Introduction to MATLAB

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Some slides/examples courtesy of:
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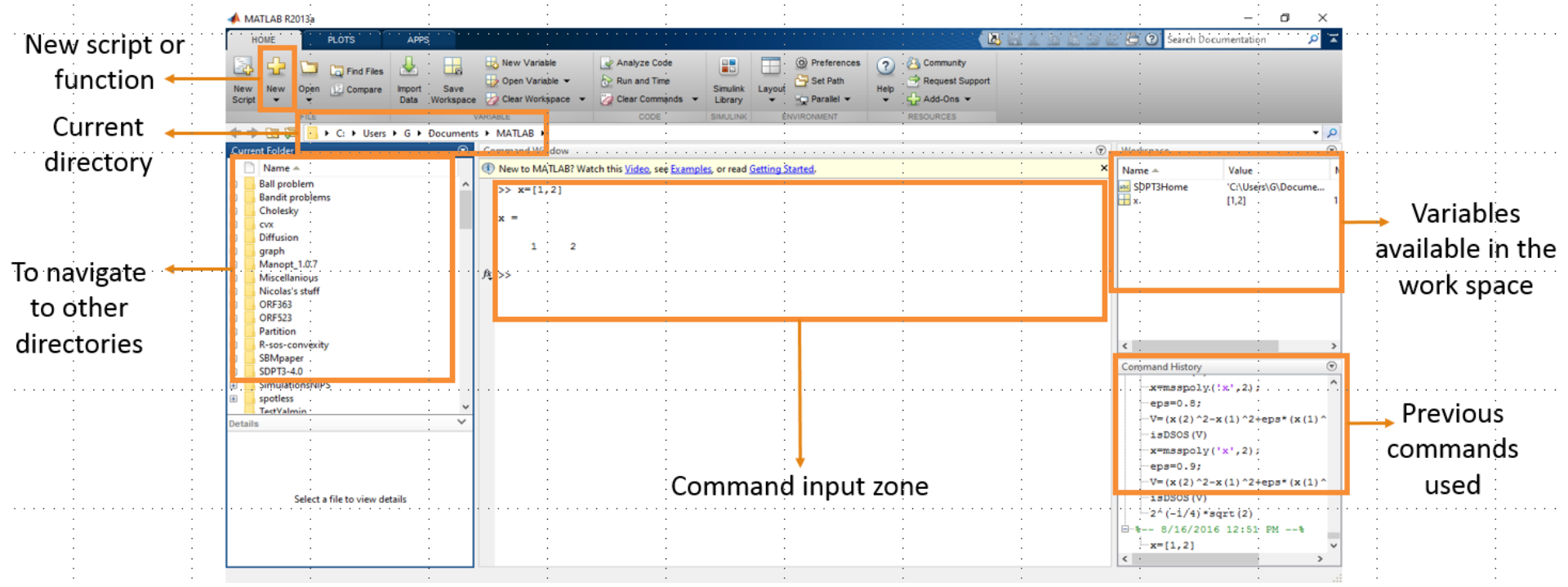
The format of this short course

- I'll use these PowerPoint slides as a guideline
- Will run the scripts in MATLAB here for you to see
- There will be a 90-min tutorial by the TAs right after my lecture so you can try things on your own
- There is a second short course tomorrow at 6:30 PM
- My slides and demos will be posted on Blackboard

Getting started

- To install: http://www.princeton.edu/software/licenses/software/matlab/

Tip: make sure you install the offline version so you can access it when off campus.



Scalar variables and assignments

```
>> 2+2

ans =

     4
```

- Scalar assignments:

```
>> a=1.23
```

- Ending semicolon

```
>> a=1.23;
```

The ending semicolon is important. If you omit it, MATLAB gives an echo response.

```
>> a=1.23456789

a =

    1.2346
```

```
>> format short
>> pi
```

```
>> format long
>> pi
```

Basic mathematical functions

- Basic operations:

```
+,-,*,/,^
```

- Trigonometric functions:

```
sin, cos, tan, atan,...
```

- Exponential functions:

```
exp, log, log10, sqrt,...
```

- Other basic functions that come in handy:

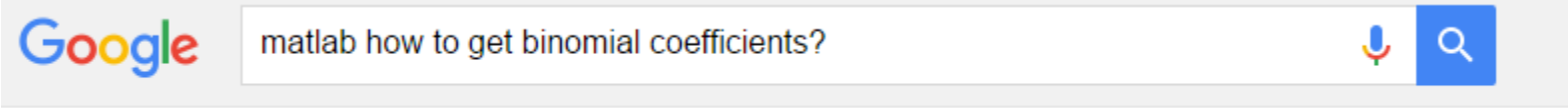
```
floor, ceil, round, mod, sign, nchoosek, ...
```

```
help elfun
```

What is more useful than my lecture

```
>> help nchoosek
```

```
>> doc nchoosek
```



Management functions

- Checking your variables:

```
who, whos
```

- Clearing stuff…

```
clc, clear, clear all, close all, clearvars -except, ...
```

- Saving variables:

```
save filename a b c

load filename
```

Vector and matrix manipulation (1/2)

- Defining a vector/matrix:

```
>> a=[1;2;3]
>> A=[1 2; 3 4; 5 6]    >> A=[1,2;3,4;5,6]
```

- Size of the data (row, then column) / length

```
>> size(A)    >> length(A)
```

- Matrix/vector operations:

```
+ - * ^        .* .^
```

standard component-wise

```
>> A^-1  >> inv(A)  >> A'
```

- Commonly used matrices:

```
>> A=ones(2,2)  >> A=zeros(2,2)  >> A=eye(2,2)
```

Vector and matrix manipulation (2/2)

- Concatenating matrices:

```
>> a=[1;2;3]   >> b=[4;5;6]
>> A=[a b]   >> A=[a';b']
```

- Random matrices:

```
>> A=rand(10,10)    >> A=randn(10,5)
>> A=randi([-5,5],10,10)    >> randn('seed',0)
```

- Submatrices and elements:

```
>> A(2,2)   >> A(2,:)   >> A(1:2,1:2)

>> A(5:end,6:end-1)    >> A([1 3],[2 4])
```

MATLAB indexing starts at 1

Logical operations

- Logical tests:

```
>> A>0    >> A==1      >> A~=0      >> A<=0
```

Returns a matrix of same size as A with 0s and 1s : 1 is the condition is met for that entry, 0 is the condition is not met for that entry

- Find function:

```
>> find(A>=0)
>> [row,col]=find(A>=0);
>> [row col]
```

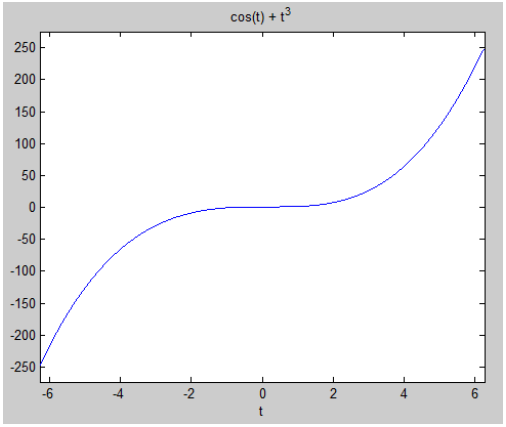
- Some other basic operations: `>> b=[2 7 3]`

```
>> [a,c]=max(b)  >> [a,c]=min(b)  >> sum(b)
>> mean(b)
```

Symbolic computation

- Useful for quick differentiation, integration, evaluation, plotting, etc.

```
>> syms x y t
>> f1=sin(x)*y^2+exp(y*x)
>> diff(f1,y)
>> diff(diff(f1,y),x)

>> f2=cos(t)+t^3;
>> int(f2)
>> int(f2,1,4)
>> double(ans)

>> subs(f2,t,4)
>> ezplot(f2)
```



Writing a MATLAB script

Editor - C:\Users\amirali\Dropbox\Research_files\AAA_GH\MATLAB_lecture_2016\script_example_eigenvalues_of_inverse.m

script_example_eigenvalues_of_inverse.m

```
1   %This is my first script!
2   clear all%good idea usually (but make sure you don't lose your vars)
3   n=3; %good idea to start with your parameters
4
5   %%
6   A=rand(3);
7   B=A*A';
8   eig_B=eig(B)
9
10  %%
11  C=inv(B)
12  eig_C=eig(C);
13
14  [eig_B 1./eig_C]
15
```

- Easy debugging, access to variables
- Running the whole script, running sections

Writing a MATLAB function

Editor - Untitled9*

script_example_eigenvalues_of_inverse.m | Untitled9*

```
1   function [ output_args ] = Untitled9( input_args )
2   %UNTITLED9 Summary of this function goes here
3   %   Detailed explanation goes here
4
5
6   end
```

Editor - C:\Users\amirali\Dropbox\Research_files\AAA_GH\MATLAB_lecture_2016\num_real_eigenvalues.m

script_example_eigenvalues_of_inverse.m | num_real_eigenvalues.m | hist_num_real_evals.m

```
1   function [m,b] = num_real_eigenvalues(A)
2   %Computes the eigenvalues of a matrix and returns the number
3   %of real ones
4   b=eig(A);
5   m=length(find(abs(imag(b))<1e-6));
6   end
```

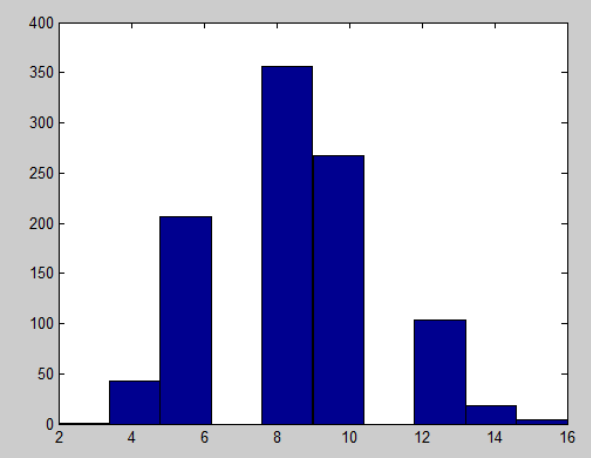
- Easy to call multiple times (in a for loop e.g.)
- Essential for larger projects

Typical call to a MATLAB function from a script

Editor - C:\Users\amirali\Dropbox\Research_files\AAA_GH\MATLAB_lecture_2016\hist_num_real_evals.m

script_example_eigenvalues_of_inverse.m | num_real_eigenvalues.m | hist_num_real_evals.m

```
1     %Count the number of real eigenvalues of a random mxm
2     %Gaussian matrix
3     clear all
4     close all
5     N=1000;
6     m=100;
7     vec=zeros(m,1);
8     for i=1:N
9         vec(i)=num_real_eigenvalues(randn(m));
10    end
11    hist(vec)
12    mean(vec)
```



Function handles

- Quick way of creating a temporary (simple) function without making a new file

```
>> g=@(x,y) exp(x)*sin(y)

g =

    @(x,y)exp(x)*sin(y)

>> g(2,3)

ans =

   1.042743656235905
```

Plotting (1/2)

- Opening a new window for a figure:

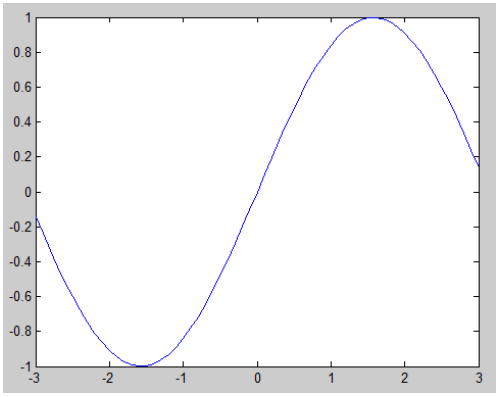
```
>> figure
```

```
>> t=0:0.1:1
```

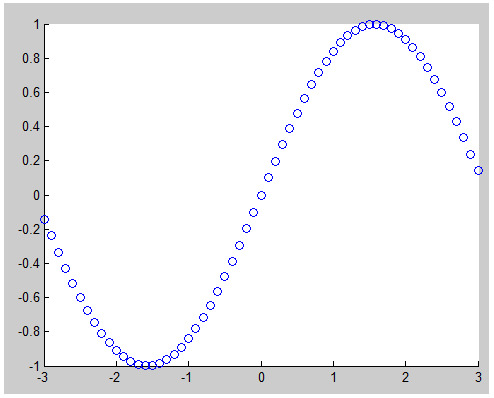
beginning step size end

- Plotting x vs y:

```
>> x=-3:0.1:3;
>> y=sin(x);
>> plot(x,y)
```




```
>> x=-3:0.1:3;
>> y=sin(x);
>> scatter(x,y)
```




```
>> plot(x,y,'color','red')
```

Plotting (2/2)

- Multiple graphs on one figure:

```
>> hold on;
>> hold off;
```

- ezplot (quick plotting, without defining a vector for input variables):

```
>> ezplot(sin(x))
```

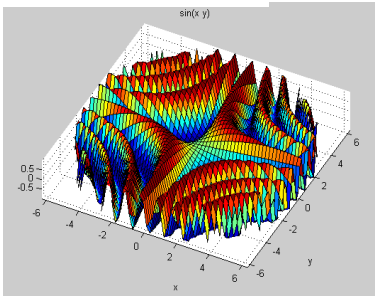
- Can also be used to plot level sets:

```
>> ezplot('(x-1)^4+(x*y-x^2)^2-1')
>> hold on
>> ezplot('(x-1)^4+(x*y-x^2)^2-4')
```

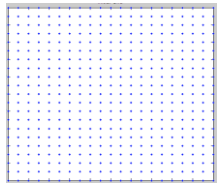
- Figure properties, grid, xlabel, …
- Saving a figure

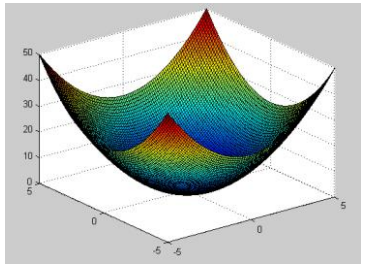
- Plotting a surface:

```
>> syms x y
>> ezsurf(sin(x*y))
```



```
>> x=-5:0.1:5;
>> y=-5:0.1:5;
>> [X,Y]=meshgrid(x,y);
>> Z=X.^2+Y.^2;
>> surf(X,Y,Z)
```





If/else statements

- If… then… else…

```
>> flag=0;
a=randn(1,1);
if a>=0 || a<=-2
    flag=1;
elseif a<=0 && a>=-1
    flag=2;
else
    flag=3;
end
a
flag
```

- Checking for equalities and inequalities

```
>> flagb=0;
b=2*rand;
if round(b)==1
    flagb=1;
elseif round(b)~=0
    flagb=2;
end
b
flagb
```

for/while loops

- For loops

```
>> s=0;
for i=1:100
    s=s+i;
end
s
```

- Nested for loops

```
>> A=zeros(10);
for i=1:length(A)
    for j=1:length(A)
        A(i,j)=nchoosek(max(i,j),min(i,j));
    end
end
A
```

- While loops

```
>> s=1;
while s<=100
    s=s*2;
end
s
```

Practice with for loops

- Write a script that tests whether a given integer is prime

```
function [ y ] = isprime_myfun( a )
%The function takes as input a number and outputs 0 or 1
%is prime or not
y=1;
for i=2:ceil(sqrt(a))
    if mod(a,i)==0
        y=0;
        break
    end
end
if a==2
    y=1;
end
```

Practice with for loops

- Write a script that lists all primes up to an integer N

```
function [nber_primes,vec_primes ] = allprimes(ub)
%Provides the number of primes and a list of the primes that are
nber_primes=0;
vec_primes=[];
for i=2:ub
    if isprime_myfun(i)==1
        nber_primes=nber_primes+1;
        vec_primes=[vec_primes; i];
    end
end
```

Vectorized computation

- Whenever possible, replace for loops with vectorized computation
  - More readable
  - Less error prone
  - Better performance

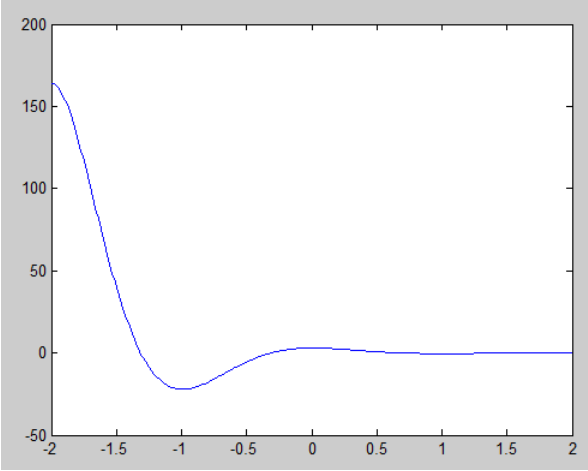
```
>> clear all
n=2000;
A=randn(n);
B=randn(n);

tic
for i=1:n
    for j=1:n
        C(i,j)=A(i,j)*B(i,j);
    end
end
toc

tic
C=A.*B;
toc
```

Vectorized computation

Task: Compute and plot the function:

$$y(t) = e^{-2t}(2\sin(\pi t) + 3\cos(\pi t))$$

```
>> t=-2:.01:2;
>> y=exp(-2*t).*(2*sin(pi*t)+3*cos(pi*t));
>> plot(t,y,'-')
```



MATLAB toolboxes

```
MATLAB
Simulink
Bioinformatics Toolbox
Communications System Toolbox
Computer Vision System Toolbox
Control System Toolbox
Curve Fitting Toolbox
DSP System Toolbox
Data Acquisition Toolbox
Database Toolbox
Datafeed Toolbox
Econometrics Toolbox
Embedded Coder
Filter Design HDL Coder
Financial Instruments Toolbox
Financial Toolbox
Fixed-Point Designer
Fuzzy Logic Toolbox
Global Optimization Toolbox
Image Acquisition Toolbox
Image Processing Toolbox
Instrument Control Toolbox
MATLAB Coder
MATLAB Compiler
MATLAB Compiler SDK
MATLAB Report Generator
Mapping Toolbox
Multivariate Polynomial Toolbox
Multivariate Polynomial Toolbox
Neural Network Toolbox
Optimization Toolbox
Parallel Computing Toolbox
Partial Differential Equation Toolbox
Robotics System Toolbox
Robust Control Toolbox
```

- Collection of m-files for a specific problem domain
- You will most likely come across some toolboxes depending on your interests

Some basic image processing

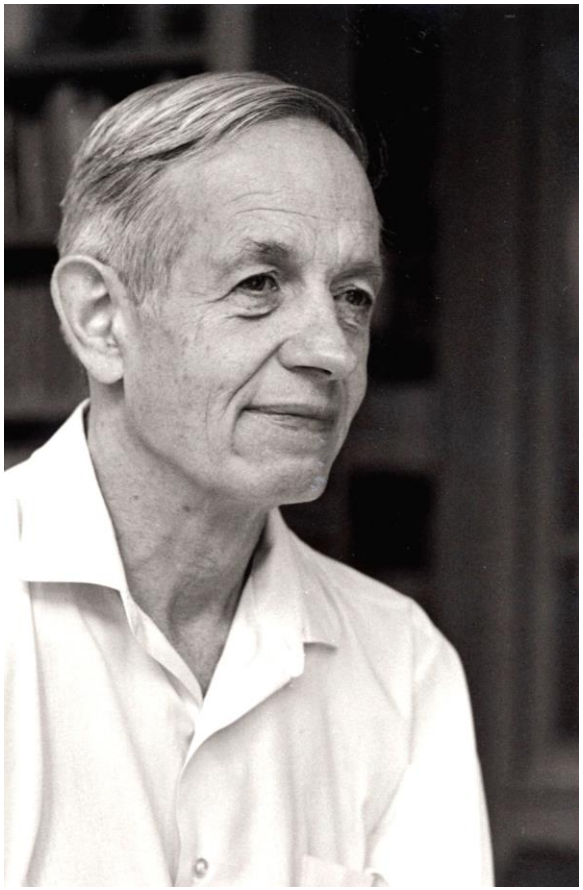
- Converting an image to black and white

```
1 -    close all
2 -    RGB = imread('tiger.JPG');
3 -    imshow(RGB)
4
5 -    I = rgb2gray(RGB);
6 -    figure
7 -    imshow(I)
8
9 -    imwrite(I,'bwtiger.JPG')
```

Image compression

- Compressing an image using the singular value decomposition

```
close all
A=imread('nash.jpg');
A=im2double(A);
A=rgb2gray(A);
[m, n]=size(A);
figure,imshow(A)

k=100;
[U,Sigma,V]=svd(A);
Uk=U(:,1:k);
Sigmak=Sigma(1:k,1:k);
Vk=V(:,1:k);
Ak=Uk*Sigmak*Vk';
figure,imshow(Ak)
pixels_saved=m*n-(n+m+1)*k
imwrite(I,'compressed_nash.JPG')
```



When stuck, you know where to go…

```
>> help functionname

>> doc functionname
```

(Can contribute back to the MATLAB community on MATLAB Central)