Matlab Basics for Math 283

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Matlab has tutorials available online at:
http://www.mathworks.com/academia/student_center/tutorials/launchpad.html

Starting up matlab:

Go to finder -> applications -> matlab701 -> matlab7.01 [Pick the current version]
From a terminal command prompt:
matlab (*display matlab desktop, access editor, helpdesk)*
matlab –nojvm (*no java virtual machine, no desktop -- faster)*
matlab –nodisplay (*no desktop, no plot windows -- faster)*
matlab –help *(to see all options)*

NOTE: ">>" is the matlab prompt.

Operators, Punctuation

Operators

Arithmetic operators in matlab:

*	/	+	-	^

follow the convention in linear algebra. Matrices must have correct dimensions for any operation. Follows order of operations. Use parentheses to change precedence

```
>> 1*2/3+4^5-4^5
ans =
    0.6667
```

Element-by-element operators operate on arrays or matrices by element (essentially operator preceded by a period):

.*	./	.^

```
>> [1 2 3].*[1 2 3]
ans =
     1     4     9
```

Matrix Operations		Array Operations	
x	1 2 3	y	4 5 6
x'	1 2 3	y'	4 5 6
x+y	5 7 9	x-y	-3 -3 -3
x + 2	3 4 5	x-2	-1 0 1
x * y	Error	x.*y	4 10 18
x'*y	32	x'.*y	Error
x*y'	4 5 6 8 10 12 12 15 18	x.*y'	Error
x*2	2 4 6	x.*2	2 4 6
x\y	16/7	x.\y	4 5/2 2
2\x	1/2 1 3/2	2./x	2 1 2/3
x/y	0 0 1/6 0 0 1/3 0 0 1/2	x./y	1/4 2/5 1/2
x/2	1/2 1 3/2	x./2	1/2 1 3/2
x^y	Error	x.^y	1 32 729
x^2	Error	x.^2	1 4 9
2^x	Error	2.^x	2 4 8

Matlab Punctuation

`%`	Denotes comment line. Information after % is ignored by matlab.
	`>> %nothing happens`
	`>>`

`,`	Comma works like blank space. Concatenates array elems along row. Shows results.
	`>> x=[1,2,3],`
	`x =`
	`     1     2     3`

`;`	Concatenates array elements along column. Suppresses printing contents of variable to screen. >> x=[1;2;3] x = 1 2 3 >> x=[1;2;3]; >>

`:`	Specifies a range of numbers. A colon in an array dimension accesses all elements in that dimension.
	`>> z=[1:0.25:2; 3:0.25:4] % row 1: 1 to 2, row 2: 3 to 4, step size/increment by 0.25`
	`z =`
	`    1.0000    1.2500    1.5000    1.7500    2.0000`
	`    3.0000    3.2500    3.5000    3.7500    4.0000`
	`>> z(:,2) %all rows, column 2`
	`ans =`
	`    1.2500`
	`    3.2500`
	`>> z(1,:) %all columns, row 1`
	`ans =`
	`    1.0000    1.2500    1.5000    1.7500    2.0000`

`'`	Apostrophe at the end of a vector or matrix gives its transpose.
	`>> z(:,2)'`
	`ans =`
	`    1.2500    3.2500`

More basic operators/functions

exp	**log**	**log10**	**log2**	**sqrt**

Basic Data Structures

Basic data constructs are arrays and matrices.
Arrays can be row vectors (*1 by n* array) or column vectors (*n by 1* array).
A *matrix* can have two dimensions (example: *m rows* and *n columns).* Multi-dimensional arrays can also be specified.

```
>> row_vect = [1 4 5];
>> column_vect = [1;4;5];
```

Concatenate column vectors along same row:

```
>> two_column_vect = [column_vect column_vect]
two_column_vect =
     1     1
     4     4
     5     5
```

Concatenate row vectors along same column:

```
>> two_row_vect = [row_vect; row_vect]
two_row_vect =
     1     4     5
     1     4     5
```

Accessing array elements

a(i)	i-th element of array **a.**
A(i , : **)**	i-th row of a matrix **A,** all columns (Can select certain columns by putting an array of indices instead of ':').
A(:, i **)**	i-th column of a matrix **A,** all rows (Can select certain rows also by putting an array of indices instead of ':').
A(i , j **)**	Element in i-th row, j-th column of matrix **A.**

Array building

zeros, ones	Builds arrays with all 0's or all 1's respectively.
	`>> x = zeros(1,3)`
	`x =`
	`     0     0     0`

eye	Creates an identity matrix.
	`>> x= eye(2,2)`
	`x =`
	`     1     0`
	`     0     1`

Some basic functions on arrays and matrices
Type 'help *function_name'* for details on usage.

size	**max**	**min**	**mean**	**std**	**var**	**sort**	**sum**	**prod**	**diff**	**dot**	**cross**

Not covered: cell arrays.

File and Workspace Management, File I/O

File and workspace management

dir, ls	Show files in active directory
delete *filename*	Remove file *filename* in active directory.
cd, pwd	Show present directory
cd *dir*	Changes the directory to *dir*
clear	Remove all variables from workplace
clear x	Remove variable x from the workplace.
who	List all variables in the workspace

File I/O

load	Syntax: load filename
	Load from file. Check out variations of use. File should have correct format (Same number of columns for each row, rows for each column) and no non-numeric characters. For instance if you have a file called test.dat in current dir:
	`>> load test.dat`
	`>> test`
	`test =`
	`     1`
	`     2`
	`     3`

save	Syntax: save *filename variable* –ascii Saves ‘variable’ in ASCII format in’filename’. `>> save test_copy.dat test -ascii`

Control Flow

Conditional Control – if , else, elseif, and switch/case

if, else, and elseif

if evaluates a logical expression and executes a group of statements based on the value of the expression. In its simplest form, its syntax is

```
if logical_expression
    statements
end
```

The else and elseif statements further conditionalize the `if` statement:

The else statement has no logical condition. The statements associated with it execute if the preceding if (and possibly elseif condition) evaluates to logical 0 (false).

The elseif statement has a logical condition that it evaluates if the preceding if (and possibly elseif condition) is false. The statements associated with it execute if its logical condition evaluates to logical 1 (true). You can have multiple elseif statements within an if block.

For some value of n:

```
if n < 0         % If n negative, display message.
    disp(’Input negative’);
elseif n == 0 % If n equals zero
       disp(’Input zero’);
else %n greater than zero is remaining case
       disp(’Input positive’);
end
```

switch, case, and otherwise

switch executes certain statements based on the value of a variable or expression. Its basic form is

```
switch expression (scalar or string)
   case value1
      statements       % Executes if expression is value1
   case value2
      statements       % Executes if expression is value2
    .
    .
   otherwise
      statements       % Executes if expression does not
                       % match any case
end
```

*** More about the difference between switch and if/elseif: http://goo.gl/dpulZ**

Loop control – for, while, break

for

The for loop executes a statement or group of statements a predetermined number of times. Its syntax is

```
for index = start:increment:end
    statements
end
```

The default increment is `1`. You can specify any increment, including a negative one. For positive indices, execution terminates when the value of the index exceeds the *end* value; for negative increments, it terminates when the index is less than the end value.

For example, this loop executes five times.

```
x=[1:10];
for n = 2:6
    x(n) = 2 * x(n);
end
```

while

The while loop executes a statement or group of statements repeatedly as long as the controlling expression is true (`1`). Its syntax is:

```
while expression
    statements
end
```

If the expression evaluates to a matrix, all its elements must be `1` for execution to continue. To reduce a matrix to a scalar value, use the `all` and `any` functions.

Increments n from 0 to 10:

```
n = 0;
while n < 10
    n = n + 1
end
```

Exit a `while` loop at any time using the ***break*** statement. Useless example that breaks at n==5:

```
n = 0;
while n < 10
    n = n + 1;
    if n ==5, break, end
end
```

Simple Plots

Basic commands

plot	Draws plot of two equal-sized vectors x,y. Style is specified by character string s where s could be for example 'b*' for blue asterisk or 'bd' for blue diamonds representing points. Default is blue line with points connected. Usage: `plot(x,y)` or `plot(x,y, s)`
hist	Draws histogram of input array. Default number of bins is 10. Usage: `hist(array)` or `hist(array, num_bins)`
xlabel	Label for x-axis. Usage: `xlabel('x axis variable')`
ylabel	Label for y-axis. Usage: `xlabel('y axis variable')`
axis	Set specified x- and y-axis limits. Usage: `axis([xmin xmax ymin ymax])`
xlim	Set x-axis limits only. Usage: `xlim([xmin xmax])`
ylim	Set y-axis limits only. Usage: `ylim([ymin ymax])`
title	Title over plot. Usage: `title('plot title')`
hold on, off	'`hold on`' causes subsequent plots to be superimposed on current one, whereas '`hold off`' specifies each new plot start afresh. Default is off.
figure	Creates a new figure window. Usage: `figure;`

Saving plots

Save plots in desired format using the figure window (File -> Save as) . To save the plot on the current figure window as a png file using the command line,type:

```
>>print(gcf, '-dpng', '-r0', 'plot_filename');
```

More plotting function examples

Type 'help function_name' for details on usage.

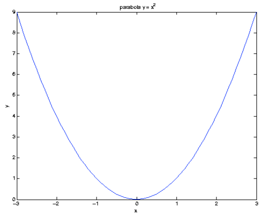
loglog	**semilogx**	**semilogy**	**plotyy**	**bar**	**scatter**	**pie**

Scripts and Functions

An M-file is a text file that contains MATLAB commands and has a .m filename extension. Use Matlab Editor/Debugger or any text editor (emacs, vi) to create *function.m* or *script.m* file. To start in MATLAB, go to File->New-> M-file

Note that the name of the function or script filename is identical to the command invoked at MATLAB prompt (without the .m extension).

Script M-files No input or output arguments and operate on variables in the workspace. Just a series of commands. Example: script.m



```
>> x = [-3:.1:3];
>> y = x .^ 2;
>> plot(x,y);
>> xlabel('x');
>> ylabel('y');
>> title('parabola y = x^2');
>> print(gcf,'-dpng','-r0','parabola.png');
>> print(gcf,'-depsc','parabola.eps');
```

```
% script.m
% series of matlab commands in a file.
x = [1:10]
mean(x)
```

Function M-files Contain a function definition line and can accept input arguments and return output arguments, and their internal variables are local to the function (unless declared global). Syntax requires the first line to be of form:

```
function [out1, …, outN] = func_name(in1, …, inN)
```

Example: stats_wrapper.m

```
function [mean_x, var_x] = stats_wrapper(x)
%stats_wrapper.m
%computes the mean and variance of array x
mean_x = mean(x);
var_x = var(x);
```

```
Example usage:
>> [m,v]= stats_wrapper([1,2,3,4,5])
m =
     3
v =
    2.5000
```

Statistics in Matlab

List of functions by category:
http://www.mathworks.com/access/helpdesk/help/toolbox/stats/

Examples:

Some CDF, PDF, Inverse functions, Random number generators

normcdf	Normal (Gaussian) cdf given value and parameters
poisscdf	Poisson cdf given value and parameters
binopdf	Binomial pdf given value and parameters
geopdf	Geometric pdf given value and parameters
norminv	Normal (Gaussian) critical values given p and parameters
poissinv	Poisson critical values given p and parameters.
normrnd	Normal (Gaussian) random numbers given parameters
poissrnd	Poisson random numbers given parameters.

Some Hypothesis Tests

ranksum	Wilcoxon rank sum test
signrank	Wilcoxon signed rank test
signtest	Sign test for paired samples
ttest	One sample t-test
ttest2	Two sample t-test
ztest	Z-test

help *function_name*

Best way to know how to correctly use built-in function and understand what it is doing.

Sources:

1. Highham, D.J., and Higham, N.J. *Matlab Guide*. SIAM, Philadelphia, 2000.
2. Martinez, W.L., and Martinez, A.R. Appendix A, *Computational Statistics Handbook With Matlab*. Chapman&Hall/CRC, New York, 2002.
3. http://www.mathworks.com/access/helpdesk/help/techdoc/matlab.html
4. http://www.mathworks.com/access/helpdesk/help/toolbox/stats/stats_product_page.html

Exercises:

Generate values from a binomial distribution

% Generate 10,000 random values from a binomial distribution and store in row vector
% *empirical_bino.* Use help to figure out input values for *binornd*.

```
>>empirical_bino = binornd(100,1/2,1,10000);
```

%Check that the mean and variance are close to that of the distribution from which it was
% generated.

```
>> mean(empirical_bino)
```

```
>> var(empirical_bino)
```

% Since binomial with p=1/2 is symmetric, check that median is also near true mean.

```
>> median(empirical_bino)
```

% Check out the distribution of the values in *empirical_bino* by plotting the histogram.
% Default number of bins is 10.

```
>>hist(empirical_bino)
```

% Use hold on to draw/trace plot of the distribution over the histogram.

```
>>[frequency, bins] = hist(empirical_bino);
>>hold on;
>>plot(bins, frequency, ’b*’); %use blue asterisk
>>xlabel(’bins’);
>>ylabel(’counts’);
>>title(’Simulated distribution’);
>>binsize=bins(2)-bins(1);
>>plot(0:100, 10000*binsize*binopdf(0:100, 100, 1/2),’r’);
```

What does it look like?

% Working with the cdf
% Get the probability that values from B(0,1) are less than or equal to the mean
% of the values in *empirical_bino*. Do the same for the median.

% First, check what we know

```
>> binocdf(50,100,1/2)

>> pmean = binocdf(mean(empirical_bino), 100,1/2)

>> pmedian = binocdf(median(empirical_bino), 100,1/2)
```

% Use the cdf to get back the critical values
% corresponding to those probability cutoffs.

% First, check what we know

```
>> binoinv(0.5, 100,1/2)

>> binoinv(pmean, 100,1/2)

>> binoinv(pmedian, 100,1/2)
```

% Plot the cdf of *empirical_bino*
% Need to sort the values in *empirical_bino* from low to high and
% get the corresponding probability Px = P(X<=x) for each value in the
% array **according to the theoretical distribution**.

```
>> Px = binocdf(sort(empirical_bino), 100,1/2);
```

% Use Figure to create a new window

```
>>figure;
```

% Plot the sorted values of empirical_bino on x-axis and
% corresponding theoretical probabilities on y-axis.

```
>>plot(sort(empirical_bino), Px)
>>xlabel(’x’)
>>ylabel(’P_x’);
>>title(’cdf of empirical bino’);
```

Odds and Ends

%because we can let us practice file i/o with pmean

```
>> save pmean_file pmean -ascii

>> load pmean_file

>> pmean_file

>> delete pmean_file
```

Function example

Create simple function called sim_bino.m that plots the distribution of `m` values generated from a binomial distribution with parameters `n` and `p` and returns the mean and variance of the observed distribution.

% Calls sim_bino with parameters `n`=100, `p`=1, `m`=100000 and saves plot as test.png
% Note that the character string ‘test’ is in single quotes.

```
>>[obs_mean, obs_var] = sim_bino(100,1/2,10000, ’test’)
```

File: sim_bino.m

```
function [obs_mean, obs_var] = sim_bino(n, p, m, plotname)
%sim_bino.m
%----------------
% Simple function that plots distribution of m values from a binomial  distribution with
% parameters n and p and saves this plot in PNG as ‘plotname’ in the current directory.

empirical_bino = binornd(n, p, 1, m);
figure;
hist(empirical_bino);
[frequency, bins] = hist(empirical_bino);
hold on;
plot(bins, frequency, ’b-*’); %use blue line and asterisk
xlabel(’bins’);
ylabel(’counts’);
title(’Simulated distribution’);

%save plot as plotname.png
print(gcf, '-dpng', '-r0',plotname);

obs_mean = mean(empirical_bino);
obs_var = var(empirical_bino);
```