CmpE 362 : Introduction to Signal Processing

Lecture 1: Variables, Scripts, and Operations

Modified from MIT 6094 Course

It is used for Educational Purposes or

Outline

(1) Getting Started

(2) Scripts

(3) Making Variables

(4) Manipulating Variables

(5) Basic Plotting

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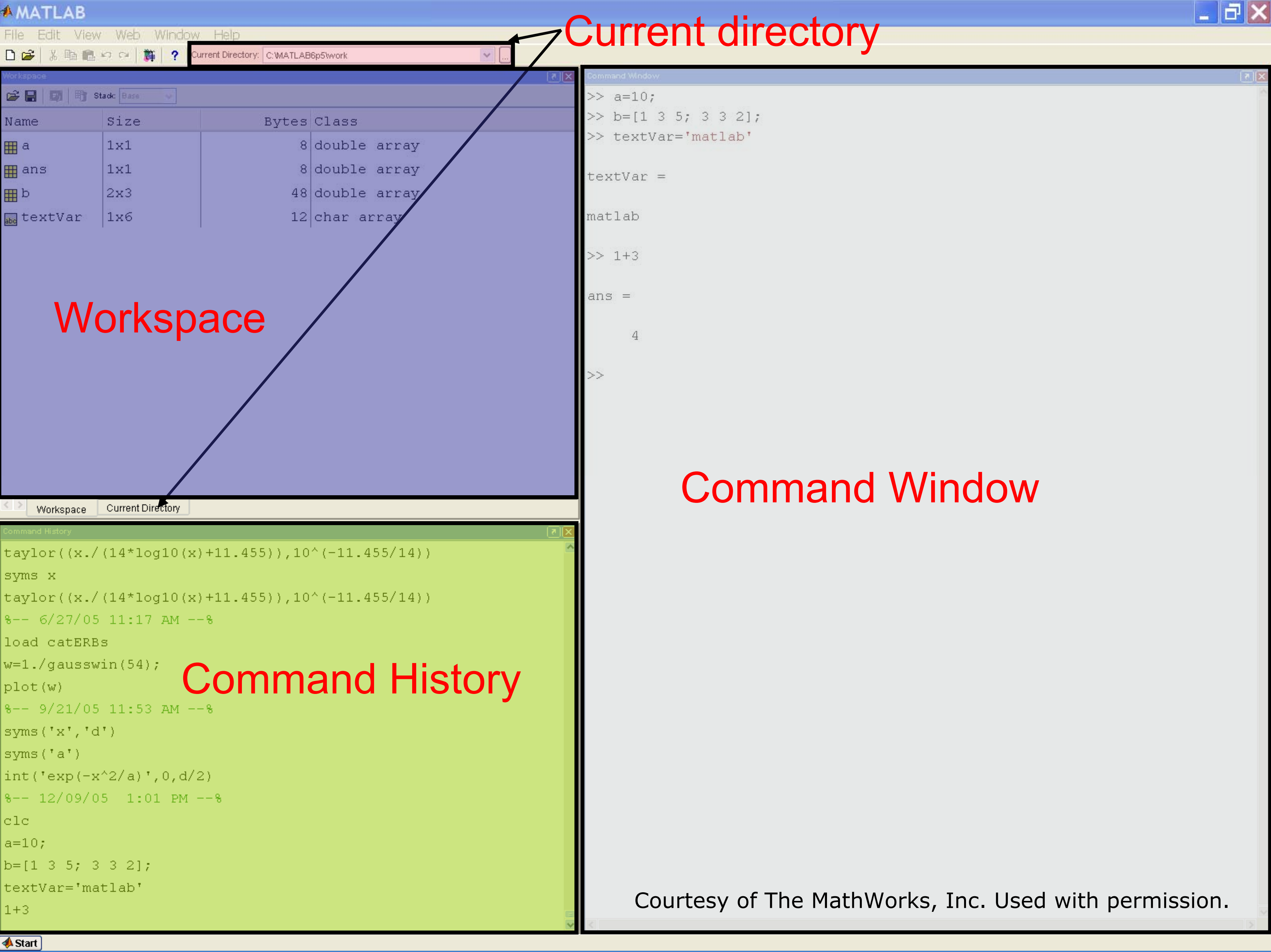

Name	Size	Bytes	Class
▦ a	1x1	8	double array
▦ ans	1x1	8	double array
▦ b	2x3	48	double array
abc textVar	1x6	12	char array

```
>> a=10;
>> b=[1 3 5; 3 3 2];
>> textVar='matlab'

textVar =

matlab

>> 1+3

ans =

     4

>>
```

```
taylor((x./(14*log10(x)+11.455)),10^(-11.455/14))
syms x
taylor((x./(14*log10(x)+11.455)),10^(-11.455/14))
%-- 6/27/05 11:17 AM --%
load catERBs
w=1./gausswin(54);
plot(w)
%-- 9/21/05 11:53 AM --%
syms('x','d')
syms('a')
int('exp(-x^2/a)',0,d/2)
%-- 12/09/05  1:01 PM --%
clc
a=10;
b=[1 3 5; 3 3 2];
textVar='matlab'
1+3
```

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Making Folders

- Use folders to keep your programs organized

- To make a new folder, click the ‘Browse’ button next to ‘Current Directory’

- Click the ‘Make New Folder’ button, and change the name of the folder. **Do NOT use spaces** in folder names. In the MATLAB folder, make two new folders: IAPMATLAB\day1

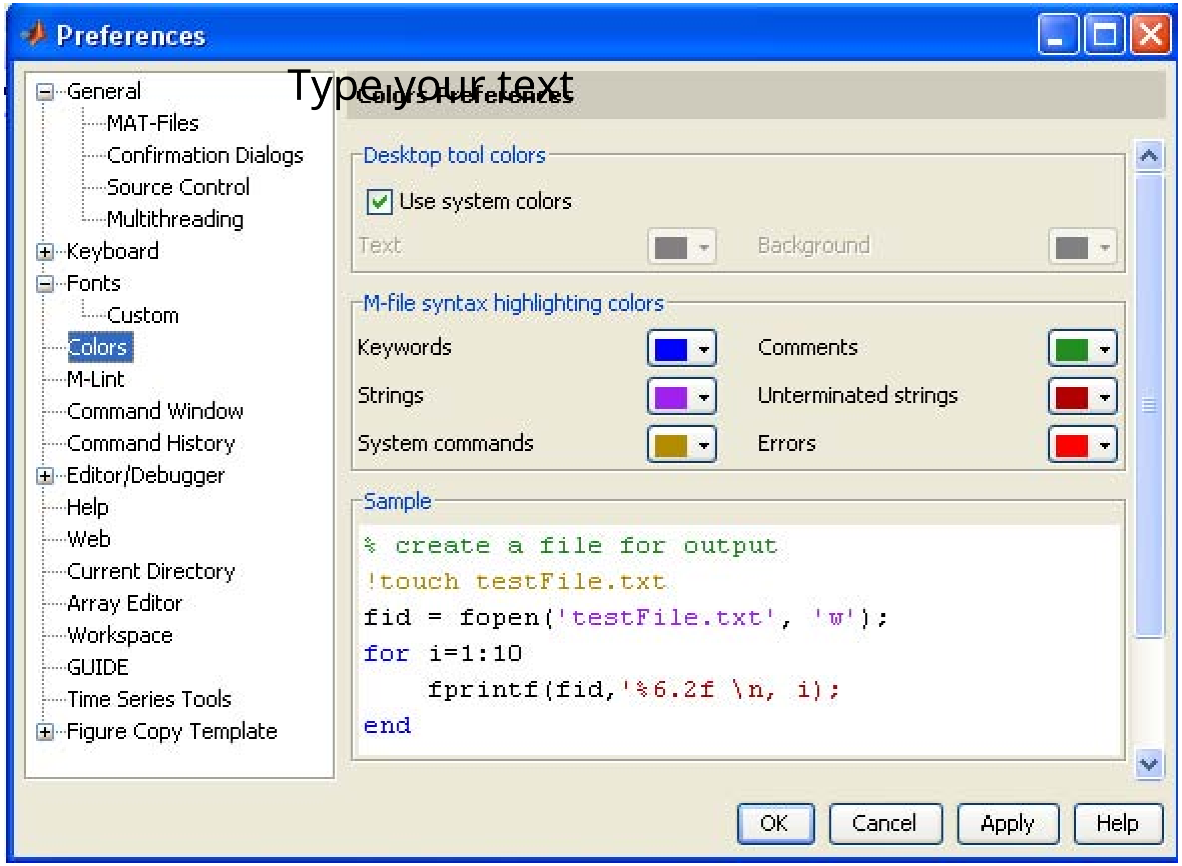
- Highlight the folder you just made and click ‘OK’
- The current directory is now the folder you just created
- To see programs outside the current directory, they should be in the Path. Use File-> Set Path to add folders to the path

Modified from MIT 6094 Course

Used for Educational Purposes

Customization

- File → Preferences
  - ➢ Allows you personalize your MATLAB experience



Type your text

Colors Preferences

Desktop tool colors

☑ Use system colors

Text	▨	Background	▨

M-file syntax highlighting colors

Keywords	🟦	Comments	🟩
Strings	🟪	Unterminated strings	🟥
System commands	🟨	Errors	🟥

Sample

```
% create a file for output
!touch testFile.txt
fid = fopen('testFile.txt', 'w');
for i=1:10
    fprintf(fid,'%6.2f \n, i);
end
```

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Help/Docs

- `help`
    - ➢ **The most** important function for learning MATLAB on your own
- To get info on how to use a function:
    - » `help sin`
        - ➢ Help lists related functions at the bottom and links to the doc
- To get a nicer version of help with examples and easy-to-read descriptions:
    - » `doc sin`
- To search for a function by specifying keywords:
    - » `doc` + Search tab

Outline

(1) Getting Started

(2) Scripts

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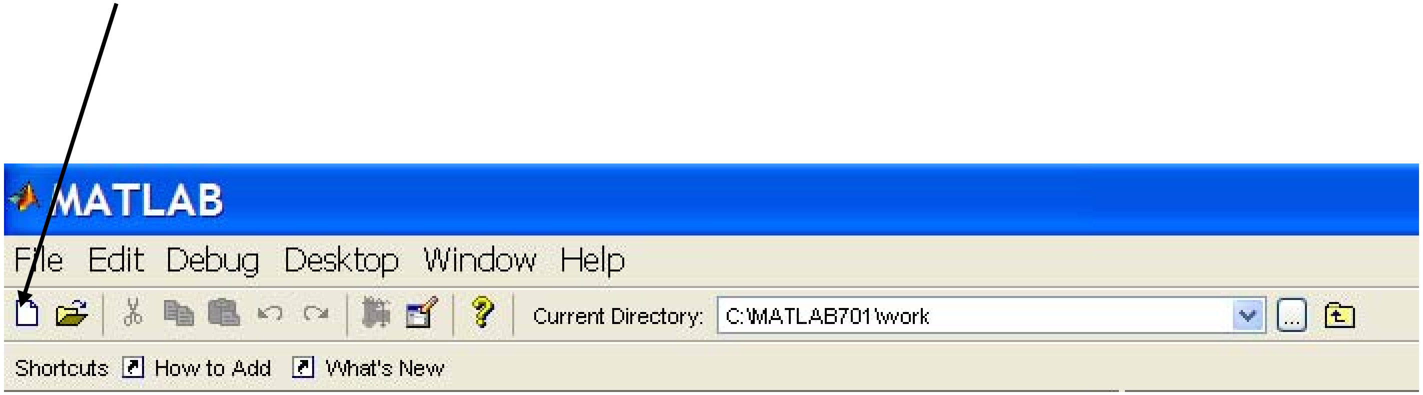
Scripts: Overview

- Scripts are
  - collection of commands executed in sequence
  - written in the MATLAB editor
  - saved as MATLAB files (.m extension)

- To create an MATLAB file from command-line

```
» edit helloWorld.m
```

- or click


MATLAB
File Edit Debug Desktop Window Help
Current Directory: C:\MATLAB701\work
Shortcuts
How to Add
What's New

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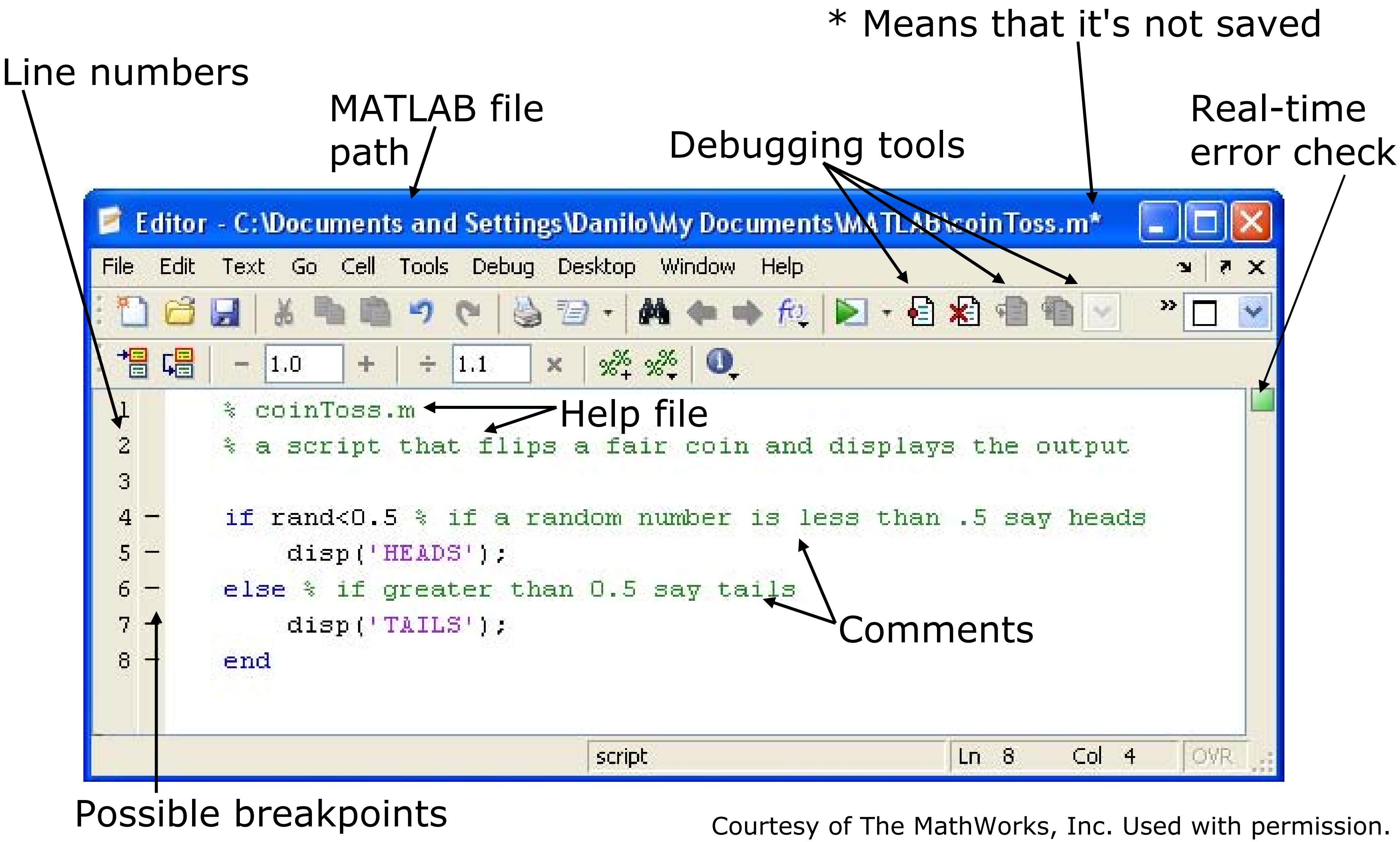
Scripts: the Editor



Editor - C:\Documents and Settings\Danilo\My Documents\MATLAB\coinToss.m*
File Edit Text Go Cell Tools Debug Desktop Window Help
1.0
1.1
script
Ln 8 Col 4
OVR

```
% coinToss.m
% a script that flips a fair coin and displays the output

if rand<0.5 % if a random number is less than .5 say heads
    disp('HEADS');
else % if greater than 0.5 say tails
    disp('TAILS');
end
```

Line numbers

MATLAB file path

Debugging tools

* Means that it's not saved

Real-time error check

Help file

Comments

Possible breakpoints

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Scripts: Some Notes

- **COMMENT!**
  - Anything following a **%** is seen as a comment
  - The first contiguous comment becomes the script's help file
  - Comment thoroughly to avoid wasting time later

- Note that scripts are somewhat static, since there is no input and no explicit output

- All variables created and modified in a script exist in the workspace even after it has stopped running

Exercise: Scripts

Make a `helloWorld` script

- When run, the script should display the following text:

```
Hello World!
I am going to learn MATLAB!
```

- **Hint:** use `disp` to display strings. Strings are written between single quotes, like `'This is a string'`

Exercise: Scripts

Make a `helloWorld` script

- When run, the script should display the following text:

```
Hello World!
I am going to learn MATLAB!
```

- **Hint:** use `disp` to display strings. Strings are written between single quotes, like `'This is a string'`

- Open the editor and save a script as helloWorld.m. This is an easy script, containing two lines of code:

```
» % helloWorld.m
» % my first hello world program in MATLAB

» disp('Hello World!');
» disp('I am going to learn MATLAB!');
```

Outline

(1) Getting Started

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Variable Types

- MATLAB is a weakly typed language
  - ➢No need to initialize variables!
- MATLAB supports various types, the most often used are
  - » **3.84**
    - ➢64-bit double (default)
  - » **‘a’**
    - ➢16-bit char
- Most variables you’ll deal with will be vectors or matrices of doubles or chars
- Other types are also supported: complex, symbolic, 16-bit and 8 bit integers, etc. You will be exposed to all these types through the homework

Naming variables

- To create a variable, simply assign a value to a name:
  - » `var1=3.14`
  - » `myString=‘hello world’`

- Variable names
  - ➢ first character must be a LETTER
  - ➢ after that, any combination of letters, numbers and _
  - ➢ CASE SENSITIVE! (`var1` is different from `Var1`)

- Built-in variables. Don’t use these names!
  - ➢ `i` and `j` can be used to indicate complex numbers
  - ➢ `pi` has the value 3.1415926…
  - ➢ `ans` stores the last unassigned value (like on a calculator)
  - ➢ `Inf` and `-Inf` are positive and negative infinity
  - ➢ `NaN` represents ‘Not a Number’

Scalars

- A variable can be given a value explicitly

```
» a = 10
```

  - ➢ shows up in workspace!

- Or as a function of explicit values and existing variables

```
» c = 1.3*45-2*a
```

- To suppress output, end the line with a semicolon

```
» cooldude = 13/3;
```

Arrays

- Like other programming languages, arrays are an important part of MATLAB
- Two types of arrays

(1) matrix of numbers (either double or complex)

(2) cell array of objects (more advanced data structure)

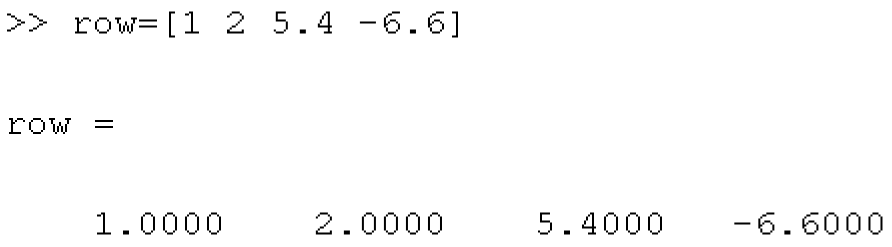
MATLAB makes vectors easy!
That’s its power!

Row Vectors

- Row vector: comma or space separated values between brackets

```
» row = [1 2 5.4 -6.6]
» row = [1, 2, 5.4, -6.6];
```

- Command window:

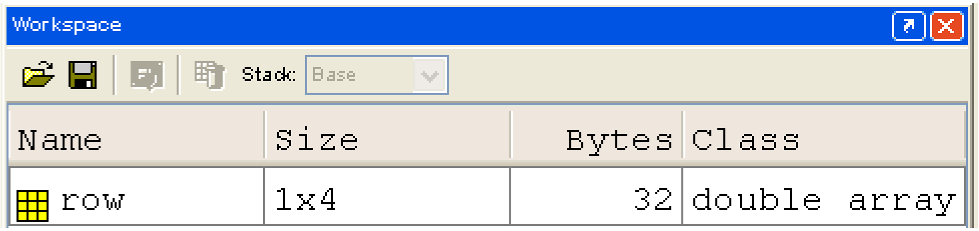


```
>> row=[1 2 5.4 -6.6]

row =

    1.0000    2.0000    5.4000   -6.6000
```

- Workspace:



Name	Size	Bytes	Class
row	1x4	32	double array

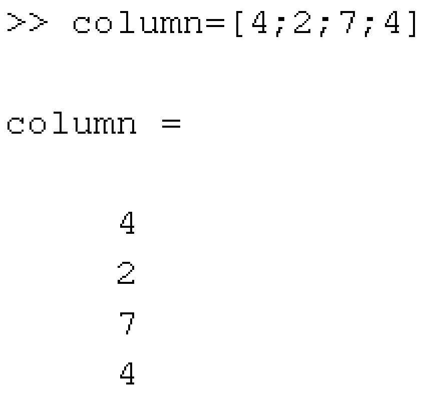
Courtesy of The MathWorks, Inc. Used with permission.

Column Vectors

- Column vector: semicolon separated values between brackets

  ```
  » column = [4;2;7;4]
  ```

- Command window:

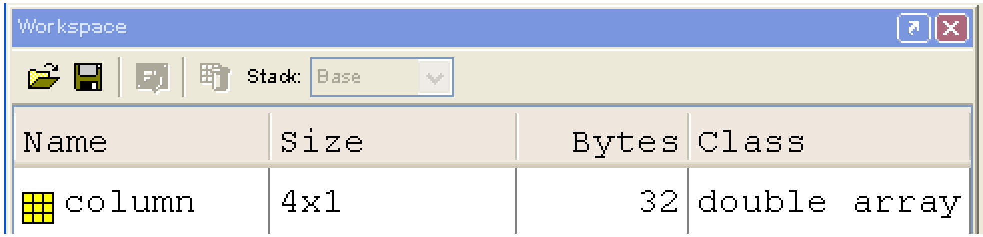


```
>> column=[4;2;7;4]

column =

     4
     2
     7
     4
```

- Workspace:

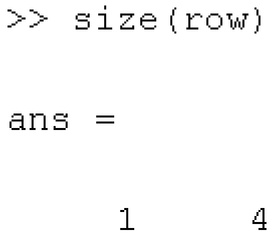


Name	Size	Bytes	Class
▦ column	4x1	32	double array

Courtesy of The MathWorks, Inc. Used with permission.

size & length

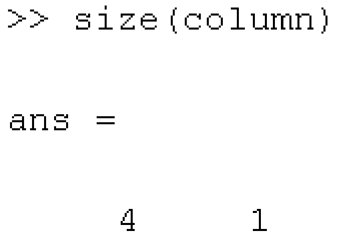
- You can tell the difference between a row and a column vector by:
  - Looking in the workspace
  - Displaying the variable in the command window
  - Using the size function



```
>> size(row)

ans =

     1     4
```

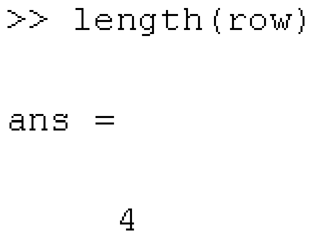


```
>> size(column)

ans =

     4     1
```

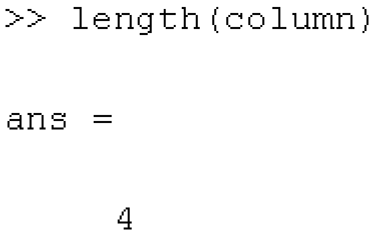
- To get a vector's length, use the length function



```
>> length(row)

ans =

     4
```



```
>> length(column)

ans =

     4
```

Matrices

- Make matrices like vectors

- Element by element

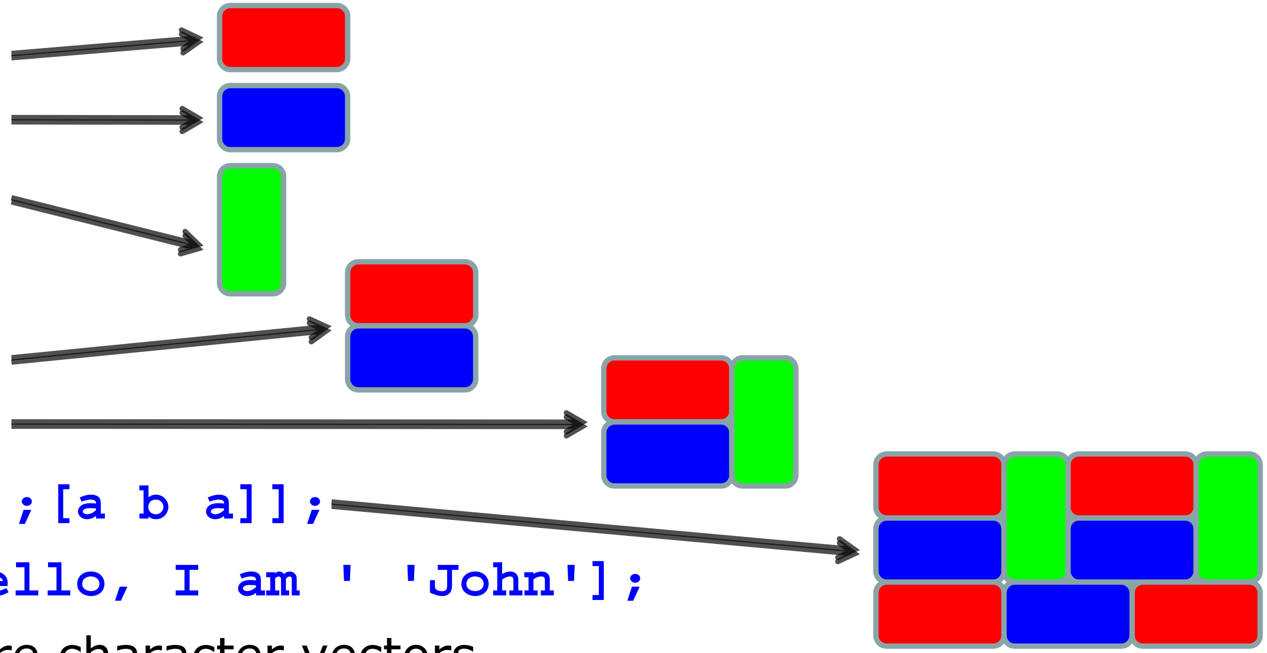
```
» a= [1 2;3 4];
```

$$a = \begin{bmatrix} 1 & 2 \\ 3 & 4 \end{bmatrix}$$

- By concatenating vectors or matrices (dimension matters)

```
» a = [1 2];
» b = [3 4];
» c = [5;6];

» d = [a;b];
» e = [d c];
» f = [[e e];[a b a]];
» str = ['Hello, I am ' 'John'];
```



  - ➢ Strings are character vectors

save/clear/load

- Use **save** to save variables to a file
  - » `save myFile a b`
    - ➢ saves variables a and b to the file myfile.mat
    - ➢ myfile.mat file is saved in the current directory
    - ➢ Default working directory is
  - » `\MATLAB`
    - ➢ Make sure you're in the desired folder when saving files. Right now, we should be in:
  - » `MATLAB\IAPMATLAB\day1`

- Use **clear** to remove variables from environment
  - » `clear a b`
    - ➢ look at workspace, the variables a and b are gone

- Use **load** to load variable bindings into the environment
  - » `load myFile`
    - ➢ look at workspace, the variables a and b are back

- Can do the same for entire environment
  - » `save myenv; clear all; load myenv;`

Exercise: Variables

Get and save the current date and time

- Create a variable `start` using the function `clock`
- What is the size of `start`? Is it a row or column?
- What does `start` contain? See `help clock`
- Convert the vector `start` to a string. Use the function `datestr` and name the new variable `startString`
- Save `start` and `startString` into a mat file named `startTime`

Exercise: Variables

Get and save the current date and time

- Create a variable `start` using the function `clock`
- What is the size of `start`? Is it a row or column?
- What does `start` contain? See `help clock`
- Convert the vector `start` to a string. Use the function `datestr` and name the new variable `startString`
- Save `start` and `startString` into a mat file named `startTime`

```
» help clock
» start=clock;
» size(start)
» help datestr
» startString=datestr(start);
» save startTime start startString
```

Exercise: Variables

Read in and display the current date and time

- In helloWorld.m, read in the variables you just saved using `load`
- Display the following text:

  I started learning MATLAB on *start date and time*

- Hint: use the `disp` command again, and remember that strings are just vectors of characters so you can join two strings by making a row vector with the two strings as sub-vectors.

Exercise: Variables

Read in and display the current date and time

- In helloWorld.m, read in the variables you just saved using `load`
- Display the following text:

  I started learning MATLAB on *start date and time*

- Hint: use the `disp` command again, and remember that strings are just vectors of characters so you can join two strings by making a row vector with the two strings as sub-vectors.

```
» load startTime
» disp(['I started learning MATLAB on ' ...
  startString]);
```

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Basic Scalar Operations

- Arithmetic operations (**+**,**-**,*****,**/**)

```
» 7/45
» (1+i)*(2+i)
» 1 / 0
» 0 / 0
```

- Exponentiation (**^**)

```
» 4^2
» (3+4*j)^2
```

- Complicated expressions, use parentheses

```
» ((2+3)*3)^0.1
```

- Multiplication is NOT implicit given parentheses

```
» 3(1+0.7) gives an error
```

- To clear command window

```
» clc
```

Built-in Functions

- MATLAB has an **enormous** library of built-in functions

- Call using parentheses – passing parameter to function

```
» sqrt(2)
» log(2), log10(0.23)
» cos(1.2), atan(-.8)
» exp(2+4*i)
» round(1.4), floor(3.3), ceil(4.23)
» angle(i); abs(1+i);
```

Exercise: Scalars

You will learn MATLAB at an exponential rate! Add the following to your helloWorld script:

- Your learning time constant is 1.5 days. Calculate the number of **seconds** in 1.5 days and name this variable `tau`
- This class lasts 5 days. Calculate the number of seconds in 5 days and name this variable `endOfClass`
- This equation describes your knowledge as a function of time t:

$$k = 1 - e^{-t/\tau}$$

- How well will you know MATLAB at `endOfClass`? Name this variable `knowledgeAtEnd`. (use `exp`)
- Using the value of `knowledgeAtEnd`, display the phrase:

At the end of 6.094, I will know X% of MATLAB

- Hint: to convert a number to a string, use `num2str`

Exercise: Scalars

```
» secPerDay=60*60*24;
» tau=1.5*secPerDay;
» endOfClass=5*secPerDay
» knowledgeAtEnd=1-exp(-endOfClass/tau);
» disp(['At the end of 6.094, I will know ' ...
  num2str(knowledgeAtEnd*100) '% of MATLAB'])
```

Transpose

- The transpose operators turns a column vector into a row vector and vice versa

```
» a = [1 2 3 4+i]
» transpose(a)
» a'
» a.'
```

- The `'` gives the Hermitian-transpose, i.e. transposes and conjugates all complex numbers
- For vectors of real numbers `.'` and `'` give same result

Addition and Subtraction

- Addition and subtraction are element-wise; sizes must match (unless one is a scalar):

$$\begin{array}{r} \begin{bmatrix}12 & 3 & 32 & -11\end{bmatrix} \\ +\begin{bmatrix}2 & 11 & -30 & 32\end{bmatrix} \\ \hline =\begin{bmatrix}14 & 14 & 2 & 21\end{bmatrix} \end{array}$$

$$\begin{bmatrix}12 \\ 1 \\ -10 \\ 0\end{bmatrix} - \begin{bmatrix}3 \\ -1 \\ 13 \\ 33\end{bmatrix} = \begin{bmatrix}9 \\ 2 \\ -23 \\ -33\end{bmatrix}$$

- The following would give an error

```
» c = row + column
```

- Use the transpose to make sizes compatible

```
» c = row' + column
» c = row + column'
```

- Can sum up or multiply elements of vector

```
» s=sum(row);
» p=prod(row);
```

Element-Wise Functions

- All the functions that work on scalars also work on vectors

```
» t = [1 2 3];
» f = exp(t);
```

  - ➢ is the same as

```
» f = [exp(1) exp(2) exp(3)];
```

- If in doubt, check a function’s help file to see if it handles vectors elementwise

- Operators (* / ^) have two modes of operation
  - ➢ element-wise
  - ➢ standard

Operators: element-wise

- To do element-wise operations, use the dot: `.` (`.*`, `./`, `.^`). BOTH dimensions must match (unless one is scalar)!

```
» a=[1 2 3];b=[4;2;1];
» a.*b, a./b, a.^b → all errors
» a.*b', a./b’, a.^(b’) → all valid
```

$$\begin{bmatrix}1 & 2 & 3\end{bmatrix}.*\begin{bmatrix}4\\2\\1\end{bmatrix} = \mathit{ERROR}$$

$$\begin{bmatrix}1\\2\\3\end{bmatrix}.*\begin{bmatrix}4\\2\\1\end{bmatrix} = \begin{bmatrix}4\\4\\3\end{bmatrix}$$

$$3\times1.*3\times1 = 3\times1$$

$$\begin{bmatrix}1 & 1 & 1\\2 & 2 & 2\\3 & 3 & 3\end{bmatrix}.*\begin{bmatrix}1 & 2 & 3\\1 & 2 & 3\\1 & 2 & 3\end{bmatrix} = \begin{bmatrix}1 & 2 & 3\\2 & 4 & 6\\3 & 6 & 9\end{bmatrix}$$

$$3\times3.*3\times3 = 3\times3$$

$$\begin{bmatrix}1 & 2\\3 & 4\end{bmatrix}.\wedge 2 = \begin{bmatrix}1^2 & 2^2\\3^2 & 4^2\end{bmatrix}$$

Can be any dimension

Operators: standard

- Multiplication can be done in a standard way or element-wise
- Standard multiplication (*****) is either a dot-product or an outer-product
  - ➢ Remember from linear algebra: inner dimensions must MATCH!!
- Standard exponentiation (**^**) can only be done on square matrices or scalars
- Left and right division (**/ \**) is same as multiplying by inverse
  - ➢ Our recommendation: just multiply by inverse (more on this later)

$$\begin{bmatrix}1 & 2 & 3\end{bmatrix} * \begin{bmatrix}4\\2\\1\end{bmatrix} = 11$$

$$1\times 3 * 3\times 1 = 1\times 1$$

$$\begin{bmatrix}1 & 2\\3 & 4\end{bmatrix} \wedge 2 = \begin{bmatrix}1 & 2\\3 & 4\end{bmatrix} * \begin{bmatrix}1 & 2\\3 & 4\end{bmatrix}$$

Must be square to do powers

$$\begin{bmatrix}1 & 1 & 1\\2 & 2 & 2\\3 & 3 & 3\end{bmatrix} * \begin{bmatrix}1 & 2 & 3\\1 & 2 & 3\\1 & 2 & 3\end{bmatrix} = \begin{bmatrix}3 & 6 & 9\\6 & 12 & 18\\9 & 18 & 27\end{bmatrix}$$

$$3\times 3 * 3\times 3 = 3\times 3$$

Exercise: Vector Operations

Calculate how many seconds elapsed since the start of class

- In helloWorld.m, make variables called `secPerMin`, `secPerHour`, `secPerDay`, `secPerMonth` (assume 30.5 days per month), and `secPerYear` (12 months in year), which have the number of seconds in each time period.
- Assemble a row vector called `secondConversion` that has elements in this order: `secPerYear`, `secPerMonth`, `secPerDay`, `secPerHour`, `secPerMinute`, `1`.
- Make a `currentTime` vector by using `clock`
- Compute `elapsedTime` by subtracting `currentTime` from `start`
- Compute `t` (the elapsed time in seconds) by taking the dot product of `secondConversion` and `elapsedTime` (transpose one of them to get the dimensions right)

Exercise: Vector Operations

```
» secPerMin=60;
» secPerHour=60*secPerMin;
» secPerDay=24*secPerHour;
» secPerMonth=30.5*secPerDay;
» secPerYear=12*secPerMonth;
» secondConversion=[secPerYear secPerMonth ...
  secPerDay secPerHour secPerMin 1];
» currentTime=clock;
» elapsedTime=currentTime-start;
» t=secondConversion*elapsedTime';
```

Exercise: Vector Operations

Display the current state of your knowledge

- Calculate `currentKnowledge` using the same relationship as before, and the `t` we just calculated:

$$k = 1 - e^{-t/\tau}$$

- Display the following text:

At this time, I know X% of MATLAB

Exercise: Vector Operations

Display the current state of your knowledge

- Calculate `currentKnowledge` using the same relationship as before, and the `t` we just calculated:

$$k = 1 - e^{-t/\tau}$$

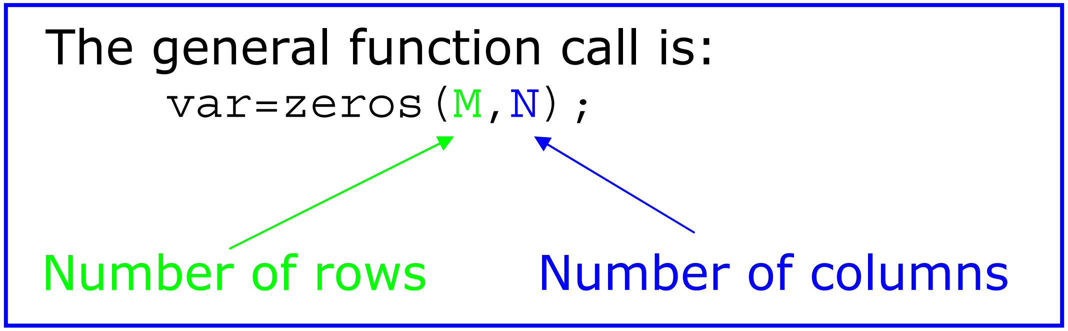
- Display the following text:

At this time, I know X% of MATLAB

```
» currentKnowledge=1-exp(-t/tau);
» disp(['At this time, I know ' ...
  num2str(currentKnowledge*100) '% of MATLAB']);
```

Automatic Initialization

- Initialize a vector of **ones**, **zeros**, or **rand**om numbers
  - » **`o=ones(1,10)`**
    - ➢ row vector with 10 elements, all 1
  - » **`z=zeros(23,1)`**
    - ➢ column vector with 23 elements, all 0
  - » **`r=rand(1,45)`**
    - ➢ row vector with 45 elements (uniform [0,1])
  - » **`n=nan(1,69)`**
    - ➢ row vector of NaNs (useful for representing uninitialized variables)



The general function call is:

```
var=zeros(M,N);
```

Number of rows

Number of columns

Automatic Initialization

- To initialize a linear vector of values use **linspace**
  - » `a=linspace(0,10,5)`
    - ➢ starts at 0, ends at 10 (inclusive), 5 values

- Can also use colon operator (**:**)
  - » `b=0:2:10`
    - ➢ starts at 0, increments by 2, and ends at or before 10
    - ➢ increment can be decimal or negative
  - » `c=1:5`
    - ➢ if increment isn’t specified, default is 1

- To initialize logarithmically spaced values use **logspace**
    - ➢ similar to **linspace**, but see **help**

Exercise: Vector Functions

Calculate your learning trajectory

- In helloWorld.m, make a linear time vector `tVec` that has 10,000 samples between 0 and `endOfClass`
- Calculate the value of your knowledge (call it `knowledgeVec`) at each of these time points using the same equation as before:

$$k = 1 - e^{-t/\tau}$$

Exercise: Vector Functions

Calculate your learning trajectory

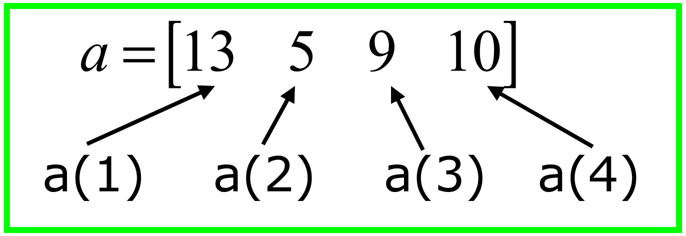
- In helloWorld.m, make a linear time vector `tVec` that has 10,000 samples between 0 and `endOfClass`
- Calculate the value of your knowledge (call it `knowledgeVec`) at each of these time points using the same equation as before:

$$k = 1 - e^{-t/\tau}$$

```
» tVec = linspace(0,endOfClass,10000);
» knowledgeVec=1-exp(-tVec/tau);
```

Vector Indexing

- MATLAB indexing starts with **1**, not **0**
  - We will not respond to any emails where this is the problem.
- a(n) returns the nth element



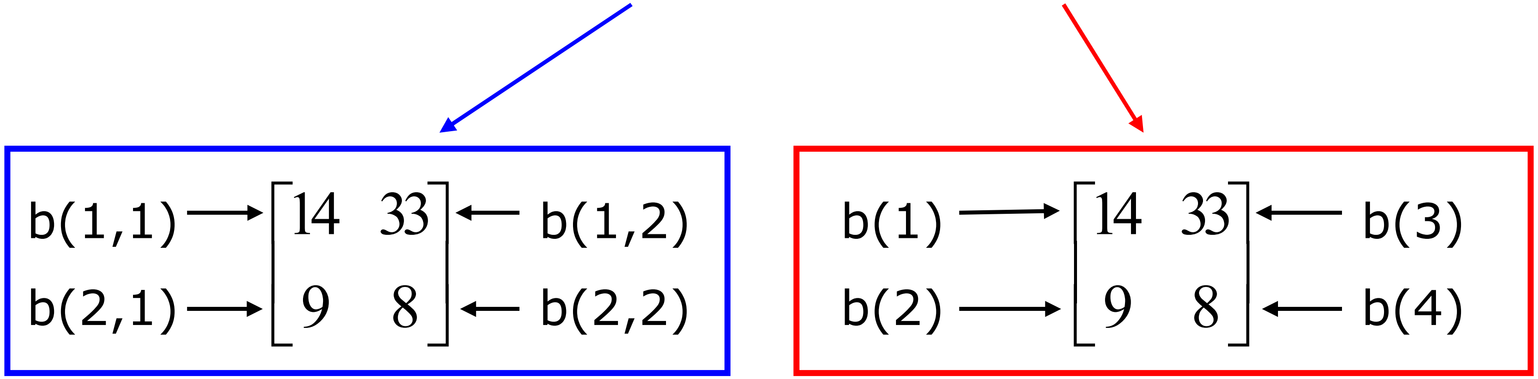
$$a = [13 \quad 5 \quad 9 \quad 10]$$

- The index argument can be a vector. In this case, each element is looked up individually, and returned as a vector of the same size as the index vector.

```
» x=[12 13 5 8];
» a=x(2:3);      →  a=[13 5];
» b=x(1:end-1);  →  b=[12 13 5];
```

Matrix Indexing

- Matrices can be indexed in two ways
  - using **subscripts** (row and column)
  - using linear **indices** (as if matrix is a vector)
- Matrix indexing: subscripts or linear indices



b(1,1) → $\begin{bmatrix} 14 & 33 \\ 9 & 8 \end{bmatrix}$ ← b(1,2)

b(2,1) → ← b(2,2)

b(1) → $\begin{bmatrix} 14 & 33 \\ 9 & 8 \end{bmatrix}$ ← b(3)

b(2) → ← b(4)

- Picking submatrices

```
» A = rand(5) % shorthand for 5x5 matrix
» A(1:3,1:2) % specify contiguous submatrix
» A([1 5 3], [1 4]) % specify rows and columns
```

Advanced Indexing 1

- To select rows or columns of a matrix, use the **:**

$$c = \begin{bmatrix} 12 & 5 \\ -2 & 13 \end{bmatrix}$$

```
» d=c(1,:);  →  d=[12 5];
» e=c(:,2);  →  e=[5;13];
» c(2,:)=[3 6];   %replaces second row of c
```

Advanced Indexing 2

- MATLAB contains functions to help you find desired values within a vector or matrix

```
» vec = [5 3 1 9 7]
```

- To get the minimum value and its index:

```
» [minVal,minInd] = min(vec);
```

  - ➢ **max** works the same way

- To find any the indices of specific values or ranges

```
» ind = find(vec == 9);
» ind = find(vec > 2 & vec < 6);
```

  - ➢ **find** expressions can be very complex, more on this later

- To convert between subscripts and indices, use **ind2sub**, and **sub2ind**. Look up **help** to see how to use them.

Exercise: Indexing

When will you know 50% of MATLAB?

- First, find the index where `knowledgeVec` is closest to 0.5. Mathematically, what you want is the index where the value of $\left|knowledgeVec - 0.5\right|$ is at a minimum (use `abs` and `min`).
- Next, use that index to look up the corresponding time in `tVec` and name this time `halfTime`.
- Finally, display the string: I will know half of MATLAB after X days
  Convert `halfTime` to days by using `secPerDay`

Exercise: Indexing

When will you know 50% of MATLAB?

- First, find the index where knowledgeVec is closest to 0.5. Mathematically, what you want is the index where the value of $\left| knowledgeVec - 0.5 \right|$ is at a minimum (use abs and min).
- Next, use that index to look up the corresponding time in tVec and name this time halfTime.
- Finally, display the string: I will know half of MATLAB after X days
  Convert halfTime to days by using secPerDay

```
» [val,ind]=min(abs(knowledgeVec-0.5));
» halfTime=tVec(ind);
» disp(['I will know half of MATLAB after ' ...
  num2str(halfTime/secPerDay) ' days']);
```

Outline

(1) Getting Started

(2) Scripts

(3) Making Variables

(4) Manipulating Variables

(5) Basic Plotting

Did everyone sign in?

Plotting

- Example

```
» x=linspace(0,4*pi,10);
» y=sin(x);
```

- Plot values against their index

```
» plot(y);
```

- Usually we want to plot y versus x

```
» plot(x,y);
```

MATLAB makes visualizing data fun and easy!

What does plot do?

- **plot** generates dots at each (x,y) pair and then connects the dots with a line
- To make plot of a function look smoother, evaluate at more points

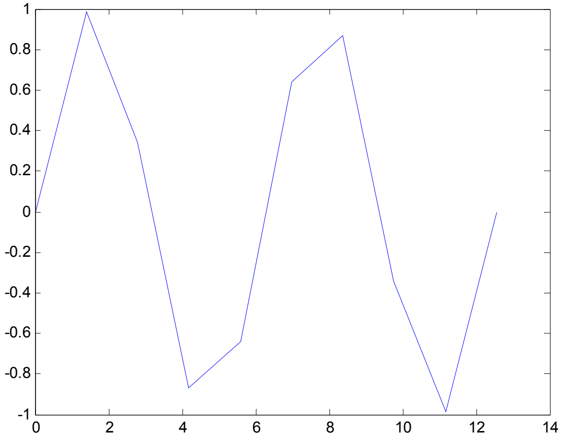
```
» x=linspace(0,4*pi,1000);
» plot(x,sin(x));
```

- x and y vectors must be same size or else you'll get an error

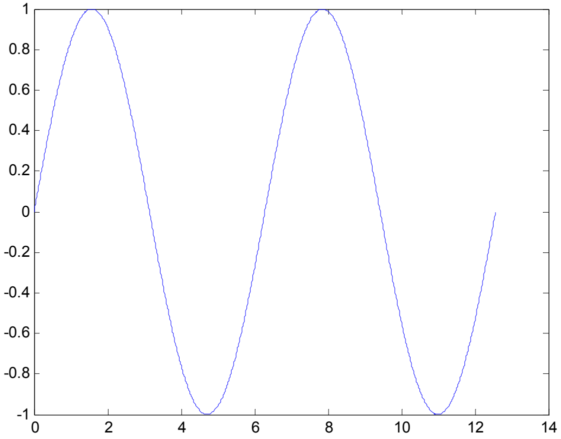
```
» plot([1 2], [1 2 3])
```

  - ➢ error!!

10 x values:



1000 x values:



Exercise: Plotting

Plot the learning trajectory

- In helloWorld.m, open a new figure (use **`figure`**)
- Plot the knowledge trajectory using **`tVec`** and **`knowledgeVec`**. When plotting, convert **`tVec`** to days by using **`secPerDay`**
- Zoom in on the plot to verify that **`halfTime`** was calculated correctly

Exercise: Plotting

Plot the learning trajectory

- In helloWorld.m, open a new figure (use `figure`)
- Plot the knowledge trajectory using `tVec` and `knowledgeVec`. When plotting, convert `tVec` to days by using `secPerDay`
- Zoom in on the plot to verify that `halfTime` was calculated correctly

```
» figure
» plot(tVec/secPerDay, knowledgeVec);
```

End of Lecture 1

(1) Getting Started

(2) Scripts

(3) Making Variables

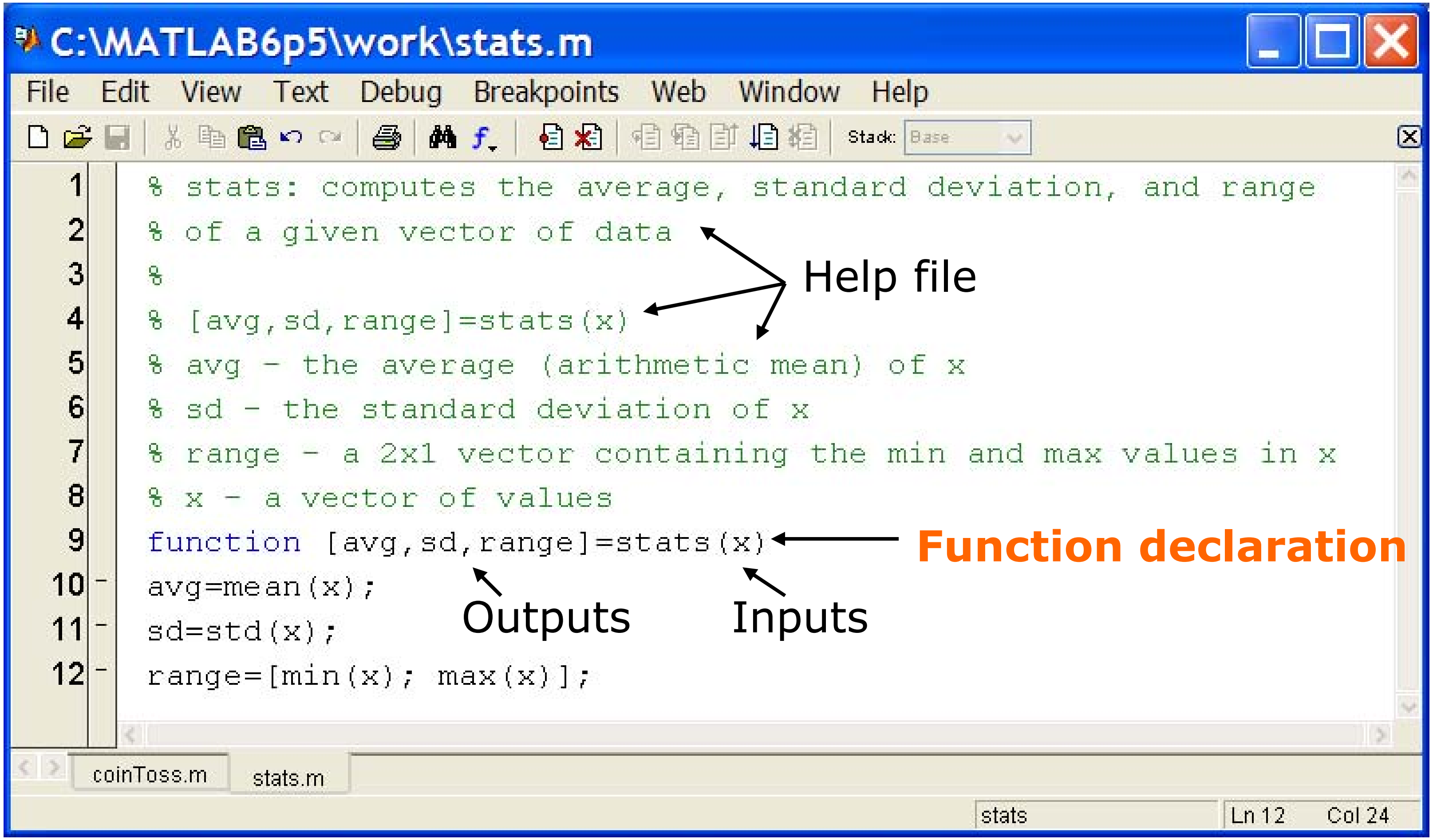
(4) Manipulating Variables

(5) Basic Plotting

Hope that wasn’t too much!!

User-defined Functions

- Functions look exactly like scripts, but for **ONE** difference
  - Functions must have a function declaration


C:\MATLAB6p5\work\stats.m
File Edit View Text Debug Breakpoints Web Window Help
Stack: Base
coinToss.m
stats.m
stats
Ln 12
Col 24

```
% stats: computes the average, standard deviation, and range
% of a given vector of data
%
% [avg,sd,range]=stats(x)
% avg - the average (arithmetic mean) of x
% sd - the standard deviation of x
% range - a 2x1 vector containing the min and max values in x
% x - a vector of values
function [avg,sd,range]=stats(x)
avg=mean(x);
sd=std(x);
range=[min(x); max(x)];
```

Help file

Function declaration

Outputs

Inputs

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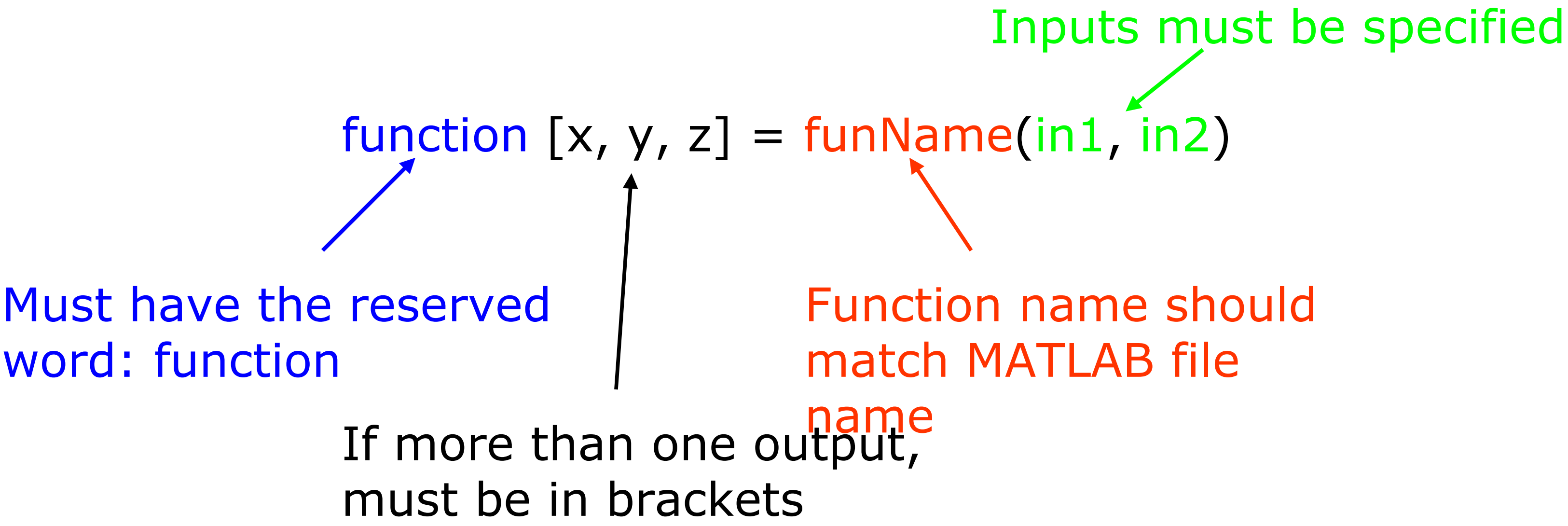
User-defined Functions

- Some comments about the function declaration



Inputs must be specified

```
function [x, y, z] = funName(in1, in2)
```

Must have the reserved word: function

Function name should match MATLAB file name

If more than one output, must be in brackets

- No need for return: MATLAB 'returns' the variables whose names match those in the function declaration
- Variable scope: Any variables created within the function but not returned disappear after the function stops running

Functions: overloading

- We're familiar with
  - » `zeros`
  - » `size`
  - » `length`
  - » `sum`

- Look at the help file for size by typing
  - » `help size`

- The help file describes several ways to invoke the function
  - ➢ D = SIZE(X)
  - ➢ [M,N] = SIZE(X)
  - ➢ [M1,M2,M3,...,MN] = SIZE(X)
  - ➢ M = SIZE(X,DIM)

Functions: overloading

- MATLAB functions are generally overloaded
  - ➢ Can take a variable number of inputs
  - ➢ Can return a variable number of outputs

- What would the following commands return:

```
» a=zeros(2,4,8); %n-dimensional matrices are OK
» D=size(a)
» [m,n]=size(a)
» [x,y,z]=size(a)
» m2=size(a,2)
```

- You can overload your own functions by having variable input and output arguments (see `varargin`, `nargin`, `varargout`, `nargout`)

Outline

(1) Functions

(2) Flow Control

(3) Line Plots

(4) Image/Surface Plots

(5) Vectorization

Relational Operators

- MATLAB uses *mostly* standard relational operators

equal	==
not equal	~=
greater than	>
less than	<
greater or equal	>=
less or equal	<=

- Logical operators

	elementwise	short-circuit (scalars)
And	&	&&
Or	|	||
Not	~	
Xor	xor	
All true	all	
Any true	any	

- Boolean values: zero is false, nonzero is true
- See **help .** for a detailed list of operators

if/else/elseif

- Basic flow-control, common to all languages
- MATLAB syntax is somewhat unique

IF

```
if cond
    commands
end
```

Conditional statement: evaluates to true or false

ELSE

```
if cond
    commands1
else
    commands2
end
```

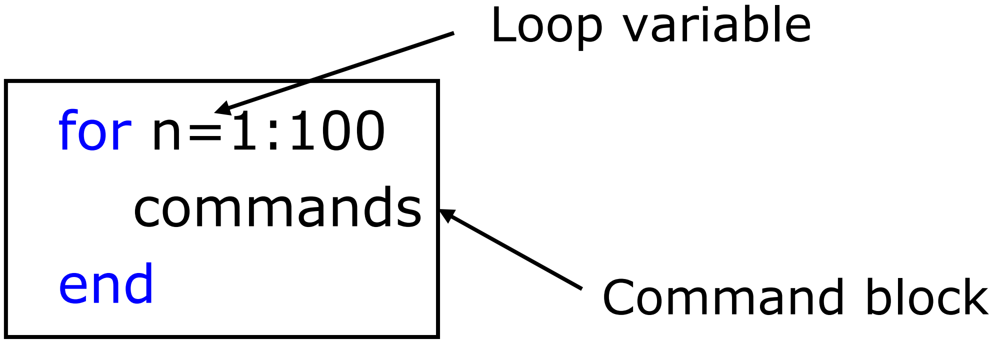
ELSEIF

```
if cond1
    commands1
elseif cond2
    commands2
else
    commands3
end
```

- No need for parentheses: command blocks are between reserved words

for

- **for** loops: use for a known number of iterations
- MATLAB syntax:



```
for n=1:100
     commands
end
```

Loop variable

Command block

- The loop variable
    - Is defined as a vector
    - Is a scalar within the command block
    - Does not have to have consecutive values (but it's usually cleaner if they're consecutive)
- The command block
    - Anything between the **for** line and the **end**

while

- The while is like a more general for loop:
  - Don't need to know number of iterations

WHILE

```
while cond
    commands
end
```

- The command block will execute while the conditional expression is true
- Beware of infinite loops!

Outline

(1) Functions

(2) Flow Control

(3) Line Plots

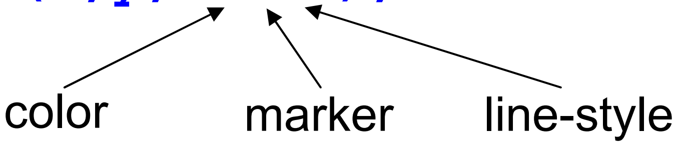
(4) Image/Surface Plots

(5) Vectorization

Plot Options

- Can change the line color, marker style, and line style by adding a string argument

```
» plot(x,y,’k.-’);
```



color marker line-style

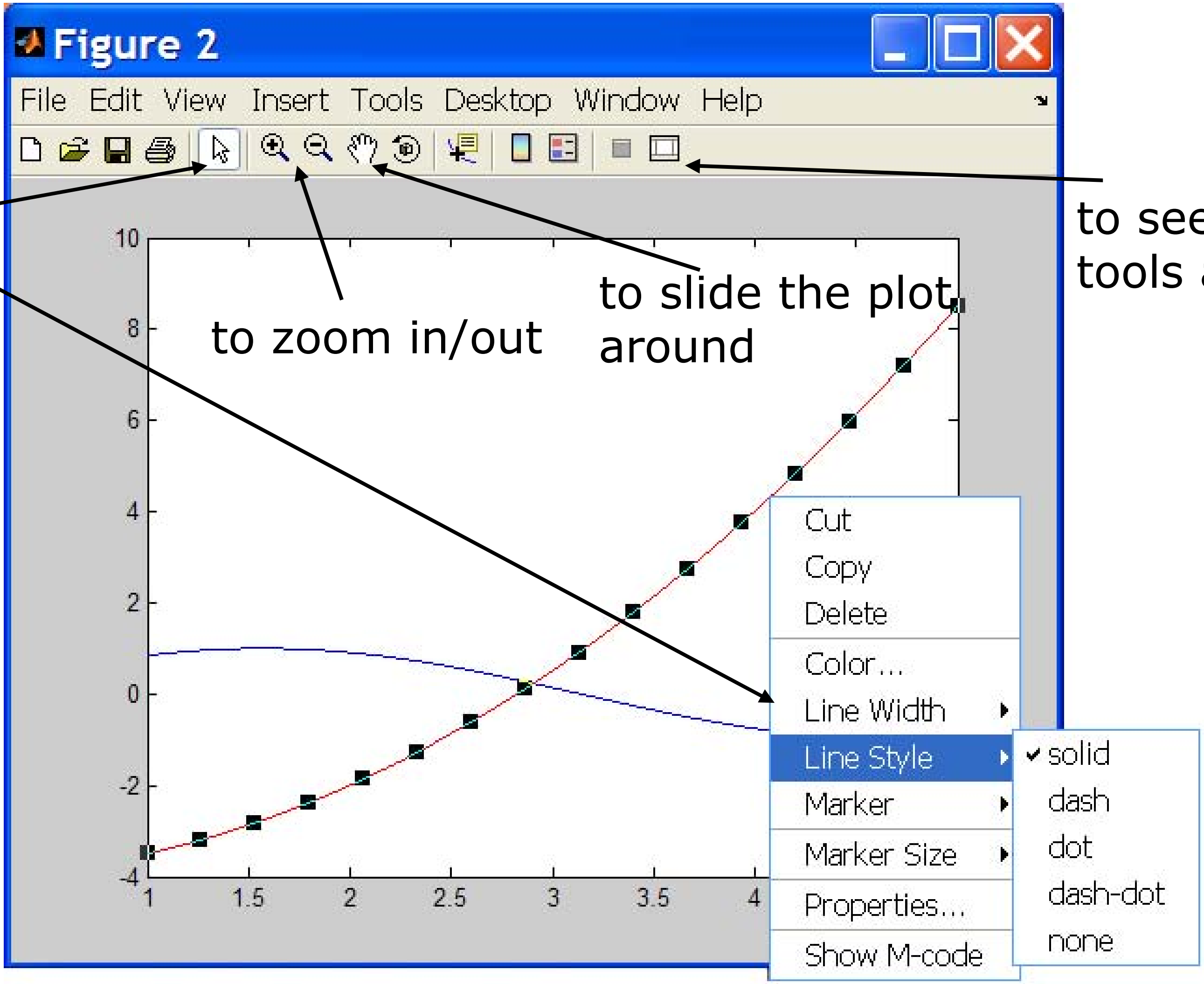
- Can plot without connecting the dots by omitting line style argument

```
» plot(x,y,’.’)
```

- Look at **help plot** for a full list of colors, markers, and linestyles

Playing with the Plot

to select lines and delete or change properties



to zoom in/out

to slide the plot around

to see all plot tools at once

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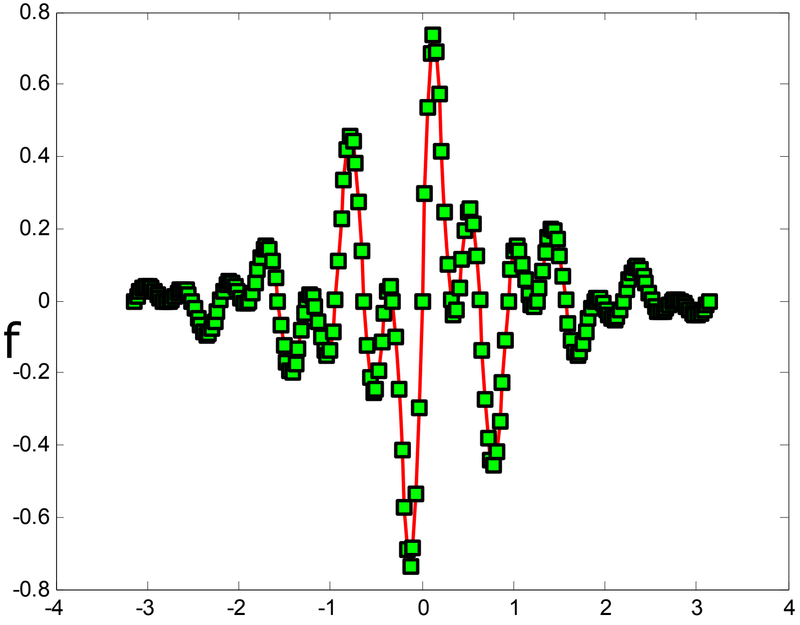
Line and Marker Options

- Everything on a line can be customized

```
» plot(x,y,'--s','LineWidth',2,...
                'Color', [1 0 0], ...
                'MarkerEdgeColor','k',...
                'MarkerFaceColor','g',...
                'MarkerSize',10)
```

You can set colors by using
a vector of [R G B] values
or a predefined color
character like 'g', 'k', etc.



- See **doc line_props** for a full list of properties that can be specified

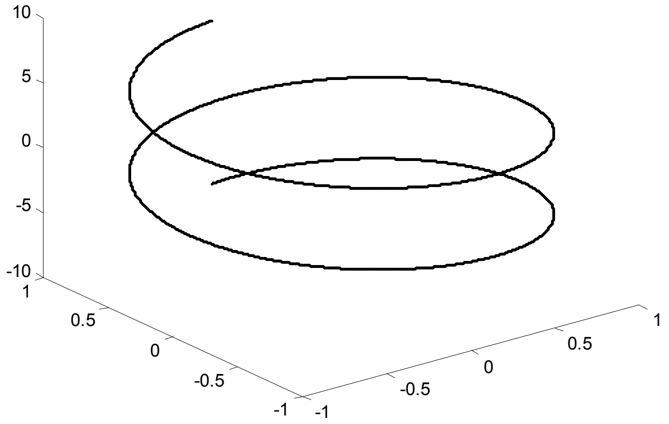
3D Line Plots

- We can plot in 3 dimensions just as easily as in 2

```
» time=0:0.001:4*pi;
» x=sin(time);
» y=cos(time);
» z=time;
» plot3(x,y,z,'k','LineWidth',2);
» zlabel('Time');
```

- Use tools on figure to rotate it
- Can set limits on all 3 axes

```
» xlim, ylim, zlim
```



Multiple Plots in one Figure

- To have multiple axes in one figure
  - » `subplot(2,3,1)`
    - ➢ makes a figure with 2 rows and three columns of axes, and activates the first axis for plotting
    - ➢ each axis can have labels, a legend, and a title
  - » `subplot(2,3,4:6)`
    - ➢ activating a range of axes fuses them into one

- To close existing figures
  - » `close([1 3])`
    - ➢ closes figures 1 and 3
  - » `close all`
    - ➢ closes all figures (useful in scripts/functions)

Copy/Paste Figures

- Figures can be pasted into other apps (word, ppt, etc)
- *Edit→ copy options→ figure copy template*
  - ➢ Change font sizes, line properties; presets for word and ppt
- *Edit→ copy figure* to copy figure
- Paste into document of interest

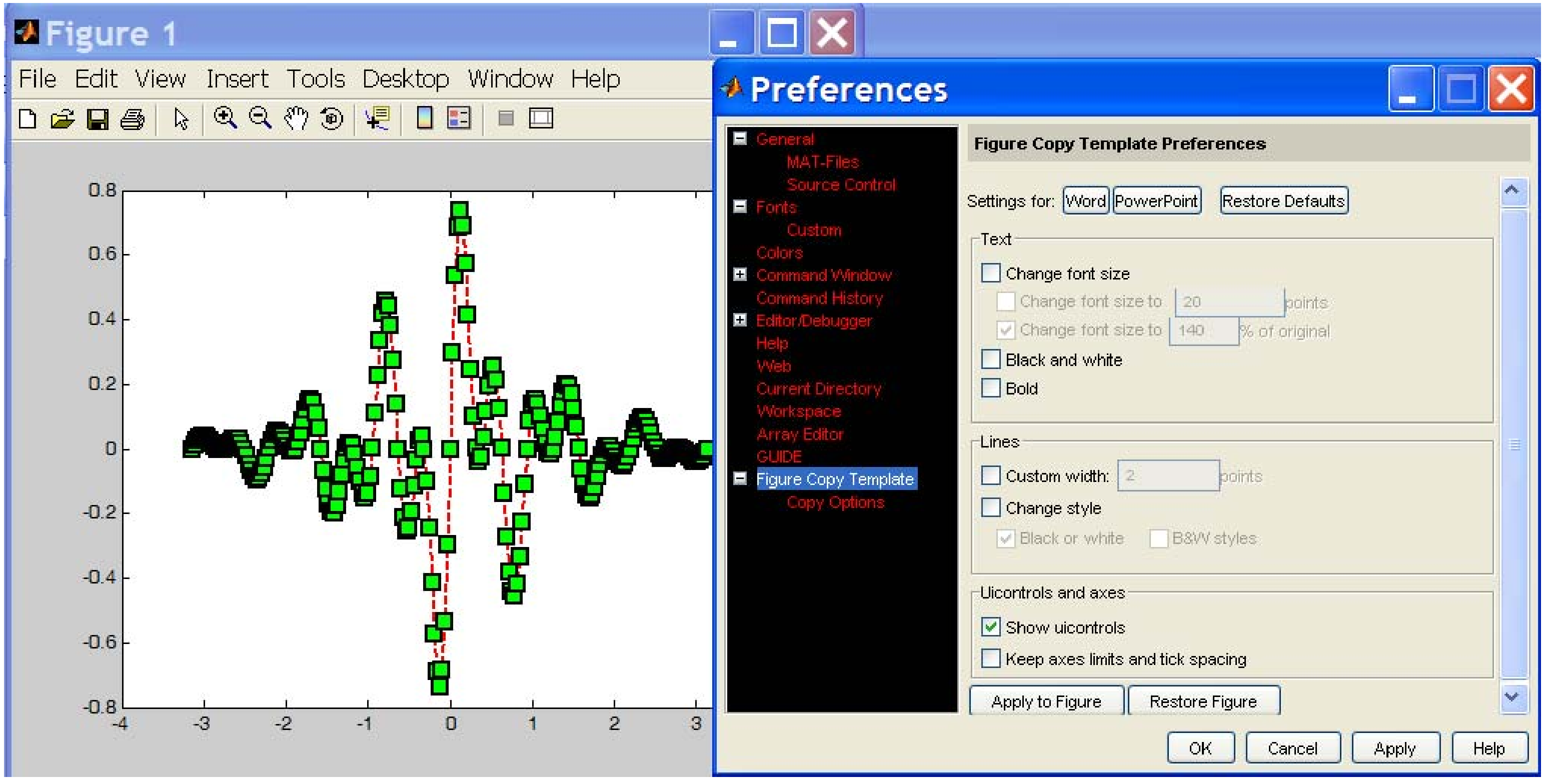


Figure Copy Template Preferences

Settings for: Word PowerPoint Restore Defaults

Text
- ☐ Change font size
  - ☐ Change font size to 20 points
  - ☑ Change font size to 140 % of original
- ☐ Black and white
- ☐ Bold

Lines
- ☐ Custom width: 2 points
- ☐ Change style
  - ☑ Black or white ☐ B&W styles

Uicontrols and axes
- ☑ Show uicontrols
- ☐ Keep axes limits and tick spacing

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Saving Figures

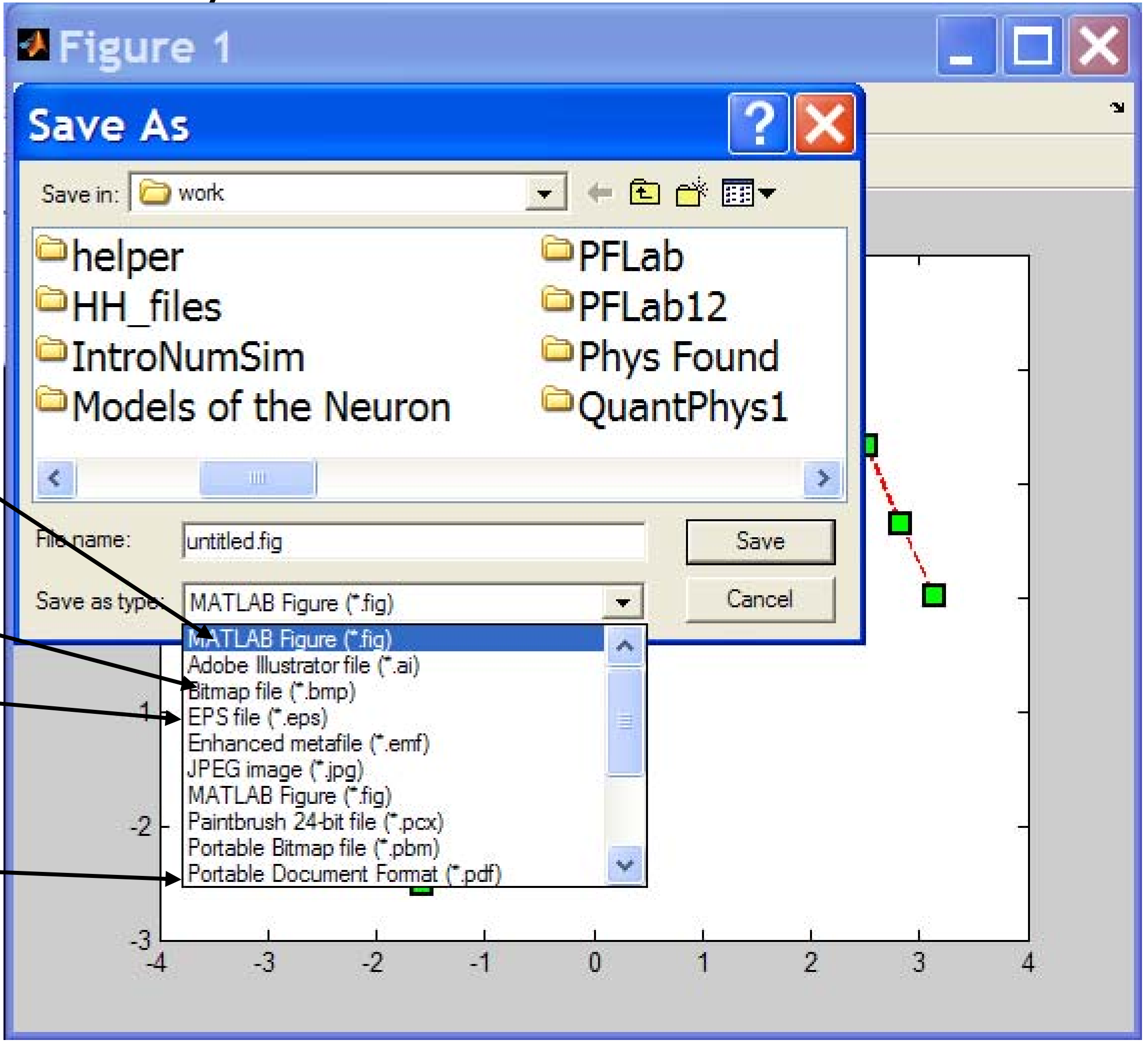
- Figures can be saved in many formats. The common ones are:

.fig preserves all information

.bmp uncompressed image

.eps high-quality scaleable format

.pdf compressed image



Save in: work

File name: untitled.fig

Save as type: MATLAB Figure (*.fig)

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