CNBC Matlab Mini-Course

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Day 1: Essentials

What Is Matlab?

- Product of The Mathworks, Inc.

  http://www.mathworks.com

- Runs on Linux, Windows, and Macs.
- Student version just $99 with manual!
- Latest release is Matlab R2014a.
- “Interactive” interface like BASIC, Python, Lisp, etc. Type in expressions and see the result.

What Is Matlab? (cont.)

- Full programming language.
- Strong on matrix manipulation and graphics.
- Optional toolboxes for statistics, image processing, signal processing, etc.
- Interfaces with C, Fortran, and Java.
- Can create stand-alone executable files.
  - HHsim, a Hodgkin-Huxley simulator developed by Dave Touretzky with help from Jon Johnson, is distributed as a stand-alone executable. (Source is also available.)

Why Should You Learn Matlab?

- Data analysis:
  - Much more versatile than a spreadsheet.
  - Extensive statistics toolbox.
  - SPM uses Matlab.
- Graphics:
  - Many ways to visualize your data – even animations!
  - Produce great figures for your papers.
- Modeling and simulation:
  - Best choice for neural net simulations.

Getting Started

- Log in to a workstation.
- Go to the menu bar at the top of your screen and select:

  Applications
  > Education
  > MATLAB

Variable Creation

```
a = 5

a = 6 ;

b = 'penguins love herring'

who

whos
```

single quote

Click on the **Workspace** tab for a graphical version of whos.

Matrix Creation

x = [1 2 3 ; 9 8 7]

zeros(3, 5)
zeros(5)
zeros(5, 1)   column vector
zeros(1, 5)   row vector

ones, rand, randn, eye

What does eye do?

Colon Creates Row Vectors

1 : 5

1 : 3 : 15

10 : -1 : 0

pts = 0 : pi/20 : 4*pi;

Size of a Matrix

whos pts

size(pts)

length(pts)

Subscripting

V = [10 20 30 40 50];

V(3) ← index from 1, not 0

M = [1 2 3; 4 5 6; 7 8 9]

M =
1 2 3
4 5 6
7 8 9

M(2,2)
M(2) ← access in **column-major** order
M(6)

Matrix Slices

V(2:4)

V(2:end)

M(1:2, 2:3)

M(:)

M(: , :)

Expanding a Matrix

a = [1 2 3]

a = [a 4]

a(7) = 5

a(end+1) = 6

b = [a ; a.^2]

Efficiency tip:

Use ZEROS(rows,cols) to preallocate large arrays instead of growing them dynamically.

Reshaping a Matrix

M = reshape(1:15, 5, 3)

M'

M' ' or (M')'

Exercise

- Create the following matrix using **only** the colon, reshape, and transpose operators.

1	2	3
4	5	6
7	8	9
10	11	12
13	14	15

Adding Rows vs. Columns

M = [1 2 ; 3 4]

M = [M ; 5 6]

V = [10 20 30] '

M = [M V]

M = [M [99; 98; 97]]

Deleting Rows or Columns

M(: , 3) = [ ]

M(2, :) = [ ]

size([ ])

Command Line Editing

- Arrow keys work like you expect
- Basic Emacs commands also work:

Forward/back char	^F / ^B
Left/right word	alt-F / alt-B
Beginning/end of line	^A / ^E
Delete forward/back char	^D / backspace
Clear line	^U
Kill to end of line	^K
Undo	^_

- Environ. > Preferences > Keyboard > Shortcuts for a list, or to switch to Windows conventions.

Command Line History

- Scrolling through the command history:
  Move to previous command ^P
  Move to next command ^N
- Can also double click (or click and drag) on an item in the Command History window
- Keyed command history:
  wh^P
- Command/function completion:
  cle<tab>
- Interrupt execution: ^C

Editing Files in Matlab

File > New > Script

Put **3+5** on the first line

Put **m = magic(5)** on the second line

Save the file as **foo.m**

Type **foo** in the Command Window

Basic Plotting

pts = 0 : pi/20 : 4*pi ;

plot(sin(pts))

plot(pts, sin(pts))

axis off / on

grid on / off

box off / on

whitebg(gcf, [0 0 0])

clf

clf reset

Plot Labeling

pl^P

xlabel('Angle \theta')

ylabel('y = sin(\theta)')

title('The Sine Function')

Multiple Plots

clf

hold on

plot(pts, sin(pts))

plot(pts, cos(pts), 'm')

plot(pts, cos(pts), 'go')

legend('sin', 'cos', 'pts')

Click and drag to position the legend.

Summary of Plot Options

- Colors: r,g,b,w   c,m,y,k
- Symbols: . o x + * s(quare) d(iamond) etc.
- Line type: - (solid), -- (dashed), : (dotted),
  -. (dash-dot)

help plot

Printing

- On the **File** pulldown menu, select **Print.**
- Or type **^P** in the figure window.
- Printing to a file:
  print -djpeg myfig.jpg
  print -depsc -r300 myfig.ps
  print -dtiff myfig.tiff
- To learn more: **help print**

Plotting With Error Bars

```
clf

y = sin(pts);

e = rand(1, length(y)) * 0.4;

errorbar(pts, y, e)
```


Multiple Figures

```
figure

bar3(abs(peaks(7)))

figure(5)

delete(2)
```

*Or type **^W** in a figure window to close it.*

Histograms

```
dat = randn(10000, 1);

hist(dat)

hist(dat, 50)

b = hist(dat, 6)

bar(b)
```


Writing Your Own Functions

File > New > Function

```
function [ y ] = parabola( x )
% PARABOLA    Computes a quadratic.
% Y = parabola(X)     May be called with a vector.
y = x .^ 2;
```

Save as parabola.m

Try:

```
parabola(5)
help parabola
clf, plot(parabola(-10 : 10),'r--s')

parabola
```

← Gives an error message. Why?

Scripts vs. Functions

- **Scripts** take no input arguments and produce no return values.
- Scripts operate in the workspace of their caller.
- If called from the command line, scripts operate in the **base workspace**.
- If called from within a function, scripts operate in the function's **local workspace** and can see and modify its local variables.

Scripts vs. Functions

- **Functions** can take zero or more arguments and return zero or more values.
- Functions operate in their own **local workspace**.
- Variabes created inside a function are local to that function.
- Local variables disappear when the function returns.

Logical Operations

Operators: == ~= < > <= >=

Can't use != as in Java or C

Logical values:
  0 means "*false*"
  1 (or any non-zero number) means "*true*"

a = (3 >= 1 : 5)   What are the type and size of a?

The IF Statement

```
if x >= 3
  y = x;
else
  y = x + 3;
  hadHelp = true;
end
```

Differences from C/C++/Java:

- No ( ) parens around the condition expression.
- No { } braces around the then/else clauses.
- Requires **end** keyword.

Short form – use commas or semicolons:
  if x>3, y=x; **else** y=x+3; hadHelp=true; **end**

Boolean Subscripting

V = [1 2 3 4 5];

V(logical([1 0 1 1 0]))

V(V >= 3)

V(V >= 3) = 0

S = 'banana cabana'

S(S == 'a') = [ ]

Control Structure: FOR Loops

```
for i = 1 : 5
  [ i  i^2 ]
end
```

```
clf, hold on
for x = pts
  plot(x, cos(x), 'kd')
  pause(1)
end
```

(you can use ^C to terminate the loop)

Control Structure: WHILE Loops

How quickly can a random accumulator reach 5?

```
accum = 0; steps = 0;
while accum < 5
  steps = steps + 1;
  accum = accum + rand(1);
end
steps, accum
```


Element-Wise Arithmetic

Element-wise operators: + − .* ./ .^

Dot means "element-wise"

M = rand(5,3)

M + 100

M .* 5   same as   M * 5

M .* M   **not same** as   M * M

M ./ M

M .^ 2

Matrix Arithmetic

m1 = rand(5,3)

m2 = rand(3, 5)

m1 * m2 (5×3) * (3×5) → (5×5)

m2 * m1 (3×5) * (5×3) → (3×3)

m1 * m1 Error! Shapes don't fit.

m1 / m2 Error! Shapes don't fit.

m1' / m2

pinv(m1) (5×3) → (3×5)

Exercise: Data Plotting Script

```
x = 0 : pi/20 : 5*pi ;
y = sin(x) + x/3 + randn(1,length(x))/4;
z = smooth(y,20)' ;
clf, hold on
plot(x, y, 'bo--')
plot(x, z, 'm', 'LineWidth', 3)
```

Save as mydata.m and run it several times.

Exercise (cont.)

Now add these additional lines:

```
maxL = [1, z(2:end) > z(1:end-1)] ;
maxR = [z(1:end-1) > z(2:end), 1];
localMax = maxL & maxR; % true if point is local maximum
px = x(localMax); px(2,:)=0; px(3,:)=NaN;
pz = z(localMax); pz(2,:)=z(localMax); pz(3,:)=NaN;
plot(px, pz, 'r')
```

For homework: figure out how it works.

Reduction Operators

M = rand(5, 3)

sum(M)

sum(M, 2) sum along 2nd dimension

sum, prod, min, max, mean, var

min(min(M))

min(M(:))

Expanding with REPMAT

- REPMAT is often used to expand a vector to fit the shape of a matrix.
- Example: adjusting a dataset to have zero mean.

```
M = rand(5, 3)
avgs = mean(M)
Mavgs = repmat(avgs, 5, 1)
Mzero = M – Mavgs
sum(Mzero)
```


Exercise

- Suppose we want the *rows* of M to sum to zero, instead of the columns.
- How would you do this, *without* using the transpose operator?

Matlab Documentation

help cos

doc cos

clf, peaks

click on rotate3D icon

which peaks

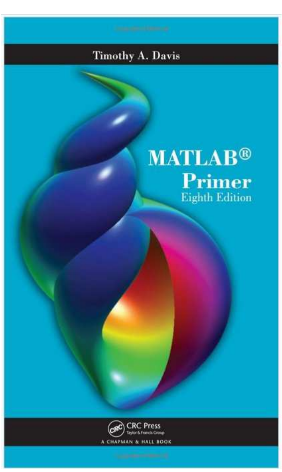
edit peaks

Yes!
You CAN see
our
source code!

lookfor rotate

Browsing Online Documentation

- Press F1 to bring up the Documentation Browser
- In the documentation browser:
  > Statistics Toolbox
    > Probability Distributions
      > Continuous Distributions
        > Beta Distribution
          > (Concepts) Beta Distribution



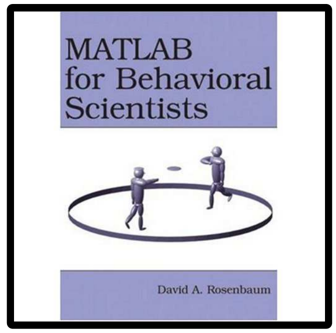
MATLAB Primer, 8th ed.

Timothy A. Davis

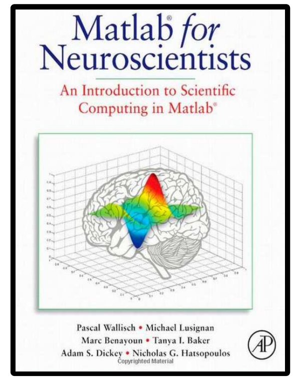
CRC Press

$15.00 at Amazon

Handy pocket reference.



Introductory Text



Examines a variety of neuroscience applications, with examples.

Ways To Learn Matlab

- Three more days of this mini-course.
- Tutorial videos at mathworks.com
- Built-in demos:
  doc demo
- Browse the online documentation
- Dozens of books:
  Amazon.com reports 5,558 search results!
- Matlab Central: user community site
  http://www.mathworks.com/matlabcentral
- Questions to support@mathworks.com