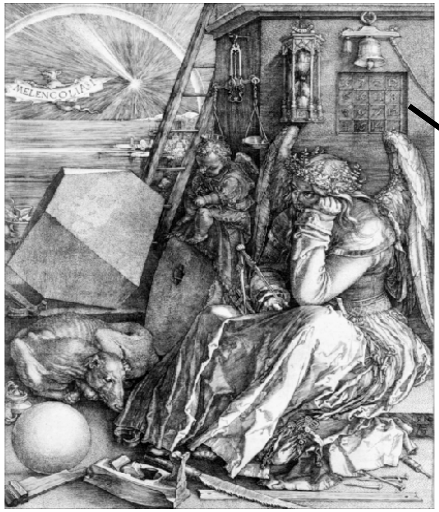
E2.5 Signals & Systems
Introduction to MATLAB

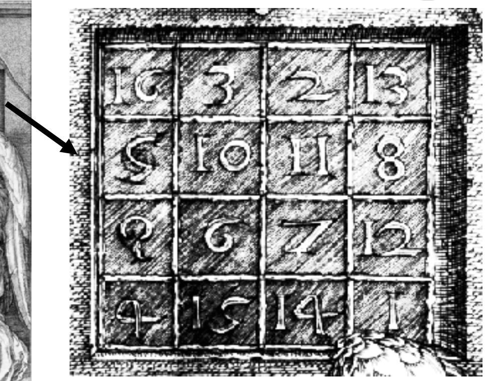
- **MATLAB** is a high-performance language for ***technical computing***. It integrates computation, visualization, and programming in an easy-to-use environment. Typical uses include:
  - Math and computation
  - Algorithm development
  - Modeling, simulation, and prototyping
  - Data analysis, exploration, and visualization
  - Scientific and engineering graphics
- MATLAB is an ***interactive*** system whose basic data element is an ***array*** that does not require dimensioning. This allows you to solve many technical computing problems, especially those with ***matrix*** and ***vector*** formulations, in a fraction of the time it would take to write a program in a scalar non-interactive language such as C or Fortran.

Five Parts of Matlab

- **The MATLAB language**
  - ❖ High-level matrix/array language with control flow statements, functions, data structures, input/output, and object-oriented programming features
- **The MATLAB working environment**
  - ❖ Facilities for managing the variables and importing and exporting data
  - ❖ Tools for developing, managing, debugging, and profiling M-files
- **Handle Graphics**
  - ❖ Two-dimensional and three-dimensional data visualization, image processing, animation, and presentation graphics
  - ❖ Graphical User Interface functions
- **The MATLAB mathematical function library**
- **The MATLAB Application Program Interface (API)**
  - ❖ Allows you to write C and Fortran programs that interact with MATLAB

Entering Matrices (1) - Magic Square





- Engraving by Albrecht Dürer, German artist and mathematician in 1514.

Entering Matrices (2) - Method 1:Direct entry

- **4 ways of entering matrices in MATLAB**:
  - Enter an explicit list of elements
  - Load matrices from external data files
  - Generate matrices using built-in functions
  - Create matrices with your own functions in M-files
- **Rules of entering matrices**:
  - Separate the elements of a row with ***`blanks`*** or commas
  - Use a ***`semicolon`*** "`;`" to indicate the end of each row
  - Surround the entire list of elements with ***`square brackets`***, `[ ]`
- To enter Dürer's matrix, simply type:

```
» A = [16 3 2 13; 5 10 11 8; 9 6 7 12; 4 15 14 1]
```

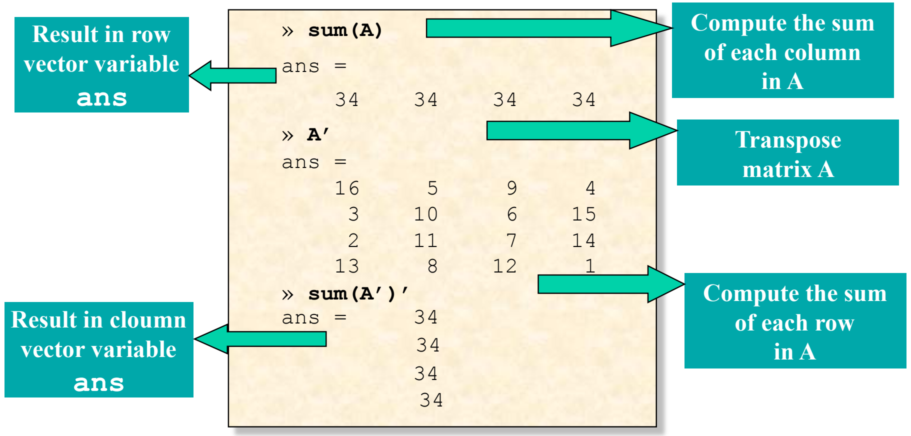
- MATLAB displays the matrix you just entered,

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

No need to define or declare size of A

Entering Matrices (3) - as lists

- Why is this a magic square? Try this in Matlab :-



```
» sum(A)
ans =
      34    34    34    34
» A'
ans =
      16     5     9     4
       3    10     6    15
       2    11     7    14
      13     8    12     1
» sum(A')'
ans =        34
             34
             34
             34
```

Compute the sum of each column in A

Result in row vector variable ans

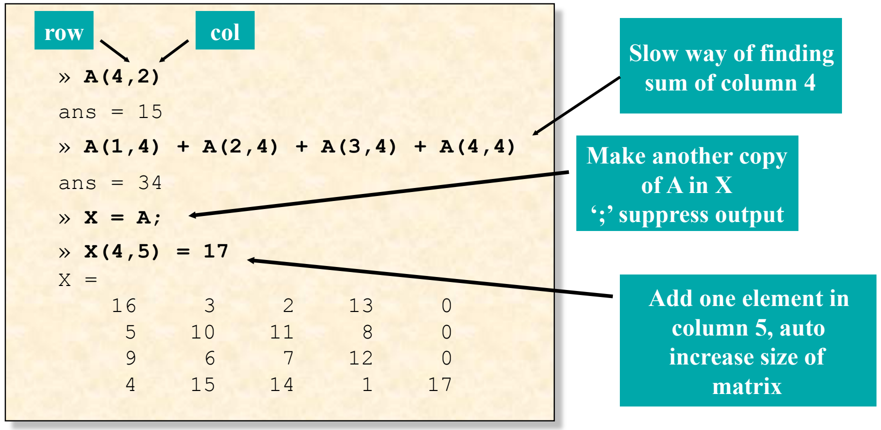
Transpose matrix A

Compute the sum of each row in A

Result in cloumn vector variable ans

Entering Matrices (4) - subscripts

- `A(i,j)` refers to element in row `i` and column `j` of `A` :-



row

col

```
» A(4,2)
ans = 15
» A(1,4) + A(2,4) + A(3,4) + A(4,4)
ans = 34
» X = A;
» X(4,5) = 17
X =
    16     3     2    13     0
     5    10    11     8     0
     9     6     7    12     0
     4    15    14     1    17
```

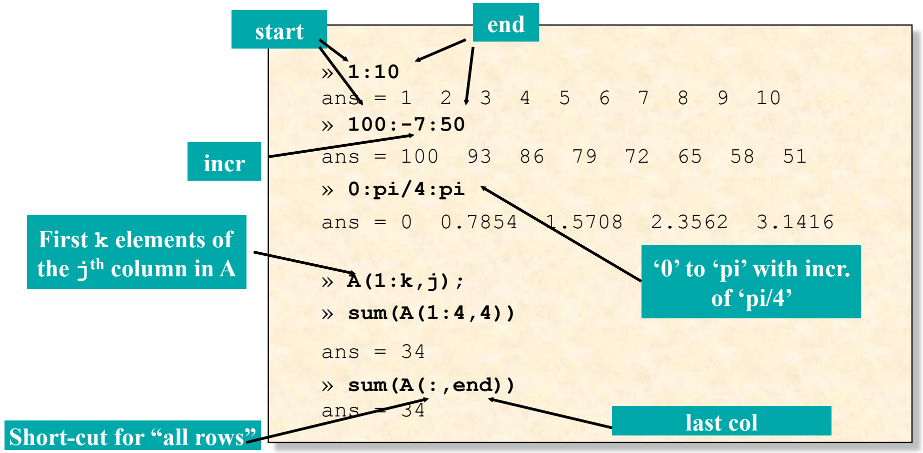
Slow way of finding sum of column 4

Make another copy of A in X
';' suppress output

Add one element in column 5, auto increase size of matrix

Entering Matrices (5) - colon : Operator

- ':' colon is used to specify range of numbers



start

end

```
» 1:10
ans = 1   2   3   4   5   6   7   8   9   10
» 100:-7:50
ans = 100  93  86  79  72  65  58  51
» 0:pi/4:pi
ans = 0   0.7854   1.5708   2.3562   3.1416

» A(1:k,j);
» sum(A(1:4,4))
ans = 34
» sum(A(:,end))
ans = 34
```

incr

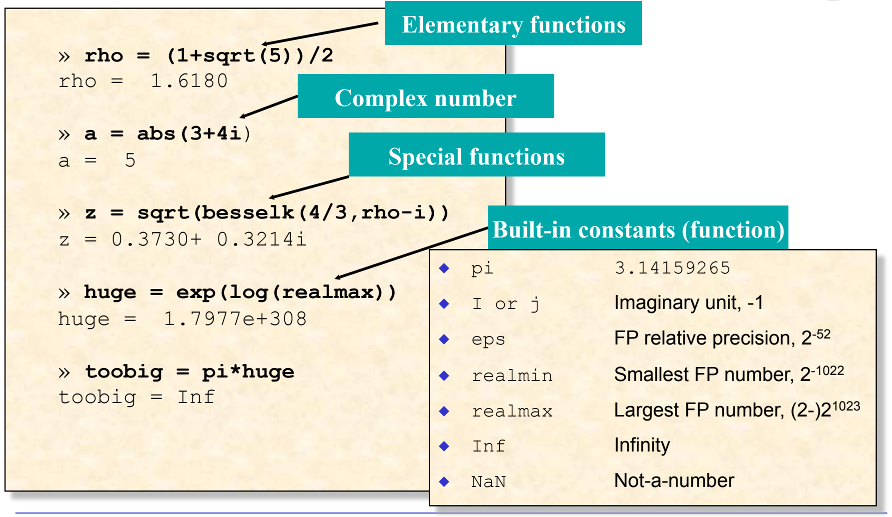
First k elements of the jth column in A

'0' to 'pi' with incr. of 'pi/4'

Short-cut for "all rows"

last col

Expressions & built-in functions



```
» rho = (1+sqrt(5))/2
rho =  1.6180

» a = abs(3+4i)
a =  5

» z = sqrt(besselk(4/3,rho-i))
z = 0.3730+ 0.3214i

» huge = exp(log(realmax))
huge =  1.7977e+308

» toobig = pi*huge
toobig = Inf
```

Elementary functions

Complex number

Special functions

Built-in constants (function)

`pi`	3.14159265
`I or j`	Imaginary unit, -1
`eps`	FP relative precision, 2^{-52}
`realmin`	Smallest FP number, 2^{-1022}
`realmax`	Largest FP number, $(2-)2^{1023}$
`Inf`	Infinity
`NaN`	Not-a-number

Entering Matrices (6) - Method 2: Generation

```
» Z = zeros(2,4)
Z =  0       0       0       0
     0       0       0       0

» F = 5*ones(3,3)
F =  5       5       5
     5       5       5
     5       5       5

» N = fix(10*rand(1,10))
N = 4       9       4       4

» R = randn(4,4)
R =  1.0668  0.2944  0.6918 -1.4410
     0.0593 -1.3362  0.8580  0.5711
    -0.0956  0.7143  1.2540 -0.3999
    -0.8323  1.6236 -1.5937  0.6900
```

Useful Generation Functions

`Zeros`	All zeros
`Ones`	All ones
`Rand`	Uniformly distributed random elements between (0.0, 1.0)
`Randn`	Normally distributed random elements, mean = 0.0, var = 1.0

Entering Matrices (7) - Method 3 & 4: Load & M-File

magik.dat

```
16.0  3.0  2.0 13.0
 5.0 10.0 11.0  8.0
 9.0  6.0  7.0 12.0
 4.0 15.0 14.0  1.0
```

```
» load magik.dat
```

Read data from file into variable `magik`

Three dots (…) means continuation to next line

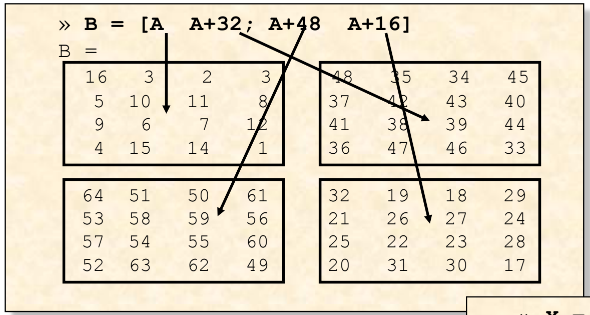
```
» magik
```

.m files can be run by just typing its name in Matlab

magik.m

```
A = [ ...
16.0  3.0  2.0 13.0
 5.0 10.0 11.0  8.0
 9.0  6.0  7.0 12.0
 4.0 15.0 14.0  1.0];
```

Entering Matrices (8) - Concatenate & delete



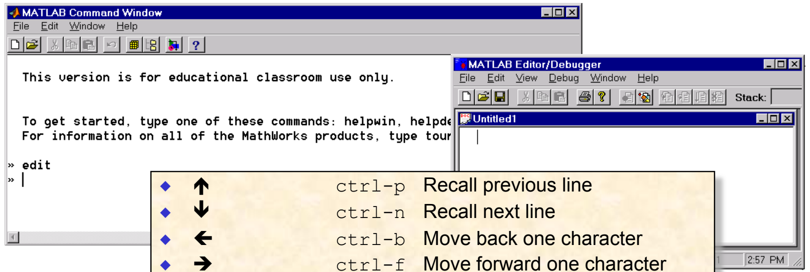
```
» B = [A  A+32; A+48  A+16]
B =
  16   3   2   3    48  35  34  45
   5  10  11   8    37  42  43  40
   9   6   7  12    41  38  39  44
   4  15  14   1    36  47  46  33

  64  51  50  61    32  19  18  29
  53  58  59  56    21  26  27  24
  57  54  55  60    25  22  23  28
  52  63  62  49    20  31  30  17
```

2nd column deleted

```
» X = A;
» X(:,2) = []
X =
   16    2   13
    5   11    8
    9    7   12
    4   14    1
```

Command Window



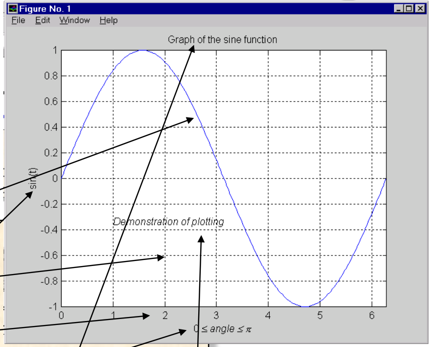
```
This version is for educational classroom use only.


To get started, type one of these commands: helpwin, helpde
For information on all of the MathWorks products, type tour

» edit
» |
```

↑	`ctrl-p`	Recall previous line
↓	`ctrl-n`	Recall next line
←	`ctrl-b`	Move back one character
→	`ctrl-f`	Move forward one character
ctrl - →	`ctrl-r`	Move right one word
ctrl - ←	`ctrl-l`	Move left one word
home	`ctrl-a`	Move to beginning of line
end	`ctrl-e`	Move to end of line
esc	`ctrl-u`	Clear line
del	`ctrl-d`	Delete character at cursor
backspace	`ctrl-h`	Delete character before cursor
	`ctrl-k`	Delete to end of line

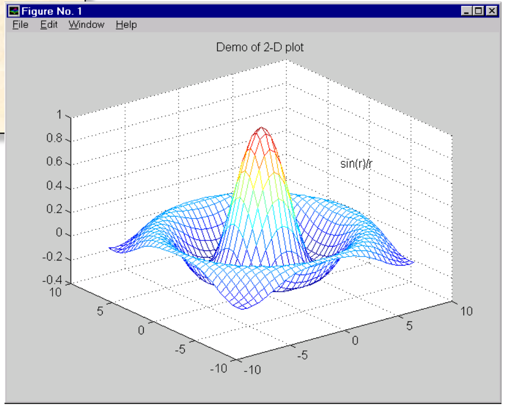
MATLAB Graphics(1) - Creating a Plot



```
» t = 0:pi/100:2*pi;
» y = sin(t);
» plot(t,y)
» grid
» axis([0 2*pi -1 1])
» xlabel('0 \leq \itangle \leq \pi')
» ylabel('sin(t)')
» title('Graph of the sine function')
» text(1,-1/3,'\it{Demonstration of plotting}')
```

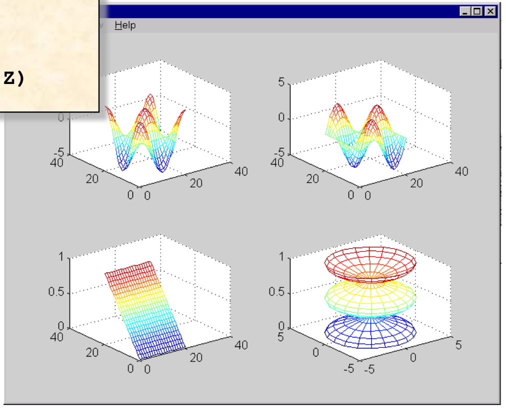
MATLAB Graphics(2) - Mesh & surface plots

```
» [X,Y] = meshgrid(-8:.5:8);
» R = sqrt(X.^2 + Y.^2) + eps;
» Z = sin(R)./R;
» mesh(X,Y,Z)
» text(15,10,'sin(r)/r')
» title('Demo of 2-D plot');
```



MATLAB Graphics(3) - Subplots

```
» t = 0:pi/10:2*pi;
» [X,Y,Z] = cylinder(4*cos(t));
» subplot(2,2,1); mesh(X)
» subplot(2,2,2); mesh(Y)
» subplot(2,2,3); mesh(Z)
» subplot(2,2,4); mesh(X,Y,Z)
```



MATLAB Graphics(3) - Subplots

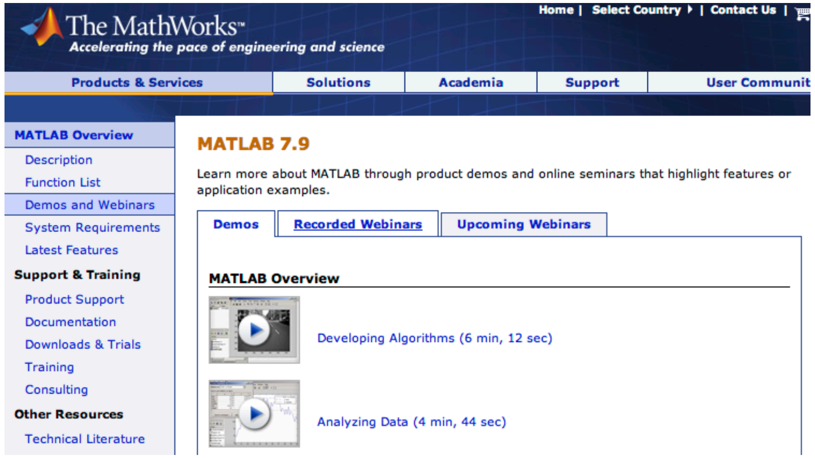
- Matlab official method: generate encapsulated postscript files -

```
» print -depsc2 mesh.eps
```

- My method:-
  - Use <***PrintScreen***> key (top right corner) to capture the plot on screen
  - Use MS Photo Editor or similar bit-map editing program to cut out the the plot that I want
  - Paste it into MS Word or MS PowerPoint or save it as .BMP/.GIF file
  - Resize as necessary
  - Fit as many as required on page
  - Type written description (or report) if needed
  - Print document to any printer (not necessarily postscript printer)

MATLAB demos and Online video Tutorial

- Matlab videos on: http://www.mathworks.com/products/matlab/demos.jsp



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MATLAB 7.9

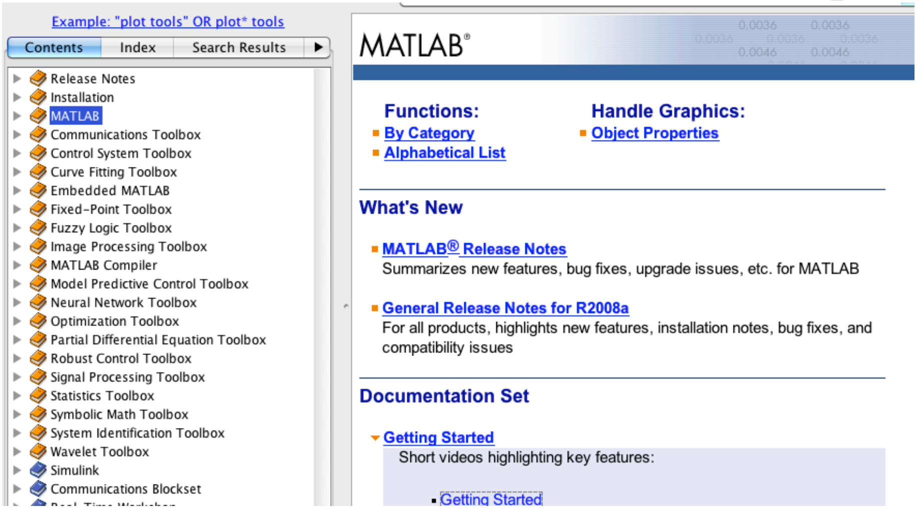
Learn more about MATLAB through product demos and online seminars that highlight features or application examples.

MATLAB Overview

Developing Algorithms (6 min, 12 sec)

Analyzing Data (4 min, 44 sec)

MATLAB Help & Documentation



Example: "plot tools" OR plot* tools

- Release Notes
- Installation
- MATLAB
- Communications Toolbox
- Control System Toolbox
- Curve Fitting Toolbox
- Embedded MATLAB
- Fixed-Point Toolbox
- Fuzzy Logic Toolbox
- Image Processing Toolbox
- MATLAB Compiler
- Model Predictive Control Toolbox
- Neural Network Toolbox
- Optimization Toolbox
- Partial Differential Equation Toolbox
- Robust Control Toolbox
- Signal Processing Toolbox
- Statistics Toolbox
- Symbolic Math Toolbox
- System Identification Toolbox
- Wavelet Toolbox
- Simulink
- Communications Blockset

MATLAB®

Functions:
- By Category
- Alphabetical List

Handle Graphics:
- Object Properties

What's New

- MATLAB® Release Notes
  Summarizes new features, bug fixes, upgrade issues, etc. for MATLAB
- General Release Notes for R2008a
  For all products, highlights new features, installation notes, bug fixes, and compatibility issues

Documentation Set

- Getting Started
  Short videos highlighting key features:
  - Getting Started

MATLAB Environment – useful commands (1)

- **Managing Commands and Functions**

addpath	Add directories to MATLAB's search path
help	Online help for MATLAB functions and M-files
path	Control MATLAB's directory search path

- **Managing Variables and the Workspace**

clear	Remove items from memory
length	Length of vector
load	Retrieve variables from disk
save	Save workspace variables on disk
size	Array dimensions
who, whos	List directory of variables in memory

MATLAB Environment (2)

- **Working with Files and the Operating Environment**

cd	Change working directory
delete	Delete files and graphics objects
diary	Save session in a disk file
dir	Directory listing
edit	Edit an M-file
!	Execute operating system command