

Linear algebra & Numerical Analysis

Introduction to MATLAB

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Outline

- What is it MATLAB?
 - MATLAB Environment and MATLAB Help
 - Variables, matrices and vectors
 - Strings
 - .m files: scripts and functions
 - Flow control
 - 2D, 3D graphics
 - Guide
-

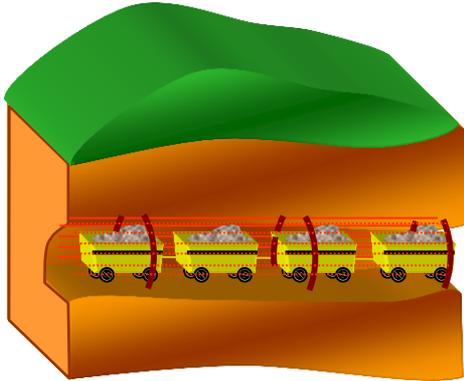
What is it MATLAB?

- MATLAB = “MATrix LABoratory”
 - a high-performance language for technical computing
 - *computation, visualization, and programming environment*
 - a modern programming language environment
 - sophisticated *data structures*
 - built-in *editing and debugging tools*
 - support of *object-oriented programming*
- an excellent tool for teaching and research
-

Matlab tools

- powerful ***built-in routines*** enable a very wide variety of computations
 - easy to use ***graphics commands*** that make the visualization of results immediately available
 - specific applications are collected in ***toolboxes***:
 - signal processing
 - symbolic computation
 - control theory
 - simulation
 - optimization
 - parallel computing
 - and several other fields of applied science and engineering
-

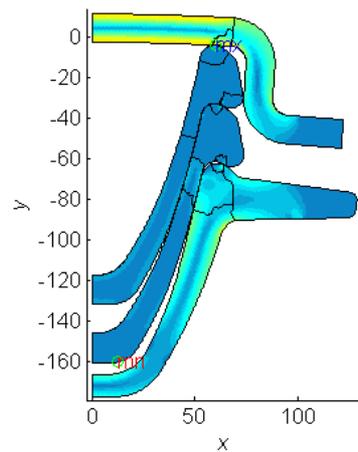
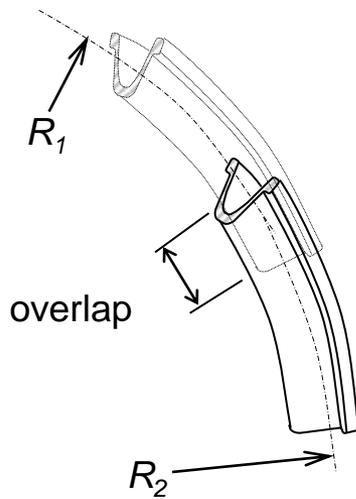
Real world problem: Mining industry



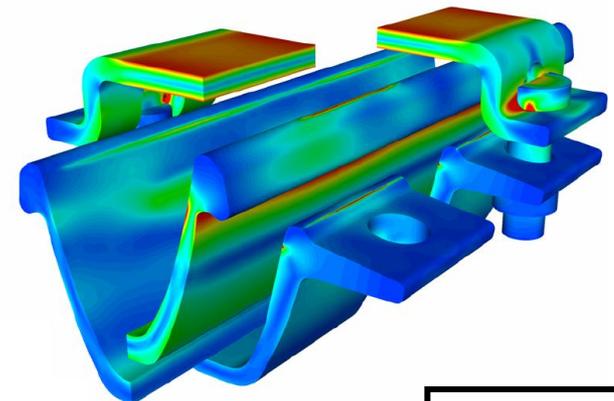
steel support



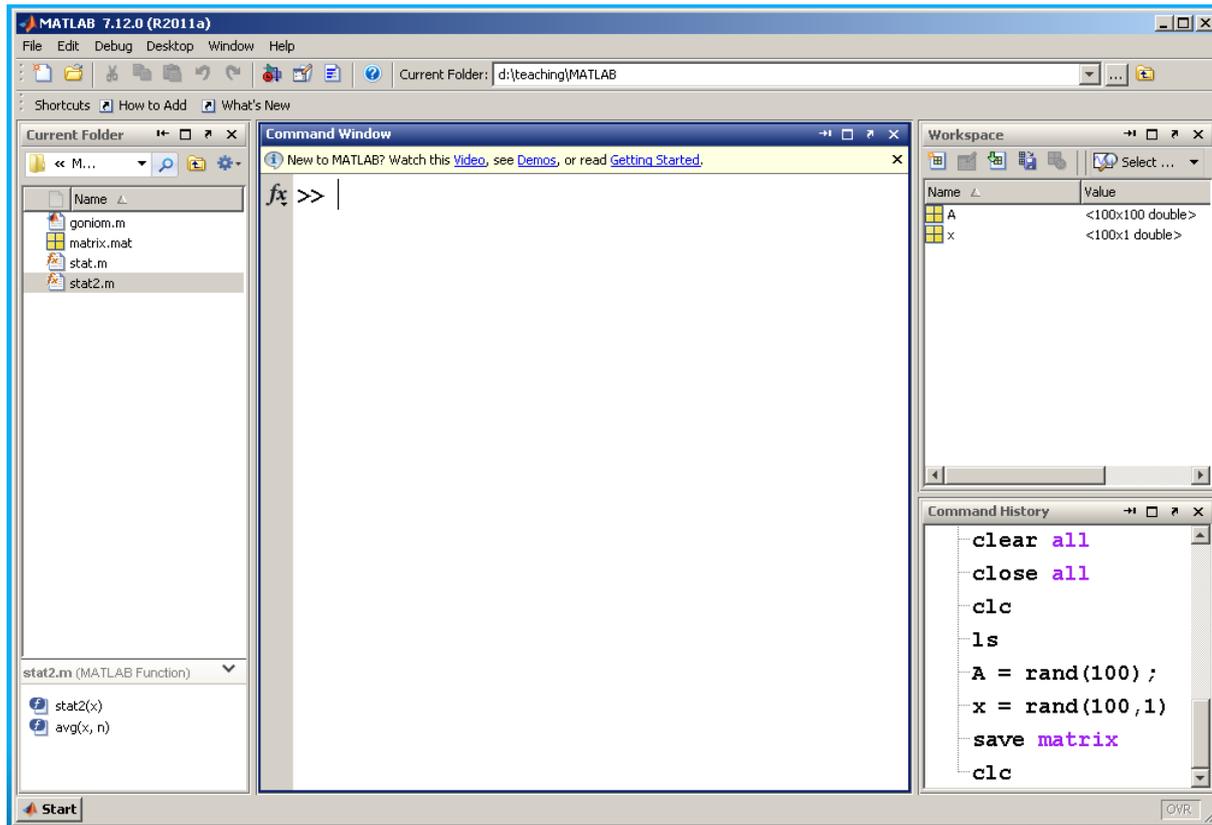
clamp joint



Von Mises stress [MPa]

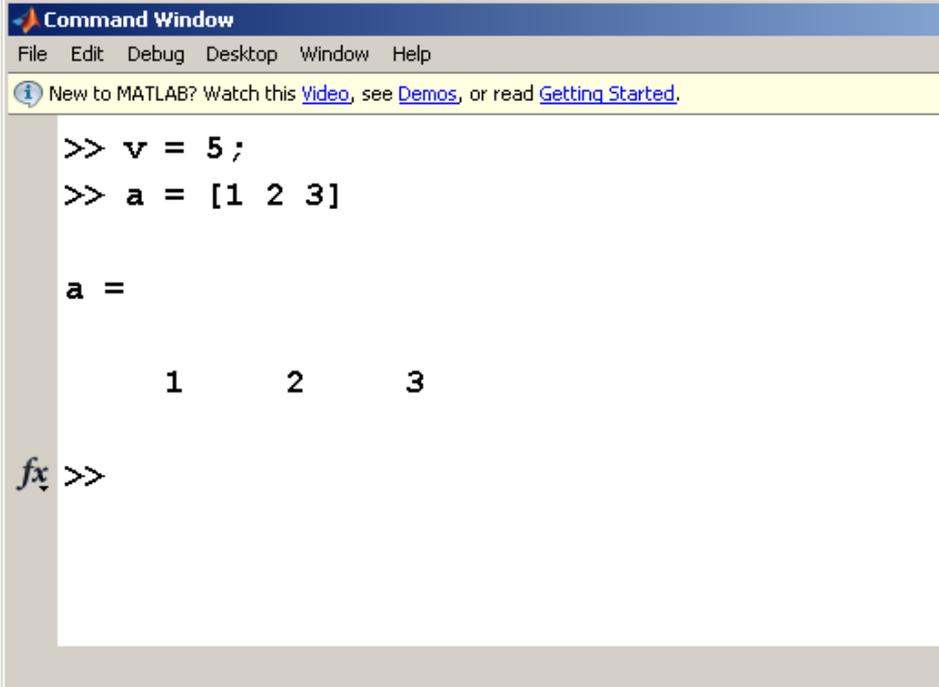


MATLAB Environment



Command Window

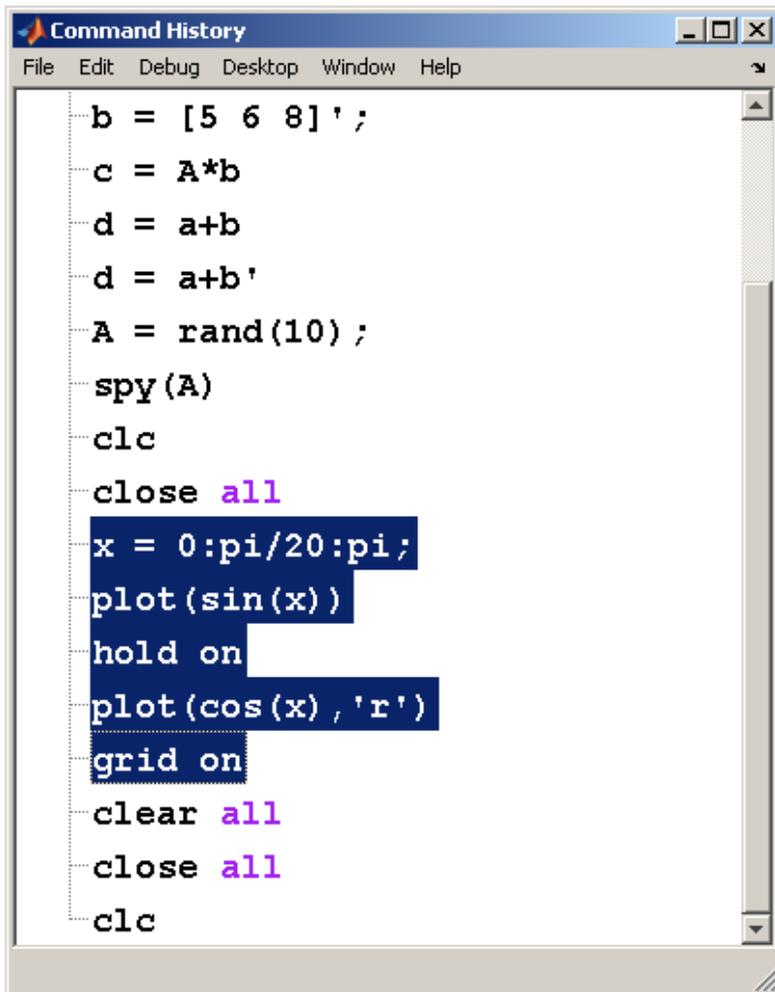
- Use the Command Window to enter variables and to run MATLAB functions and scripts. MATLAB displays the results.
- Press the up arrow key ↑ to recall a statement you previously typed. Edit the statement as needed, and then press **Enter** to run it.



The screenshot shows the MATLAB Command Window interface. The title bar reads "Command Window" and the menu bar includes "File", "Edit", "Debug", "Desktop", "Window", and "Help". A yellow banner at the top contains the text: "New to MATLAB? Watch this [Video](#), see [Demos](#), or read [Getting Started](#)." The main area of the window displays the following text:

```
>> v = 5;  
>> a = [1 2 3]  
  
a =  
  
     1     2     3  
  
fx >>
```

Command History

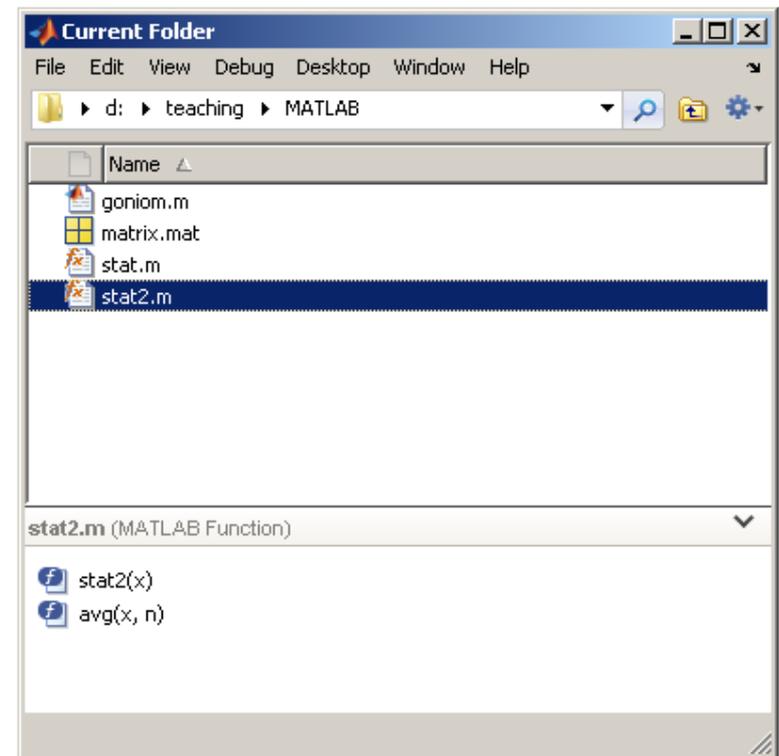


```
Command History
File Edit Debug Desktop Window Help
b = [5 6 8]';
c = A*b
d = a+b
d = a+b'
A = rand(10);
spy(A)
clc
close all
x = 0:pi/20:pi;
plot(sin(x))
hold on
plot(cos(x), 'r')
grid on
clear all
close all
clc
```

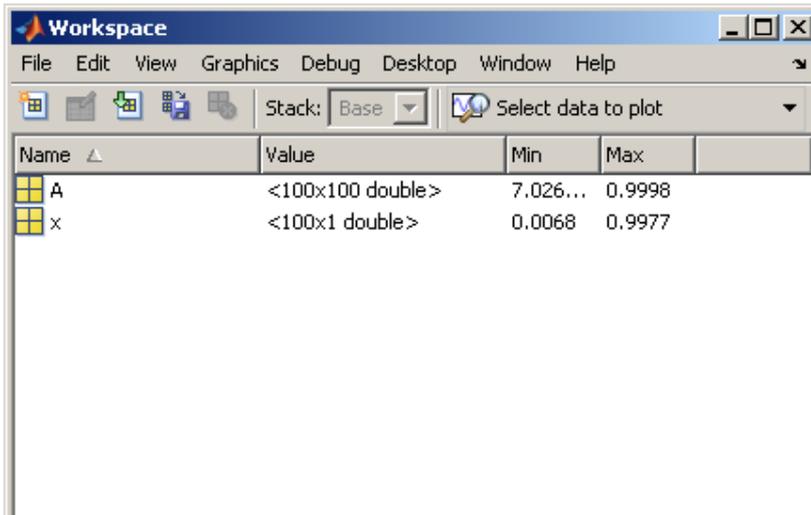
- Statements you enter in the Command Window are **logged** in the Command History.
- You can **view and search** for previously run statements, as well as copy and execute selected statements
- You can also **create a file** from selected statements.

Current Folder

- MATLAB limits where it looks for files so it can locate them more quickly.
- The file must be in one of these locations:
 - MATLAB current folder
 - A folder that is on the MATLAB search path
- The Current Folder browser is a tool for managing files.



Workspace



- The Workspace consists of the set of variables stored in memory.
- You add variables to the workspace by using functions, running function and script files, and loading saved workspaces.

```
>> who
```

```
Your variables are:
```

```
A x
```

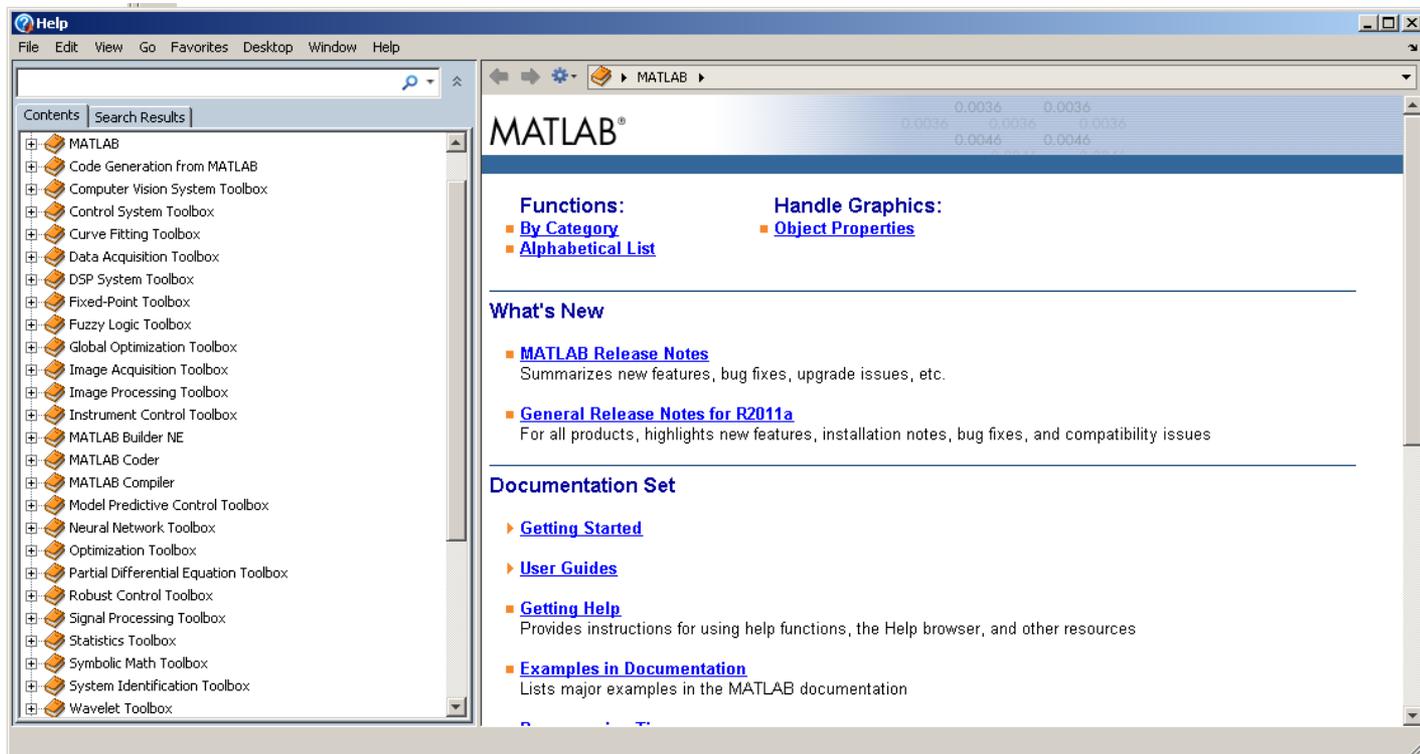
```
>> whos
```

Name	Size	Bytes	Class	Attributes
A	100x100	80000	double	
x	100x1	800	double	

Help and Documentation

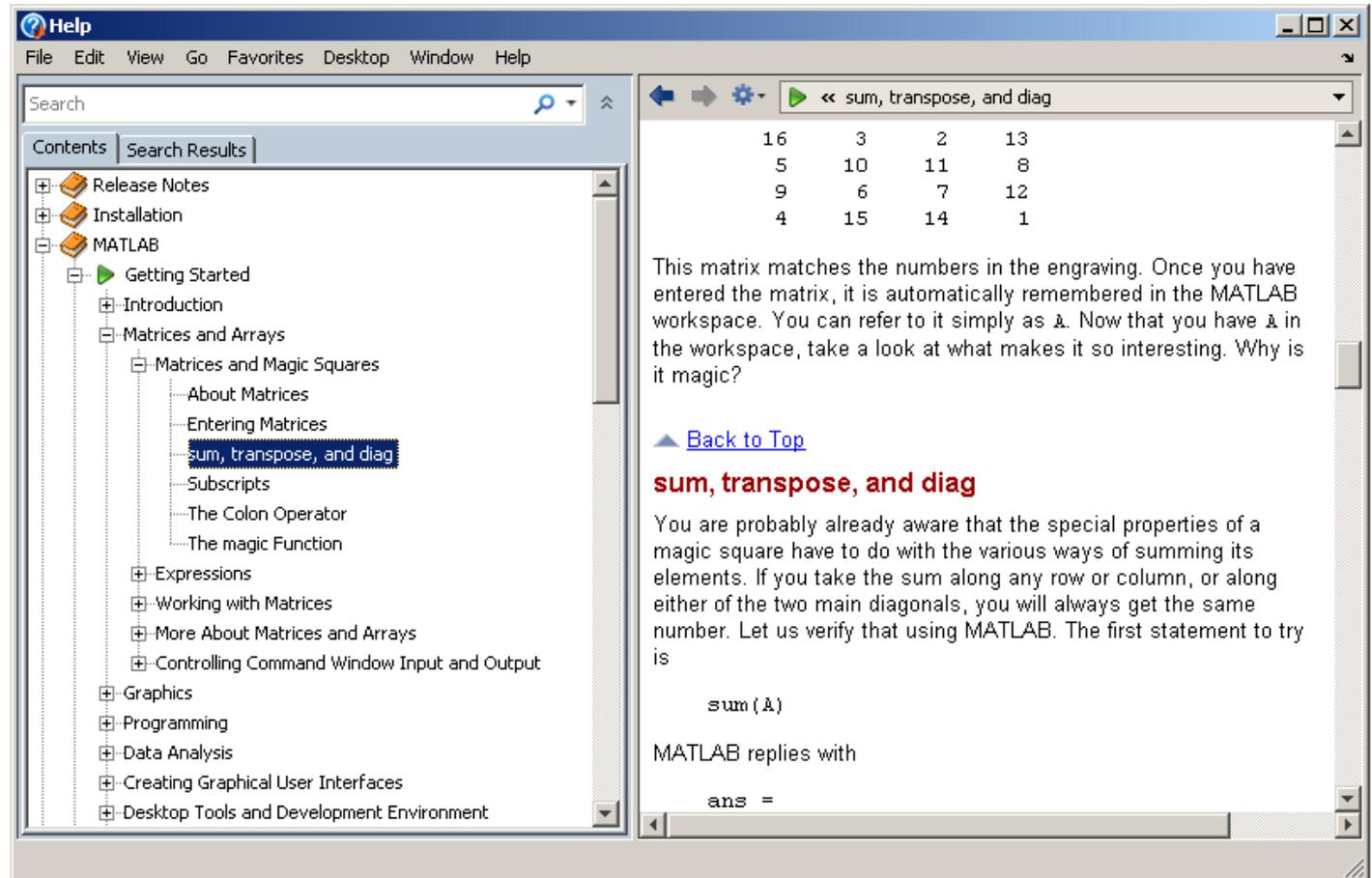


- There are different ways to get help, depending on your needs.



Help: Contents

- Look for getting started guides, code examples, demos, and more.



The screenshot shows the MATLAB Help window with the 'sum, transpose, and diag' page selected. The left pane shows the 'Contents' tree with 'sum, transpose, and diag' highlighted. The right pane displays a 4x4 magic square matrix, a paragraph of text, a 'Back to Top' link, and a code example.

Search

File Edit View Go Favorites Desktop Window Help

Contents Search Results

- Release Notes
- Installation
- MATLAB
 - Getting Started
 - Introduction
 - Matrices and Arrays
 - Matrices and Magic Squares
 - About Matrices
 - Entering Matrices
 - sum, transpose, and diag**
 - Subscripts
 - The Colon Operator
 - The magic Function
 - Expressions
 - Working with Matrices
 - More About Matrices and Arrays
 - Controlling Command Window Input and Output
 - Graphics
 - Programming
 - Data Analysis
 - Creating Graphical User Interfaces
 - Desktop Tools and Development Environment

Navigation: < > ⚙️ ▶️ << sum, transpose, and diag >>

16	3	2	13
5	10	11	8
9	6	7	12
4	15	14	1

This matrix matches the numbers in the engraving. Once you have entered the matrix, it is automatically remembered in the MATLAB workspace. You can refer to it simply as `A`. Now that you have `A` in the workspace, take a look at what makes it so interesting. Why is it magic?

[▲ Back to Top](#)

sum, transpose, and diag

You are probably already aware that the special properties of a magic square have to do with the various ways of summing its elements. If you take the sum along any row or column, or along either of the two main diagonals, you will always get the same number. Let us verify that using MATLAB. The first statement to try is

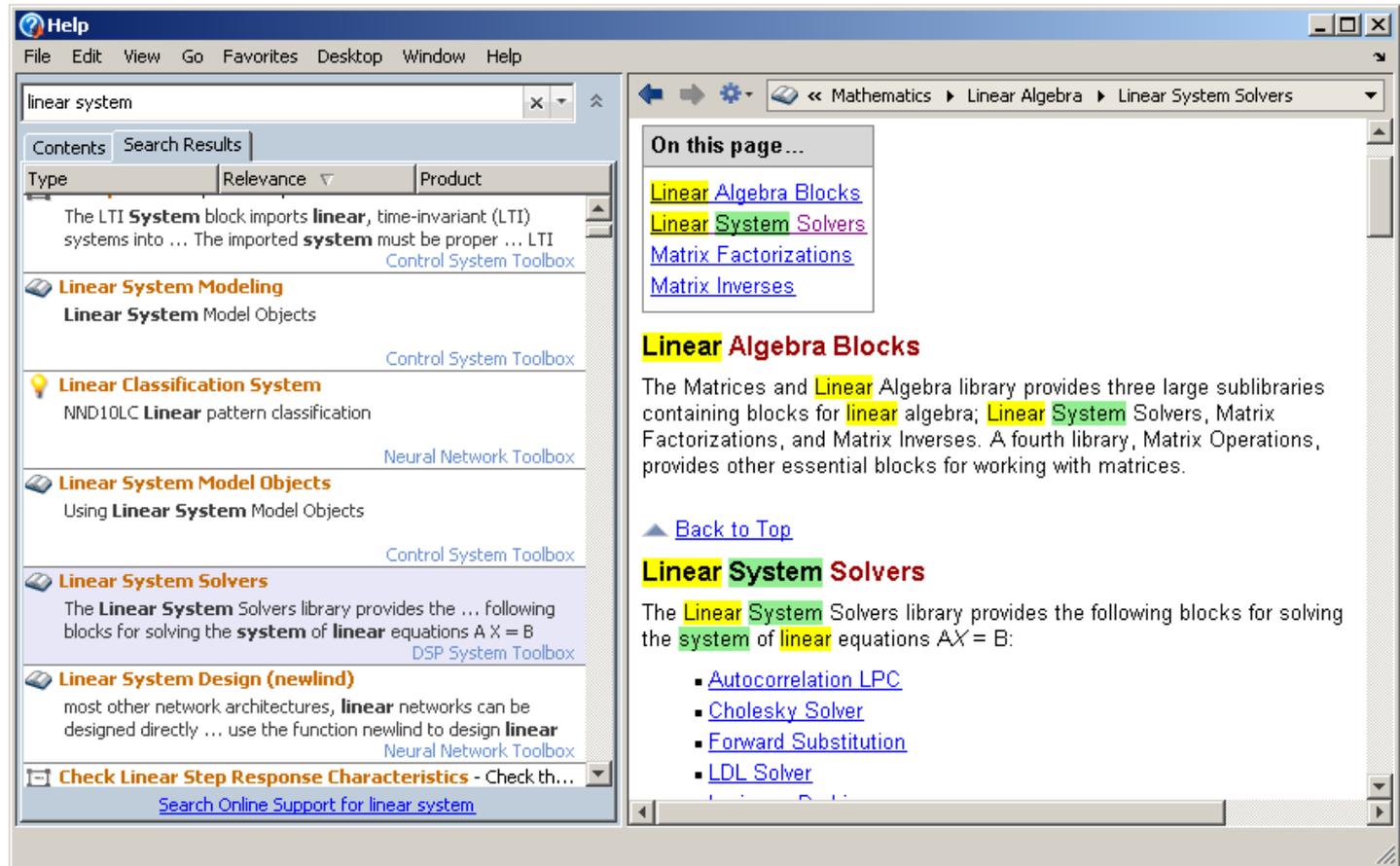
```
sum(A)
```

MATLAB replies with

```
ans =
```

Help: Search Results

- In the Help browser **Search** field, enter the words you want to look for.



The screenshot shows the MATLAB Help browser interface. The search field contains the text "linear system". The search results are displayed in a list on the left side of the window, with the following items:

- Linear System Modeling**
Linear System Model Objects
Control System Toolbox
- Linear Classification System**
NND10LC Linear pattern classification
Neural Network Toolbox
- Linear System Model Objects**
Using Linear System Model Objects
Control System Toolbox
- Linear System Solvers**
The Linear System Solvers library provides the ... following blocks for solving the system of linear equations $A X = B$
DSP System Toolbox
- Linear System Design (newlind)**
most other network architectures, linear networks can be designed directly ... use the function newlind to design linear
Neural Network Toolbox
- Check Linear Step Response Characteristics** - Check th...
Search Online Support for linear system

The right side of the window shows the content of the selected search result, "Linear System Solvers". It includes a "On this page..." section with links to "Linear Algebra Blocks", "Linear System Solvers", "Matrix Factorizations", and "Matrix Inverses". Below this, the "Linear Algebra Blocks" section describes the Matrices and Linear Algebra library, and the "Linear System Solvers" section lists the following blocks for solving the system of linear equations $A X = B$:

- Autocorrelation LPC
- Cholesky Solver
- Forward Substitution
- LDL Solver

MATLAB Help

- From command window

```
>> help spones
```

```
SPONES Replace nonzero sparse matrix elements with ones.
```

```
R = SPONES(S) generates a matrix with the same sparsity  
structure as S, but with ones in the nonzero positions.
```

```
See also spfun, spalloc, nnz.
```

```
Reference page in Help browser
```

```
doc spones
```

Matrices and vectors

Run in MATLAB Command Window

```
>> echodemo vectors_matrices
```

Useful matrix functions

- **A'** – *transpose of matrix A. Also transpose(A).*
 - **det (A)** – *determinant of A*
 - **eig (A)** – *eigenvalues and eigenvectors*
 - **inv (A)** – *inverse of A*
 - **svd (A)** – *singular value decomposition*
 - **norm (A)** – *matrix or vector norm*
 - **find (A)** – *find indices of elements that are nonzero.*
Can also pass an expression to this function,
e.g. find(A > 1) finds the indices of elements of A greater than 1.
-

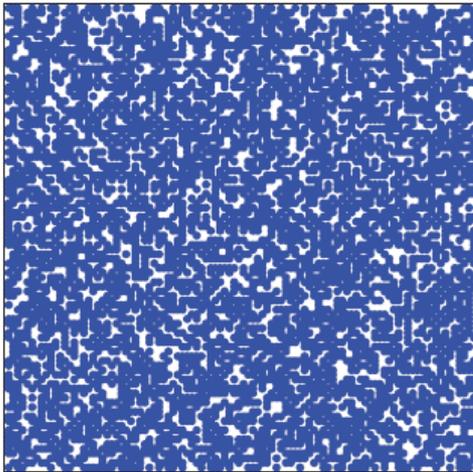
Useful matrices

A few other useful matrices are:

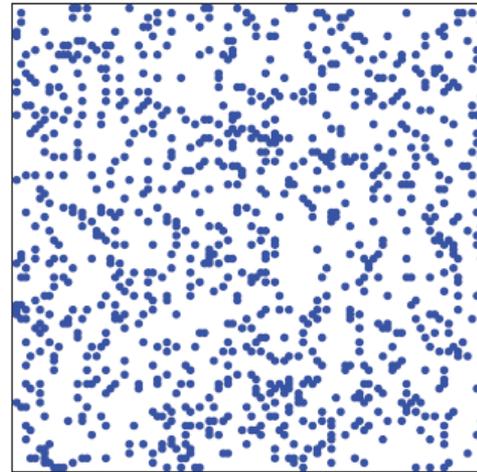
- **zeros** – *create a matrix of zeros*
 - **ones** – *create a matrix of ones*
 - **rand** – *create a matrix of random numbers*
 - **eye** – *create an identity matrix*
-

Sparse matrices

Sparse matrix have the large number of zero elements



nz = 5495



nz = 952

The sparse attribute allows MATLAB to:

- Store only the nonzero elements of the matrix, together with their indices.
- Reduce computation time by eliminating operations on zero elements.

Sparse matrices

Example

$$A = \begin{pmatrix} 1 & 0 & 0 & 2 \\ 0 & 3 & 0 & 0 \\ 0 & 4 & 5 & 0 \\ 0 & 0 & 6 & 7 \end{pmatrix}$$

```
i = [1 2 3 4 1 3]'; %indices of rows
```

```
j = [1 2 2 3 4 4]; %indices of columns
```

```
v = [1 3 4 6 2 7]'; %values
```

```
A=[1 0 2 0 0; 0 1 0 0 1; 2 0 0 2 0; 3 1 2 0 0] %saved as full
```

```
B = sparse(A) % B saved as sparse
```

```
C = full(B) % C saved as full
```

Sparse matrices

```
n=5; e=ones(n,1); %vector of ones
A = spdiags([-e 2*e -e], -1:1, n, n); %sparse matrix nxn with
% 2's on diagonal and -1 on subdiagonale and superdiagonale

[I,J,V]=find(S); %returns a vector V containing the values
% that correspond to the row and column indices I and J.

I=[1 1 2 3]; J=[1 3 2 4]; V=[1 1.5 2 3.7]; m=5; n=6;
S=sparse(I,J,V,m,n); %generate mxn sparse matrix from I,J,V

spy(S) %plots the sparsity pattern of the matrix S.
speye(5,4); %sparse identity
nnz(S) %number of nonzero elements

sprand, sprandn, sprandsym
```

Strings

```
str = 'Dr. John Doe'; %create string

%join 2 strings
str1 = strcat(str, ', ', '1970') %ignore spaces
str2 = [str, ', ', '1970'] %do not ignore the spaces

T=1323.56;
sprintf('Temperature T=%10.4fK', T) %format data to string
ans =
Temperature T= 1323.5600K

strcmp('hello', 'Hello') %compare 2 strings
ans =
    0
```

Scripts

- external files, have a filename extension of .m
- **the simplest MATLAB programs**, a sequence of statements and comments
- useful for automating blocks of MATLAB commands, such as computations you have to perform repeatedly from the command line
- **operate on existing data in the workspace**
- **do not return output arguments** – any variables that they create remain in the workspace

goniom.m

```
% Script example:  
% Evaluating goniometric  
% functions in pi/2  
x=pi/2;  
s=sin(x); c=cos(x);  
t=tan(x); co=cot(x);  
disp([s,c,t,co]); %show results
```

```
>> goniom  
1.0e+016 *  
  
0.0000 0.0000 1.6331 0.0000
```


Functions

- external files, have a filename extension of .m
- First line: function declaration with **input and output** arguments
`function [out1, out2, ...] = myfun(in1, in2, ...)`
- The variables within the body of the function are **all local** variables.

- **Anonymous Functions**
- **Primary and Subfunctions**
- **Nested Functions**

stat.m

```
function [mean,stdev] = stat(x)
n = length(x);
mean = sum(x)/n;
stdev = sqrt(sum((x-mean).^2/n));
```

```
>> [mean stdev] = stat([52/4 5.2 7.9])
mean =
    8.7000
stdev =
    3.2342
```

Functions

Anonymous Functions

- a simple form of the MATLAB function that is defined within a single statement.
- You can define an anonymous function right at the command line, or within a function or script.

```
>> sqr = @(x) x.^2;  
>> sqr(7)
```

```
ans =
```

```
49
```

```
>> f = @(x) 5*x^2 + 3*x + 5;  
>> f(0)
```

```
ans =
```

```
5
```

Functions

Primary and Subfunctions

- Any function (except anonymous) must be defined within a file.
- Each such function file contains a required *primary function* that appears first, and any number of *subfunctions* that may follow the primary.
- Primary functions can be called from outside of the file that defines them, while subfunctions cannot. Subfunctions are visible only to the primary function and other subfunctions within their own file.

stat2.m

```
function [mean,stdev] = stat2(x)
n = length(x);
mean = avg(x,n);
stdev = sqrt(sum((x-avg(x,n)).^2)/n);
```

```
function mean = avg(x,n)
mean = sum(x)/n;
```

```
>>[mean stdev]=stat2([1 2 5])
```

```
mean =
      2.6667
```

```
stdev =
      1.6997
```

Functions

Nested Functions

- You can define functions within the body of another function. These are said to be *nested* within the outer function.
- A nested function has **access to the workspaces of all functions inside of which it is nested**. A variable that has a value assigned to it by the primary function can be read or overwritten by a function nested at any level within the primary.

```
function x = A(p1, p2)
...
    function y = B(p3)
        ...
    end
...
end
```

Flow Control:

Conditional Control: if-else-elseif

```
% Generate a random number
a = randi(100, 1);
% If it is even, divide by 2
if rem(a, 2) == 0
    disp('a is even')
    b = a/2;
end
```

```
a = randi(100, 1);
if a < 30
    disp('small')
elseif a < 80
    disp('medium')
else
    disp('large')
end
```

Conditional Control: switch

```
mynumber = input('Enter a number:');
```

```
switch mynumber
    case -1
        disp('negative one');
    case 0
        disp('zero');
    case 1
        disp('positive one');
    otherwise
        disp('other value');
end
```

Loop Control: for

- The **for** loop repeats a group of statements a fixed, predetermined number of times. A matching end delineates the statements.

```
for n = 3:32
    r(n) = rank(magic(n));
end
r
```

It is a good idea to indent the loops for readability, especially when they are nested:

```
for i = 1:m
    for j = 1:n
        H(i,j) = 1/(i+j);
    end
end
```

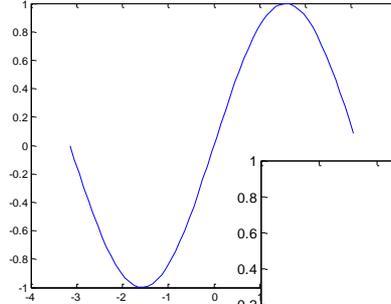
Loop Control: while

- The **while** loop repeats a group of statements an indefinite number of times under control of a logical condition. A matching end delineates the statements.

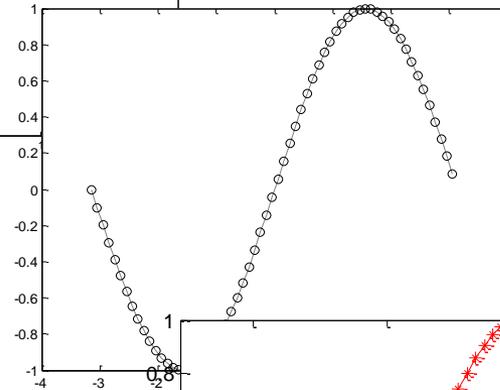
```
n = 5;  
fact = 1;  
while (n>1)  
    fact = fact*n;  
    n = n-1;  
end
```

2D graphics: plot

```
x = -pi:.1:pi;  
y = sin(x);  
plot(x,y)
```



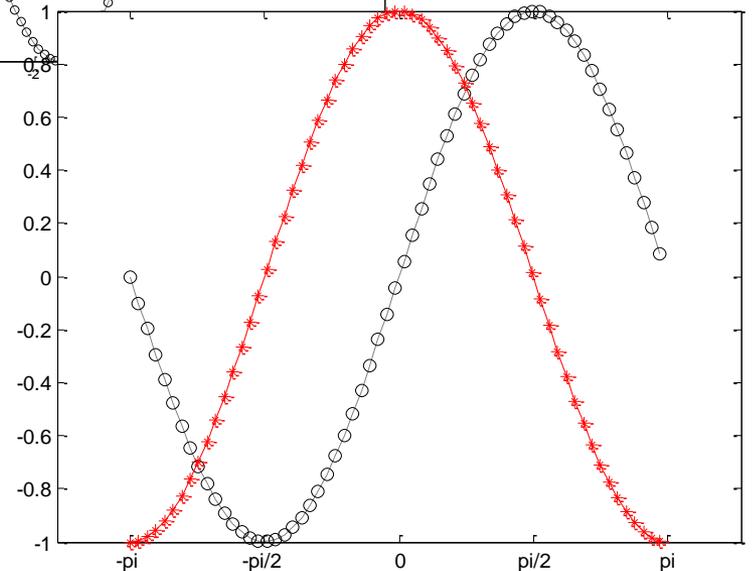
```
plot(x,y,'ko:')
```



```
set(gca,'XTick',-pi:pi/2:pi)  
set(gca,'XTickLabel',...  
{ '-pi', '-pi/2', '0', 'pi/2', 'pi' })
```

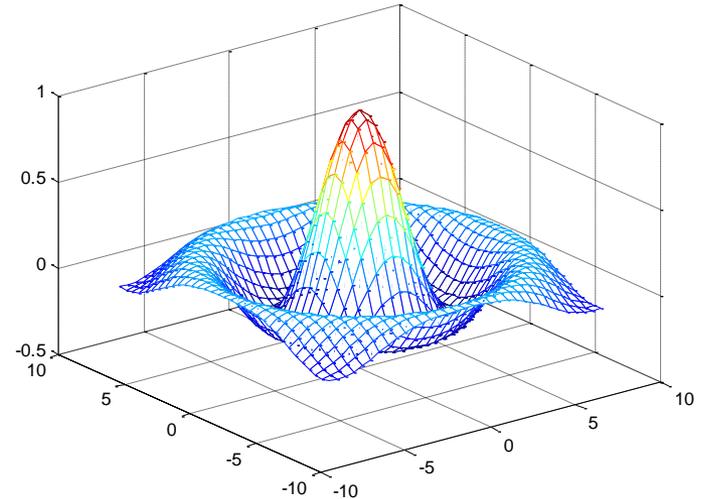
```
hold on
```

```
z = cos(x);  
plot(x,z,'r-*')
```

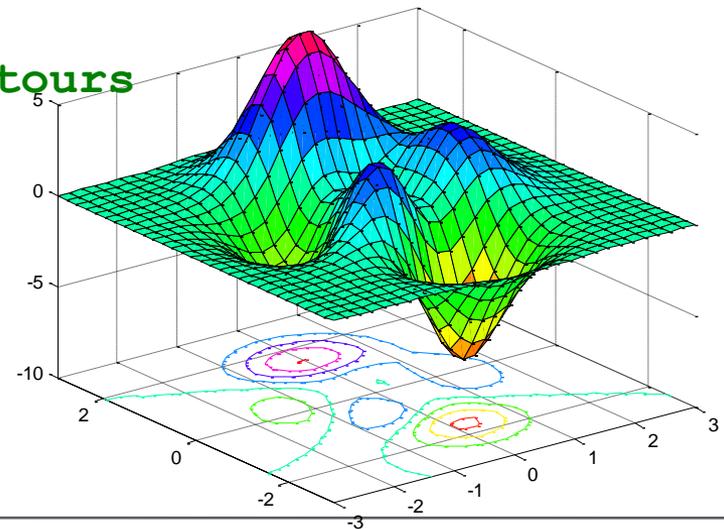


3D graphics: mesh, surf

```
figure
[X,Y] = meshgrid(-8:.5:8);
R = sqrt(X.^2 + Y.^2) + eps;
Z = sin(R) ./ R;
mesh(X,Y,Z)
```

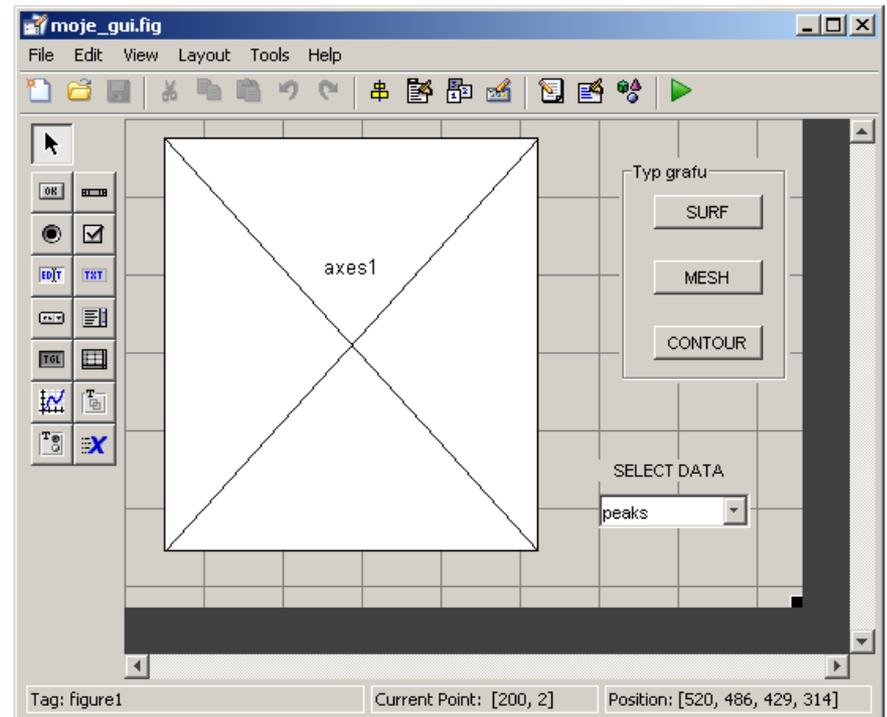


```
figure
[X,Y,Z] = peaks(30);
surf(X,Y,Z)      %surf(X,Y,Z) with contours
colormap hsv
axis([-3 3 -3 3 -10 5])
```

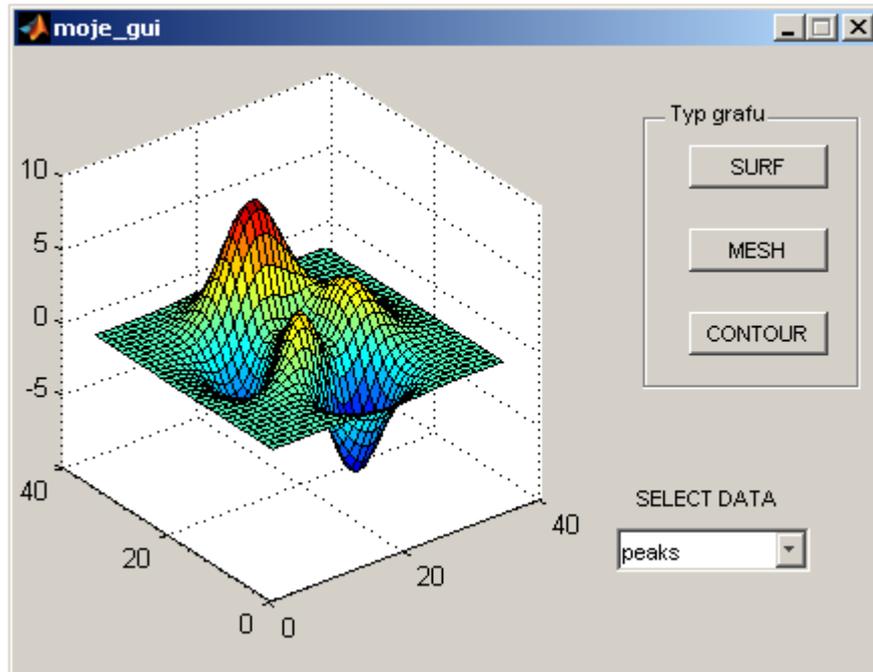


Creating GUI with GUIDE

- GUIDE, the MATLAB Graphical User Interface Development Environment, provides a set of tools for creating graphical user interfaces (GUIs). These tools greatly simplify the process of laying out and programming GUIs
- When you open a GUI in GUIDE, it is displayed in the Layout Editor, which is the control panel for all of the GUIDE tools. The following figure shows the Layout Editor with a blank GUI template.



Creating GUI with GUIDE



`>> moje_gui`

- video file (11 min):

http://www.mathworks.com/support/2011a/matlab/7.12/demos/Creating_aGUIwithGUIDE_viewlet_swf.html

References

- **Matlab: Instructions to download:**
http://homel.vsb.cz/~dom033/predmety/NMM/matlab_download
 - **Introduction to MATLAB:**
http://web.gps.caltech.edu/classes/ge11d/doc/matlab_Resource_Seminar.pdf
 - David Houcque, **INTRODUCTION TO MATLAB FOR ENGINEERING STUDENTS:**
<http://www.mccormick.northwestern.edu/docs/efirst/matlab.pdf>
 - **Getting Started Guide:**
http://www.mathworks.com/help/pdf_doc/matlab/getstart.pdf
-