${\rm Matlab} \ {\rm Tutorial}$

Part 1: Basics

Applied Mathematics , Fall 2012

Marcus Pendergrass Hampden-Sydney College

Outline

Getting Started

- 2 Example Session
- 3 Arithmetic Operations
- 4 Variables And Arrays
- Basic Plotting
- 6 Saving Your Work

MATLAB Tutorial

r. Pendergrass

Getting Started

Example Session

Arithmetic Operations

Variables And Arrays

Basic Plotting

► To start MATLAB, double-click the "MATLAB R2012a" icon:



▶ This brings up the MATLAB desktop...

MATLAB Tutorial

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The Matlab Desktop

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MATLAB Tutorial

Getting Starte

► The MATLAB desktop has several useful components...

The MATLAB Desktop – Command Window

MATLAB Tutorial

Started

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► You work with MATLAB interactively in the Command Window

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MATLAB Tutorial

Getting Starte

► The Current Folder window shows the current directory

The MATLAB Desktop – Workspace

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The Workspace window shows the variables you've defined

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Example Session

Define A Variable

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Getting Started Example Session Arithmetic Operations Variables And Arrays Basic Plotting Saving Your Work

▶ Let's set a variable x equal to 3...

Define A Variable

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▶ Pressing return tells MATLAB to execute your command.

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Example Session

Define A Variable

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▶ MATLAB echoes the result back to you in the command window.

Example Session

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Manipulate the variable using normal arithmetic operations...

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Getting Started Example Session Arithmetic Operations Variables And Arrays Basic Plotting Saving Your Work

MATLAB stores the result in the variable ans.

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Using The History Window

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Double-click on a command in the history window to re-execute it.

Dr. Pendergrass (H-SC)

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> Saving Your Work

Double-click on a command in the history window to re-execute it.

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Clearing The Command Window

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▶ The command clc clears the command window.

Clearing The Command Window

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clc doesn't clear the variables themselves, only the display.

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Predefined Constants



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MATLAB knows the value of π. It is stored in the pre-defined variable pi.

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Suppressing Output



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You can suppress MATLAB's command window output by ending a command with a semicolon (;).

Suppressing Output



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You can suppress MATLAB's command window output by ending a command with a semicolon (;).

Built-In Functions

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▶ Most common mathematical functions are built into MATLAB.

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Built-In Functions

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▶ Most common mathematical functions are built into MATLAB.

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String Variables For Text

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Text can be stored in string variables.

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> You can do lots of manipulations with string variables as well.

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String Variables For Text

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> You can do lots of manipulations with string variables as well.

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► The help browser is your friend. Access it from the Help menu (Help → Product Help). MATLAB Tutorial

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▶ You can either browse from the contents pane...

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…or search by typing in the search box.

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...or search by typing in the search box.

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Practice

Practice 1.1

Let x = 3 and y = 5. Perform the following calculations in MATLAB's command window:

1.
$$z = 3x - 4y + 2$$

2.
$$w = \frac{y}{3x+z}$$

$$3. \ \alpha = \sqrt{100 + z}$$

Practice 1.2

Look up the sprintf command using MATLAB's help browser. Use it to display the string 'My value of alpha is xxxx.', where xxxx is replaced by the value of α you calculated in the last problem.

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Basic Arithmetic Operators

- addition
- subtraction
- multiplication
- / division
- exponentiation

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Order Of Operations

Order Of Operations

- 1. Calculations done from left to right
- 2. Parenthesized items evaluated first
 - Nested parentheses evaluated from innermost to outermost
- 3. function calls evaluated next (e.g. sqrt, cos, etc...)
- 4. exponents and radicals evaluated next
- 5. unary negations evaluated next
- 6. multiplications and divisions evaluated next
- 7. addition and subtraction evaluated last

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Example: Order Of Operations

$$4+24/2^{3}+6*(5+\cos(pi)) = 4+24/2^{3}+6*(5+-1)$$

= 4+24/2^{3}+6*(5-1)
= 4+24/2^{3}+6*4
= 4+24/8+6*4
= 4+3+6*4
= 4+3+24
= 7+24
= 31

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Practice

Practice 1.3

Evaluate the following expressions by hand using the correct order of operations:

- 1. 8-6-3/2^2+1-5
- 2. 4^1/2^3
- 3. 2/3+2^{sin(0)}

Practice 1.4

Give the MATLAB commands to evaluate the following expressions.

- 1. $\frac{x}{1+x^2}$ 2. $\frac{x+1}{1+x^2}$ 3. $2^{(2^x)}$
- **4**. $4\cos(2\pi x)$

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Variables And Variable Names

To create a variable, just assign a value to a name:

```
>> a = 3;
>> favMovie1982 = 'Blade Runner';
```

Rules for variable names:

- first character must be a letter
- ▶ other characters must be letters, numbers, or underscores (_).
- variable names are case sensitive: myVar is different from myvar.
- Built-in variables (don't assign to these names):
 - pi stands for $\pi = 3.1415926...$
 - ans stores the last unassigned value.
 - Inf stands for positive infinity.
 - ▶ NaN stands for "not a number" (e.g. 0/0).

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Vectors, Matrices, and Arrays

- A array is a variable that can hold multiple values at the same time.
- The most common type of array is a matrix, which is a two-dimensional rectangular array.
- A vector is a one-dimensional rectangular array.
- There are also multidimensional arrays that have more than two dimensions.
- Sometimes we refer to plain everyday numbers as scalars.

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Creating Vectors

<pre>Create a vector by typing entries within square brackets: >> myVec = [-1 3 pi 2.7183]</pre>					
-1.0000	3.0000	3.1416	2.7183	Variables And Arrays	

Creating Vectors

There's a special syntax to create a vector of evenly-spaced entries:

► The general syntax for this is

[startValue : skipValue : endValue]

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Referencing Vector Entries

▶ Reference individual entries in a vector by their position:

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Creating Matrices

Similarly you can create a matrix by typing in the entries individually. Use a semicolon (;) for the row separator.

>> myMatrix = [1 2 3; 4 5 6]

myMatrix =

- 1 2 3 4 5 6
- This is a 2×3 matrix: 2 rows, 3 columns.

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Referencing Matrix Entries

Again, you reference individual entries in a matrix by their position, first the row number, then the column number:

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Matrix Creation Commands

You can create a matrix of all zeros using the zeros command. For example, to create a 2 × 4 zero matrix, use

```
>> M = zeros(2,4)
M =
0 0 0 0
0 0 0 0
```

- The first argument is the number of rows, the second is the number of columns.
- ▶ There is a similar command called ones.

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Creating Random Matrices

The rand command creates a matrix whose entries are random numbers uniformly distributed on [0, 1]:

>> rM = rand(3,2) rM =

- 0.8147 0.9134 0.9058 0.6324 0.1270 0.0975
- There is a similar command called randn. It creates matrices whose entries have the standard normal distribution.
- There's another command called randi. It creates matrices whose entries are random integers.
- For more info consult the Help Browser.

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Row and Column Vectors

- Notice that a vector is just a matrix with only one row; i.e. a 1 × n matrix. Sometimes we call these row vectors.
- A $n \times 1$ matrix (i.e. just one column) is called a column vector.

```
>> colVec = randn(3,1)
```

- colVec = -0.4336 0.3426 3.5784
- note: MATLAB distinguishes between row and column vectors!
- note: The transpose operator (.') converts row vectors to column vectors and vice versa.

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+, -, *, /, and $\hat{}$ are defined for array variables, but only in certain cases:

A+B and A-B are defined so along as A and B are the same size (same number of rows and columns). In this case the sum or difference is computed *entrywise*:

$$\left(\begin{array}{rrr}1&2\\3&4\end{array}\right)+\left(\begin{array}{rrr}5&6\\7&8\end{array}\right)=\left(\begin{array}{rrr}6&8\\10&12\end{array}\right)$$

The definitions of A*B, A/B, and A^n come from the mathematical field of Linear Algebra. We do not need them at present.

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Vectorized Operations On Arrays

MATLAB does define an entrywise product (.*), entrywise quotient (./), and entrywise exponentiation $(.^)$.

A.*B and A./B compute the entrywise product and quotient of A and B. A and B must be of the same size.

$$\left(\begin{array}{rrr}1&2\\3&4\end{array}\right).*\left(\begin{array}{rrr}5&6\\7&8\end{array}\right)=\left(\begin{array}{rrr}5&12\\21&32\end{array}\right)$$

▶ A. în raises each entry of A to the nth power:

$$\left(\begin{array}{cc}1&2\\3&4\end{array}\right).^{3}=\left(\begin{array}{cc}1&8\\27&64\end{array}\right)$$

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Vectorized Operations On Arrays

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$$\left(\begin{array}{rrr}1&2\\3&4\end{array}\right) \cdot \ast \left(\begin{array}{rrr}5&6\\7&8\end{array}\right) = \left(\begin{array}{rrr}5&12\\21&32\end{array}\right)$$

• A. în raises each entry of A to the nth power:

$$\begin{pmatrix} 1 & 2 \\ 3 & 4 \end{pmatrix} \cdot \mathbf{\hat{3}} = \begin{pmatrix} 1 & 8 \\ 27 & 64 \end{pmatrix}$$

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Vectorized Operations On Arrays

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$$\left(\begin{array}{rrr}1&2\\3&4\end{array}\right) \cdot \ast \left(\begin{array}{rrr}5&6\\7&8\end{array}\right) = \left(\begin{array}{rrr}5&12\\21&32\end{array}\right)$$

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$$\left(\begin{array}{rrr}1&2\\3&4\end{array}\right).\mathbf{\hat{3}}=\left(\begin{array}{rrr}1&8\\27&64\end{array}\right)$$

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- ▶ 3 + A adds three to every entry of A. Similarly A 3 subtracts three from every entry of A.
- ▶ 4 * A multiplies every entry of A by four. Similarly A / 4 divides every entry of A by four.
- ▶ 2 . A computes powers of two using the entries of A.

>> 2 .^ [1 2 3 4]

ans =

2.0000 4.0000 8.0000 16.0000

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ans =

2.0000 4.0000 8.0000 16.0000

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MATLAB's built-in functions are vectorized. If you give them an array as input, the function will be applied to each entry in the array.

>> v = [1 4 9 16];

>> sqrt(v)

ans =

1.0000 2.0000 3.0000 4.0000

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Vectorized Operations

Compute
$$\frac{1}{1+x^2}$$
, where $x = \begin{bmatrix} -3 \\ \vdots \end{bmatrix}$.

Solution

>> y = 1 ./ $(1 + x.^2)$							

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Vectorized Operations

Compute
$$\frac{1}{1+x^2}$$
, where x = [-3 : 3].

Solution

;	>> x = [-3 :	3]						
3	x =							
	-3.0000	-2.0000	-1.0000	0.0000	1.0000	2.0000	3.0000	
>> y = 1 ./ (1 + x.^2)								
2	y =							
	0.1000	0.2000	0.5000	1.0000	0.5000	0.2000	0.1000	

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Practice

Practice 1.5

What do the following MATLAB commands do?

1. [1 : 99]

- 2. var1 = [0 : 5 : 200];
- 3. var2 = [10 : -1 : 1]

Practice 1.6

Use the Help Browser to look up the randi command. Use randi to create a 3×5 array of random integers, with all entries between 1 and 100. What is the position (row number, column number) of the maximum entry in your array?

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Practice

Practice 1.7

Write a MATLAB command to

- 1. make a row vector containing the odd numbers from 1 to 37.
- 2. make a 3×4 matrix containing all 1's.
- 3. make a column vector containing five random integers, each between 1 and 6.

Practice 1.8

In three lines of MATLAB code, create two random 3×3 arrays, and compute the entrywise product of them. Use sprintf to display the (3,2) entry to the command window.

Practice 1.9

In a single line of $\rm Matlab$ code compute the cube roots of the even integers between 2 and 20 inclusive.

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Basic Plotting

Bar Plots Of Vectors

The function bar makes a bar plot of a vector.

```
>> v = randn(1,5);
>> bar(v);
```



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Stem Plots Of Vectors

▶ The function stem makes a "stem plot" of a vector.

```
>> v = randn(1,5);
>> stem(v);
```



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Function Plotting

To plot a function, put the x-values in one array, the y-values in another array, and use the plot command.

```
>> xVals = [0 : 0.1 : 4*pi];
>> yVals = sin(xVals);
>> plot(xVals,yVals);
```



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Function Plotting

Use a "format string" to change the color of the plot. Let's redo the previous plot in red.

```
>> xVals = [0 : 0.1 : 4*pi];
>> yVals = sin(xVals);
>> plot(xVals,yVals, 'r');
```



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Function Plotting

There is a host of commands for adding titles, axis labels, legends, and other decorations to a graph. Here's a small sample of the possibilities:

```
>> xVals = [0 : 0.1 : 4*pi];
>> yVals = sin(xVals);
>> plot(xVals,yVals);
>> xlim([0,4*pi]);
>> ylim([-1.1,1.1]);
>> xlabel('seconds');
>> ylabel('flow (liters/min)');
>> title('Flow Rate vs. Time');
```

This gives us...

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You can also use the controls on the figure's menu and toolbar to edit the graph.

Play around with these commands, and explore the possibilities...

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Vectorizing In Plots

```
Plot y = \sin(x)/x for x \in [-20, 20].
```

Solution

```
>> x = [-20 : 0.1 : 20];
>> y = sin(x) ./ x; % note vectorized arithmetic
>> plot(x,y)
```

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Vectorizing In Plots

Plot
$$y = \sin(x)/x$$
 for $x \in [-20, 20]$.

Solution

>> x = [-20 : 0.1 : 20]; >> y = sin(x) ./ x; % note vectorized arithmetic >> plot(x,y)

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Vectorizing In Plots

Plot
$$y = \sin(x)/x$$
 for $x \in [-20, 20]$.

Solution

```
>> x = [-20 : 0.1 : 20];
>> y = sin(x) ./ x; % note vectorized arithmetic
>> plot(x,y)
```



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Practice

Practice 1.10

Use the Help Browser to look up the randi command. Use randi to create a 1×20 column vector of random integers, with all entries between 1 and 10. Make a stem plot of this vector.

Practice 1.11

Plot $y = e^x$ for x between -1 and 1. Label your axes, and provide a title for your plot.

Practice 1.12

Plot $y = \frac{1 - \cos(x)}{x^2}$ for x between -30 and 30. Label your axes, and provide a title for your plot.

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Use the **save** command to save workspace variables to the current directory:

Save all workspace variables to the file myFile.mat in the current directory:

>> save myFile;

note: MATLAB automatically adds the .mat extension.

Save only the variables x, y, and z to myFile.mat:

>> save myFile x y z;

The load command loads these variables to the workspace:

>> load myFile;

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Saving MATLAB Figures

Saving figures as .fig files enables you to reload them later without having to regenerate all the data and decorations.



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Saving figures as .fig files enables you to reload them later without having to regenerate all the data and decorations.



You can also save figures in standard graphics formats, like .png, .jpg, etc. (.png is recommended.)

MATLAB Tutorial

Practice

Practice 1.13

Create variables x = 3, y = [10 : -1 : 1], and z = 'robertFrost'. Save these to a file named foo.mat in the current folder. Look up the help on the clear command, and use it to clear all your workspace variables. Now if you double-click the file foo.mat from MATLAB's current folder window, what happens?

Practice 1.14

Make an accurate plot of $y = \tan(x)/x$ for $x \in [-2\pi, 2\pi]$. Save your plot to a figure file named tan.fig. Kill the existing plot window, then double click on tan.fig in the current folder window. What happens?

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