MATLAB for Image Processing

CS638-1 TA: Tuo Wang

tuowang@cs.wisc.edu

Feb 12th, 2010

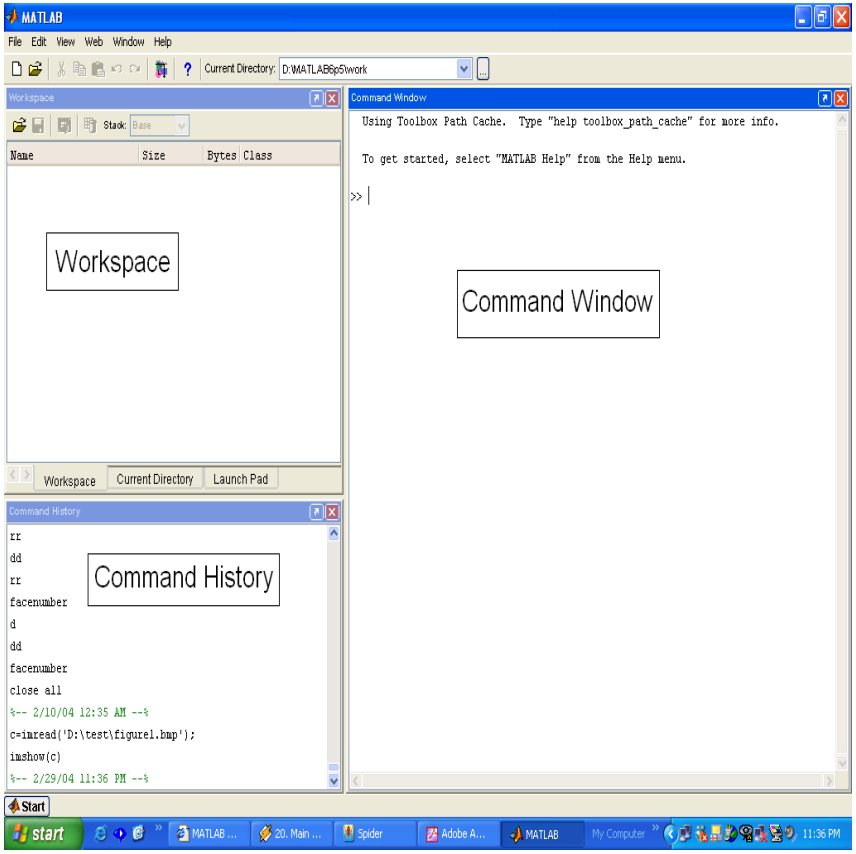
Outline

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

What is MATLAB?

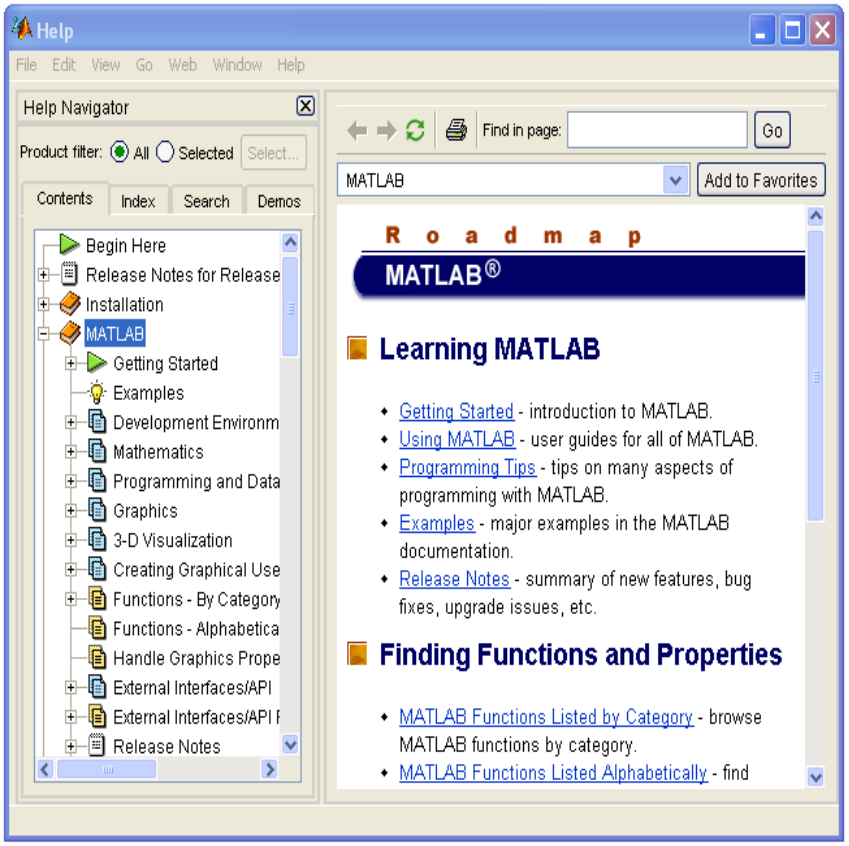
- MATLAB = Matrix Laboratory
- “MATLAB is a high-level language and interactive environment that enables you to perform computationally intensive tasks faster than with traditional programming languages such as C, C++ and Fortran.” (www.mathworks.com)
- MATLAB is an interactive, interpreted language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

The MATLAB Environment



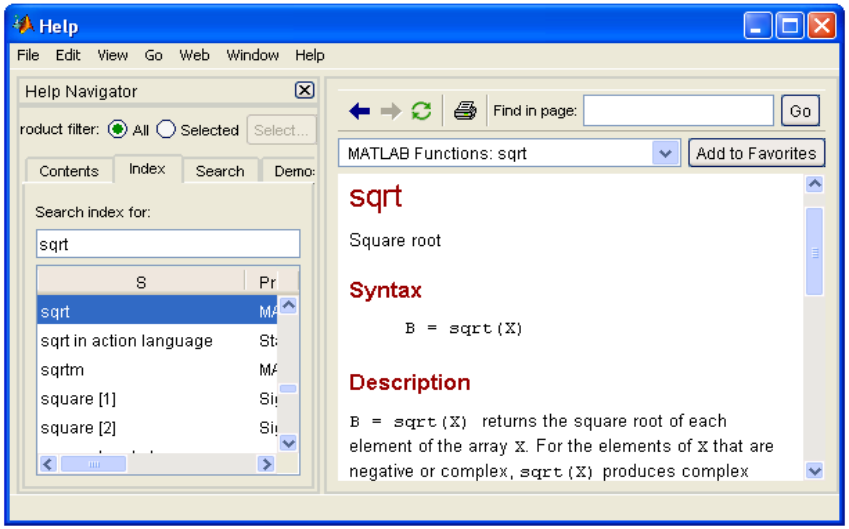
- MATLAB window components:
  - Workspace
    - > Displays all the defined variables
  - Command Window
    - > To execute commands in the MATLAB environment
  - Command History
    - > Displays record of the commands used
  - File Editor Window
    - > Define your functions

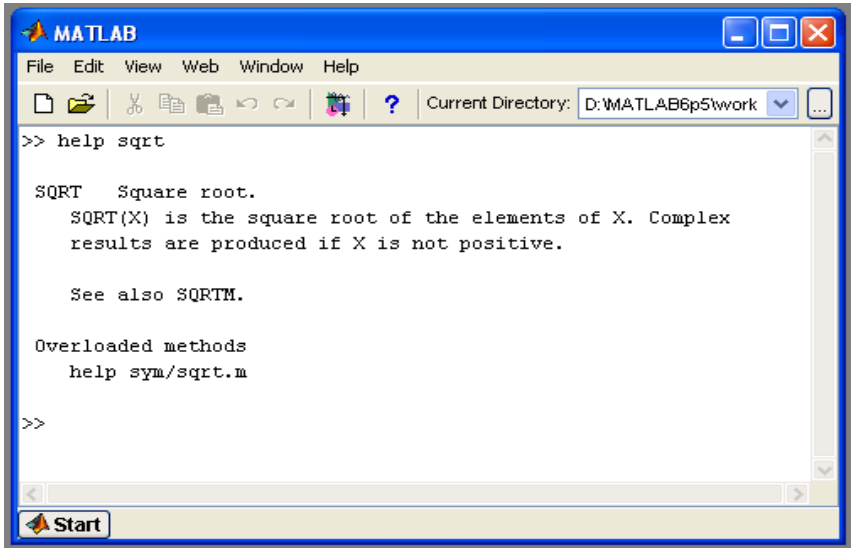
MATLAB Help



- 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 (cont.)





- 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

- CODE

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

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

- CODE

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

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
```

switch (cont.)

- Note:
  - Only the statements between the matching `CASE` and the next `CASE`, `OTHERWISE`, or `END` are executed
  - Unlike C, the `SWITCH` statement does not fall through (so `BREAK`s are unnecessary)

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 (cont.)

- 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 titile')` – 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

- CODE and Debug CODE

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
  - Basics & Examples
- **Image Processing with MATLAB**
  - **Basics & Examples**

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)

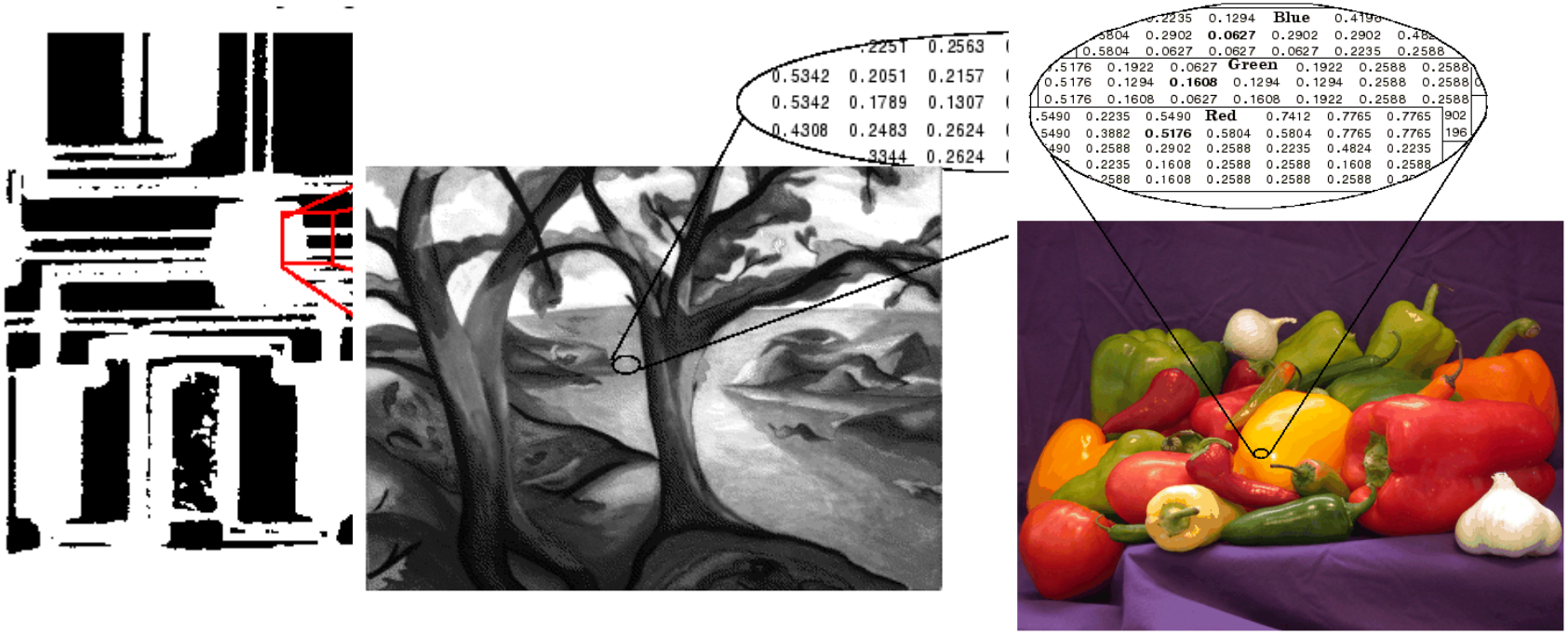


Image Import and Export

- Read and write images in Matlab

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

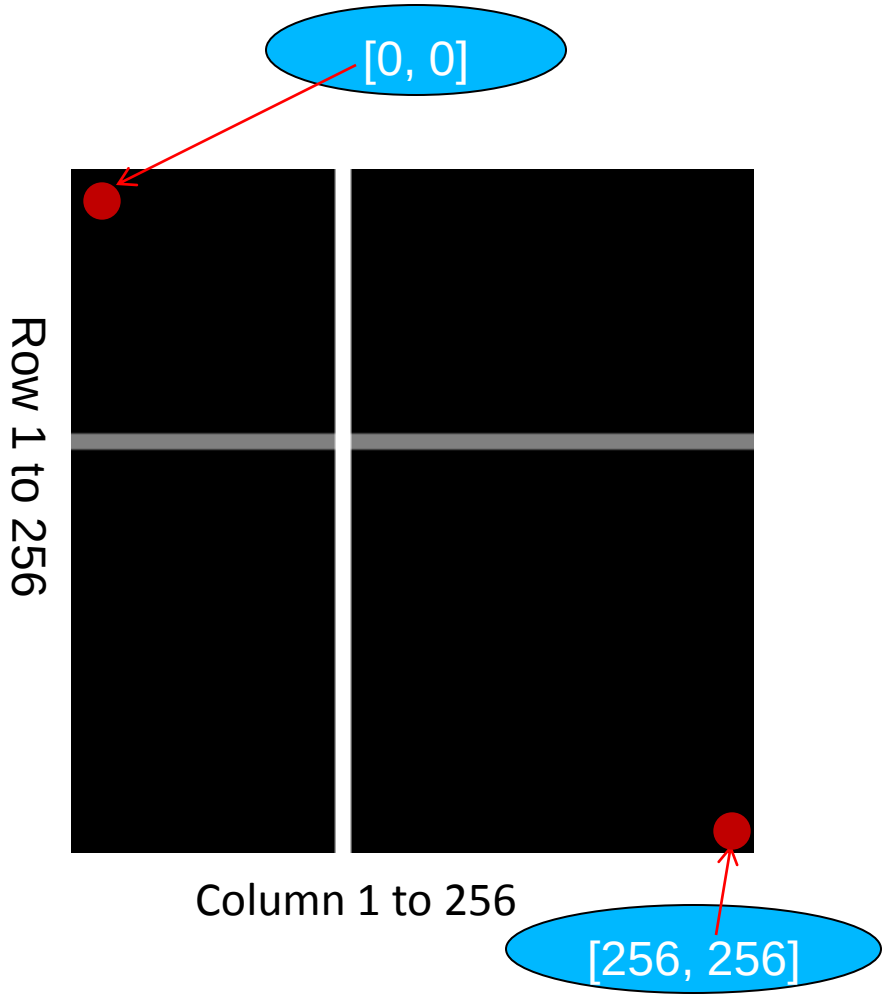
- Alternatives to `imshow`

```
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);
```

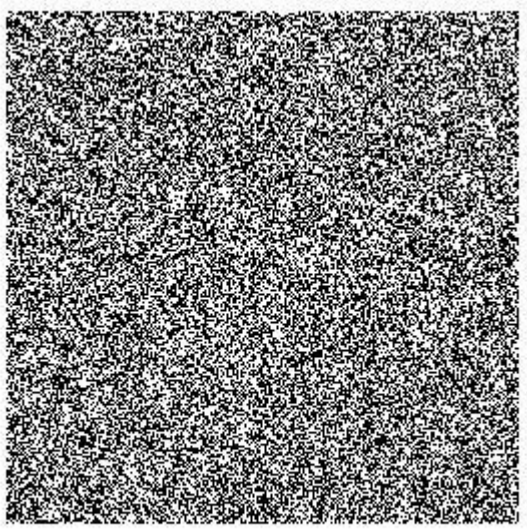


Image Display

- `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
  - Basics & Examples
- Image Processing with MATLAB
  - Basics & **Examples**

Examples working with Images (11 different examples)

https://www.youtube.com/watch?v=GnD4Z3JvyNk&list=PL9ADE09052E08CC57

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
  - 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 (cont.)

- 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!

THE END

- Thanks for your attention! ☺
- Questions?