TeraSoft
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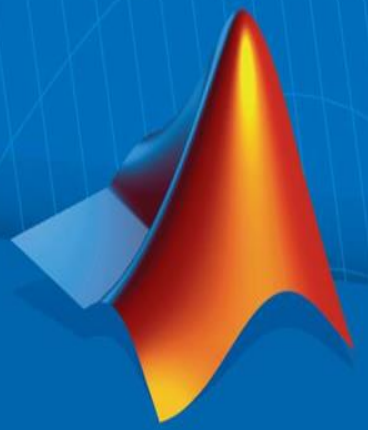

MATLAB FUNDAMENTALS AND PROGRAMMING TECHNIQUES

(BASIC)

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MathWorks
Accelerating the pace of engineering and science

Course Outline

- Working with the MATLAB User Interface
- Variables and Commands
- Array Creation and Analysis
- Working with Data Files
- Visualization with Array
- Automating Commands with Scripts
- Appendix: Data Type

How to Use This Manual

- Code font is used for code, function names and URLs. It also occurs on the slides in one of the lower corners as reference to relevant files or commands for the example.

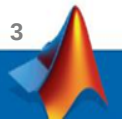
```
>> command_line_code
>>[a,b,c] = command_in_file(d,f);
```

- At times, code may run off the line. The line continuation character (…) is used to show this. These are valid MATLAB statements if typed as shown, including carriage returns.

```
>> [CFlowAmounts, CFlowDates, TFactors] = ...
cfamounts(couponRate, settle, maturity);
```

- Menu items, options and key names are highlighted in bold in the notes sections.
  Use Ctrl+C to break out of execution.
  Click on File, Set Path ... to open the Path Browser.

```
>> try this at the prompt
```

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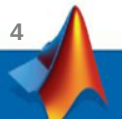
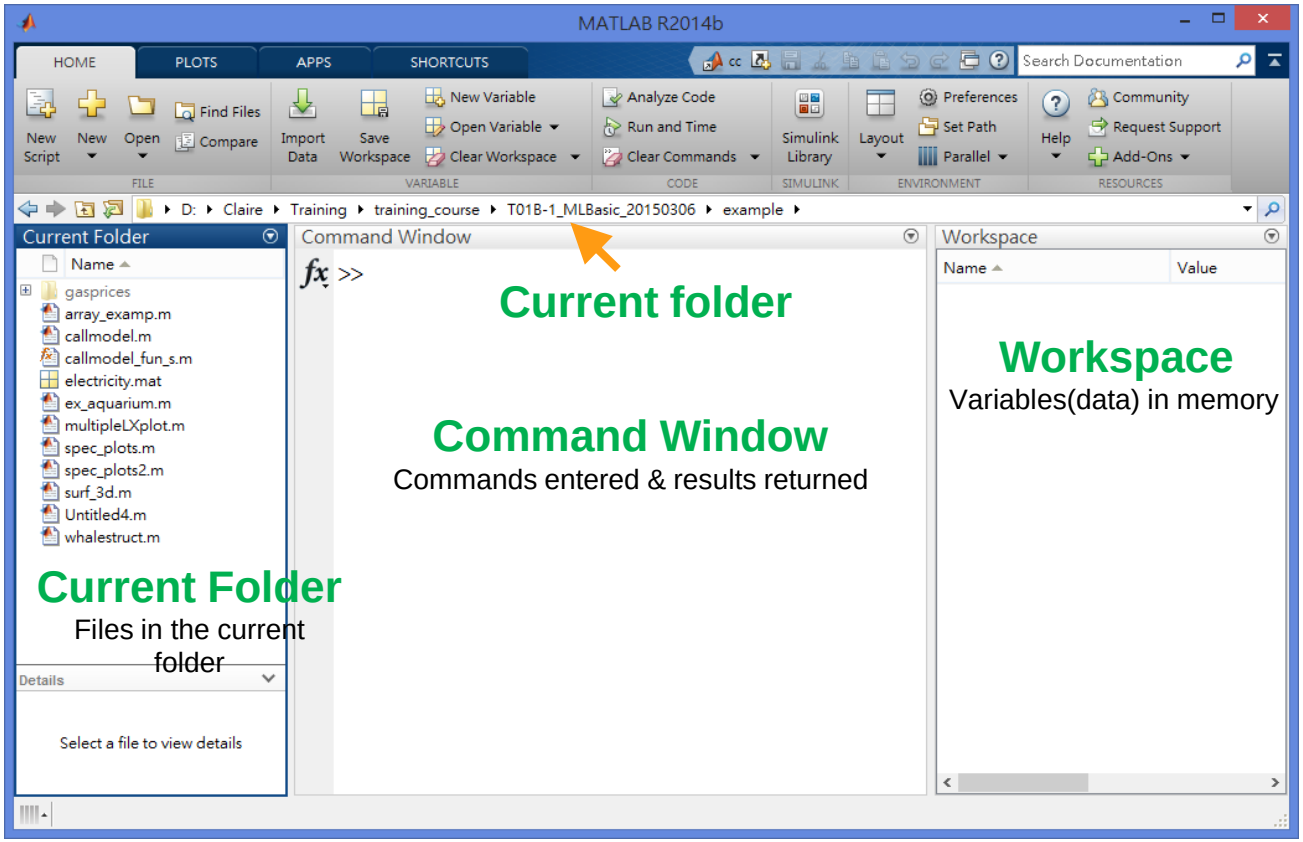
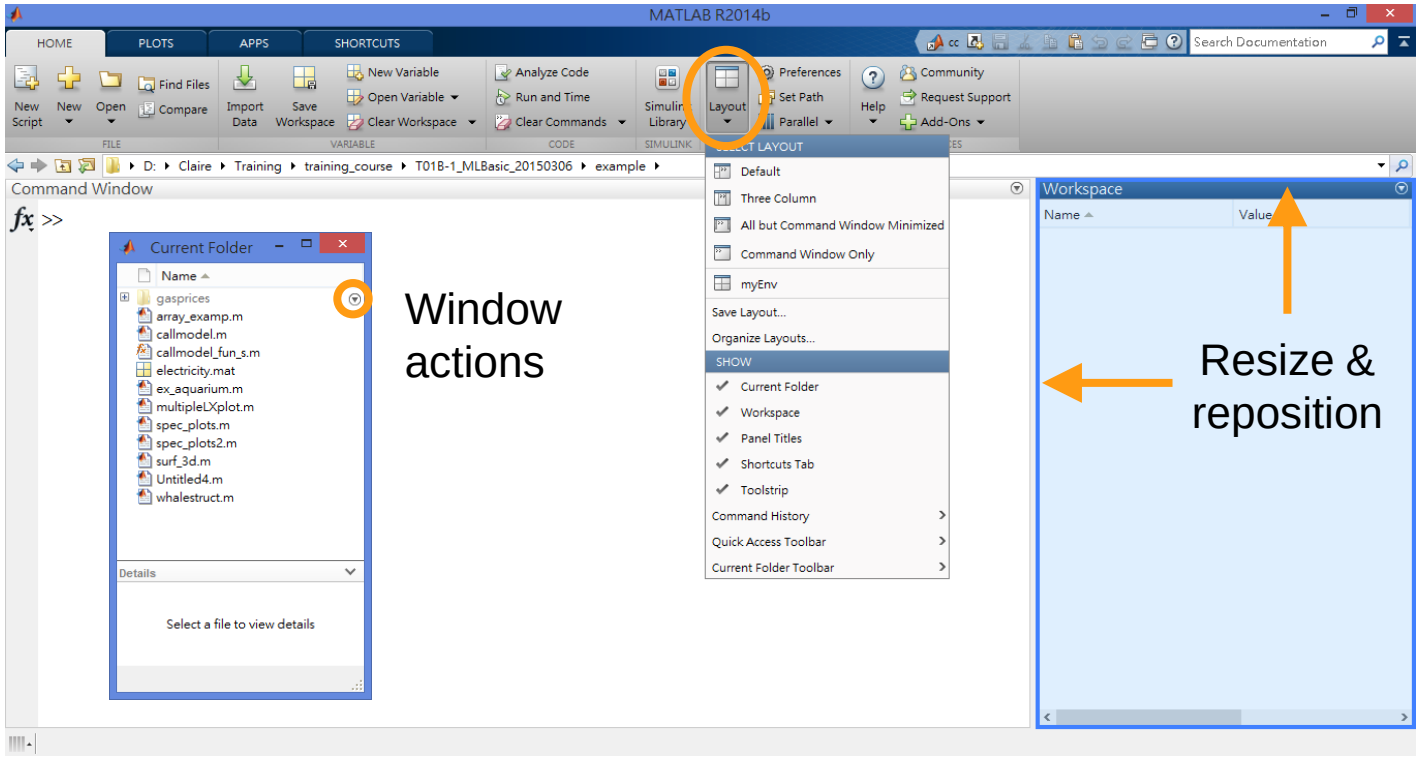


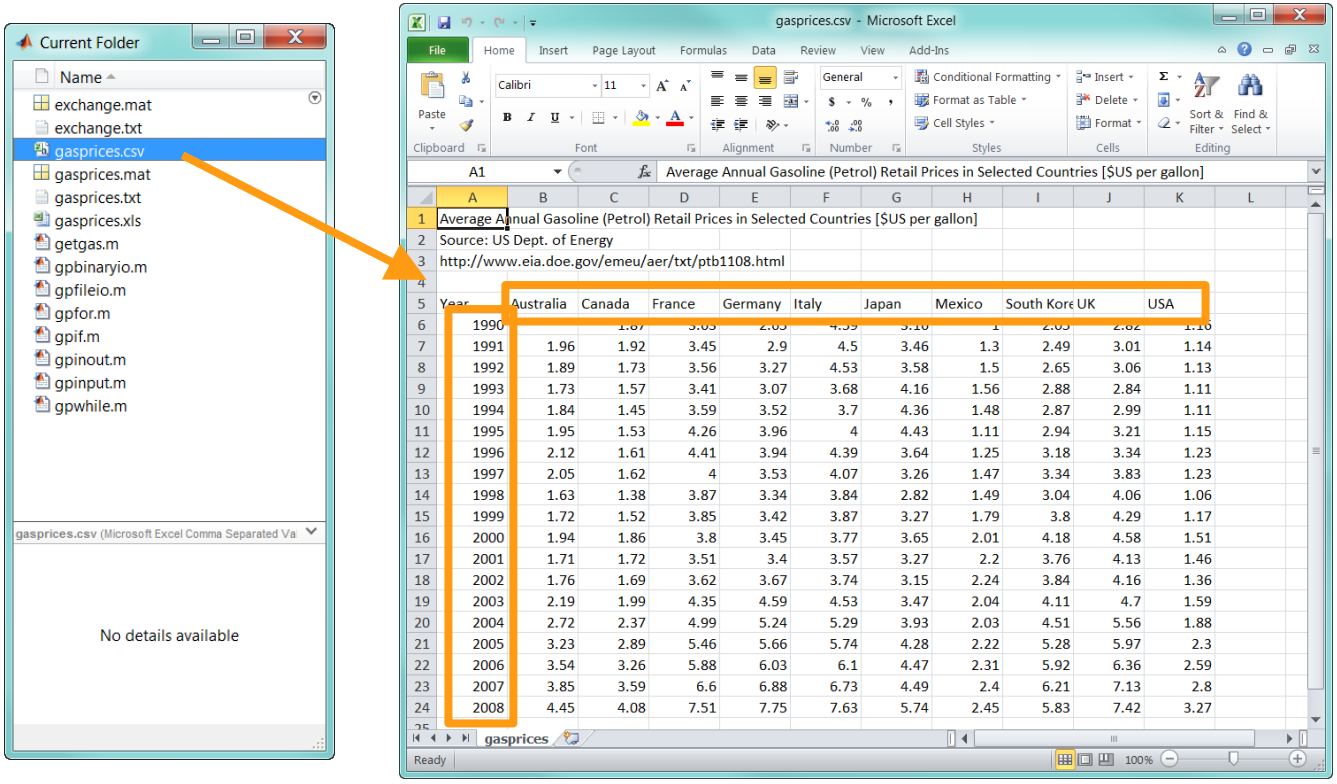
The MATLAB® Desktop



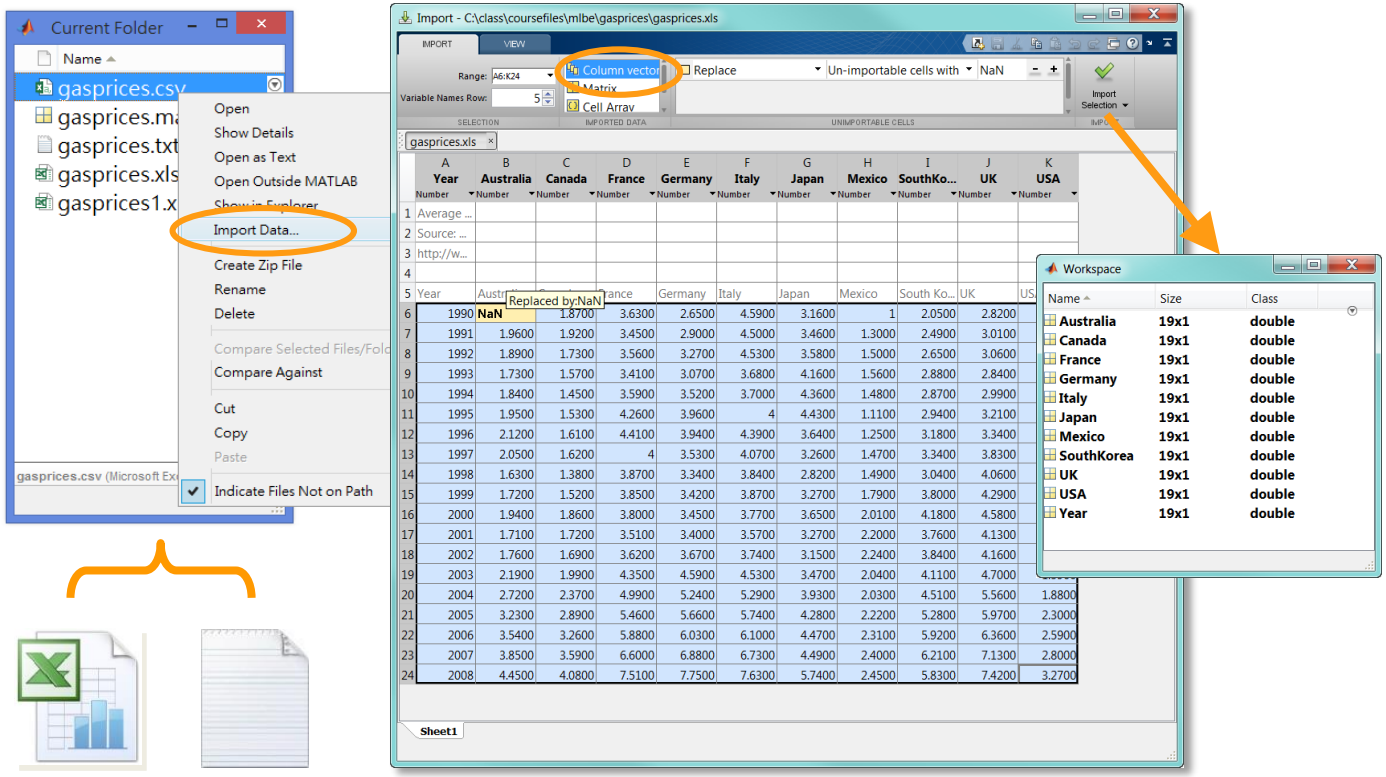
Customizing the Desktop



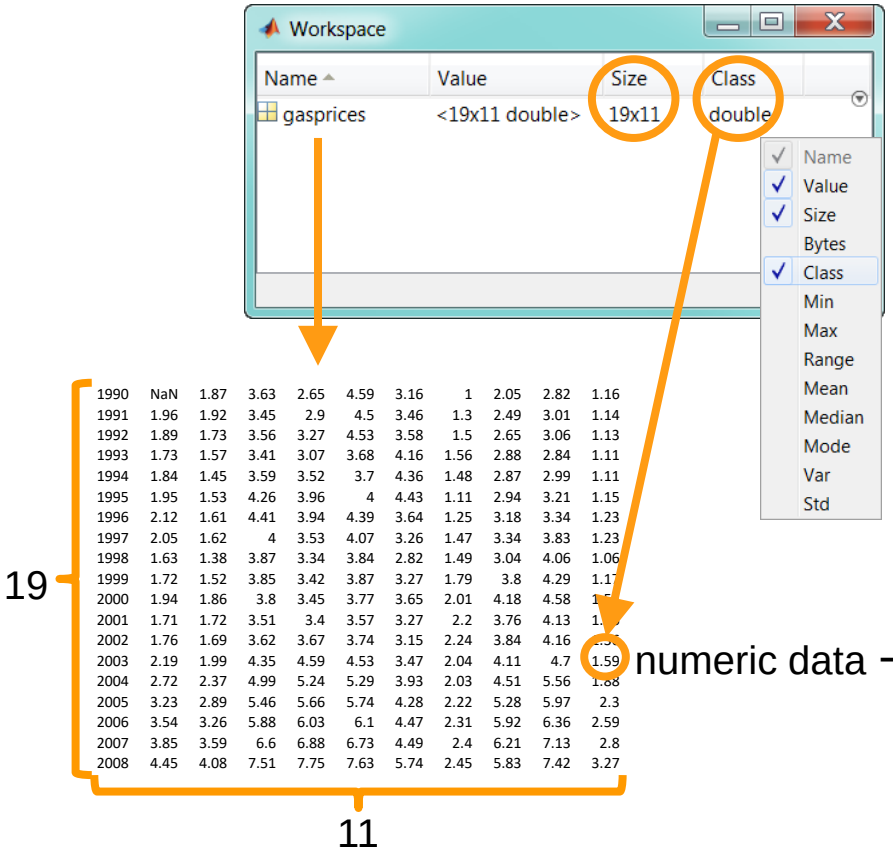
Course Example: Gas Price Data



Interactively Importing

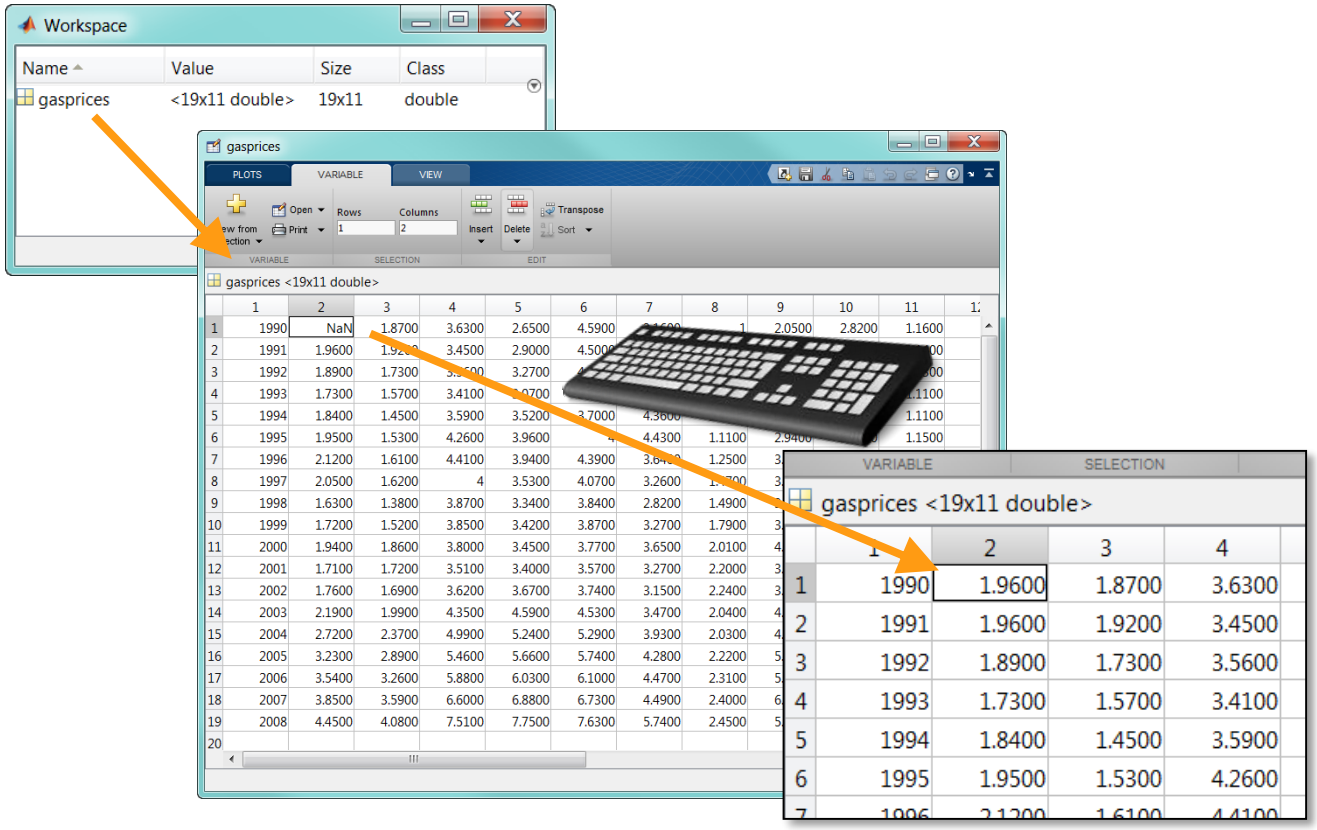


Variables in the Base Workspace

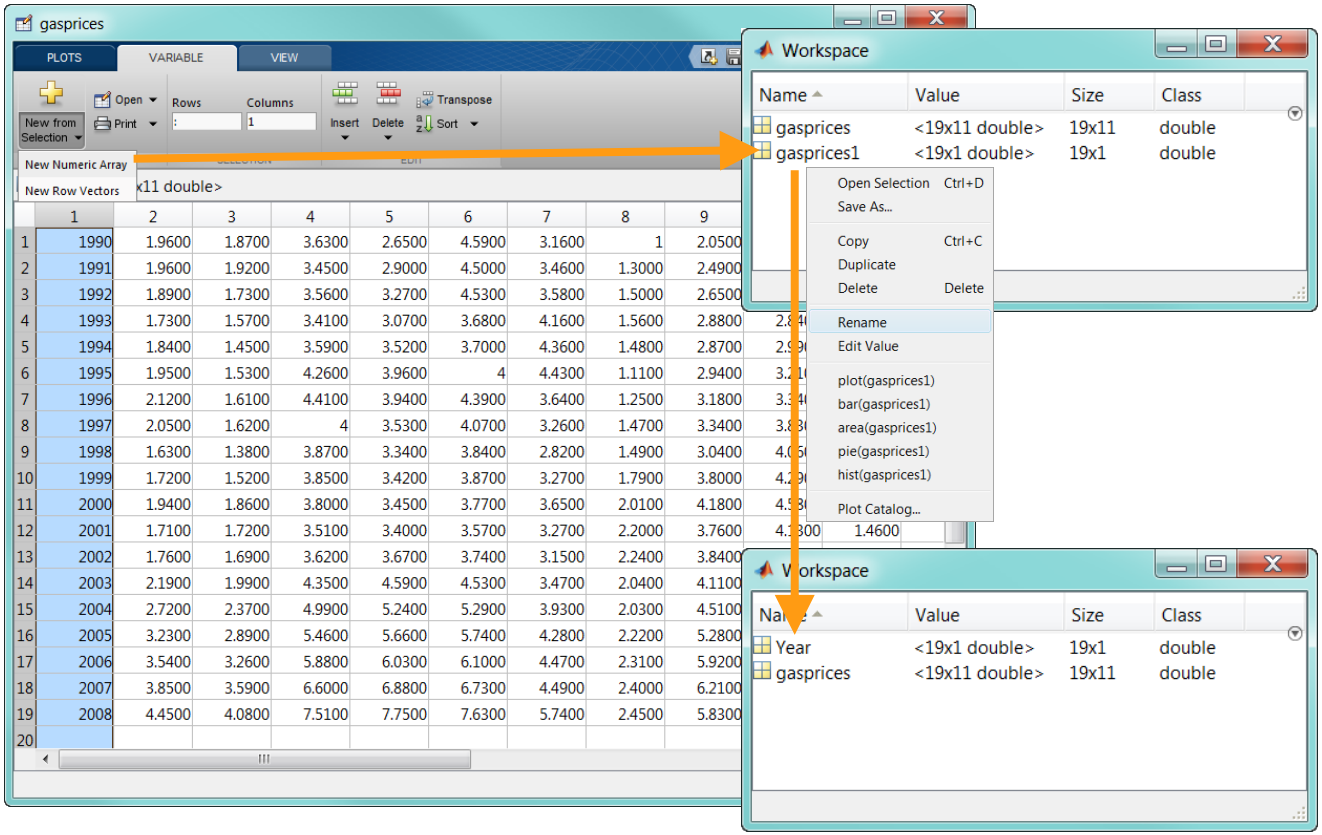


numeric data → "**double precision**"

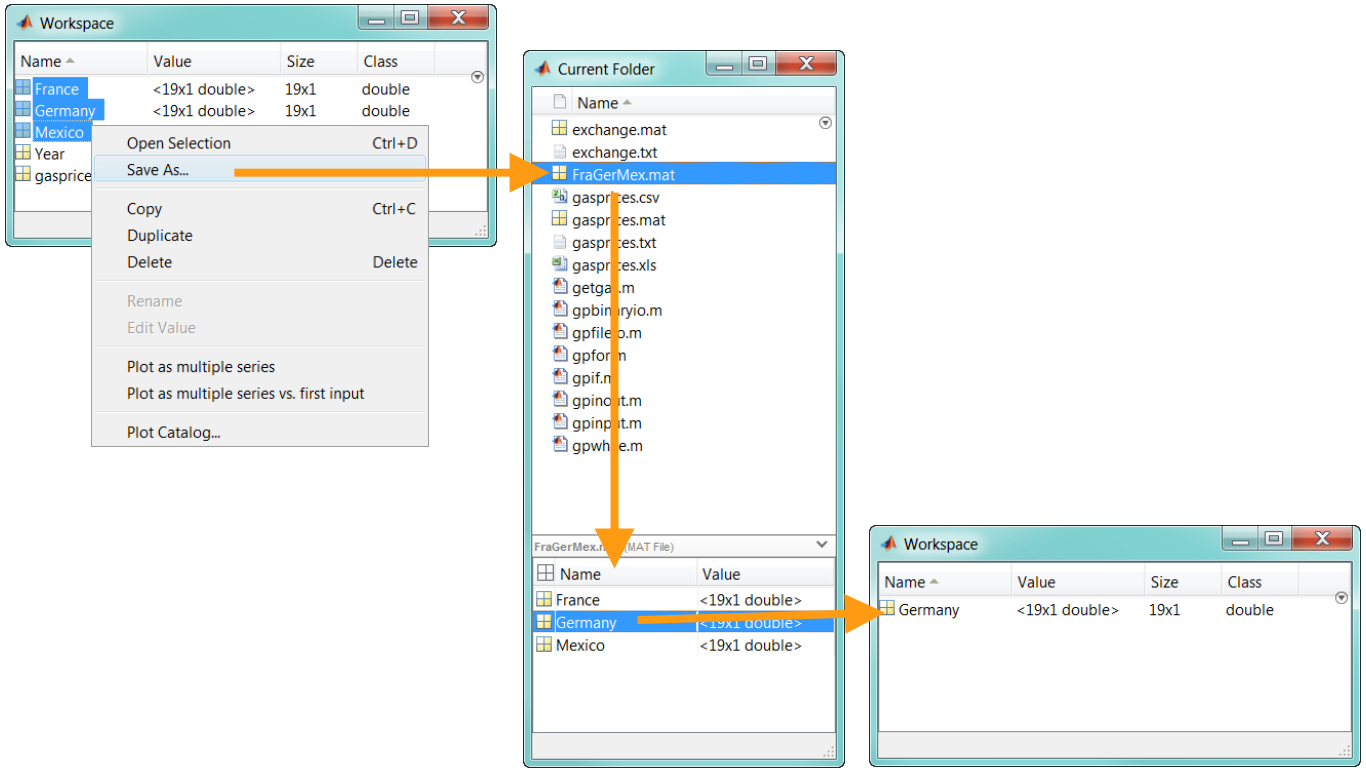
The Variable Editor



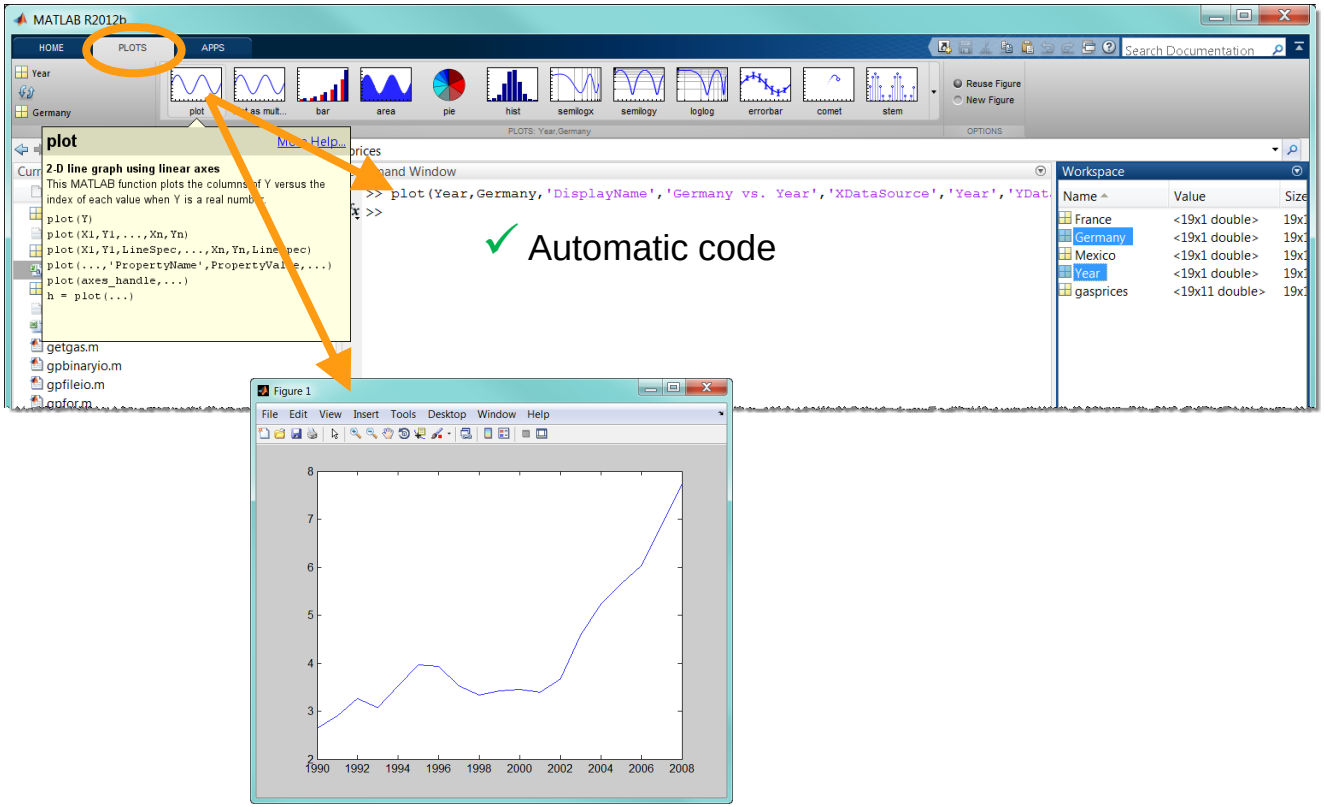
New Variables



Saving and Loading Variables

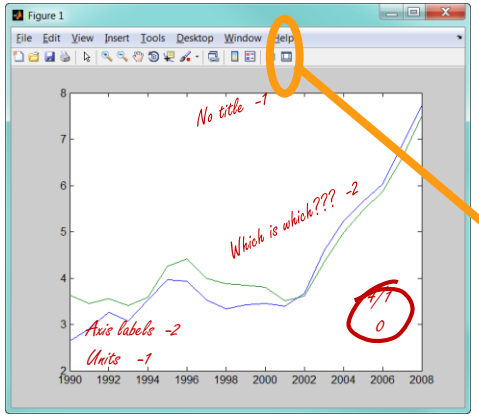


Plotting the Data



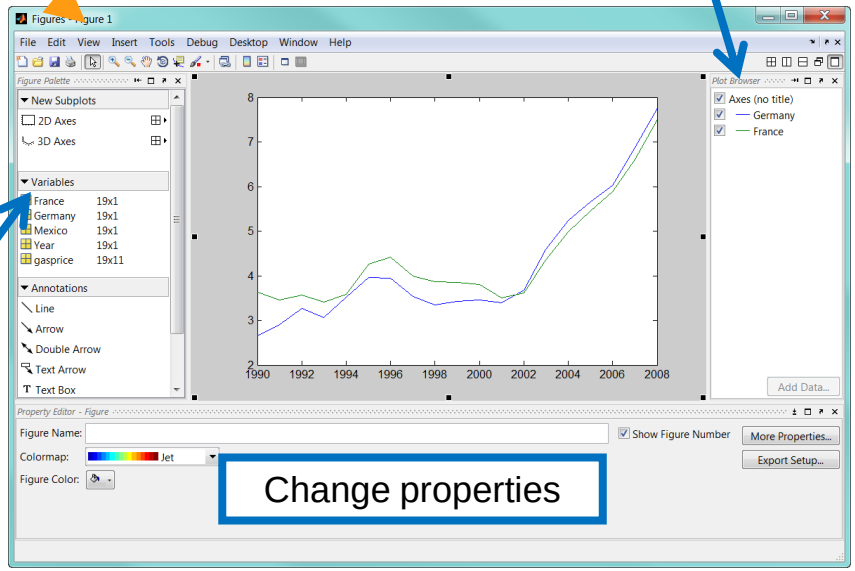
✓ Automatic code

Plot Tools



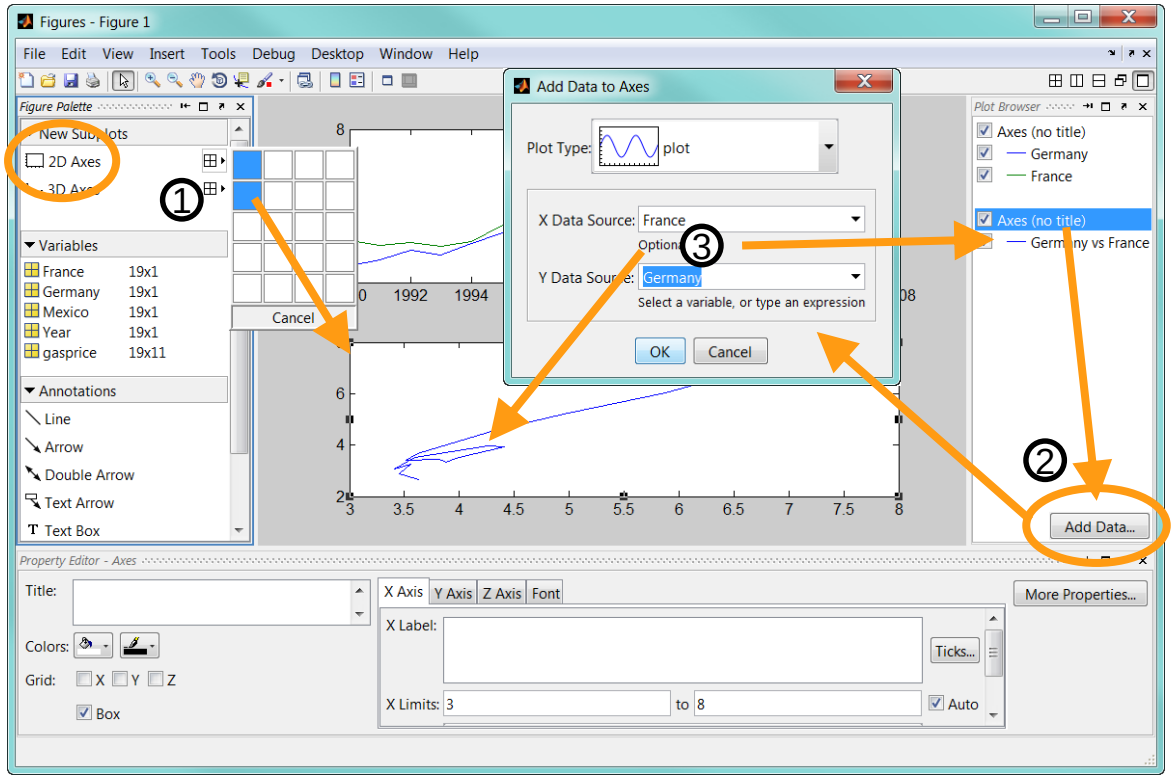
Select plot components

Add plot elements

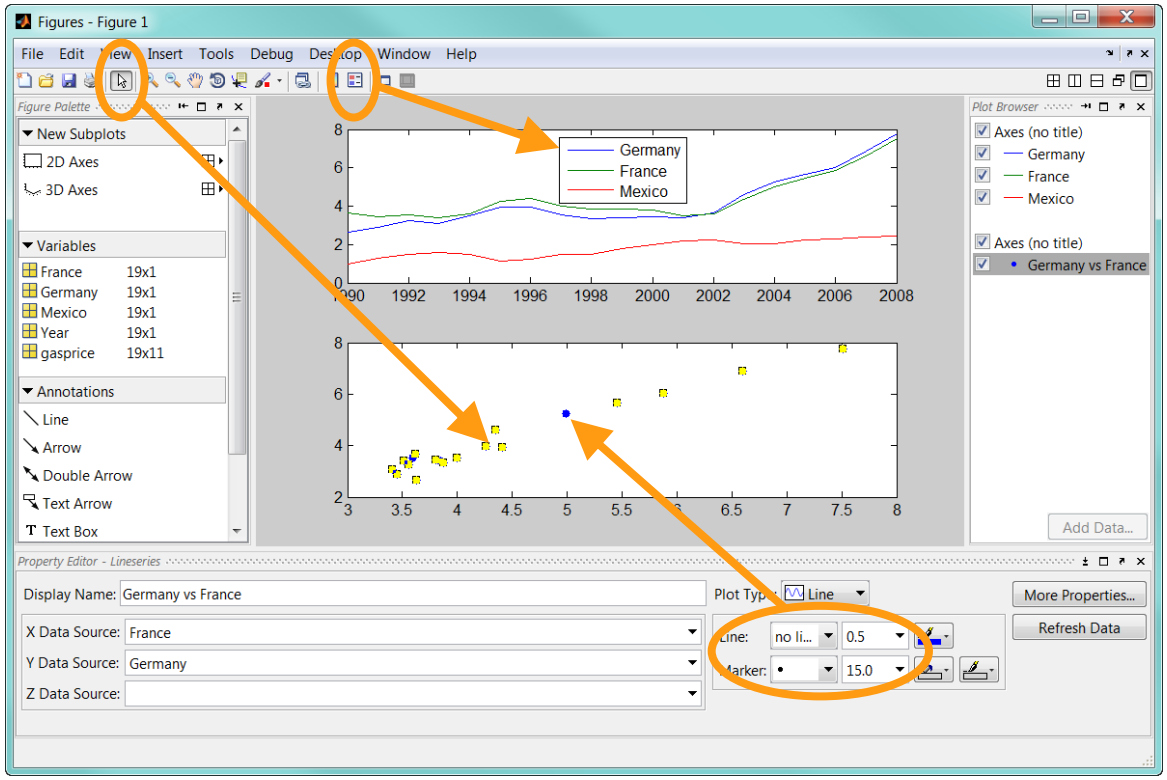


Change properties

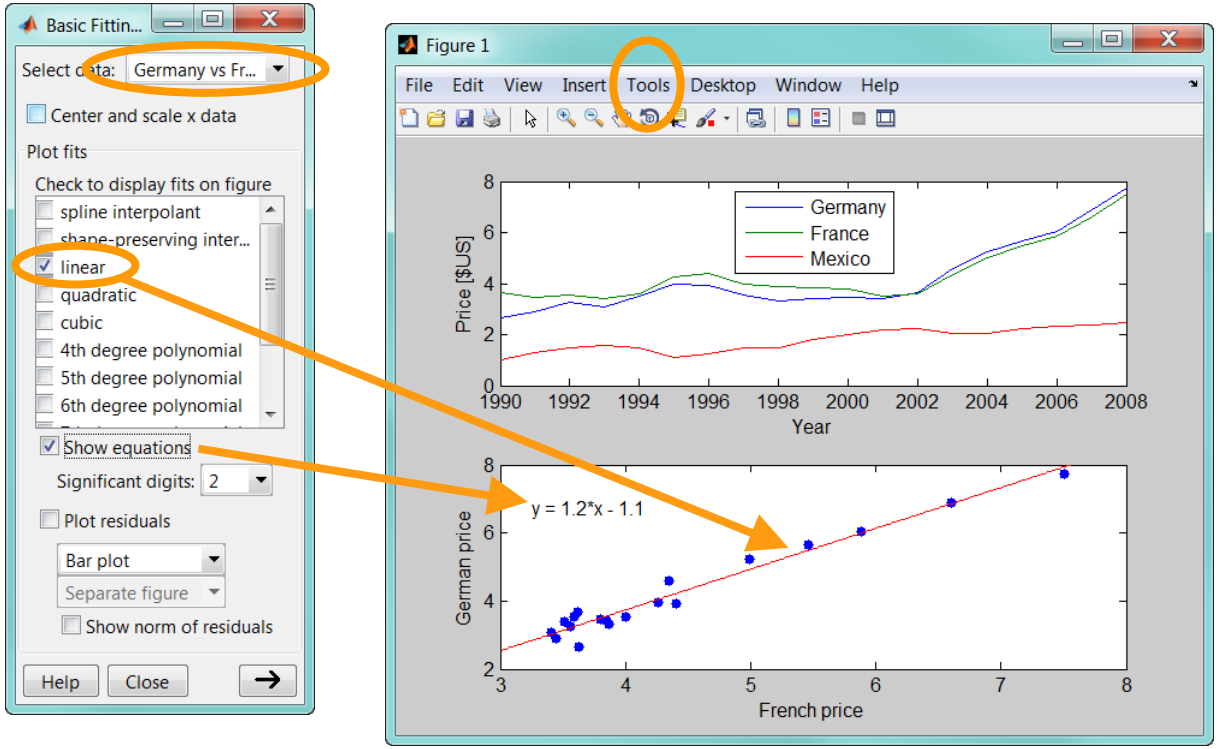
Multiple Plots



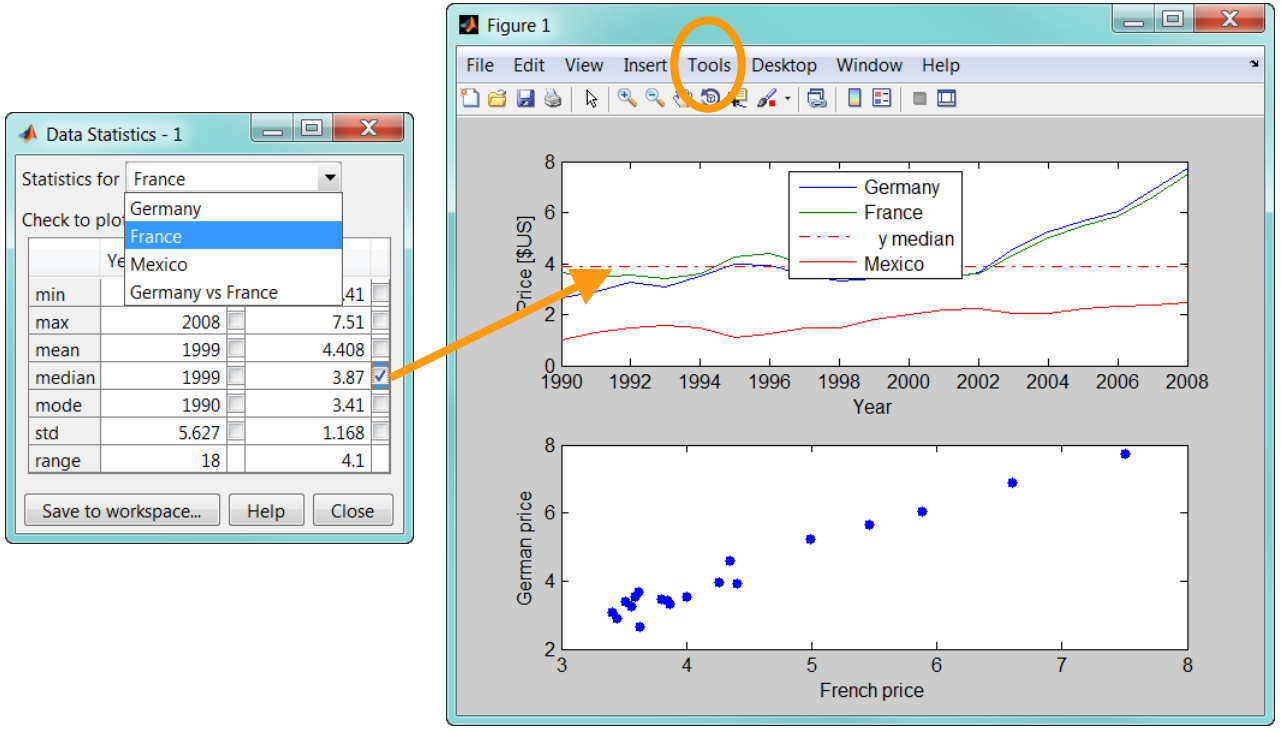
Formatting the Plot



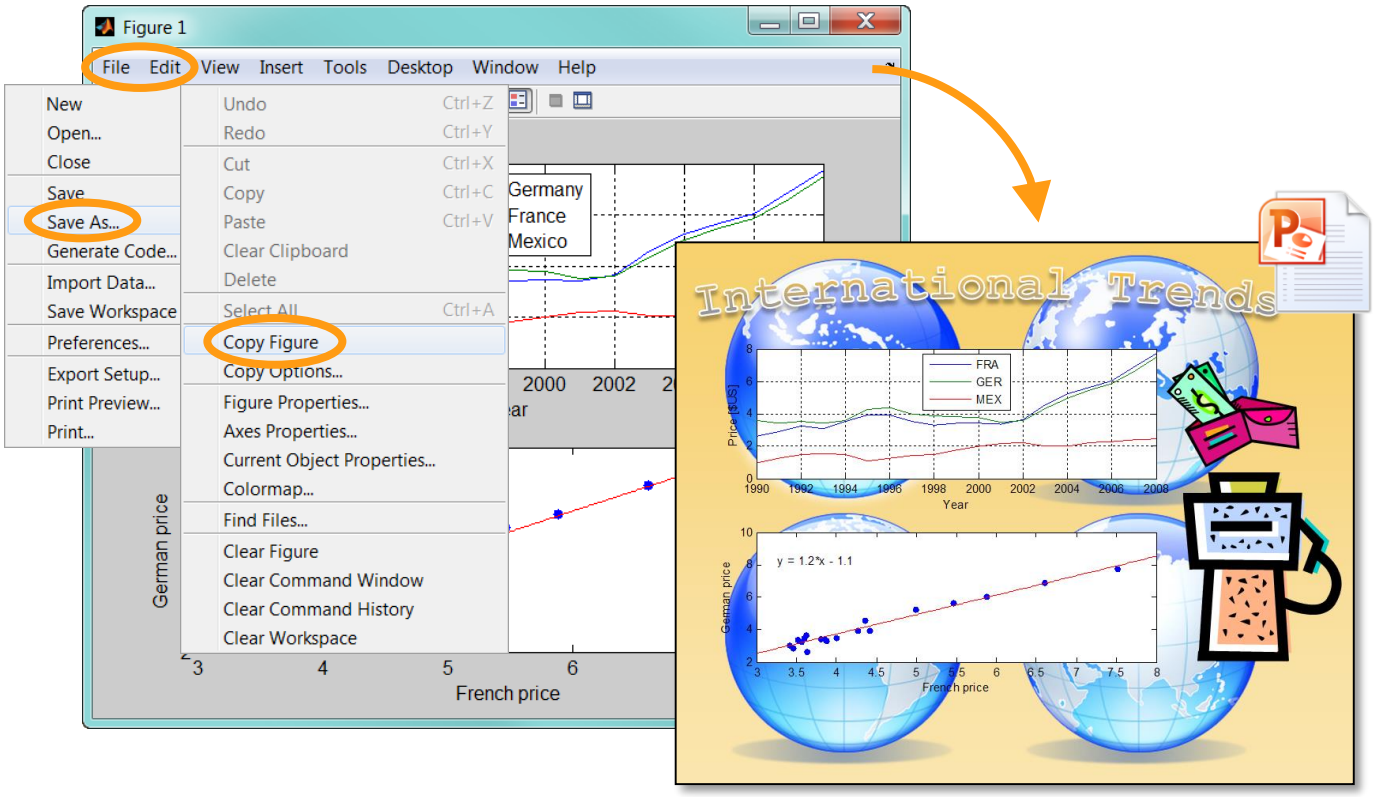
Basic Fitting Tool



Data Statistics Tool

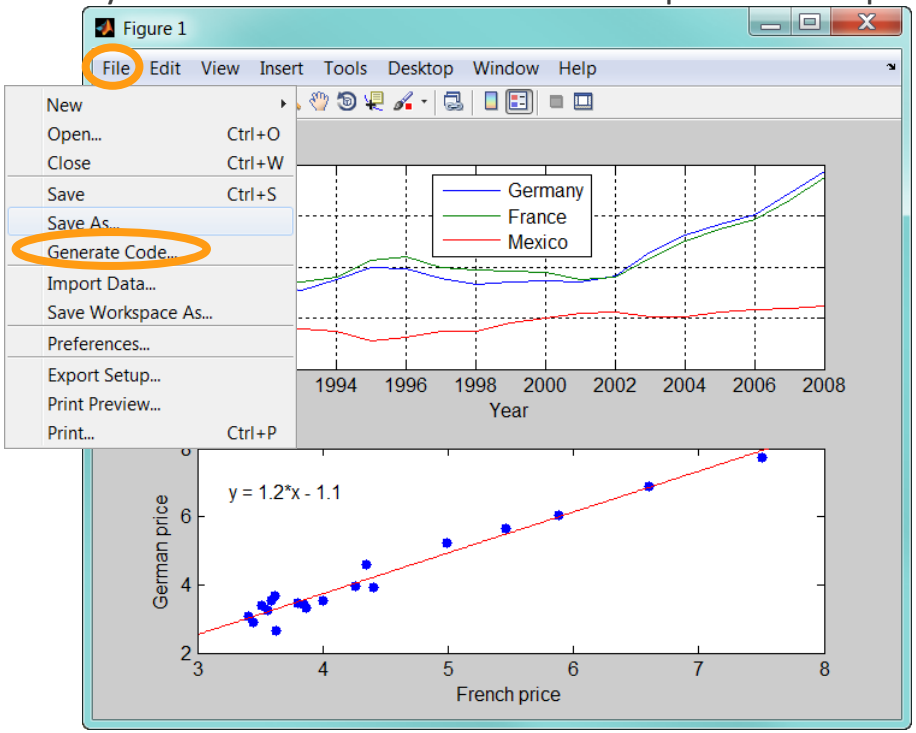


Exporting to Another Application

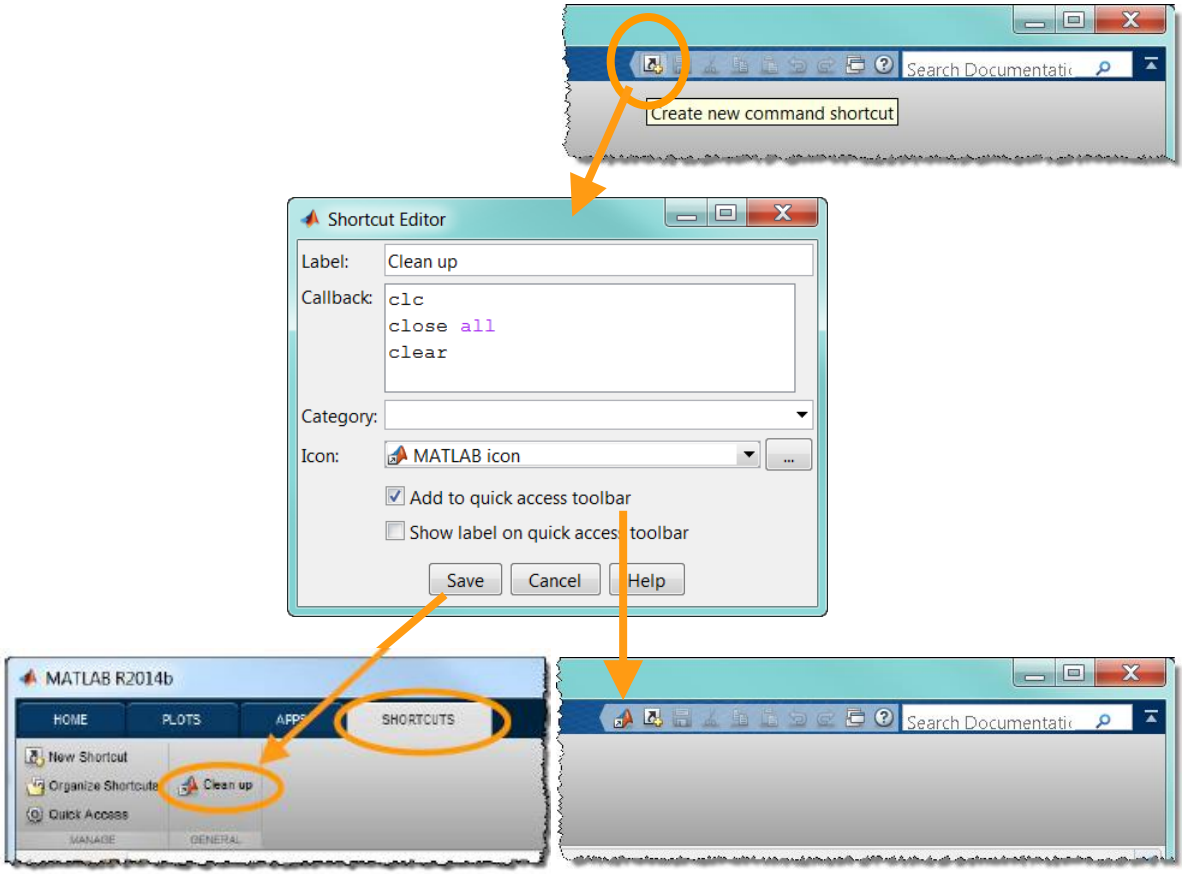


Generate M-file

- Automatically Create MATLAB Commands to Reproduce Graphics



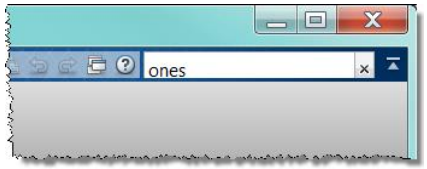
Shortcuts



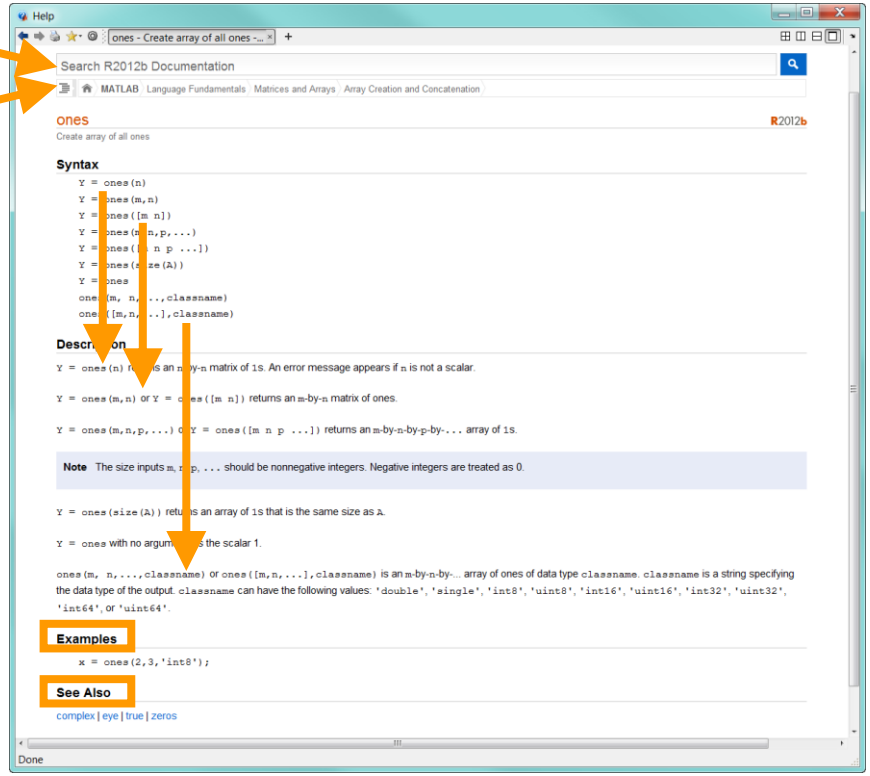
Help and Documentation

search

browse




```
help
doc
docsearch
```



Chapter 1 Test Your Knowledge

1. Where does MATLAB display a listing of the variables currently in memory and their associated attributes?
   A. Command Window
   B. Workspace browser
   C. Current Directory browser
   D. Command History

2. The default MATLAB variable type is:
   A. Single
   B. Double
   C. Cell

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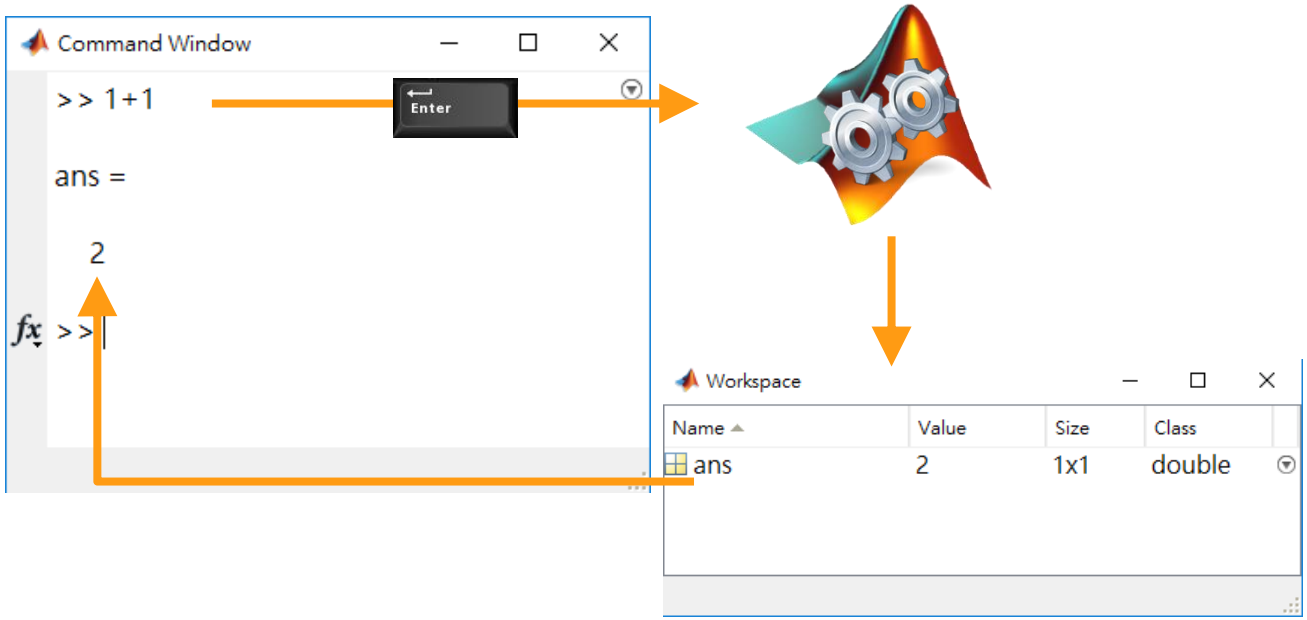
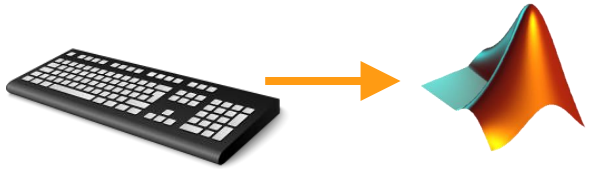
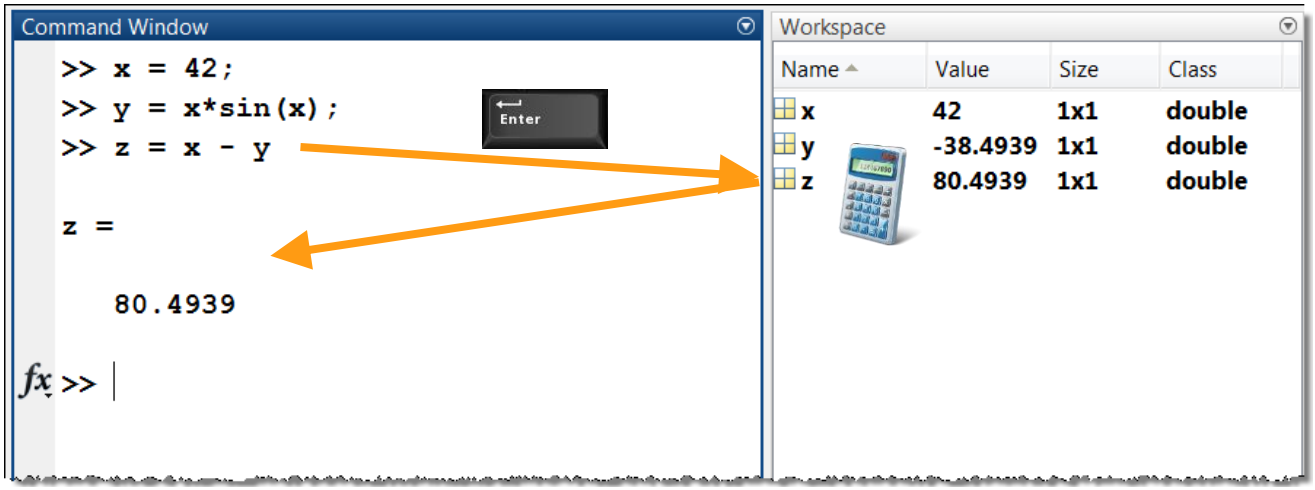
High-level Calculator

Operators: + - * / ^

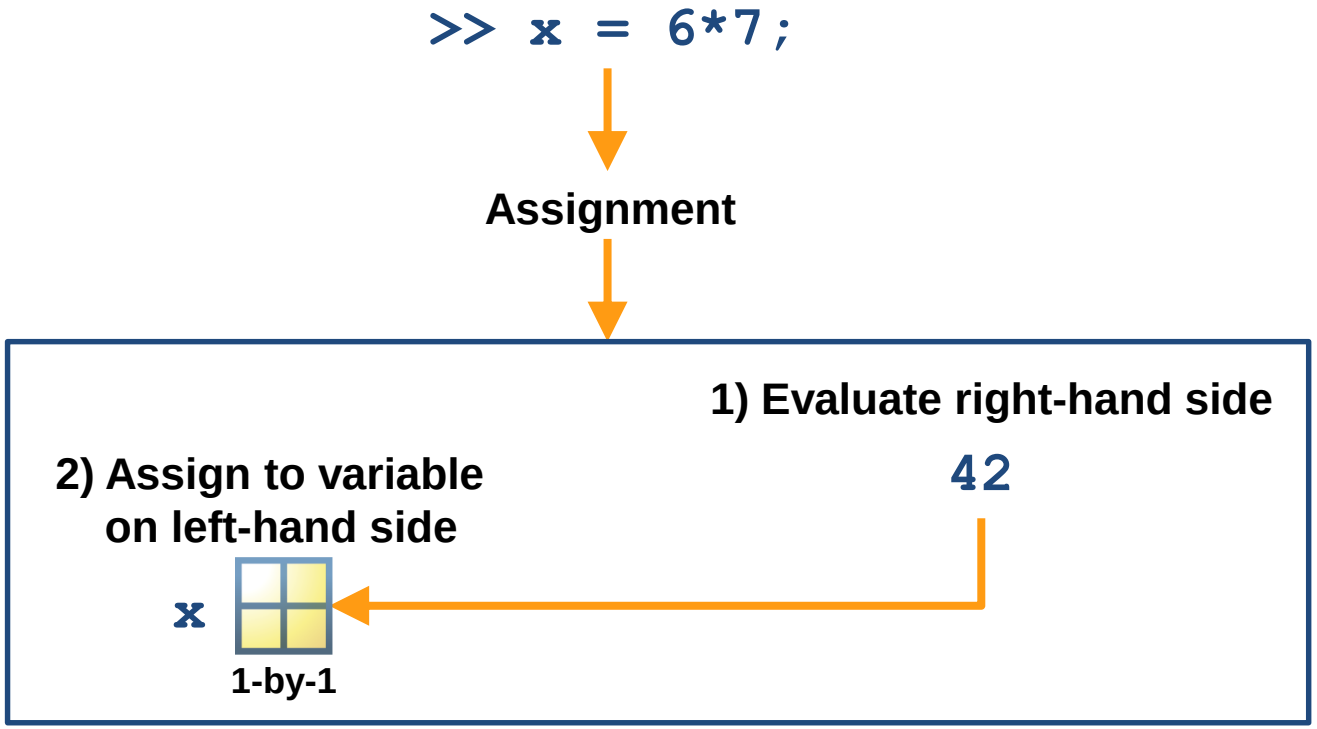


MATLAB® Commands





Storing Data in Variables



Chapter 2 Test Your Knowledge

1. The default MATLAB variable type is:
   A. Single
   B. Double
   C. Cell
2. Calculate question below :
   - $\mathbf{0.1} \times \frac{\mathbf{2}}{\mathbf{5}} + \mathbf{8}^{\mathbf{7}}$
   - $\boldsymbol{sin}(\mathbf{0.8}\boldsymbol{\pi})$
   - $\mathbf{10}^{\boldsymbol{ln}(\mathbf{13})\times\mathbf{6}}$
   - Find e^{x}, $x = \frac{\sqrt{(5+8)}}{49}$

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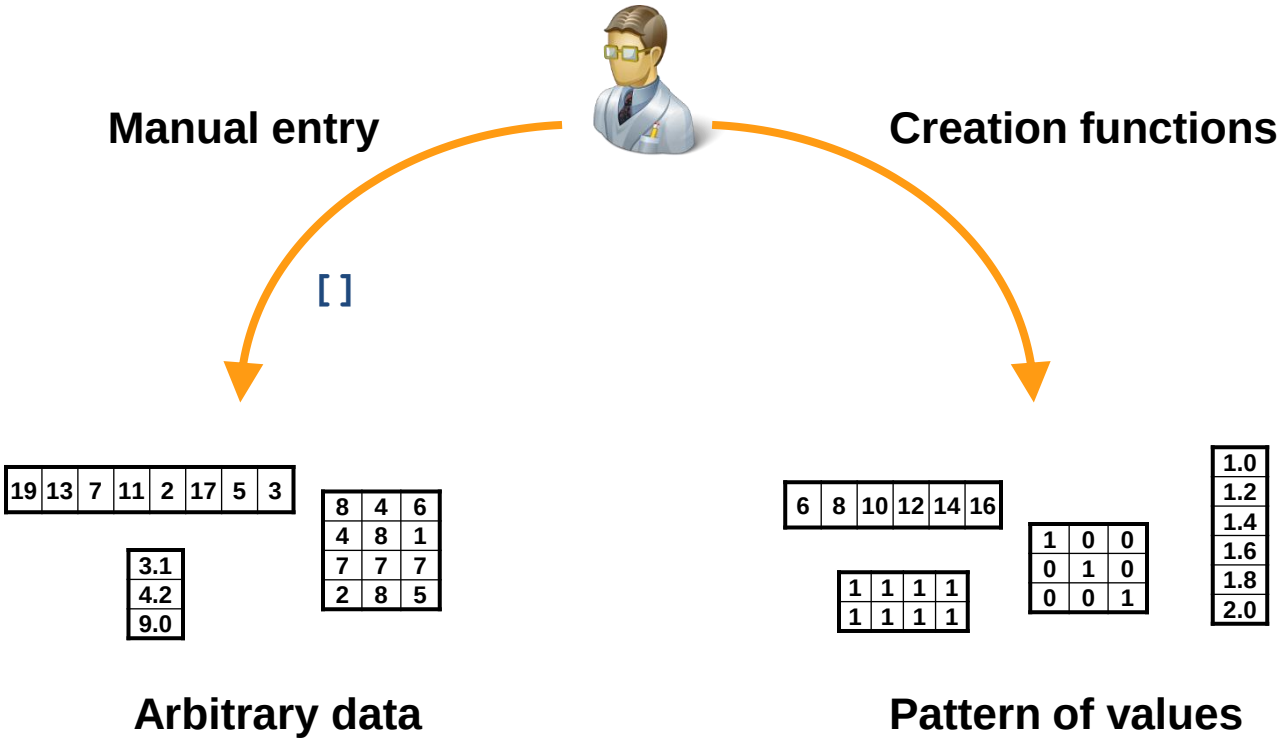
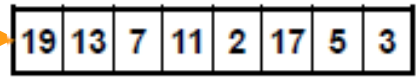
Creating Array

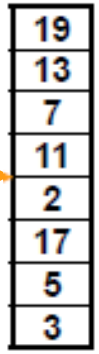


Entering Vectors Manually

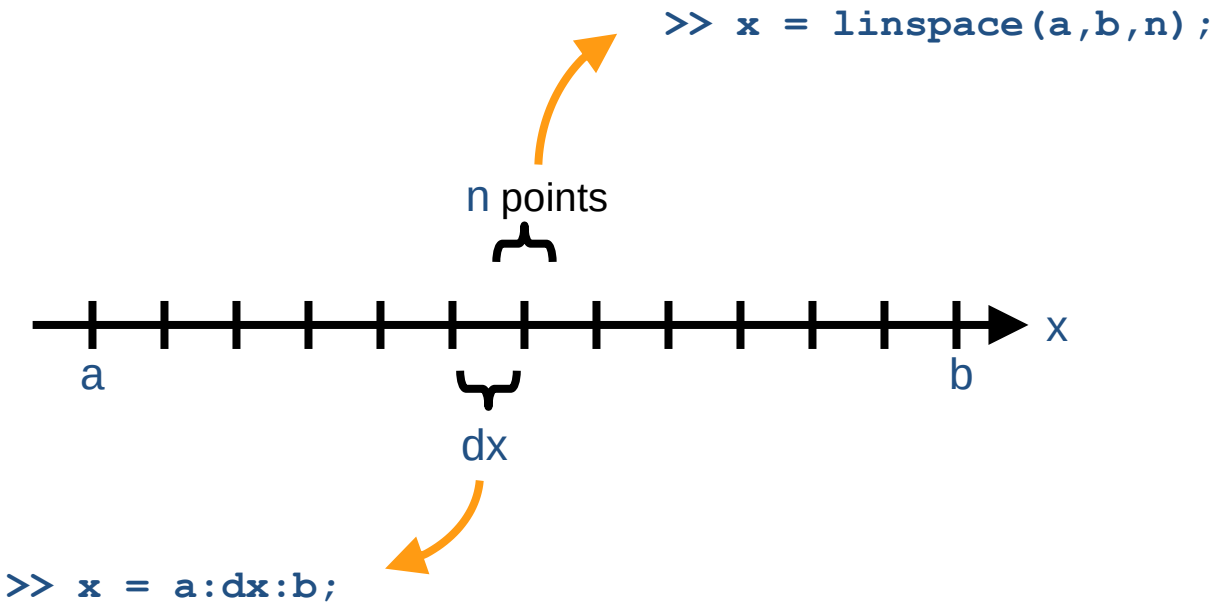
```
>> x = [19 13 7 11 2 17 5 3]
```




```
>> x = [19;13;7;11;2;17;5;3]
```



Creating Vectors of Equally Spaced Values



Entering Matrices Manually

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

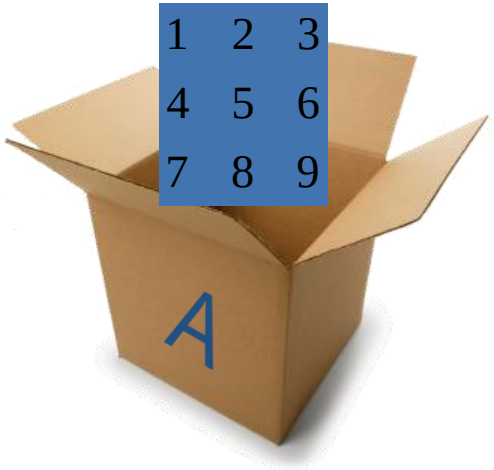
or

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

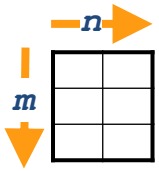
or

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

} data entry mode

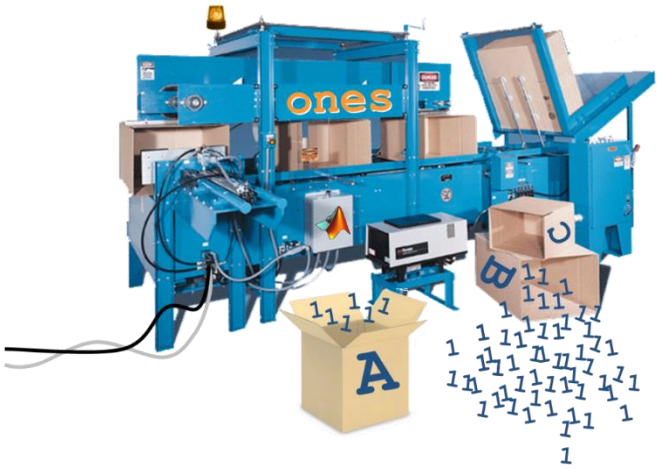


Creating Matrices




```
>> A = fun(m,n);
```

compan	pascal
eye	rand
gallery	randi
hadamard	randn
hankel	rosser
hilb	toeplitz
invhilb	vander
magic	wilkinson
ones	zeros



Concatenating Arrays

A

2	3
5	7
11	13

B

-1	1
1	-1

C

0
8
0

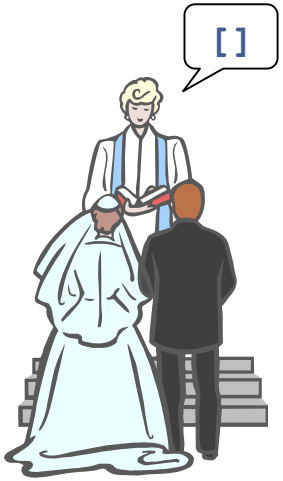
```
>> X = [A;B]
```

2	3
5	7
11	13
-1	1
1	-1

```
>> Y = [A,C]
```

2	3	0
5	7	8
11	13	0

!!!Please notice the dimension

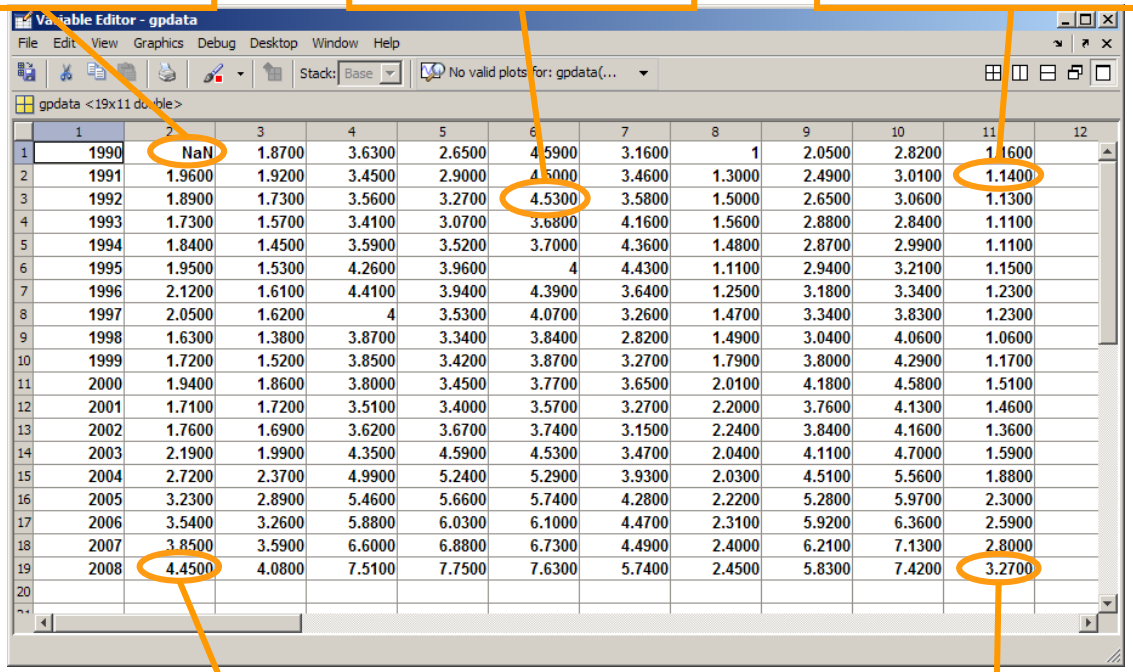


Row, Column Indexing

```
>> gpdata(1,2)
```

```
>> gpdata(3,6)
```

```
>> gpdata(2,end)
```



	1	2	3	4	5	6	7	8	9	10	11	12
1	1990	NaN	1.8700	3.6300	2.6500	4.5900	3.1600	1	2.0500	2.8200	1.1600	
2	1991	1.9600	1.9200	3.4500	2.9000	4.5000	3.4600	1.3000	2.4900	3.0100	1.1400	
3	1992	1.8900	1.7300	3.5600	3.2700	4.5300	3.5800	1.5000	2.6500	3.0600	1.1300	
4	1993	1.7300	1.5700	3.4100	3.0700	3.6800	4.1600	1.5600	2.8800	2.8400	1.1100	
5	1994	1.8400	1.4500	3.5900	3.5200	3.7000	4.3600	1.4800	2.8700	2.9900	1.1100	
6	1995	1.9500	1.5300	4.2600	3.9600	4	4.4300	1.1100	2.9400	3.2100	1.1500	
7	1996	2.1200	1.6100	4.4100	3.9400	4.3900	3.6400	1.2500	3.1800	3.3400	1.2300	
8	1997	2.0500	1.6200	4	3.5300	4.0700	3.2600	1.4700	3.3400	3.8300	1.2300	
9	1998	1.6300	1.3800	3.8700	3.3400	3.8400	2.8200	1.4900	3.0400	4.0600	1.0600	
10	1999	1.7200	1.5200	3.8500	3.4200	3.8700	3.2700	1.7900	3.8000	4.2900	1.1700	
11	2000	1.9400	1.8600	3.8000	3.4500	3.7700	3.6500	2.0100	4.1800	4.5800	1.5100	
12	2001	1.7100	1.7200	3.5100	3.4000	3.5700	3.2700	2.2000	3.7600	4.1300	1.4600	
13	2002	1.7600	1.6900	3.6200	3.6700	3.7400	3.1500	2.2400	3.8400	4.1600	1.3600	
14	2003	2.1900	1.9900	4.3500	4.5900	4.5300	3.4700	2.0400	4.1100	4.7000	1.5900	
15	2004	2.7200	2.3700	4.9900	5.2400	5.2900	3.9300	2.0300	4.5100	5.5600	1.8800	
16	2005	3.2300	2.8900	5.4600	5.6600	5.7400	4.2800	2.2200	5.2800	5.9700	2.3000	
17	2006	3.5400	3.2600	5.8800	6.0300	6.1000	4.4700	2.3100	5.9200	6.3600	2.5900	
18	2007	3.8500	3.5900	6.6000	6.8800	6.7300	4.4900	2.4000	6.2100	7.1300	2.8000	
19	2008	4.4500	4.0800	7.5100	7.7500	7.6300	5.7400	2.4500	5.8300	7.4200	3.2700	
20												

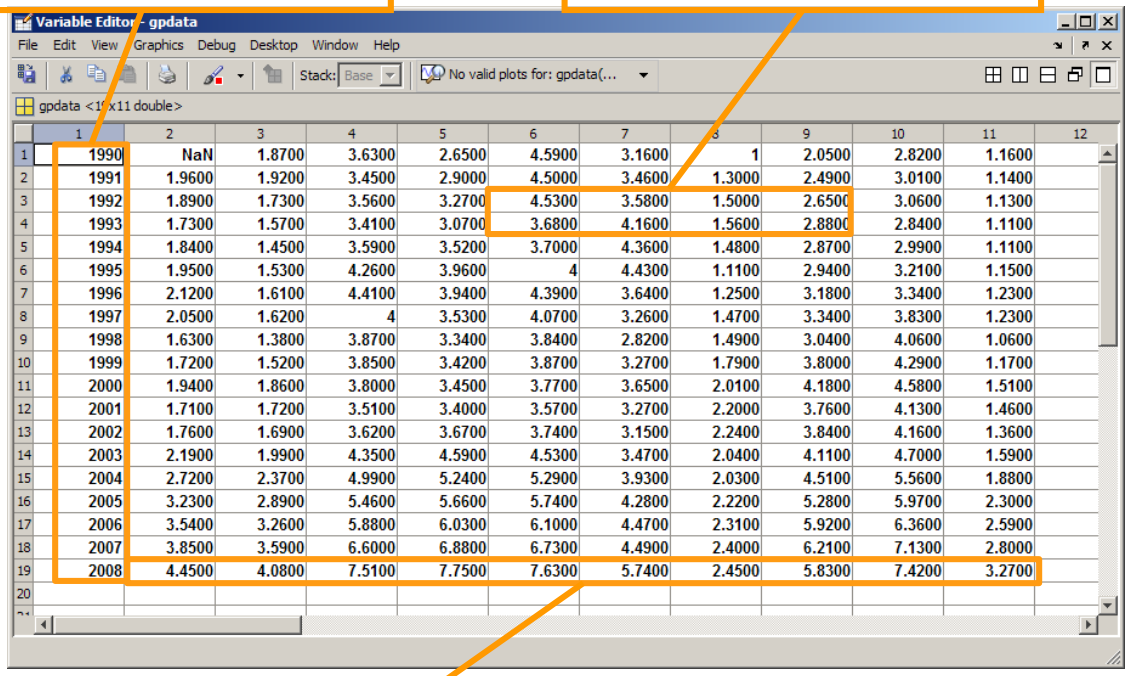
```
>> gpdata(end,2)
```

```
>> gpdata(end,end)
```

Multiple Row, Column Indices

```
>> Year = gpdata(:,1)
```

```
>> gpdata([3,4],6:9)
```



	1	2	3	4	5	6	7	8	9	10	11	12
1	1990	NaN	1.8700	3.6300	2.6500	4.5900	3.1600	1	2.0500	2.8200	1.1600	
2	1991	1.9600	1.9200	3.4500	2.9000	4.5000	3.4600	1.3000	2.4900	3.0100	1.1400	
3	1992	1.8900	1.7300	3.5600	3.2700	4.5300	3.5800	1.5000	2.6500	3.0600	1.1300	
4	1993	1.7300	1.5700	3.4100	3.0700	3.6800	4.1600	1.5600	2.8800	2.8400	1.1100	
5	1994	1.8400	1.4500	3.5900	3.5200	3.7000	4.3600	1.4800	2.8700	2.9900	1.1100	
6	1995	1.9500	1.5300	4.2600	3.9600	4	4.4300	1.1100	2.9400	3.2100	1.1500	
7	1996	2.1200	1.6100	4.4100	3.9400	4.3900	3.6400	1.2500	3.1800	3.3400	1.2300	
8	1997	2.0500	1.6200	4	3.5300	4.0700	3.2600	1.4700	3.3400	3.8300	1.2300	
9	1998	1.6300	1.3800	3.8700	3.3400	3.8400	2.8200	1.4900	3.0400	4.0600	1.0600	
10	1999	1.7200	1.5200	3.8500	3.4200	3.8700	3.2700	1.7900	3.8000	4.2900	1.1700	
11	2000	1.9400	1.8600	3.8000	3.4500	3.7700	3.6500	2.0100	4.1800	4.5800	1.5100	
12	2001	1.7100	1.7200	3.5100	3.4000	3.5700	3.2700	2.2000	3.7600	4.1300	1.4600	
13	2002	1.7600	1.6900	3.6200	3.6700	3.7400	3.1500	2.2400	3.8400	4.1600	1.3600	
14	2003	2.1900	1.9900	4.3500	4.5900	4.5300	3.4700	2.0400	4.1100	4.7000	1.5900	
15	2004	2.7200	2.3700	4.9900	5.2400	5.2900	3.9300	2.0300	4.5100	5.5600	1.8800	
16	2005	3.2300	2.8900	5.4600	5.6600	5.7400	4.2800	2.2200	5.2800	5.9700	2.3000	
17	2006	3.5400	3.2600	5.8800	6.0300	6.1000	4.4700	2.3100	5.9200	6.3600	2.5900	
18	2007	3.8500	3.5900	6.6000	6.8800	6.7300	4.4900	2.4000	6.2100	7.1300	2.8000	
19	2008	4.4500	4.0800	7.5100	7.7500	7.6300	5.7400	2.4500	5.8300	7.4200	3.2700	
20												

```
>> gp08 = gpdata(end,2:end)
```

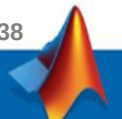
Linear Indexing

```
>> A = magic(5)
A =
```

1	17	6	24	11	1	16	8	21	15
2	23	7	5	12	7	17	14	22	16
3	4	8	6	13	13	18	20	23	22
4	10	9	12	14	19	19	21	24	3
5	11	10	18	15	25	20	2	25	9

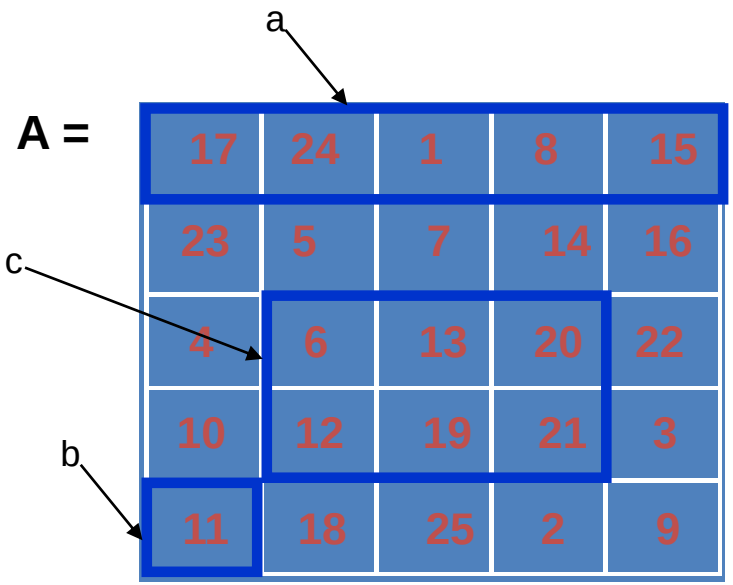
Indices Data

end

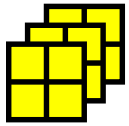


Exercise

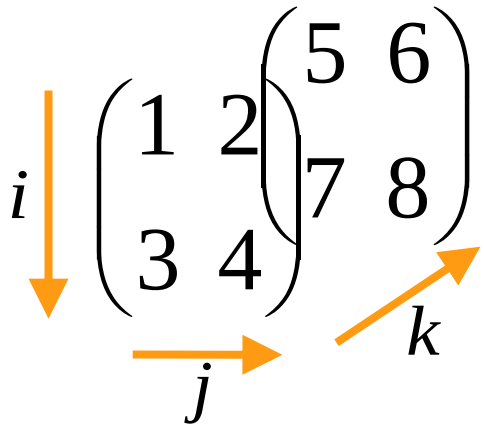
- `A = magic(5)`
- `a=A(?)`
- `b=A(?)`
- `c=A(?)`



Multidimensional Arrays



`A(i,j,k)`

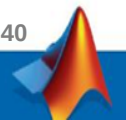


Construct

```
>> A(:,:,1) = [1, 2; 3, 4];
>> A(:,:,2) = [5, 6; 7, 8];
>> B = rand(2,2,3);
```

Access

```
>> A(:,2,1)
ans =
    2
    4
```

Chapter 3-1 Test Your Knowledge

1. (Select all that apply) Which of the following will create a matrix with three rows?

```
A. A = [zeros(2,4);ones(1,4)];
B. A = [1;2;3,4;5;6];
C. A = [1,2;3,4;5,6]';
D. A = rand(3);
```

2. Given a 5-by-5 matrix A, `A(4:end,3:4)` will produce a matrix of what size?

   A. 1-by-2
   B. 2-by-2
   C. 2-by-3
   D. 3-by-2

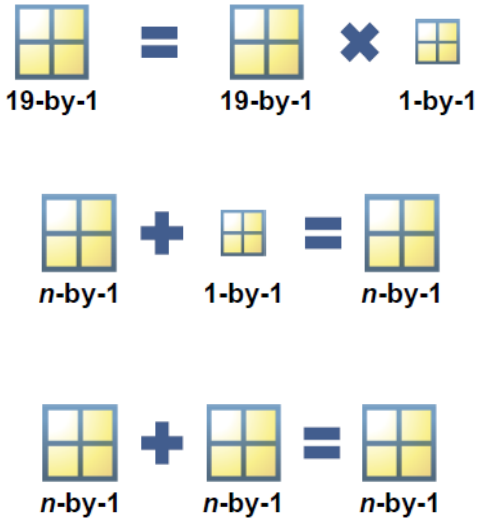
3. (Select all that apply) Which commands are equivalent to the command `>> x = 1.4:2:6.8;`?

```
A. X = [1.4 2 6.8];
B. X = [1.4 6.8];
C. X = [1.4 3.4 5.4];
D. X = [1.4 3.4 5.4 6.8];
E. X = [3.4 5.4];
```


Array Operations

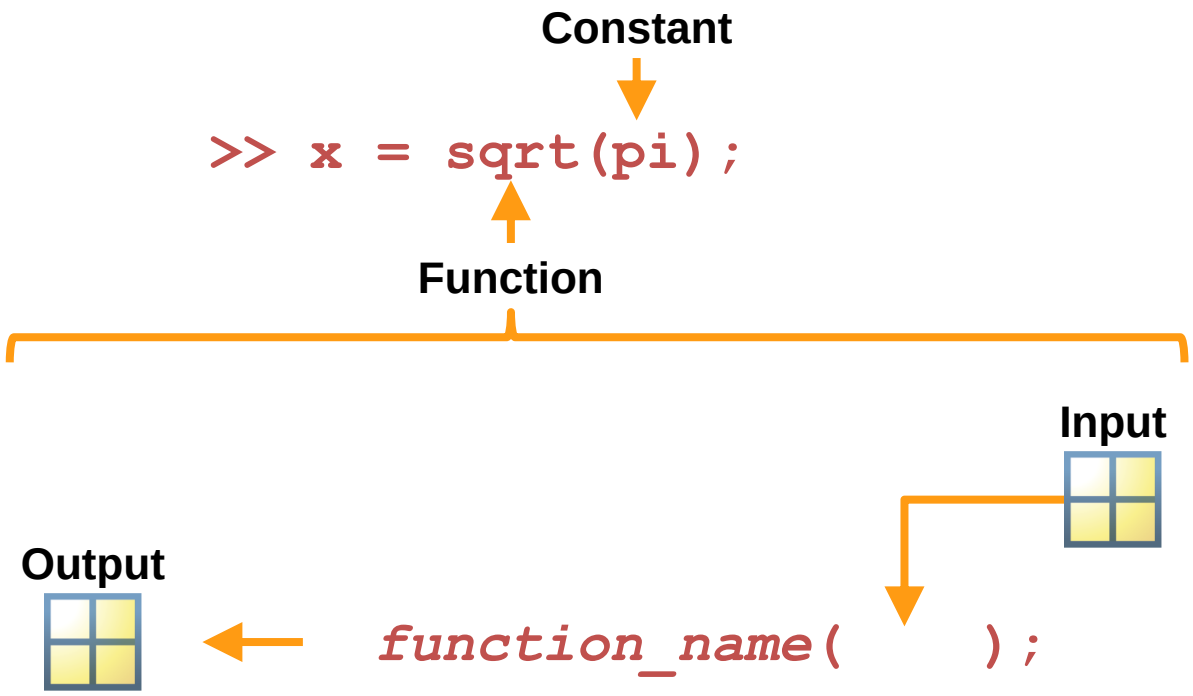
```
>> GMSum = Germany + Mexico
```

3.65	=	2.65	+	1.00
4.20		2.90		1.30
4.77		3.27		1.50
4.63		3.07		1.56
5.00		3.52		1.48
5.07		3.96		1.11
5.19		3.94		1.25
5.00		3.53		1.47
4.83		3.34		1.49
5.21		3.42		1.79
5.46		3.45		2.01
5.60		3.40		2.20
5.91		3.67		2.24
6.63		4.59		2.04
7.27		5.24		2.03
7.88		5.66		2.22
8.34		6.03		2.31
9.28		6.88		2.40
10.20		7.75		2.45



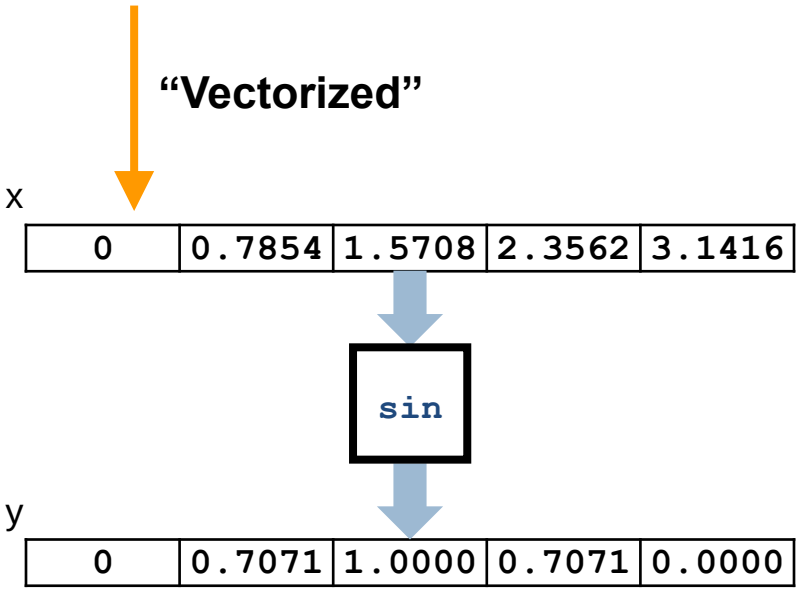

```
>> load gasprices
```

Using Built-In Functions and Constants



Mathematical Functions

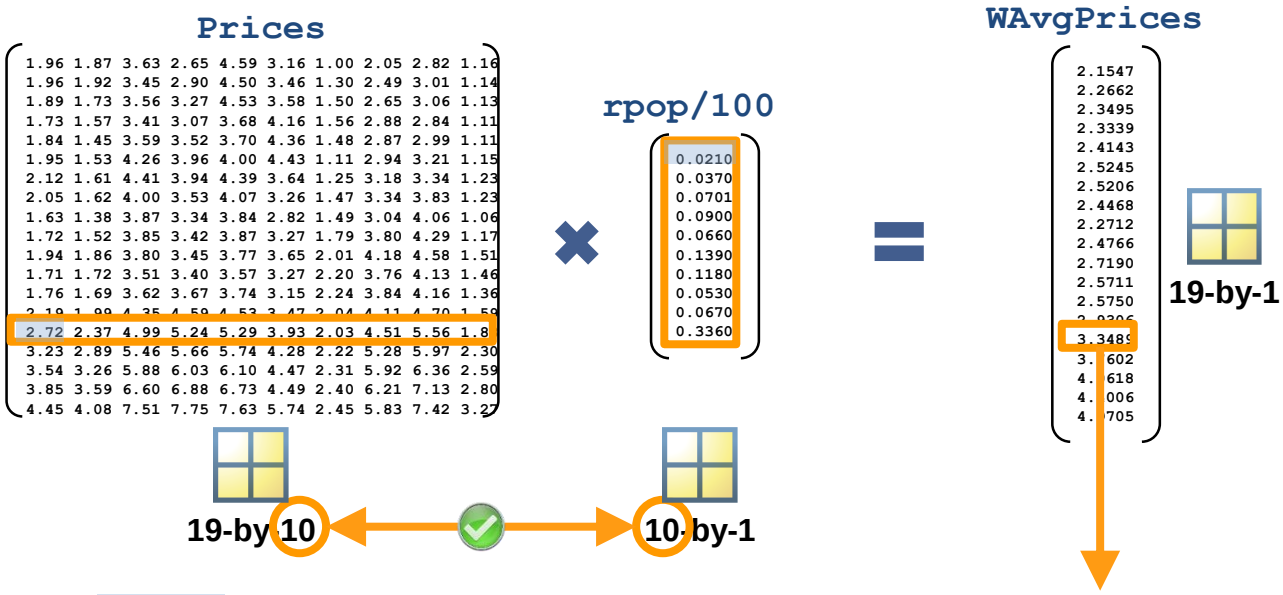
```
>> y = sin(x);
```



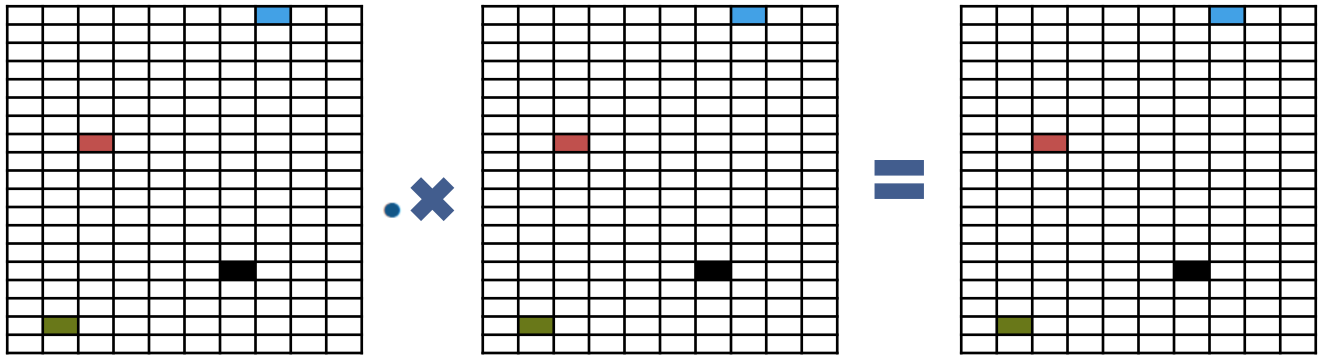

```
sin
sind
sinh
asin
exp
log
log2
log10
sqrt
nthroot
abs
angle
floor
ceil
round
mod
```

Matrix Operations

Inner dimensions must be equal!!

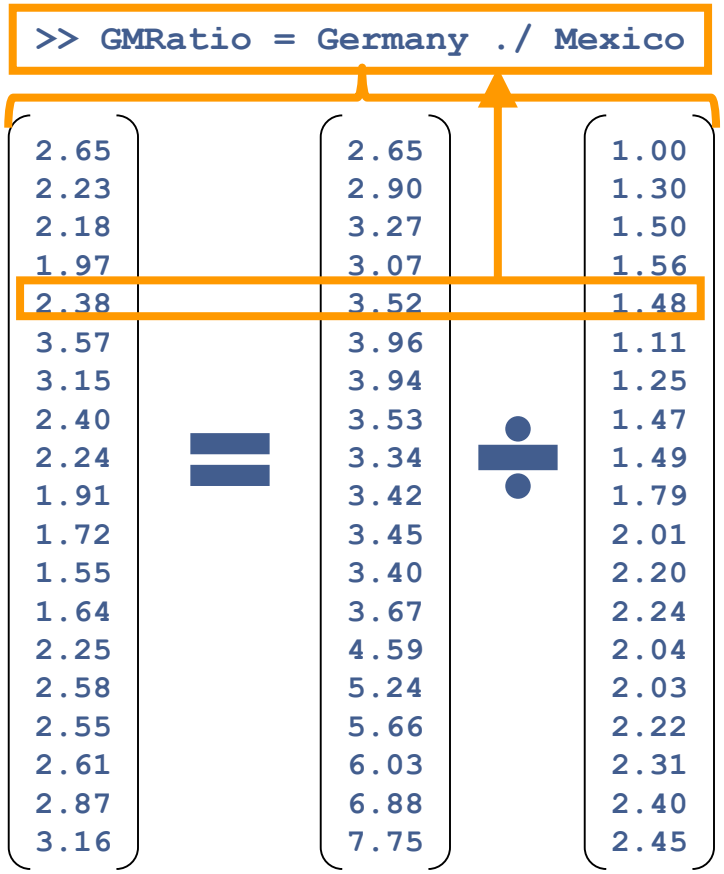


Array Operations

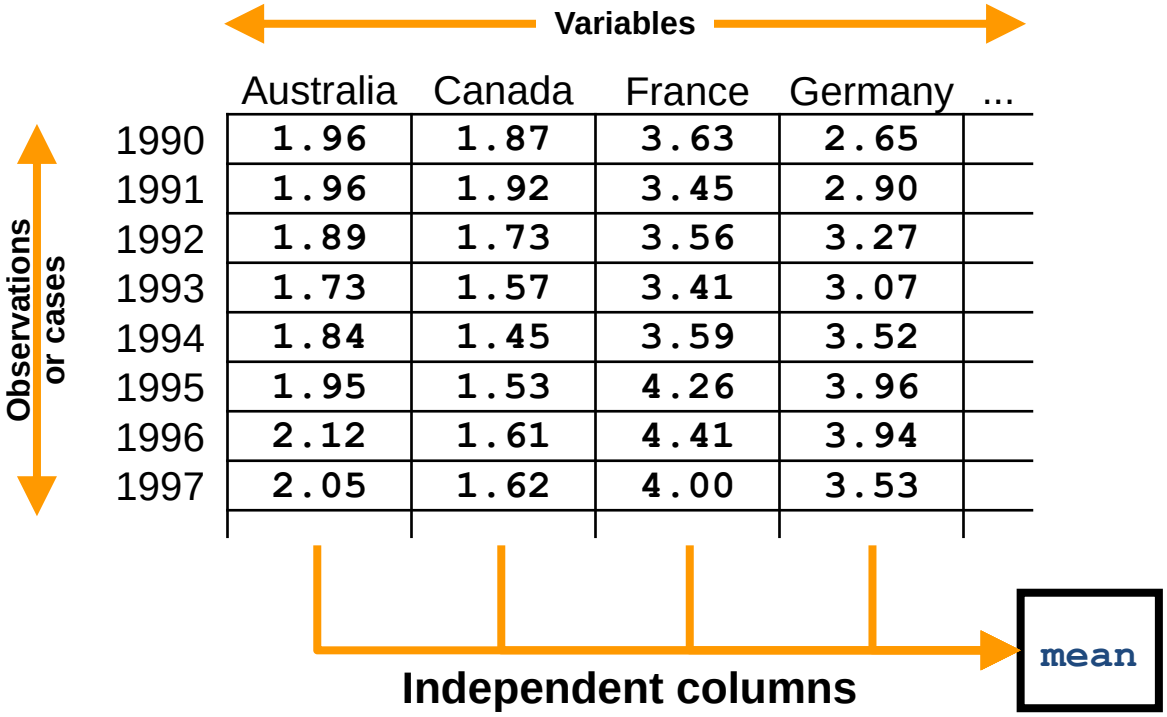


Array Operations (Cont.)

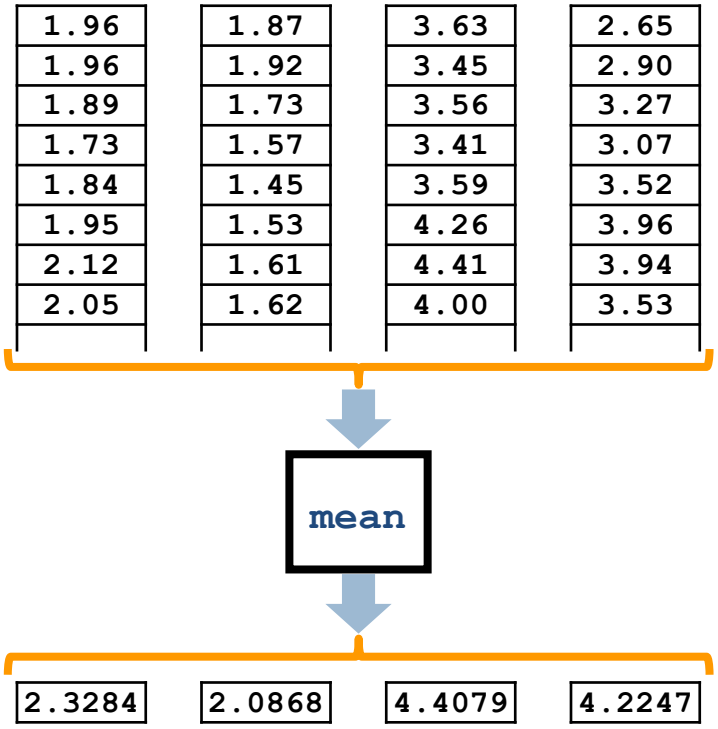
Matrices must have the same dimensions!!



Data in the MATLAB® Environment



Statistical Operations




```
max
min
mean
median
std
sum
prod
diff
gradient
cumsum
cumprod
corrcoef
cov
```

Example: Array Operations

- In most languages - use loops:

```
>> tic; for I = 1:10000
Density(I) = Mass(I)/(Length(I)*Width(I)*Height(I));
end; toc
elapsed_time =
   4.7260
```

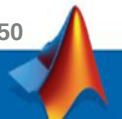
Use TIC and TOC to measure elapsed time

- In MATLAB - use array operations:

```
>> tic; Density = Mass./(Length.*Width.*Height); toc
elapsed_time =
     0
```

Vectorized code is much faster than loops

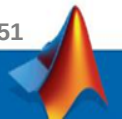
```
>> array_examp
```

Chapter 3-2 Test Your Knowledge

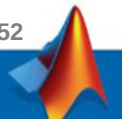
1. (Select all that apply) Given two matrices, `A` and `B`, where `A` is a 2-by-3 matrix and `B` is a 3-by-2 matrix, which of the following operations are valid?
   - **A.** `A+B`
   - **B.** `A.+B`
   - **C.** `A*B`
   - **D.** `A.*B`

2. Given a vector `x`, what is the command to add 3 to each element, double that value, then sum all the resulting values?
   - **A.** `sum(2*x+3)`
   - **B.** `sum(2*[x(k)+3])`
   - **C.** `sum[2*x+3]`
   - **D.** `sum(2*(x+3))`

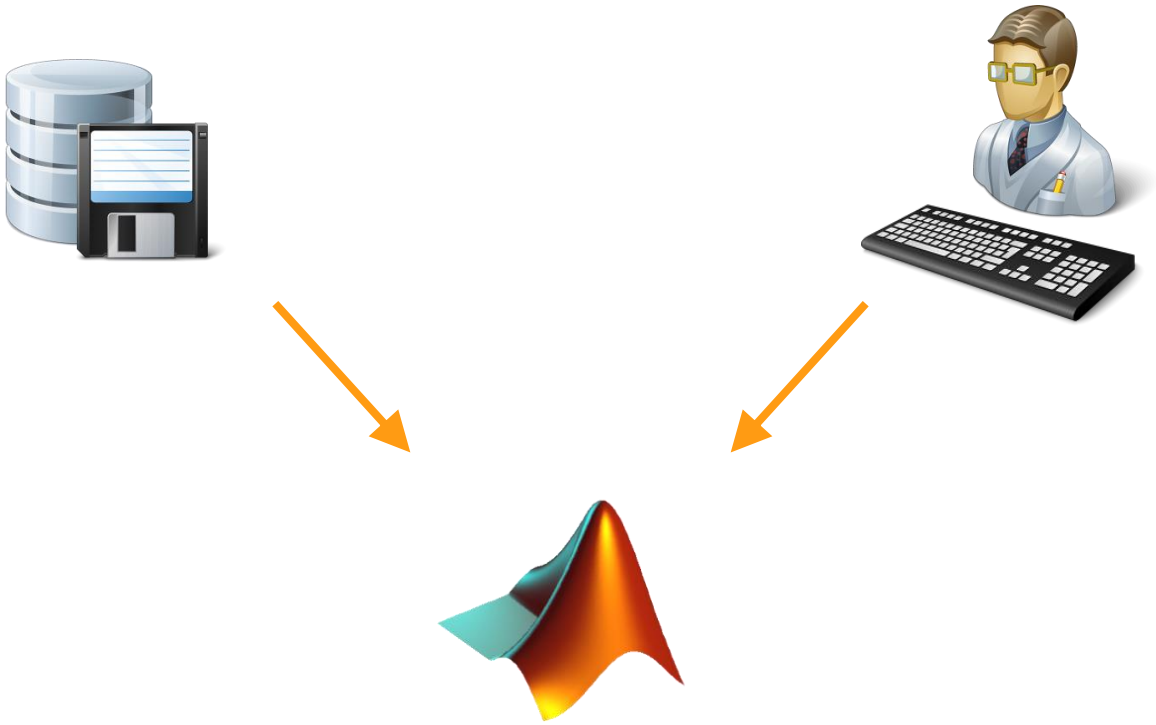


Course Outline

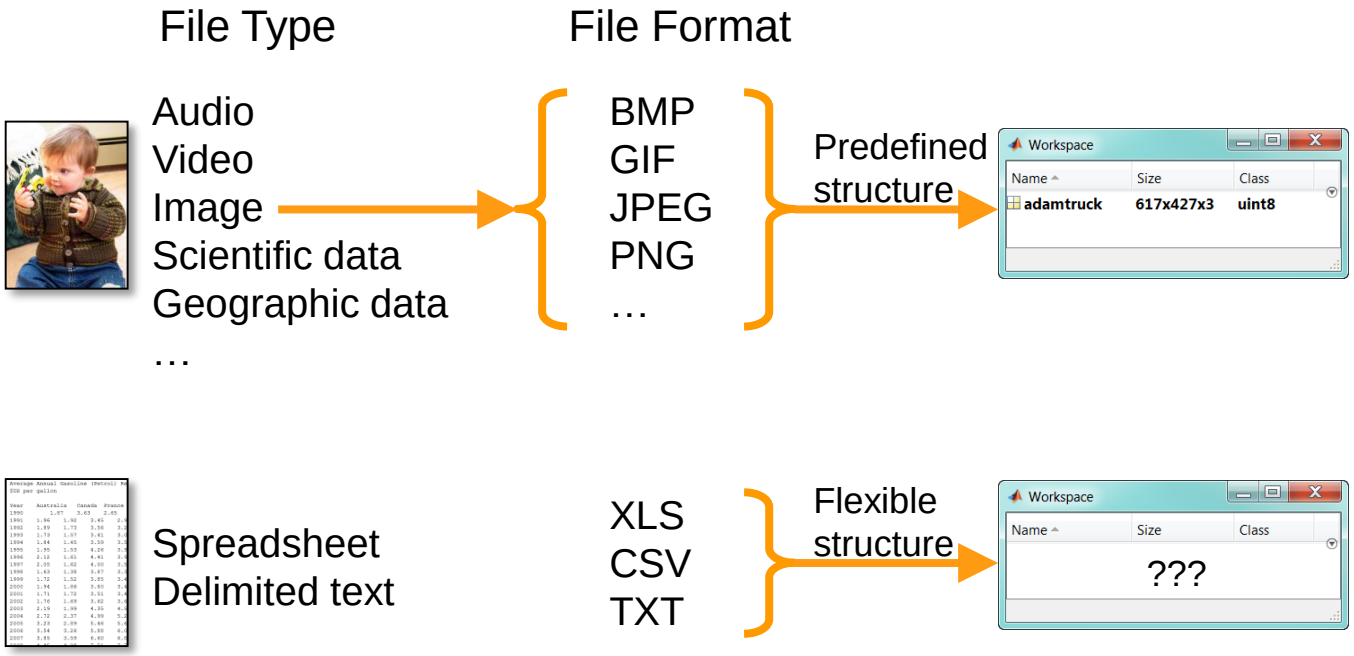
- Working with the MATLAB User Interface
- Variables and Commands
- Array Creation and Analysis
- Working with Data Files
- Visualization with Array
- Automating Commands with Scripts
- Appendix: Data Type



Getting Data into MATLAB®



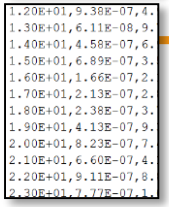
File Types and File Formats



Reading and Writing Fixed-Structure Files

audioread

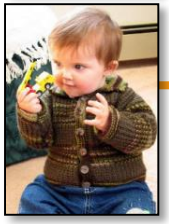
cdfread



csvread

dlmread

h5read



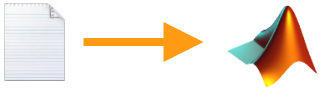
imread

ncread

urlread

xmlread

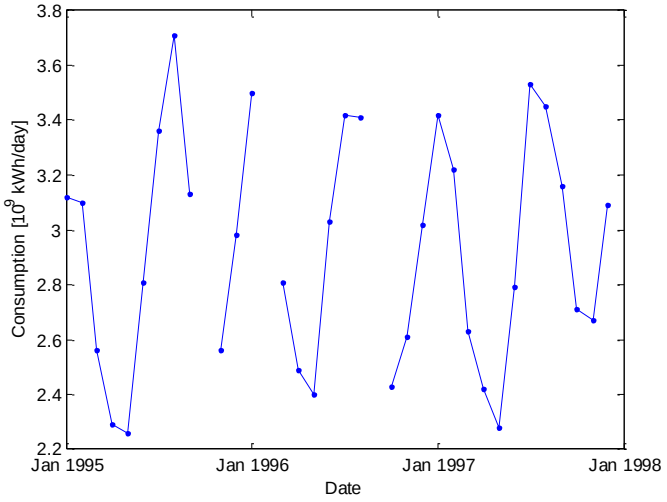
...



```
data = xyzread('file.xyz')
```

```
xyzwrite(data,'file.xyz')
```

Dealing with Missing Data




```
>> load electricityNaNs
>> x = Residential(215:220);
>> mean(x)
>> nnz(isnan(x))
```

```
mean
```

```
3.1900
    0
4.0300
    0
4.3800
    0

   NaN
3.4300
    0
3.0500
    0
```

```
ans =
   NaN
```

```
>> nanmean(x)
```

```
3.1900
    0
4.0300
    0
4.3800
    0

   NaN
3.4300
    0
3.0500
    0
```

```
>> x(isnan(x)) =
[];
>> mean(x)
```

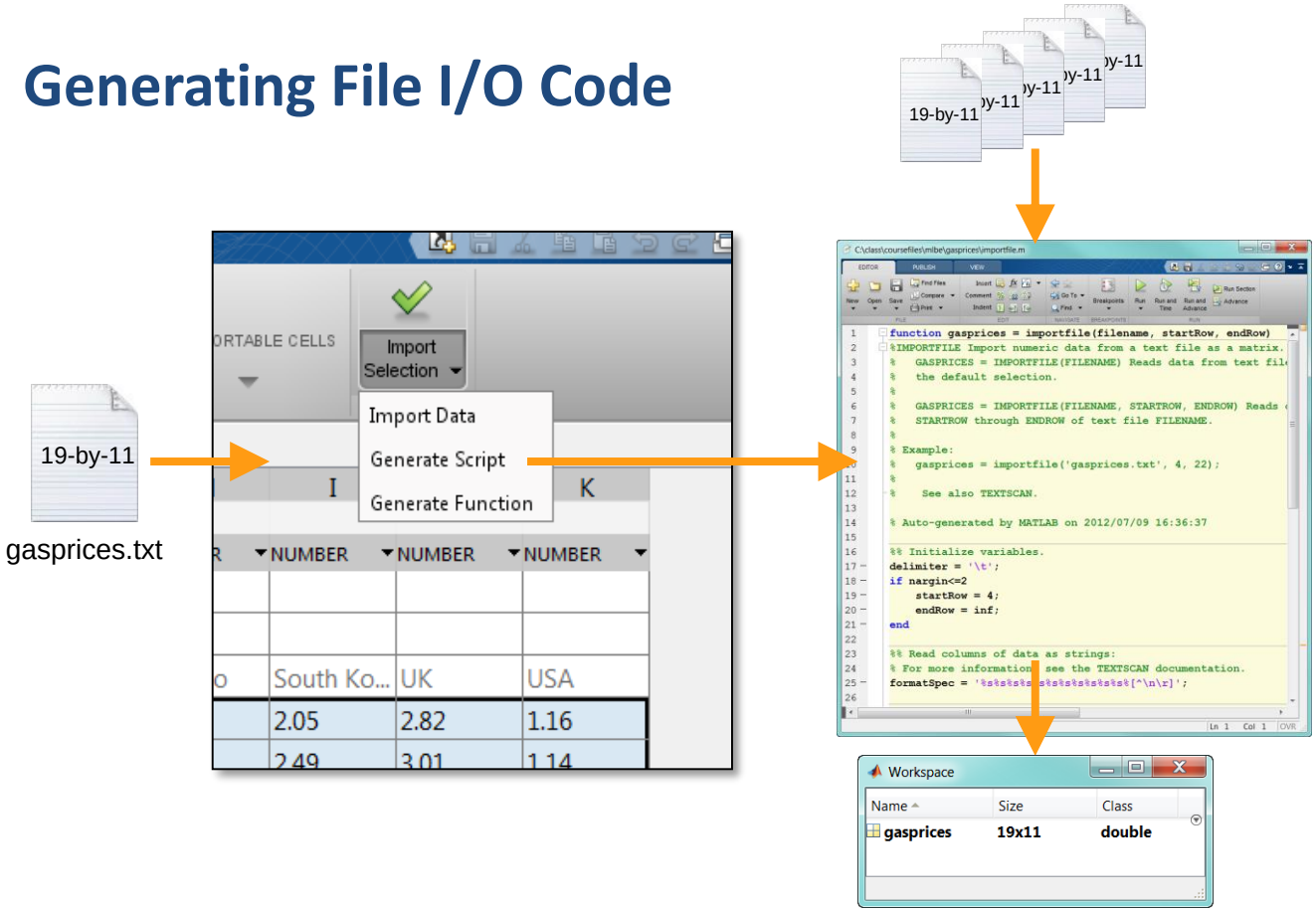
```
3.1900
    0
4.0300
    0
4.3800
    0

3.4300
    0
3.0500
    0
```

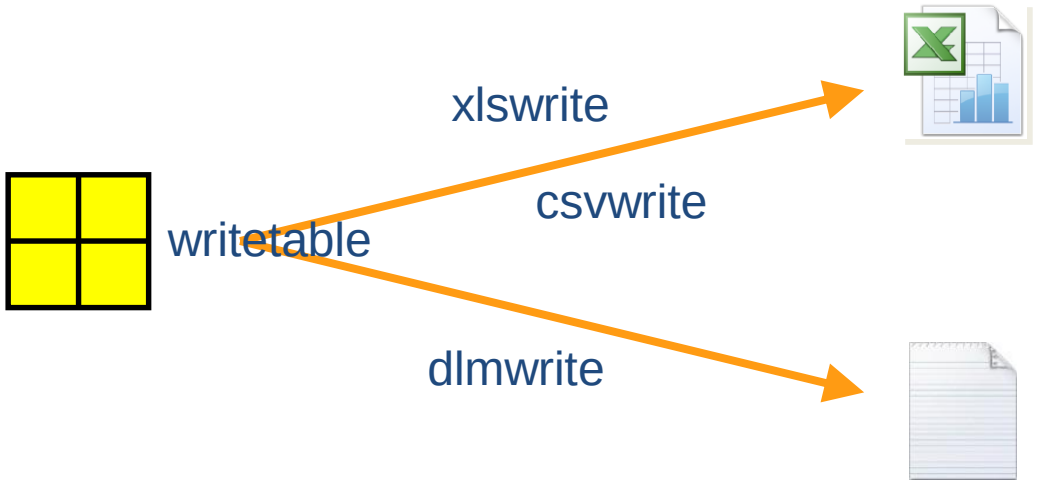
```
>> x(isnan(x)) =
3.8808;
>> mean(x)
```

```
3.1900
    0
4.0300
    0
4.3800
    0
3.8808
3.4300
    0
3.0500
    0
```

Generating File I/O Code



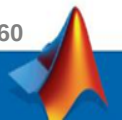
Exporting Spreadsheets



Chapter 4 Test Your Knowledge

1. (Select all that apply) Which of the following can you change when importing a delimited text file with the Import Tool?
   A. Which columns to import.
   B. The format (text, number, date, etc.) of each column.
   C. The delimiter character.
   D. How to import missing values.

2. Suppose “ABC” is a supported format in MATLAB. Which command would import data from an ABC file mydata.abc into a matrix A?
   A. `mydata = abcread(A);`
   B. `abcread(A,mydata);`
   C. `abcread('mydata.abc',A);`
   D. `A = abcread('mydata.abc');`
   E. `A = abcread(mydata);`



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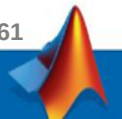
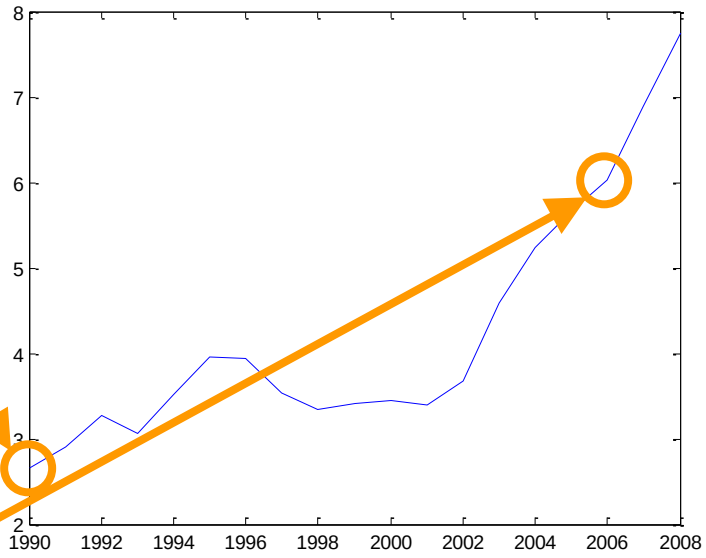


Plotting Vectors

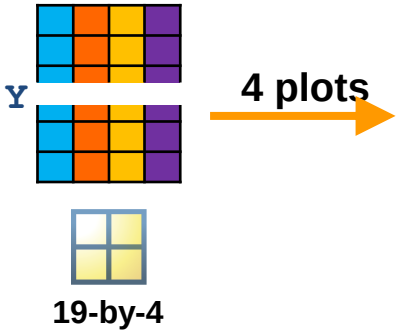
```
>> plot(Year,Germany)
```

1990	2.65
1991	2.90
1992	3.27
1993	3.07
1994	3.52
1995	3.96
1996	3.94
1997	3.53
1998	3.34
1999	3.42
2000	3.45
2001	3.40
2002	3.67
2003	4.59
2004	5.24
2005	5.66
2006	6.03
2007	6.88
2008	7.75

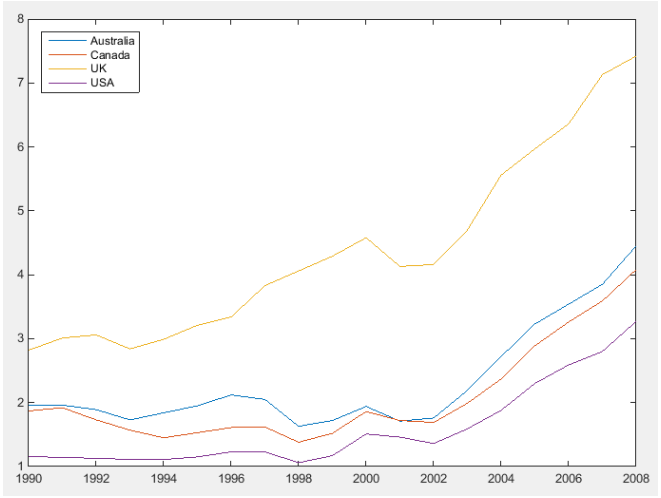


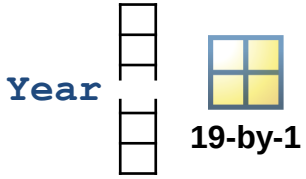
Plotting Multiple Columns

```
>> EndIdx = [1 2 9 10];
>> Y = Prices(:, EndIdx);
>> plot(Year,Y)
>> legend(country(EndIdx),'Location','NW')
```



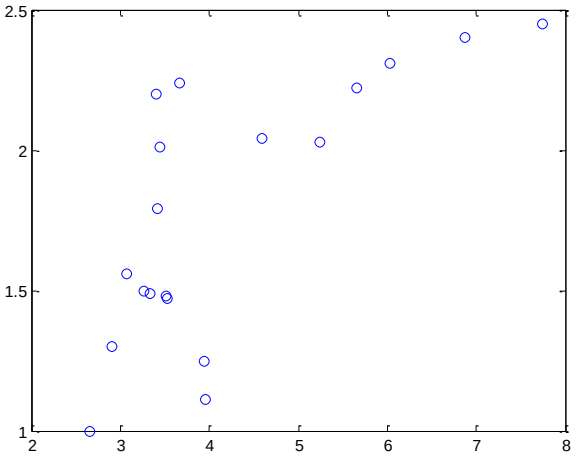
4 plots





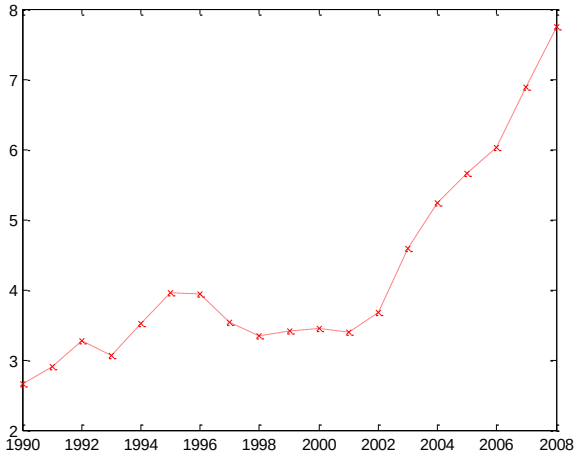
Plot Options

Data Type



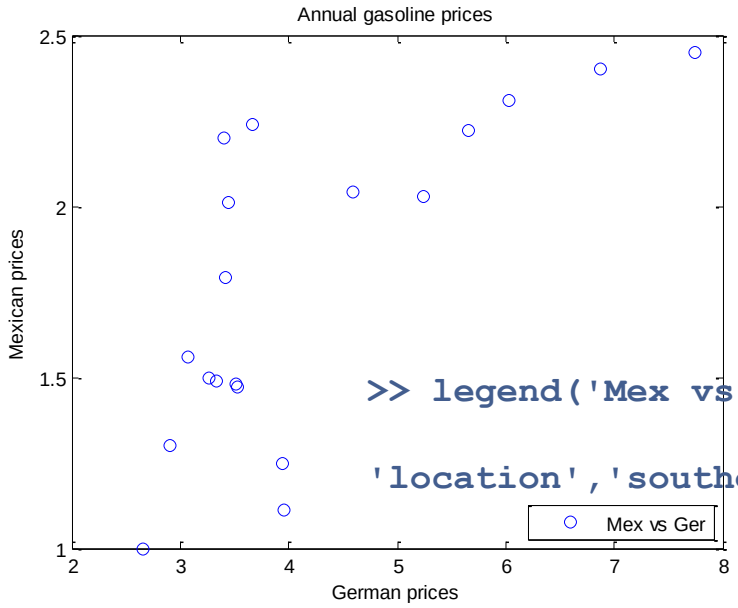

```
>> plot(Germany,Mexico,'o')
```

```
>> plot(Year,Germany,'rx:')
```



Annotating Plots

```
>> title('Annual gasoline prices')
```



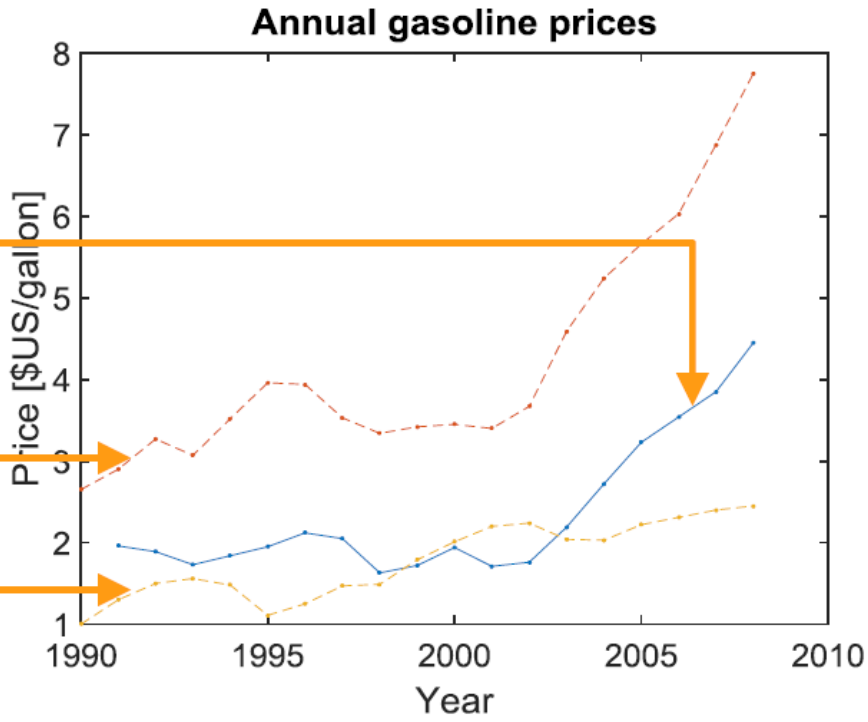

```
>> ylabel('Mexican prices')
```

```
>> legend('Mex vs Ger',...
'location','southeast')
```

```
>> xlabel('German prices')
```

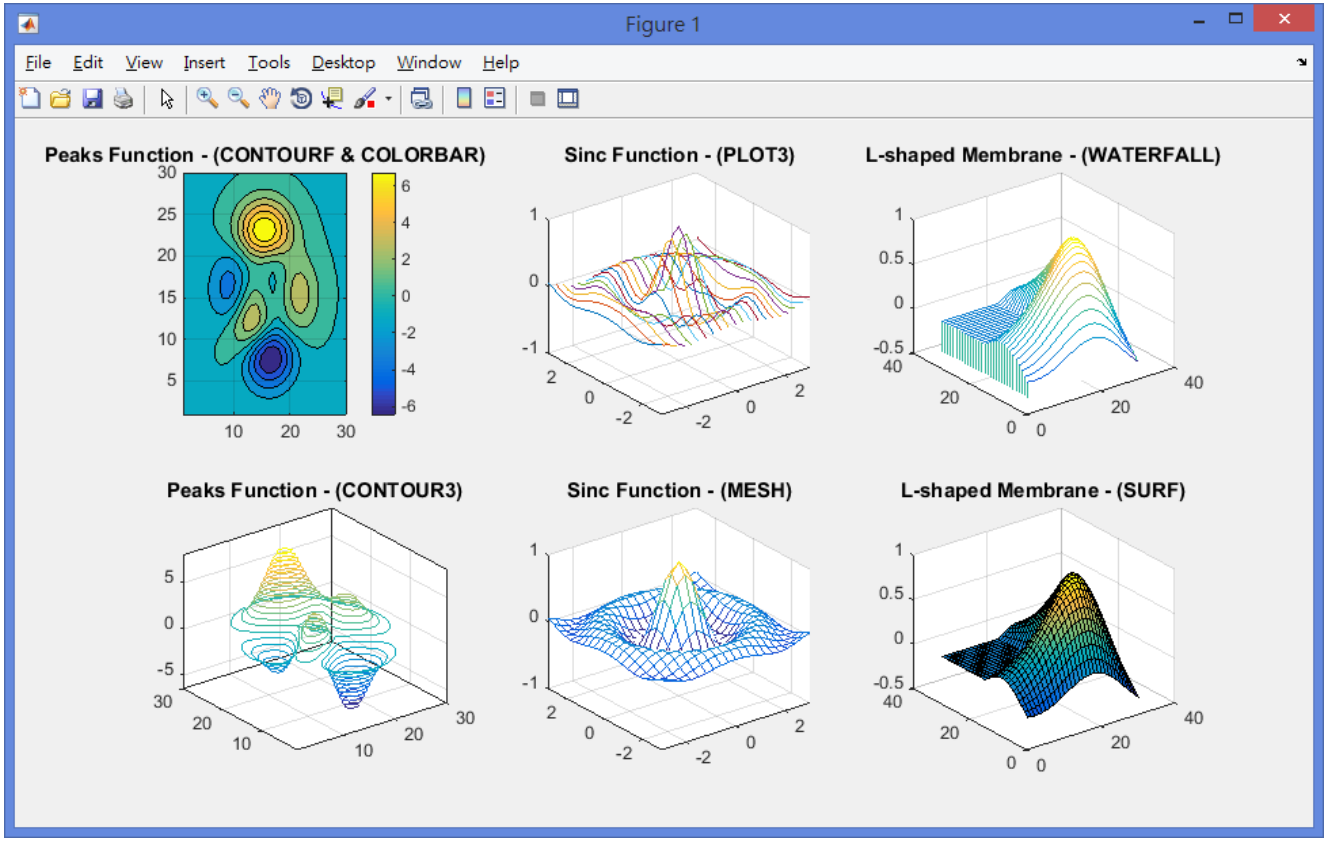
Adding Plots

```
plot(...)
hold on
plot(...)
plot(...)
hold off
```



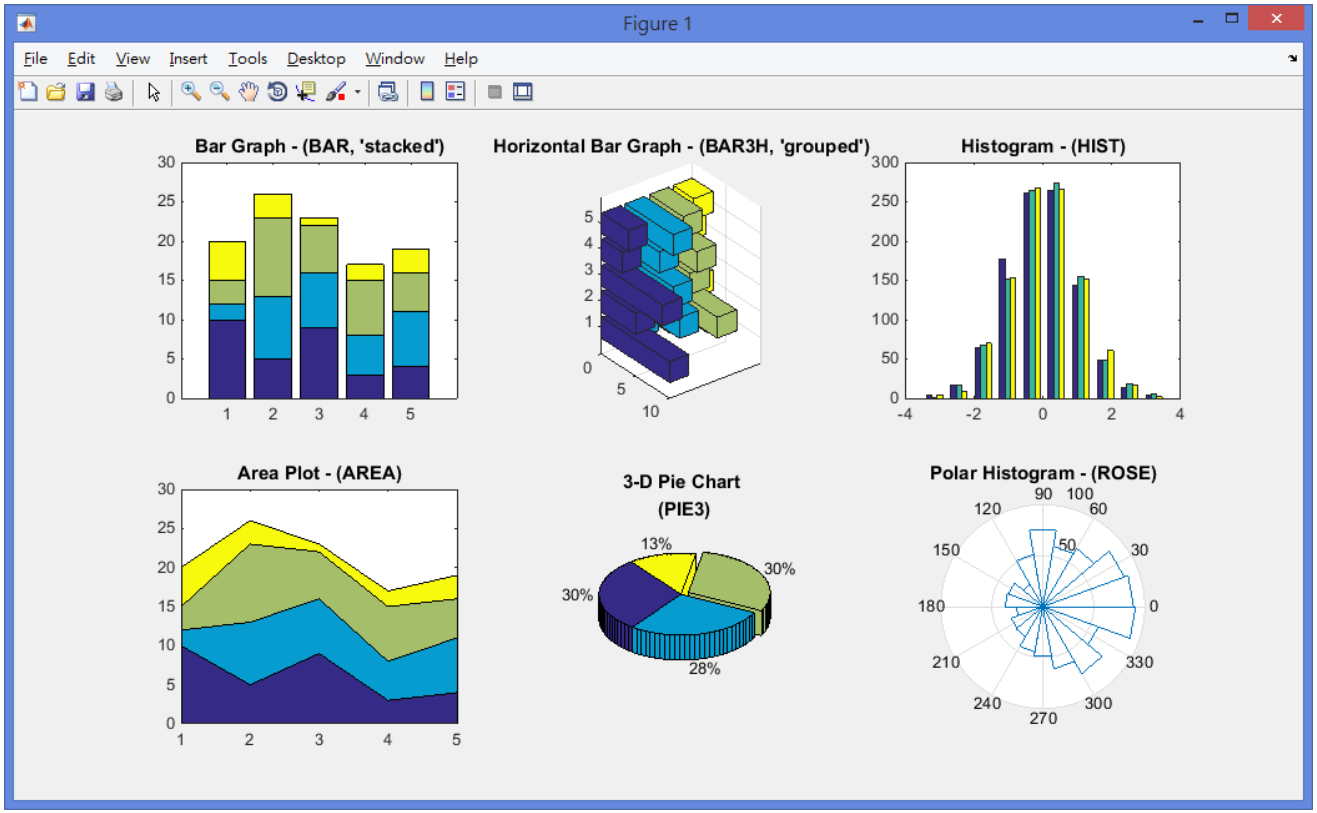

```
>> edit multipleLXplot
```

3-D Surface Plotting



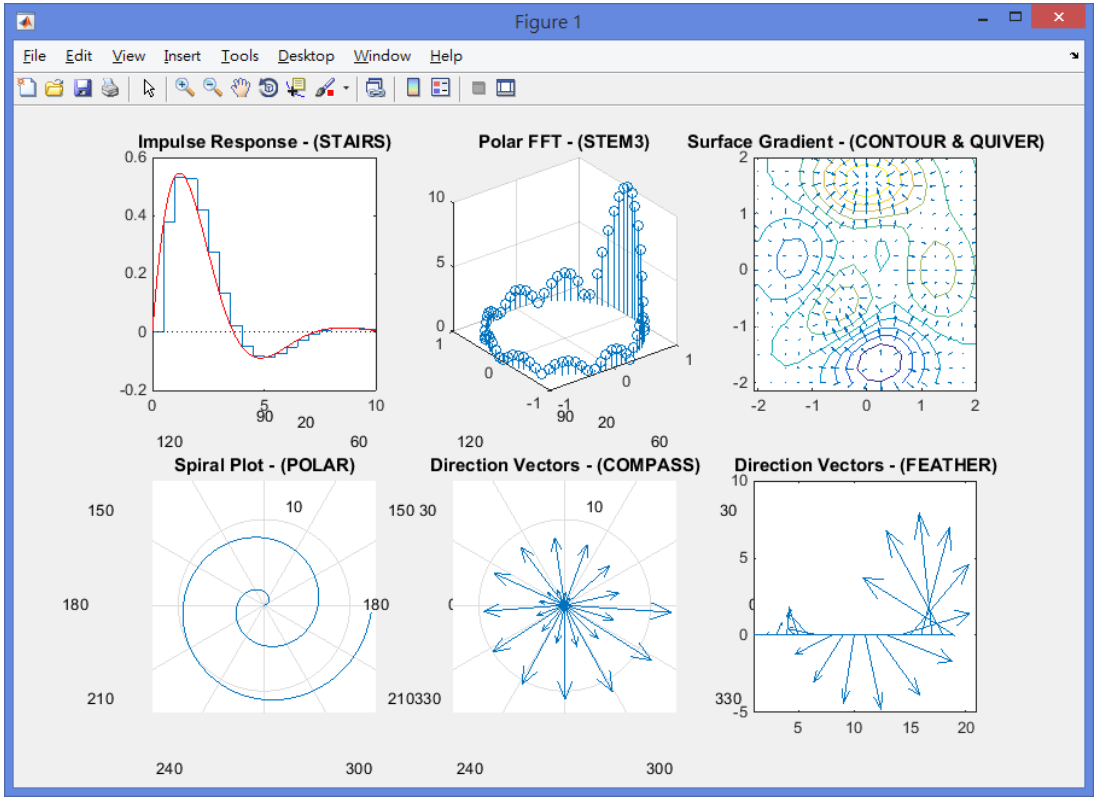

```
>> surf_3d
```

Specialized Plotting Routines




```
>> spec_plots
```

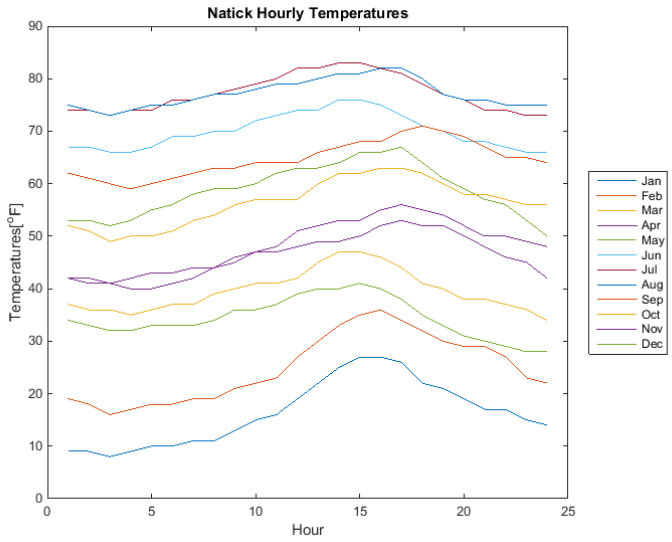
Specialized Plotting Routines (Continued)




```
>> spec_plots2
```

Exercise: Natick Hourly Temperatures

1. Load `natickData.mat`.
2. Calculate the average temperature for each month.
3. Determine which month had the largest standard deviation.
4. Determine which month had the largest range (max – min).
5. Plot temperature vs. time for each month.




```
>> edit
natickTemps
```

Chapter 5 Test Your Knowledge

1. (Select all that apply) Which of the following will create a scatter plot of `frogs` on the horizontal axis and `GDP` on the vertical axis, with red markers at the data points?
   A. `plot(GDP,frogs,'ro')`
   B. `plot(GDP,frogs,'o','r')`
   C. `plot(frogs,GDP,'ro')`
   D. `plot(frogs,GDP,'red')`

2. If `A` is a 15-by-7 matrix, which of the following commands will result in five line plots on the same axes?
   A. `plot(A(:))`
   B. `plot(A(:,3:end))`
   C. `plot(A(11:end,:))`
   D. `plot(A(2:6))`

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Example: Modeling a Whal Call

e

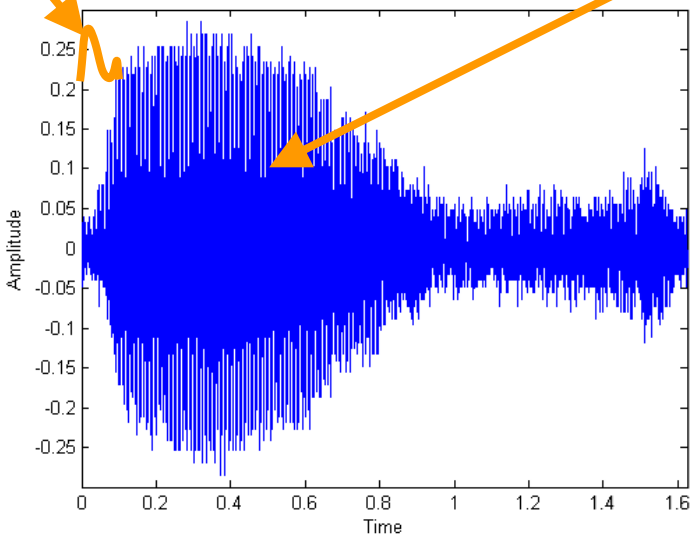
Amplitude modulated: $y(t) = A(t)y_0(t)$

Decaying oscillation

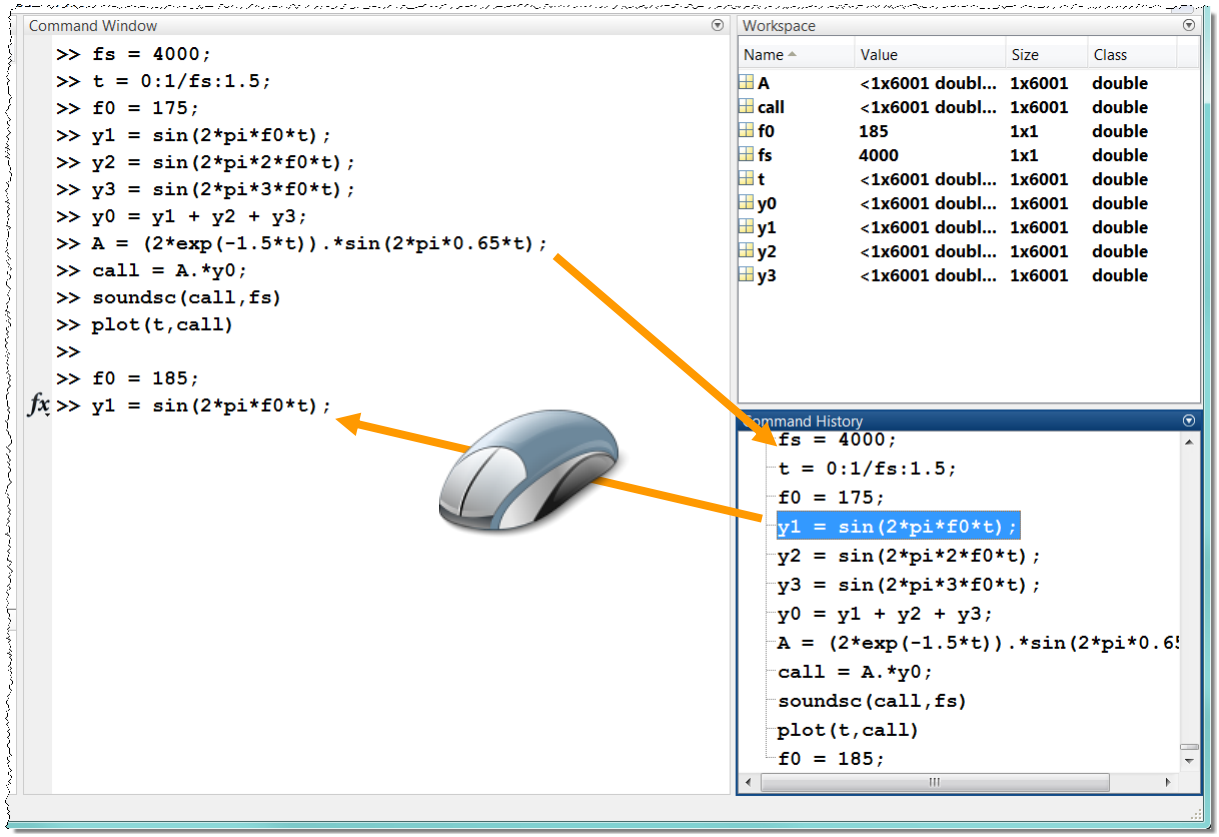
$A(t) = A_0 e^{-Bt} \sin(2\pi f_m t)$

Sum of harmonics of a fundamental frequency

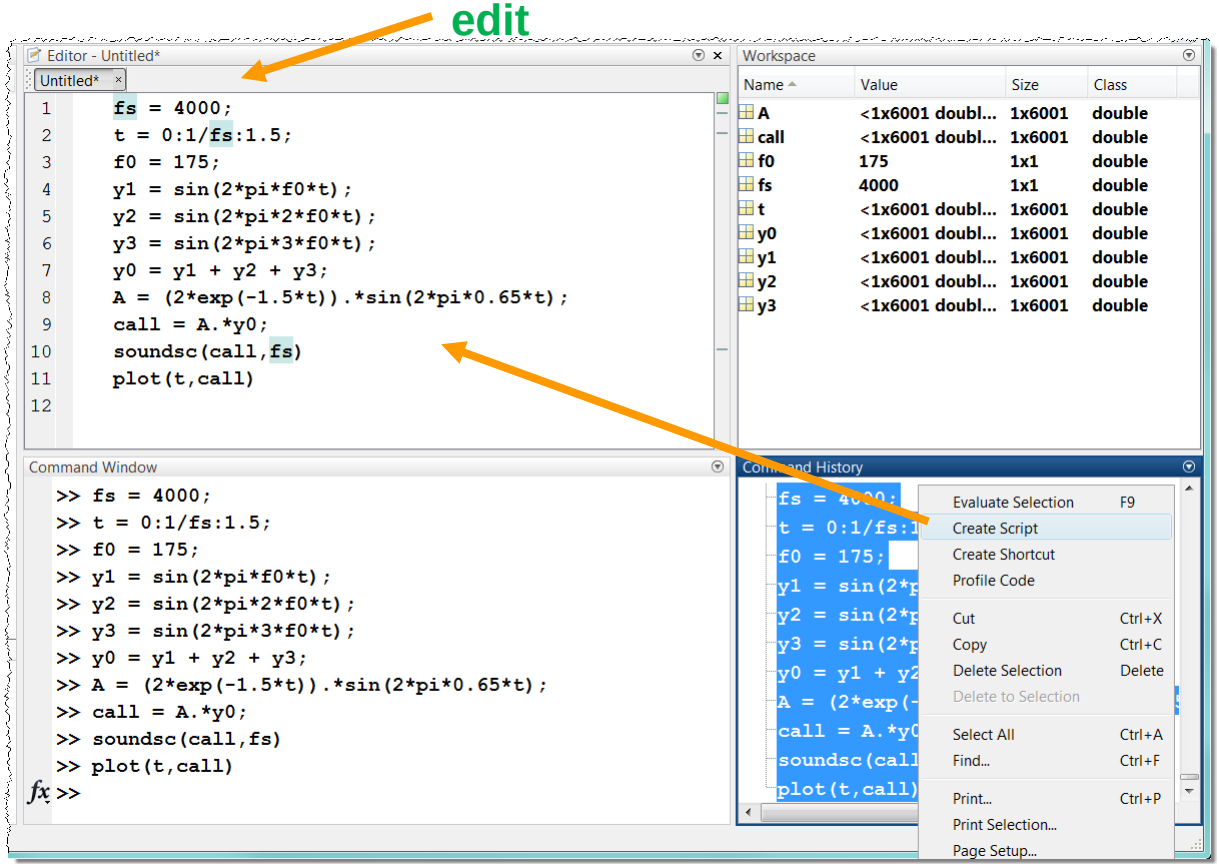
$y_0(t) = \sum_n \sin(2\pi n f_0 t)$



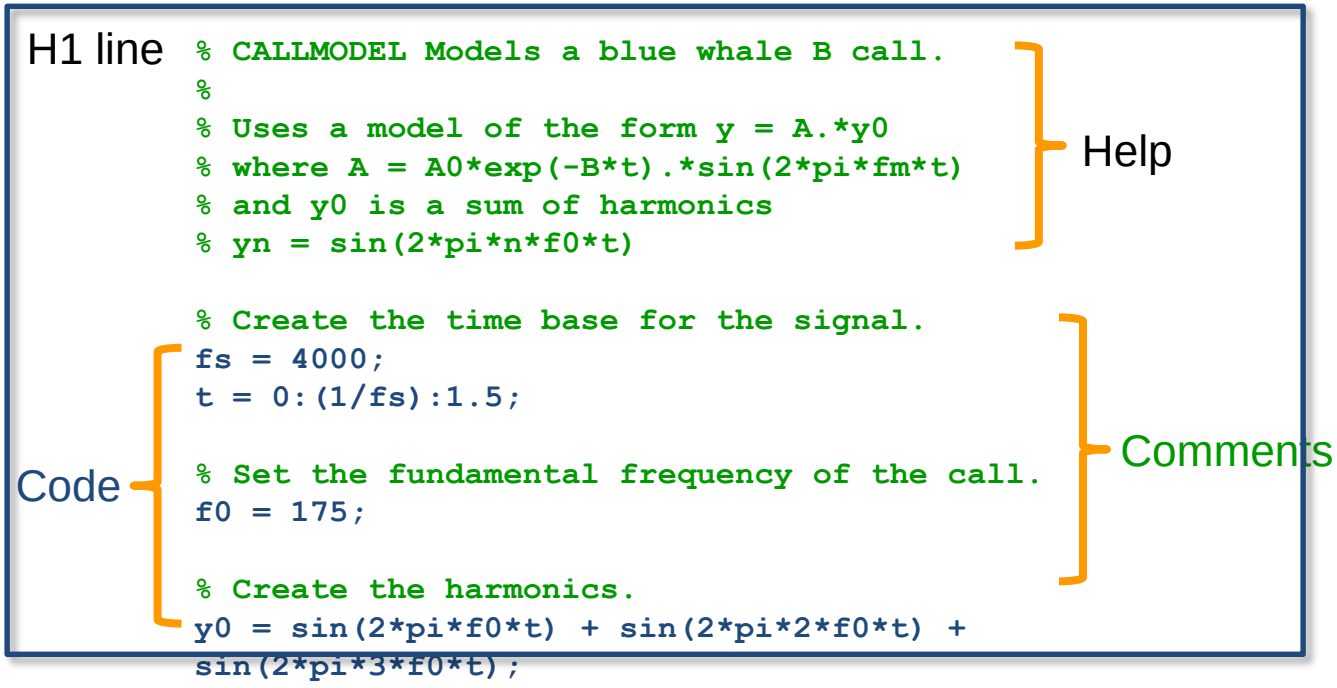
The Command History



The MATLAB® Editor

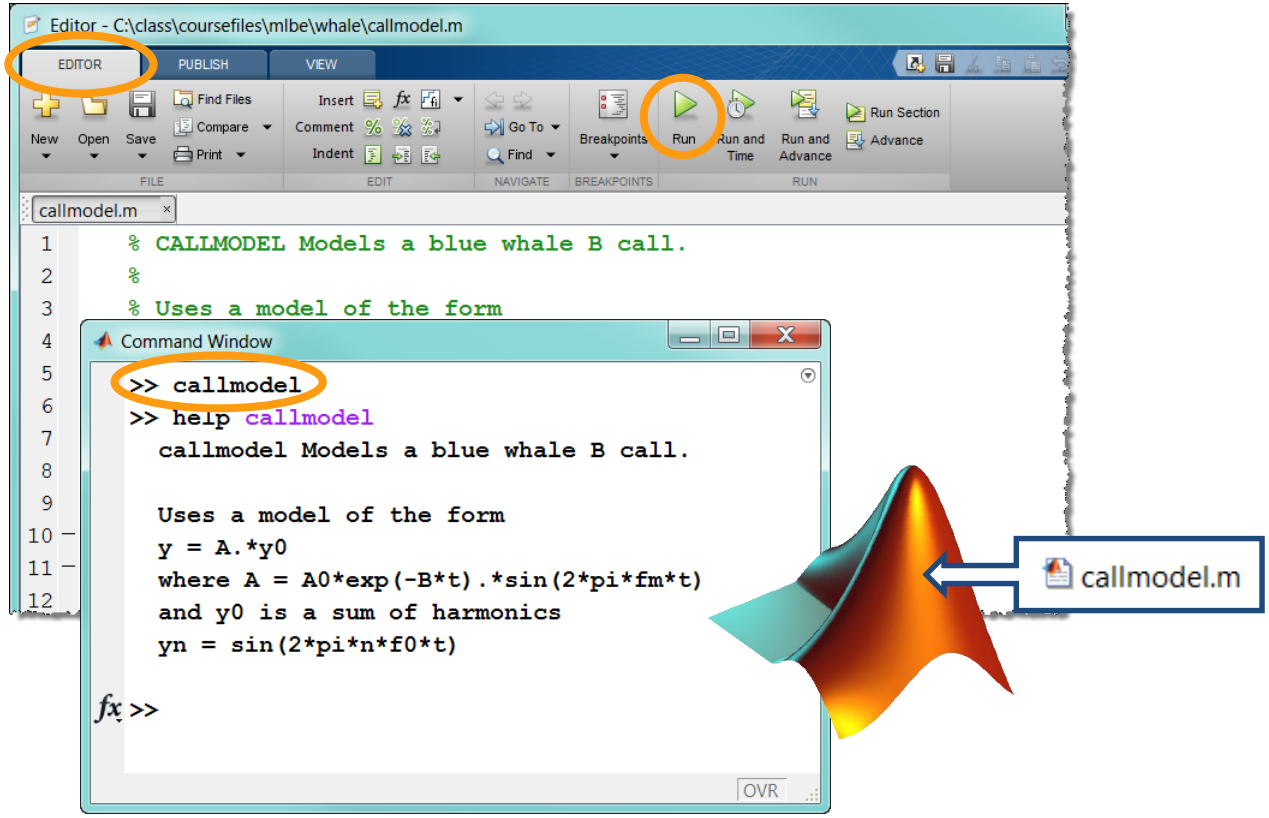


Script Files



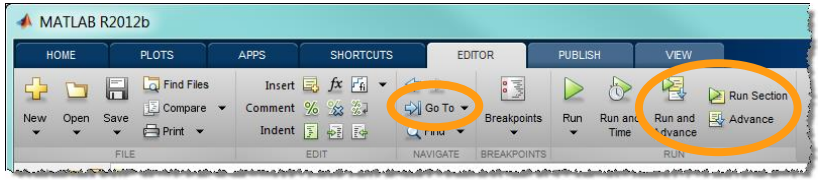

```
>> edit callmodel.m
```

Running a Script



Code Sections

- Create the time base for the signal
- Set the fundamental frequency of the call
- Create the harmonics
- Create the envelope
- Create the call
- Plot the model call and listen to it



%%

```
%% Set the fundamental frequency of the call.
f0 = 175;

%% Create the harmonics.
y0 = sin(2*pi*f0*t) + sin(2*pi*2*f0*t) + sin(2*pi*3

%% Create the envelope
% Set the additional parameters in the model.
A0 = 2; % Initial amplitude.
B  = 1.5; % Amplitude decay rate.
fm = 0.65; % Frequency of the modulating envelope.
% Create the envelope
A  = A0*exp(-B*t).*sin(2*pi*fm*t);

%% Create the call.
call = A.*y0;
```

Publishing Code

```
%% Set the fundamental frequency of the call.
f0 = 175;

%% Create the harmonics.
y0 = sin(2*pi*f0*t) + sin(2*pi*2*f0*t) + sin(2*pi*3

%% Create the envelope
% Set the additional parameters in the model.
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% Create the envelope
A  = A0*exp(-B*t).*sin(2*pi*fm*t);

%% Create the call.
call = A.*y0;
```
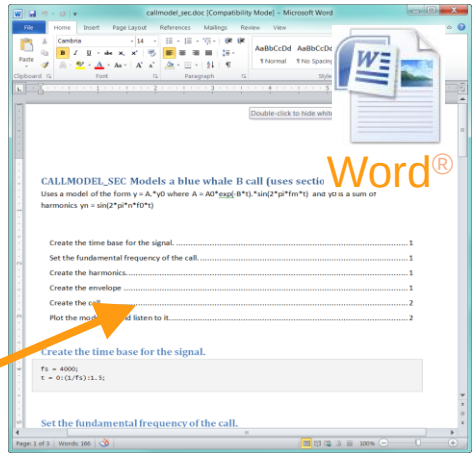
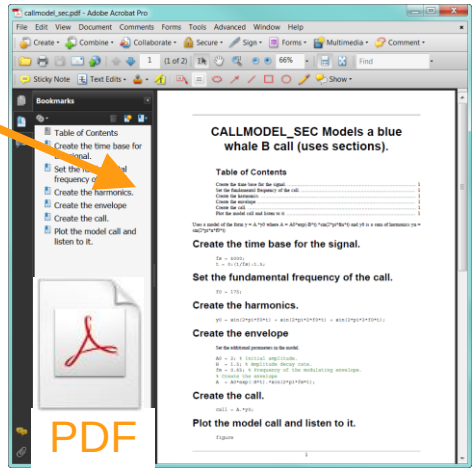





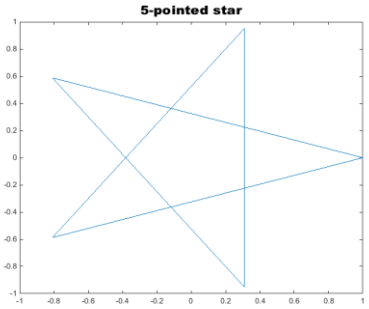
Exercise: N-Pointed Star

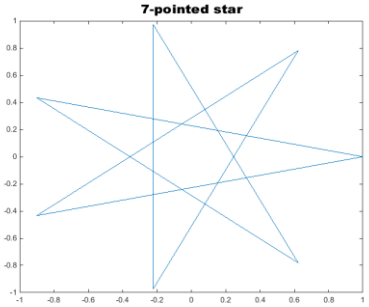
- Create a script to draw a 5-pointed and a 7-pointed star using the equations

$$x = cos\left(\frac{(n-1)t\pi}{n}\right)$$

$$y = sin\left(\frac{(n-1)t\pi}{n}\right)$$

with t = 0, 1, 2, …, 100

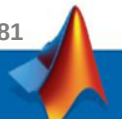




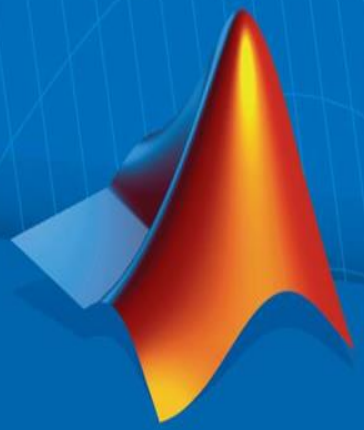

```
>> edit nPointStar
```

Chapter 6 Test Your Knowledge

- T/F: Anything following a % sign is ignored by MATLAB as a comment.
- T/F: In section mode, you can modify your code and rerun it without having to save the file.
- T/F: Script files can access and modify any variables already in the base MATLAB workspace.



TeraSoft
www.terasoft.com.tw



Q & A

Thank you very much

Have a good time

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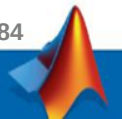
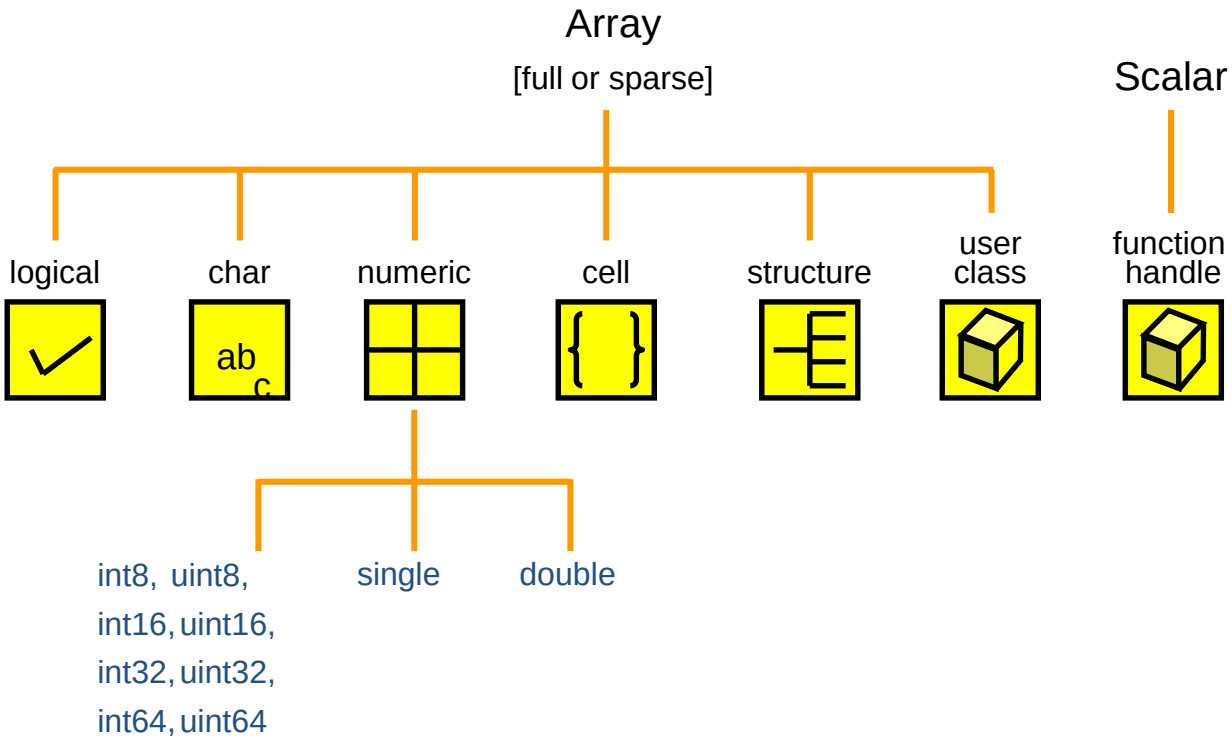


MATLAB® Data Types



Integer Arrays

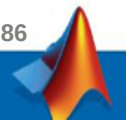
$$\begin{pmatrix} 1 & 2 \\ 3 & 4 \end{pmatrix}$$

Construct

```
>> A = uint8([1, 2; 3, 4]);
```

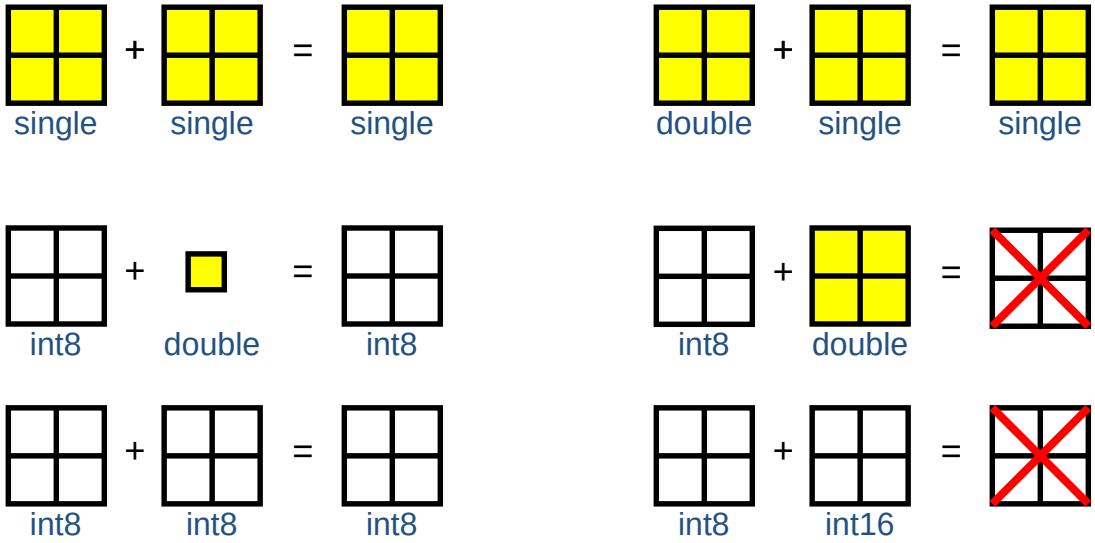
Access

```
>> A(:,2)
ans =
   2
   4
```

Nondouble Arithmetic

back



Characters and Strings

back

```
>> y = x
>> y = 'x'
```

variable

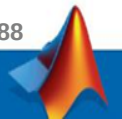
character

```
>> MarkA = 'Friends, Romans, countrymen, lend me your ears';
```

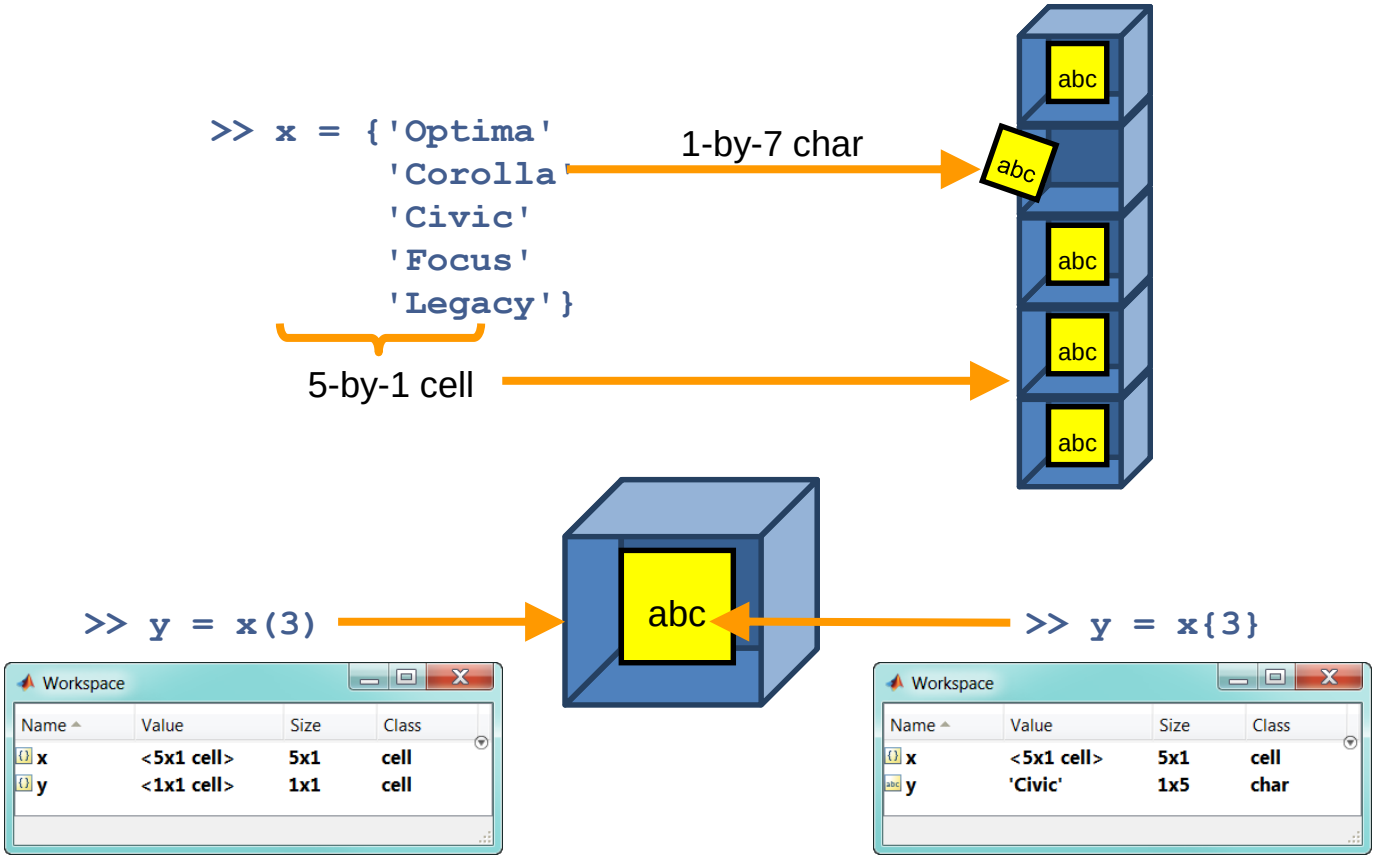
1-by-46 char array

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
'F'	'r'	'i'	'e'	'n'	'd'	's'	','	' '	'R'	'o'	'm'	'a'	'n'	's'	','	' '	'c'

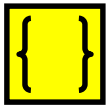
```
>> FriendNationality = MarkA(10:15)
```

Cell Arrays (1)



Cell Arrays (2)



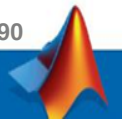
$$\begin{pmatrix} 3.14 & & foo \\ bar & \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix} & 2 \\ & B & \end{pmatrix}$$

Construct

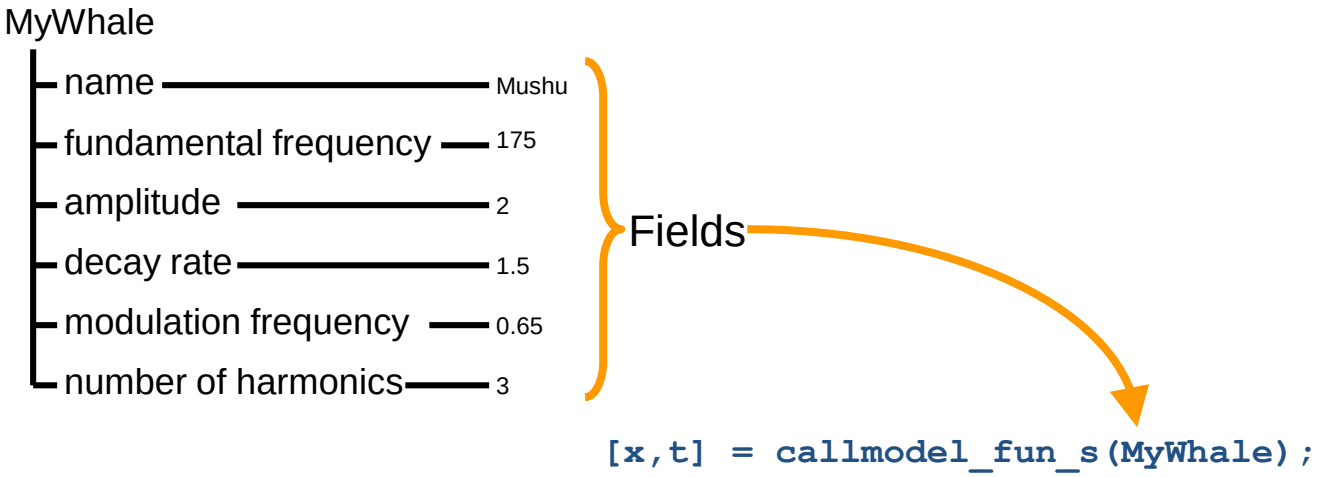
```
>> A = {pi,[],'foo';...
       'bar',eye(2),2;...
       [],B,[]};
```

Access

```
>> A{2,2}(:,2)
ans =
      0
      1
```

Structures

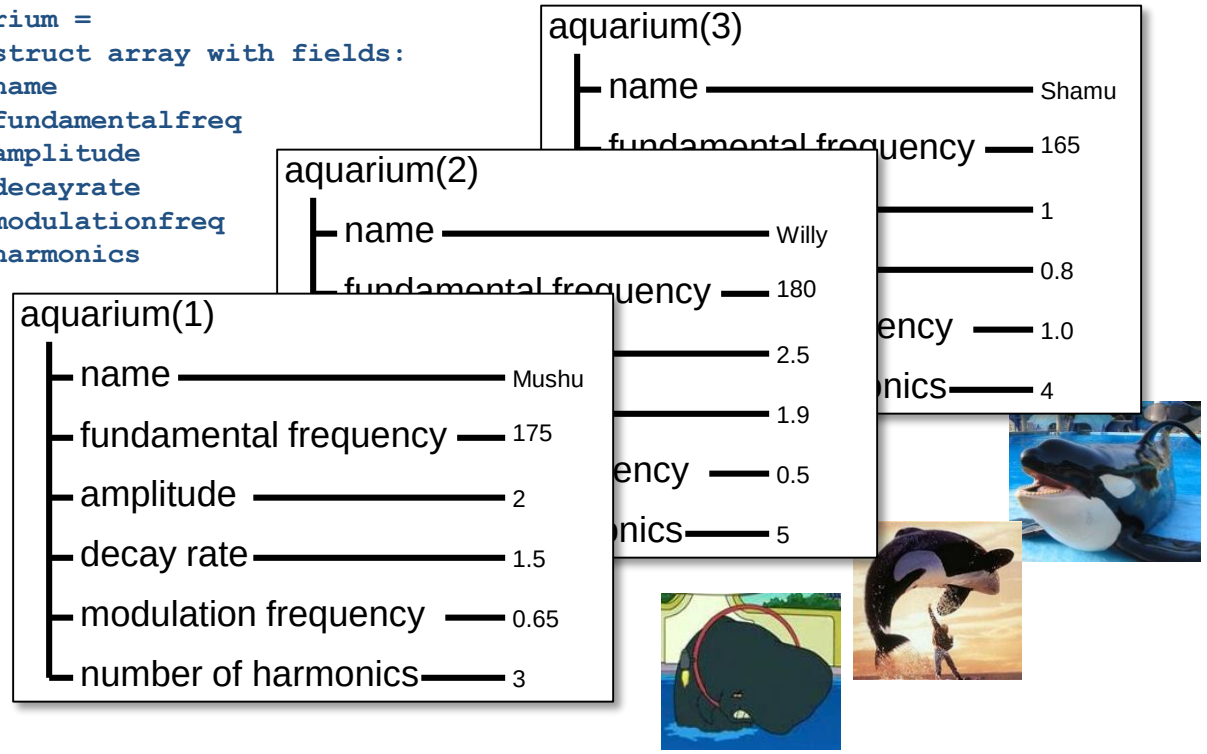



```
>> edit
whalestruct
```

Structure Arrays

```
>> aquarium

aquarium =
1x3 struct array with fields:
    name
    fundamentalfreq
    amplitude
    decayrate
    modulationfreq
    harmonics
```




```
>> ex_aquarium
```

Indexing into Structure Arrays