MATLAB
for Image Processing

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Outline

- **Introduction to MATLAB**
- Image Processing with MATLAB

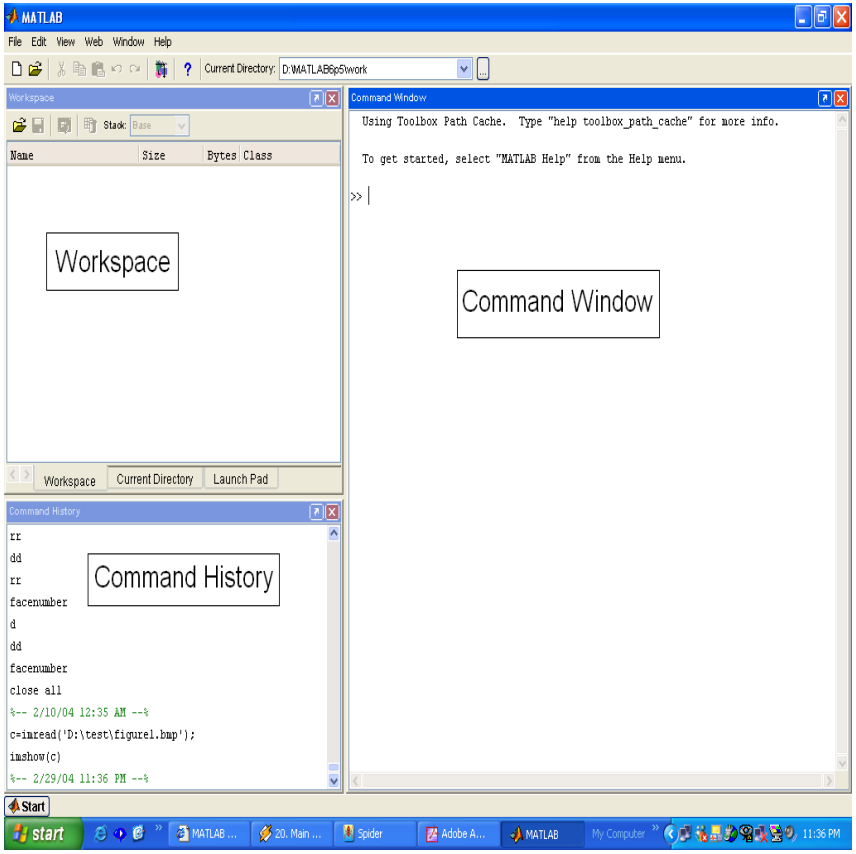
What is MATLAB?

- MATLAB = Matrix Laboratory
- "MATLAB is a **high-level language** and **interactive environment** that enables you to perform computationally intensive tasks faster than with traditional programming languages such as C, C++ and Fortran." (www.mathworks.com)
- MATLAB is an interactive, **interpreted language** that is designed for **fast numerical matrix calculations**

MATLAB tutorials on the net

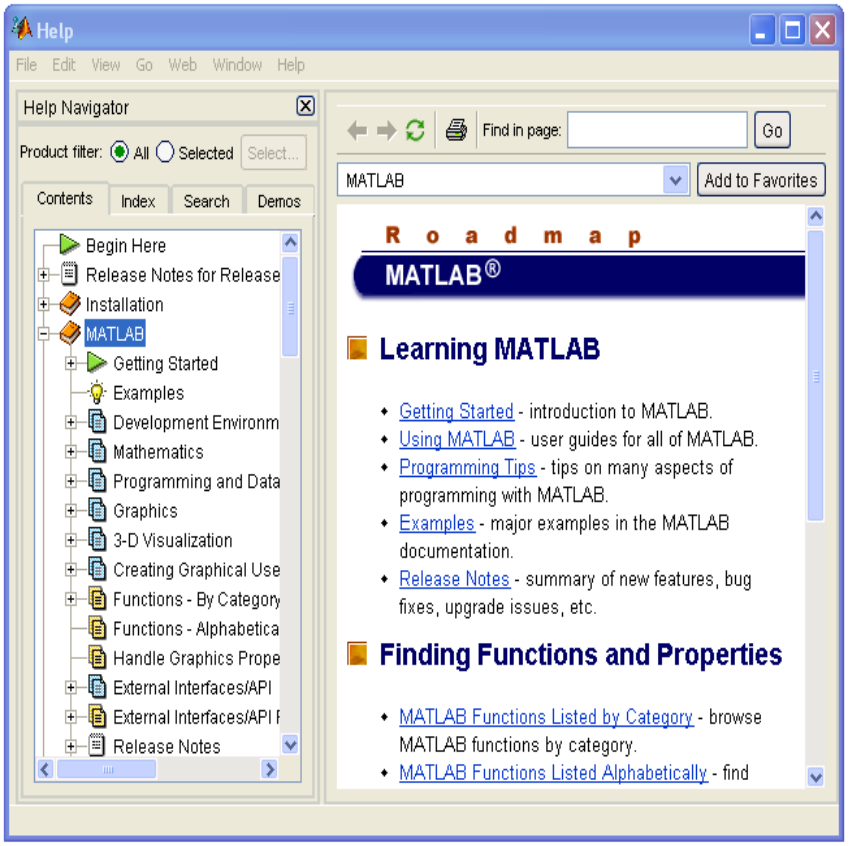
- http://www.mathworks.it/academia/student_center/tutorials/launchpad.html
- http://www.cyclismo.org/tutorial/matlab/
- http://www.math.ufl.edu/help/matlab-tutorial/
- http://lmgtfy.com/?q=matlab+tutorial

The MATLAB Environment



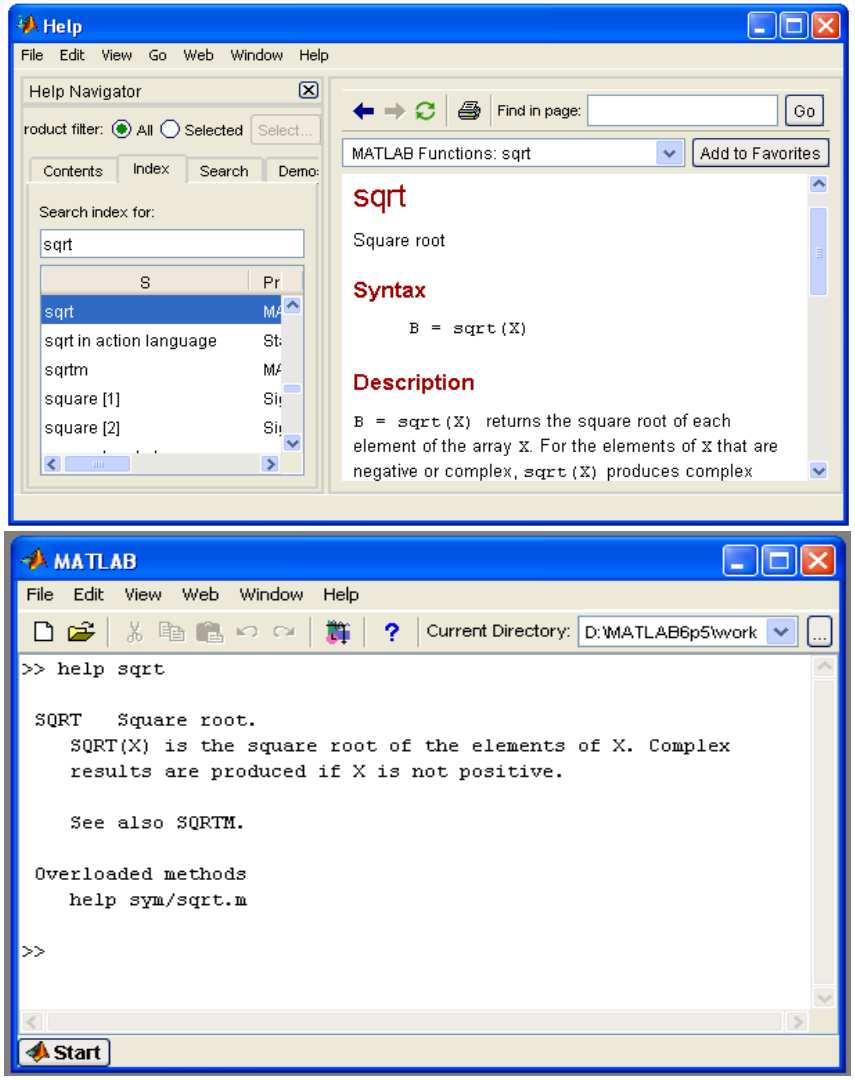
- MATLAB window components:
  - Workspace
    - > Displays all the defined variables
  - Command Window
    - > To execute commands in the MATLAB environment
  - Command History
    - > Displays record of the commands used
  - File Editor Window
    - > Define your functions

MATLAB Help



- MATLAB Help is an extremely powerful assistance to learning MATLAB
- Help not only contains the theoretical background, but also shows **demos for implementation**
- MATLAB Help can be opened by using the HELP pull-down menu

MATLAB Help



- Any command description can be found by typing the command in the search field
- As shown above, the command to take square root (sqrt) is searched
- We can also utilize MATLAB Help from the command window as shown

More about the Workspace

- **who, whos** – current variables in the workspace
- **save** – save workspace variables to *.mat file
- **load** – load variables from *.mat file
- **clear** – clear workspace variables

Matrices in MATLAB

- Matrix is the main MATLAB data type
- How to build a matrix?
  - A=[1 2 3; 4 5 6; 7 8 9];
  - Creates matrix A of size 3 x 3

```
A =
     1     2     3
     4     5     6
     7     8     9
```

- Special matrices:
  - zeros(n,m), ones(n,m), eye(n,m), rand(), randn()

Matrices and Vectors

- matrix `x = [1 2 3; 5 1 4; 3 2 -1]`

```
x =
1    2    3
5    1    4
3    2   -1
```

- vector `x = [1 2 5 1]`

```
x = 1   2   5   1
```

- transpose `y = x.'`

```
y =
    1
    2
    5
    1
```

Matrices and Vectors

- x(i,j) subscription

```
y=x(2,3)

y =     4
```

- whole row

```
y=x(3,:)

y =    3     2    -1
```

- whole column

```
y=x(:,2)        y =

                    2

                    1

                    2
```

Exercises: Vectors

```
1. x = [3 4 7 11]                    % create a row vector (spaces)
2. x = 3:8                           % colon generates list; default stride 1
3. x = 8:-1:0                        % hstarti : hstridei : hstopi specifies list
4. xx = [ 8 7 6 5 4 3 2 1 0];        %  same as last; semicolon suppresses output
5. xx                                % display contents
6. x = linspace(0,1,11)              % generate vector automatically
7. x = 0:0.1:1                       % same thing
8. y = linspace(0,1);                % note semicolon!
9. length(x)
10. length(y)
11. size(x)
12. size(y)
13. y(3)                             % access single element
14. y(1:12)                          % access first twelve elements
15. y([3 6 9 12])                    % access values specified in a vector!
16. x'                               % transpose
17. z = [ 1+2*i 4-3*i ]
18. z'
19. z.'                              % note difference in transposes!
20. 3*[1 2 5]                        % factor replicated, multiplies each element
```

Basic Operations on Matrices

- All operators in MATLAB are defined on matrices: **+, -, *, /, ^, sqrt, sin, cos**, etc.
- Element-wise operators defined with a preceding dot: **.*, ./, .^**
- size(A) – size vector
- sum(A) – columns sums vector
- sum(sum(A)) – sum of all the elements

Variable Name in Matlab

- Variable naming rules
  - must be unique in the first 63 characters
  - must begin with a letter
  - may not contain blank spaces or other types of punctuation
  - may contain any combination of letters, digits, and underscores
  - are case-sensitive
  - should not use Matlab keyword
- Pre-defined variable names
  - pi

Logical Operators

- ==, <, >, (not equal) ~=, (not) ~

- **find('condition')** – Returns indexes of A's elements that satisfy the condition in the matrix or vector

Logical Operators (cont.)

- Example:

```
>>A=[7 3 5; 6 2 1], Idx=find(A<4)
    A=
        7 3 5
        6 2 1
    Idx=
        3
        4
        6
```

Flow Control

- MATLAB has five flow control constructs:
  - **if** statement
  - **switch** statement
  - **for** loop
  - **while** loop
  - **break** statement

if

- IF statement condition
  - The general form of the IF statement is

```
IF expression
    statements
ELSEIF expression
    statements
ELSE
    statements
END
```

switch

- SWITCH – Switch among several cases based on expression
- The general form of SWITCH statement is:

```
SWITCH switch_expr
    CASE case_expr,
        statement, ..., statement
    CASE {case_expr1, case_expr2, case_expr3, ...}
        statement, ..., statement
        ...
    OTHERWISE
        statement, ..., statement
END
```

for

- FOR repeats statements a specific number of times

- The general form of a FOR statement is:

```
FOR variable=expr
    statements
END
```

while

- WHILE repeats statements an indefinite number of times

- The general form of a WHILE statement is:

```
WHILE expression
    statements
END
```

Scripts and Functions

- There are two kinds of M-files:
  - **Scripts**, which do not accept input arguments or return output arguments. They operate on data in the workspace
  - **Functions**, which can accept input arguments and return output arguments. Internal variables are local to the function

Functions in MATLAB

- Example:
  - A file called STAT.M:

```
function [mean, stdev]=stat(x)
%STAT Interesting statistics.
n=length(x);
mean=sum(x)/n;
stdev=sqrt(sum((x-mean).^2)/n);
```

  - Defines a new function called STAT that calculates the mean and standard deviation of a vector. **Function name and file name should be the SAME!**

Visualization and Graphics

- plot(x,y),plot(x,sin(x)) – plot 1D function
- figure, figure(k) – open a new figure
- hold on, hold off – refreshing
- axis([xmin xmax ymin ymax]) – change axes
- title('figure title') – add title to figure
- mesh(x_ax,y_ax,z_mat) – view surface
- contour(z_mat) – view z as topo map
- subplot(3,1,2) – locate several plots in figure

Saving your Work

- **save mysession**

  % creates mysession.mat with all variables

- **save mysession a b**

  % save only variables a and b

- **clear all**

  % clear all variables

- **clear a b**

  % clear variables a and b

- **load mysession**

  % load session

Outline

- Introduction to MATLAB

- **Image Processing with MATLAB**

What is the Image Processing Toolbox?

- The Image Processing Toolbox is a collection of functions that extend the capabilities of the MATLAB's numeric computing environment. The toolbox supports a wide range of image processing operations, including:
  - Geometric operations
  - Neighborhood and block operations
  - Linear filtering and filter design
  - Transforms
  - Image analysis and enhancement
  - Binary image operations
  - Region of interest operations

Images in MATLAB

- MATLAB can import/export several image formats:
  - BMP (Microsoft Windows Bitmap)
  - GIF (Graphics Interchange Files)
  - HDF (Hierarchical Data Format)
  - JPEG (Joint Photographic Experts Group)
  - PCX (Paintbrush)
  - PNG (Portable Network Graphics)
  - TIFF (Tagged Image File Format)
  - XWD (X Window Dump)
  - raw-data and other types of image data
- Data types in MATLAB
  - Double (64-bit double-precision floating point)
  - Single (32-bit single-precision floating point)
  - Int32 (32-bit signed integer)
  - Int16 (16-bit signed integer)
  - Int8 (8-bit signed integer)
  - Uint32 (32-bit unsigned integer)
  - Uint16 (16-bit unsigned integer)
  - Uint8 (8-bit unsigned integer)

Images in MATLAB

- Binary images : {0,1}
- Intensity images : [0,1] or uint8, double etc.
- RGB images : m × n × 3
- Multidimensional images: m × n × p (p is the number of layers)

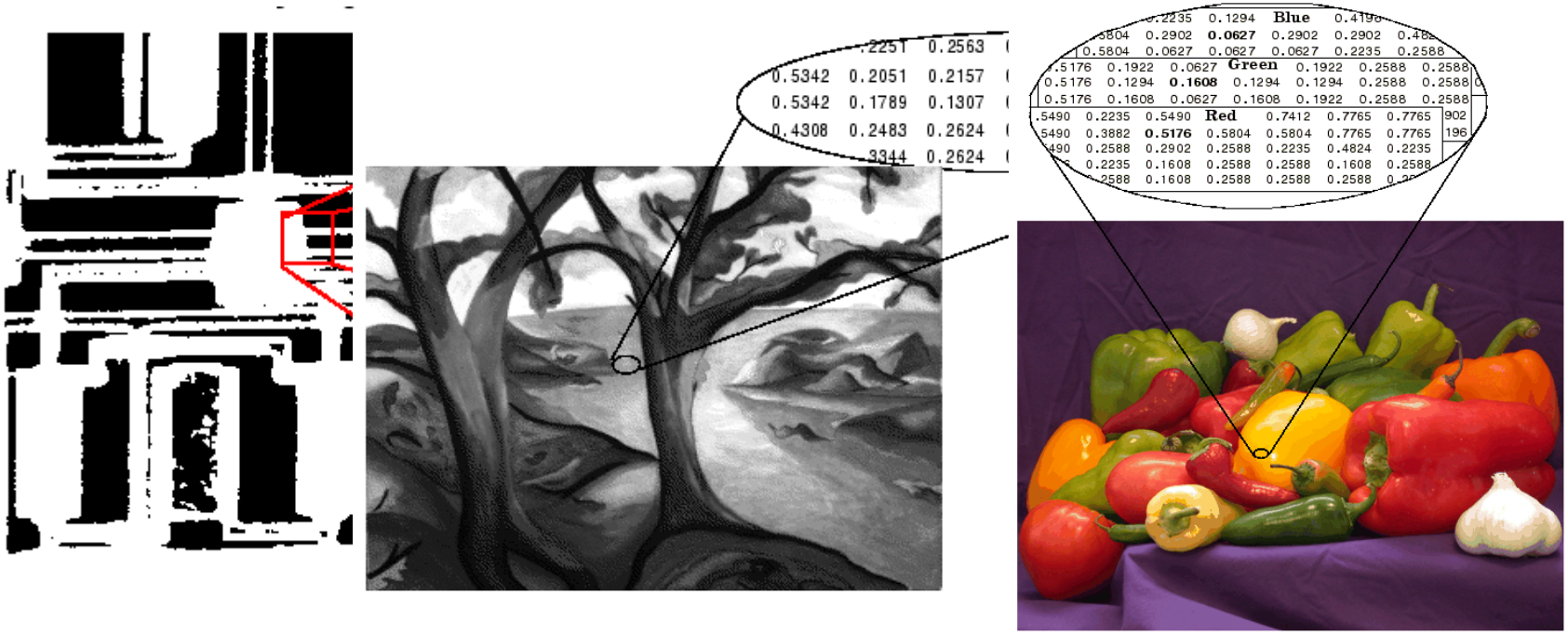


Image Import and Export

- Read and write images in Matlab

```
img = imread('apple.jpg');
dim = size(img);
figure;
imshow(img);
imwrite(img, 'output.bmp', 'bmp');
```

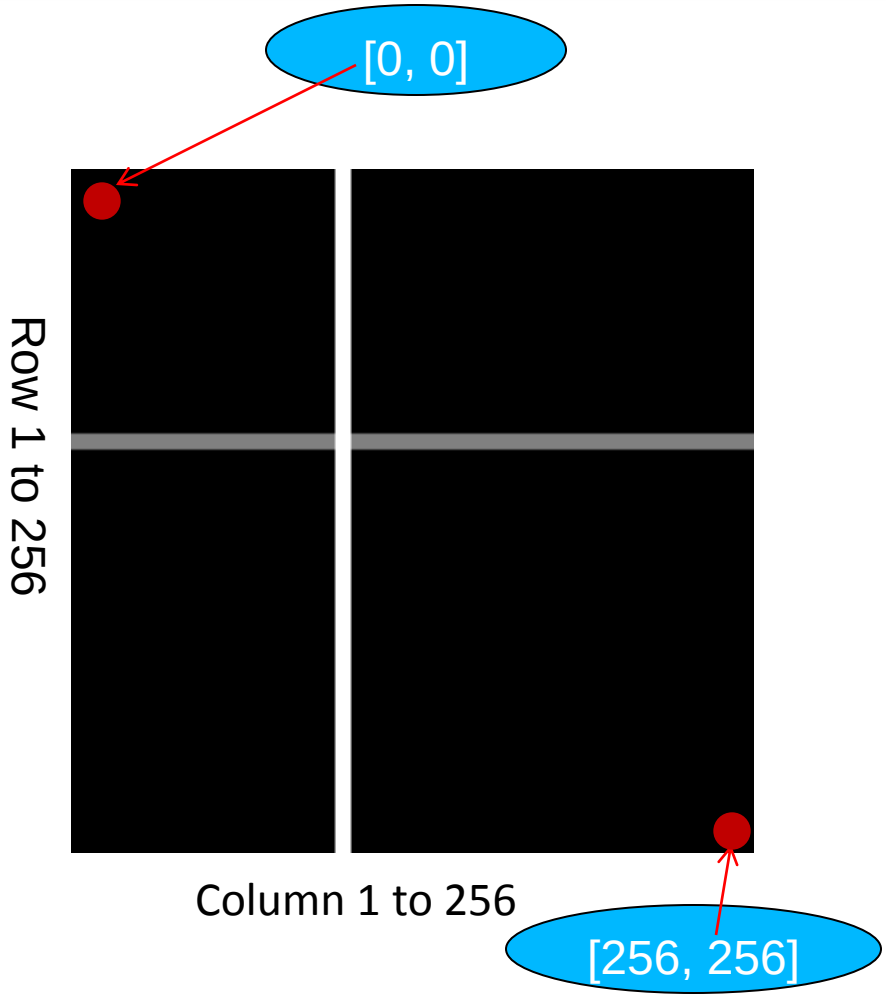
- Alternatives to imshow

```
imagesc(I)
imtool(I)
image(I)
```

Images and Matrices

How to build a matrix (or image)?
Intensity Image:

row = 256;
col = 256;
img = zeros(row, col);
img(100:105, :) = 0.5;
img(:, 100:105) = 1;
figure;
imshow(img);



Images and Matrices

Binary Image:

```
row = 256;
col = 256;
img = rand(row, col);
img = round(img);
figure;
imshow(img);
```

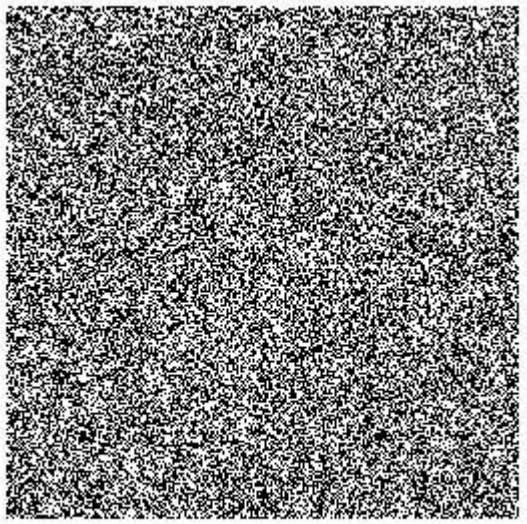


Image Display

- image - create and display image object
- imagesc - scale and display as image
- imshow - display image
- colorbar - display colorbar
- getimage - get image data from axes
- truesize - adjust display size of image
- zoom - zoom in and zoom out of 2D plot

Image Conversion

- gray2ind - intensity image to index image
- im2bw - image to binary
- im2double - image to double precision
- im2uint8 - image to 8-bit unsigned integers
- im2uint16 - image to 16-bit unsigned integers
- ind2gray - indexed image to intensity image
- mat2gray - matrix to intensity image
- rgb2gray - RGB image to grayscale
- rgb2ind - RGB image to indexed image

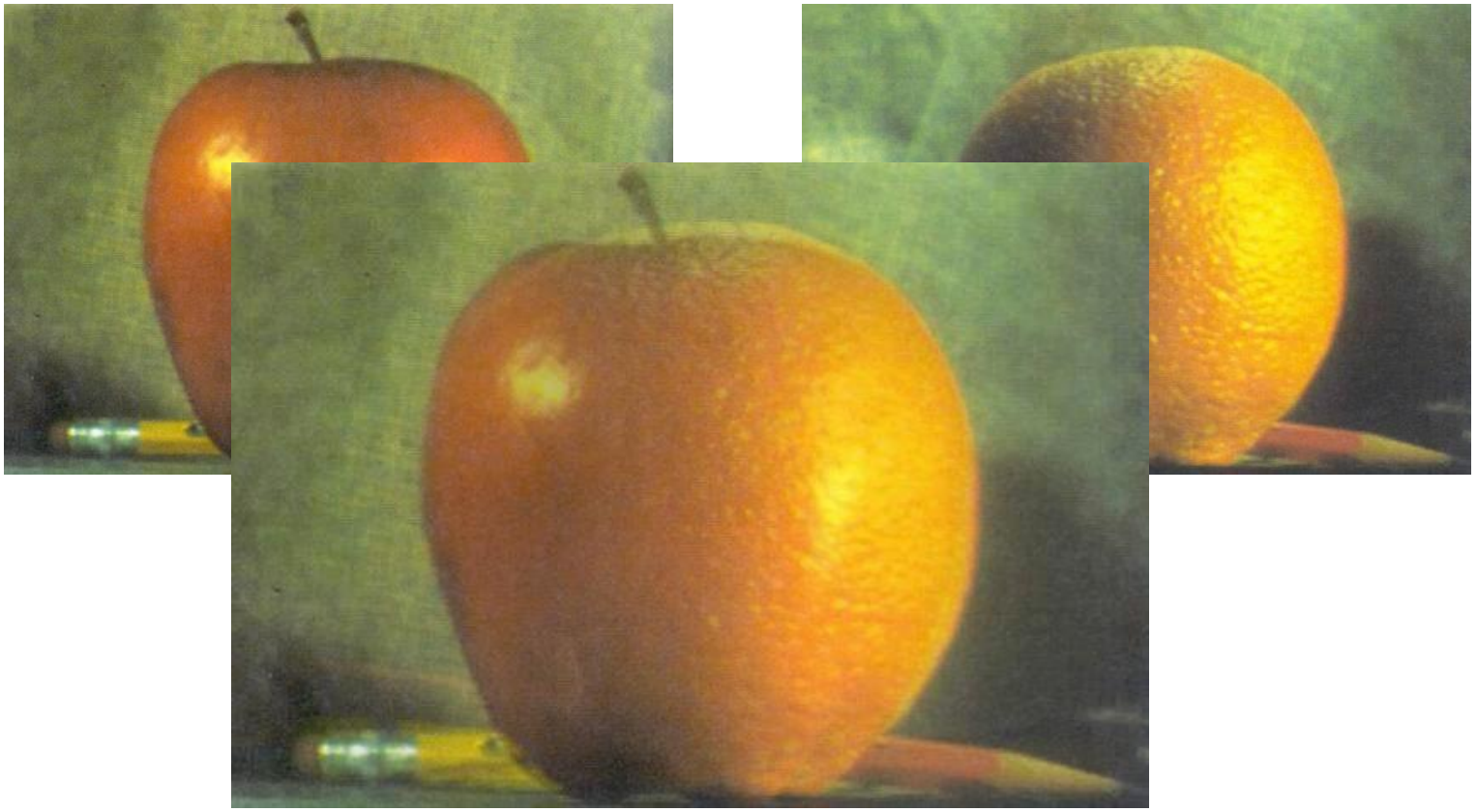
Image Operations

- RGB image to gray image
- Image resize
- Image crop
- Image rotate
- Image histogram
- Image histogram equalization
- Image DCT/IDCT
- Convolution

Outline

- Introduction to MATLAB
- Image Processing with MATLAB
  - **Examples**

Examples working with Images



Performance Issues

- The idea: MATLAB is
  - very fast on vector and matrix operations
  - Correspondingly slow with loops

- Try to avoid loops
- Try to vectorize your code

  http://www.mathworks.com/support/tech-notes/1100/1109.html

Vectorize Loops

- Example
- **http://http://profs.sci.univr.it/~mendezguerrero/Lab01/apple.jpg**
- **http://http://profs.sci.univr.it/~mendezguerrero/Lab01/orange.jpg**
  - Given image matrices, A and B, of the same size (540*380), blend these two images

    apple = imread('apple.jpg');

    orange = imread('orange.jpg');
- Poor Style

```
% measure performance using stopwatch timer
tic
for i = 1 : size(apple, 1)
    for j = 1 : size(apple, 2)
        for k = 1 : size(apple, 3)
            output(i, j, k) = (apple(i, j, k) + orange(i, j, k))/2;
        end
    end
end
toc
```

- Elapsed time is 0.138116 seconds

Vectorize Loops

- Example
  - Given image matrices, A and B, of the same size (600*400), blend these two images

```
apple = imread('apple.jpg');
orange = imread('orange.jpg');
```

- Better Style

```
tic  % measure performance using stopwatch timer
output = (apple + orange)/2;
toc
```

- Elapsed time is 0.099802 seconds
- Computation is faster!

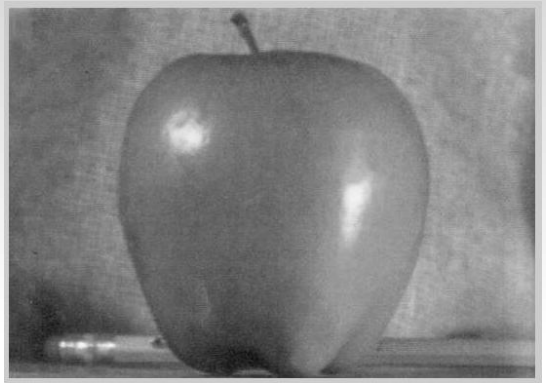
Image Histogram

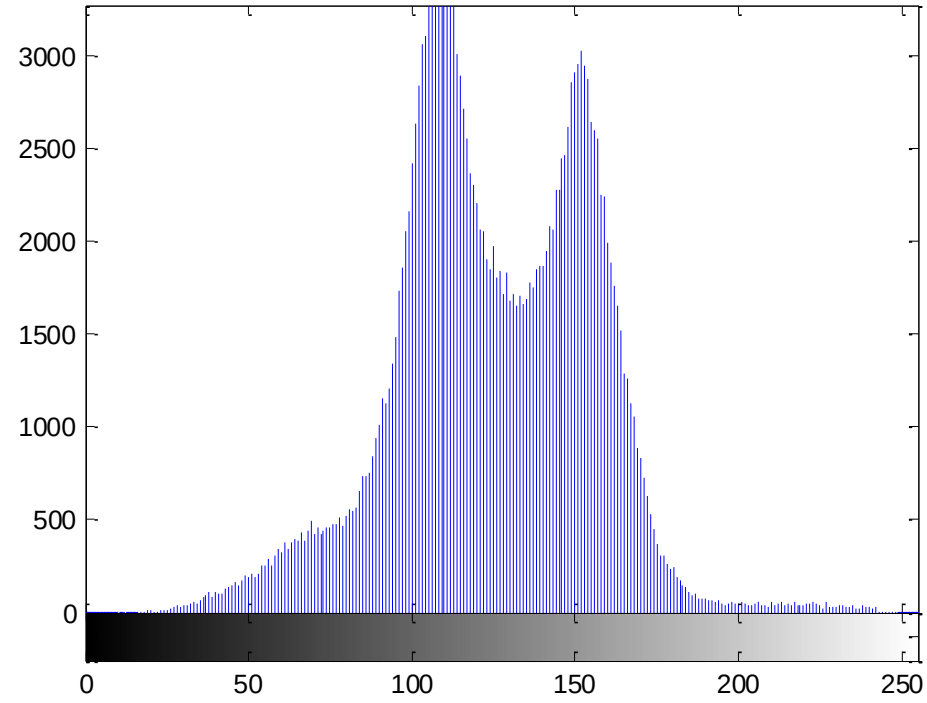
- Histograms for image enhancement
- A **bin** is a subdivision of the intensity scale

h=imhist(image,bins)

- applegray=rgb2gray(apple); %convert to grayscale
- h=imhist(applegray); %create histogram with default number of bins (256)

- h=imhist(applegray, 128); %half number of bins




3000
2500
2000
1500
1000
500
0
0
50
100
150
200
250

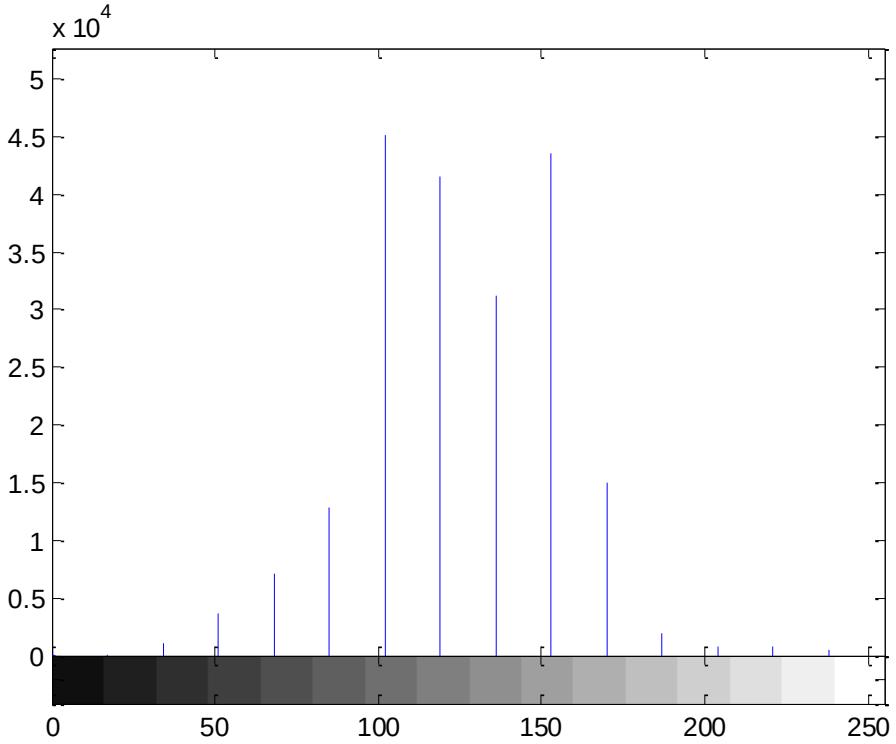

x 10^4
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
50
100
150
200
250

Image Histogram

- Manually change the histogram plot using the **bar** function

- h=imhist(appleg); %create the histogram
- h1=h(1:10:256); %sample h every 10 elements
- horz=1:10:256; %horizontal scale
- bar(horz,h1); %use bar function, specifying x and y
- axis([0 255 0 4000])
- set(gca, 'xtick', 0:50:255)
- set(gca, 'ytick', 0:250:4000)

- Take the time to understand the code!

Questions?

- Study the tutorials!