mydata.txt', 'r');
>> fd = fopen('output.dat', 'w');
```

Reading and Writing formatted data

- Open a file (for reading or writing)
- Write data in file

Example

```
>> fd = fopen(’mydata.txt’, ’r’);
>> fd = fopen(’output.dat’, ’w’);
>> fprintf(fd, ’%s’, string_varible);
>> fprintf(fd, ’%d’, integer_varible);
>> fprintf(fd, ’%f’, float_varible);
>> fprintf(fd, ’%lf’, double_precision);
```

Reading and Writing formatted data

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>> fprintf(fd, ’%lf’, double_precision);
>> [var, count] = fscanf(fd, ’%lf’, 10);
>> matrix1 = fscanf(fd, ’%lf’, [4 5]);
```

Reading and Writing formatted data

- Open a file (for reading or writing)
- Write data in file
- Reading data from file
- Closing a file

Example

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>> fclose(fd);
```

Reading and Writing formatted data

- Open a file (for reading or writing)
- Write data in file
- Reading data from file
- Closing a file
- Formatted output on screen

Example

```
>> fd = fopen(’mydata.txt’, ’r’);
>> fd = fopen(’output.dat’, ’w’);
>> fprintf(fd, ’%s’, string_varible);
>> fprintf(fd, ’%d’, integer_varible);
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>> fprintf(fd, ’%lf’, double_precision);
>> [var, count] = fscanf(fd, ’%lf’, 10);
>> matrix1 = fscanf(fd, ’%lf’, [4 5]);
>> fclose(fd);
>> fprintf(’hello everyone, my name is %s\n’, name);
```

Writing Programs

Writing Programs

- Programs are written as m-files. They are interpreted by matlab as programs. There are two kinds of programs -

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    2. **Functions** accept input argument and produce output variables. All internal variables are local to the function and commands operate on the *function workspace*.
- If duplicate functions (names) exist, the first in the search path (from *path* command) is executed.

Script Example

Find Primes between 1 and 100

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Find Primes between 1 and 100

```
% finding primes between 1 and 100
prime(1) = 2;
for num = 3:2:100
    max_divisor = round(sqrt(num));
    divisible = 0;
    for j = 1:length(prime)
        if prime(j) > max_divisor
            break
        end
        if rem(num, prime(j)) == 0
            divisible = 1;
            break
        end
    end
    if divisible == 0
        prime(end+1) = num;
    end
end
disp(prime)
```

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```

Function Example

Find Primes between 1 and n

Function Example

Find Primes between 1 and n

```
function [prime] = find_primes(n)
    prime(1) = 2;
    for num = 3:2:n
        if isprime(num, prime)
            prime(end+1) = num;
        end
    end
end
```

Function Example

Find Primes between 1 and n

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    prime(1) = 2;
    for num = 3:2:n
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            prime(end+1) = num;
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        end
    end
end
function [flag] = isprime(n, prime)
    flag = true;
    max_divisor = round(sqrt(n));
    for j = 1:length(prime)
        if prime(j) < max_divisor && rem(n, prime(j) == 0
            flag = false;
            break
        end
    end
end
```

Function Example

Find Primes between 1 and n

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function [prime] = find_primes(n)
    prime(1) = 2;
    for num = 3:2:n
        if isprime(num, prime)
            prime(end+1) = num;
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    flag = true;
    max_divisor = round(sqrt(n));
    for j = 1:length(prime)
        if prime(j) < max_divisor && rem(n, prime(j) == 0
            flag = false;
            break
        end
    end
end
```

Function Example

Find Primes between 1 and n

```
function [prime] = find_primes(n)
    prime(1) = 2;
    for num = 3:2:n
        if isprime(num, prime)
            prime(end+1) = num;
        end
    end
end
function [flag] = isprime(n, prime)
    flag = true;
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2. **Function** - local variables
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   - Can be accessed only from functions that define them
3. **Global** - global variables
   - Variables defined on command-line, in scripts, and in functions
   - Can be access from command-line, scripts and functions
   - Need to declare variable as global before using it

For Loop

Used to iterate for known fixed values specified as an array.

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    some matlab commands;
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Example

```
for k = [0.1 0.4 3 7.3 -19.3 ]
    some matlab commands;
end
```

Example

```
for i = 1:4
    for j = 1:4
        a(i,j) = (i + j)^2
    end
end
```

While Loop

Used to iterate till some condition is satisfied

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Example

```
while value < 10
    some matlab commands;
end
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Example

```
while value < 10
    some matlab commands;
end
```

Example

```
while (a < 3) & (b ~= 4)
    some matlab commands;
end
```

If Condition

Used to execute statements based on conditions.

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Example

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if i > 10
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end
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    some matlab commands;
end
```

Example

```
if x < 10
    disp(’value less than 10’)
elseif x <= 20
    disp(’value between 10 and 20’)
elseif x <= 40
    disp(’value between 20 and 40’)
else
    disp(’value greater than 40’)
end
```

Switch Condition

Used to execute statements based on values of a variable

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Used to execute statements based on values of a variable

Example

```
switch lower(method)
    case {’linear’, ’bilinear’}
        disp(’Method is linear’)
    case ’cubic’
        disp(’Method is cubic’)
    otherwise
        disp(’Unknown method’)
end
```

break / continue

Used to control the iterations

break / continue

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Example

```
sum = 0;
for i = 1:100
    if rem(i, 2) == 0
        continue
    end
    sum = sum + i;
    if sum > 78
        break
    end
end
```

break / continue

Used to control the iterations

- If a number is even, skip it

Example

```
sum = 0;
for i = 1:100
    if rem(i, 2) == 0
        continue
    end
    sum = sum + i;
    if sum > 78
        break
    end
end
```

break / continue

Used to control the iterations

- If a number is even, skip it
- When sum reaches 78, stop processing

Example

```
sum = 0;
for i = 1:100
    if rem(i, 2) == 0
        continue
    end
    sum = sum + i;
    if sum > 78
        break
    end
end
```

Functions

Handling variable number of input/output arguments.

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Example

```
function [sum, varargout] = calculate(varargin)
% CALCULATE    Calculate sum and product of arguments
%
    sum = 0;
    prod = 1;
    for i = 1:nargin
        sum = sum + varargin{i};
        prod = prod * varargin{i};
    end
    if nargout == 2
        varargout{1} = prod;
    end
end
```

Functions

Handling variable number of input/output arguments.

Example

```
>> help calculate
  CALCULATE   Calculate sum and product of arguments

>> calculate(1, 2, 3, 4)

ans =
     10

>> [a1, a2] = calculate(2, 3, 4)

a1 =
     9

a2 =
    24
```

Operators

Operators

- Relational operators - Compare between two values

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

- Logical operators - Operate on conditions

&	Element-wise logical AND
&&	Short-circuit logical AND
|	Element-wise logical OR
||	Short-circuit logical OR
~	Logical complement (NOT)
xor	Exclusion OR

Logical Functions

any(x)	returns 1 if any element of x is non-zero
all(x)	returns 1 if all elements of x are non-zero
isnan(x)	returns 1 at each NaN in x
isinf(x)	returns 1 at each infinity in x
finite(x)	returns 1 at each finite value in x
find(x)	returns indices of each non-zero value in x

Toolboxes

MATLAB has a large collection of toolboxes. Some of the commonly used toolboxes:

- Curve Fitting (cftool, sftool)
- Neural Network (nntool)
- Optimization (optimtool)
- Image Processing (imtool, implay)
- Spline (splinetool)
- Statistics (polytool, nlintool, rstool)
- Sytem Identification (ident)
- Model Predictive Control (mpctool)
- Symbolic Math (mupad)

Finding roots of a polynomial

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$$p(x) = x^3 + 4x^2 - 7x - 10$$

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>> p = [ 1 4 -7 -10 ];
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>> y = polyval(p, x);
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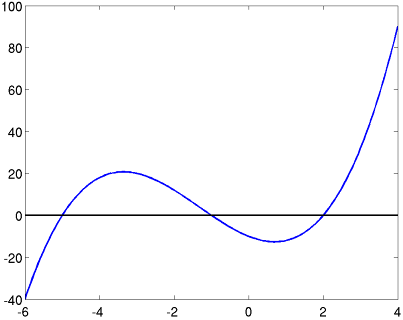
Example

```
>> p = [ 1 4 -7 -10 ];
>> x = linspace(-6, 4);
>> y = polyval(p, x);
>> plot(x, y);
```



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>> plot(x, y);
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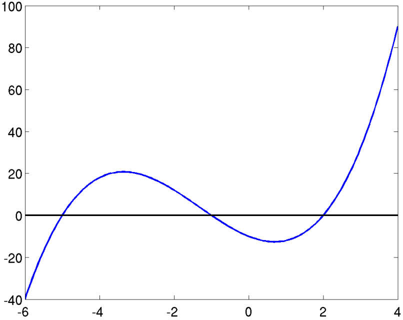
```



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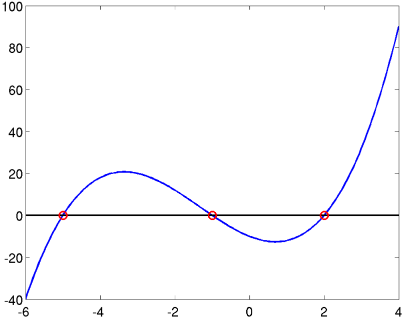
Example

```
>> p = [ 1 4 -7 -10 ];
>> x = linspace(-6, 4);
>> y = polyval(p, x);
>> plot(x, y);
>> r = roots(p)

r =
   -5.0000
    2.0000
   -1.0000
```



Finding zeros of a function

Example

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>> x = linspace(0,1);
>> y = humps(x);
```

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```
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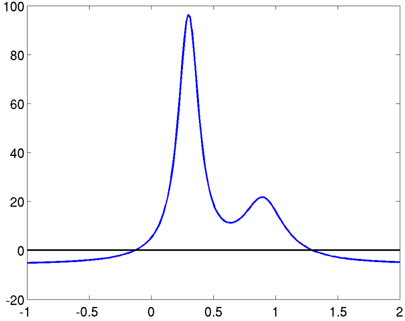
>> plot(x, y);
```



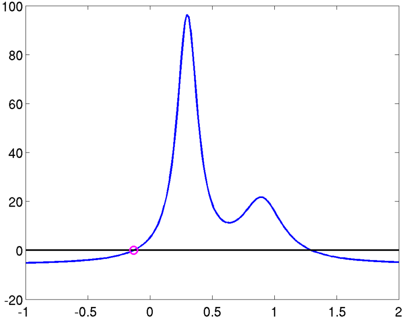
Finding zeros of a function

Example

```
>> x = linspace(0,1);
>> y = humps(x);
>> plot(x, y);

>> fzero(@humps, 1)

ans =
   -0.1316
```



Finding zeros of a function

Example

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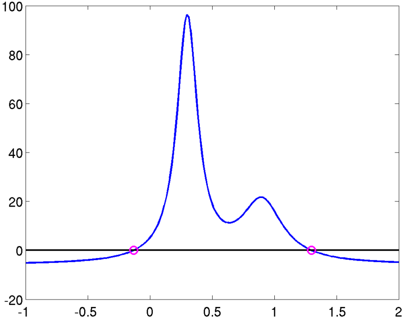
>> x = linspace(0,1);
>> y = humps(x);
>> plot(x, y);

>> fzero(@humps, 1)

ans =
   -0.1316

>> fzero(@humps, 1)

ans =
    1.2995
```



Questions?

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Example

```
>> why

How should I know?
```