MATLAB Tutorial

CSE 6367: Computer Vision

Instructor: William J. Beksi

Introduction

- **MATLAB** (MAtrix LABoratory) is a numerical computing environment that allows matrix manipulations, plotting of functions and data, algorithm implementation, etc.

Introduction

- **MATLAB** (MAtrix LABoratory) is a numerical computing environment that allows matrix manipulations, plotting of functions and data, algorithm implementation, etc.
- Toolboxes, such as the **Image Processing Toolbox** and the **Computer Vision System Toolbox**, provide a comprehensive set of algorithms and apps for image processing and computer vision

MATLAB Environment

- The MATLAB environment consists of the following components:

MATLAB Environment

- The MATLAB environment consists of the following components:
  - Workspace - Displays all of the defined variables

MATLAB Environment

- The MATLAB environment consists of the following components:
  - Workspace - Displays all of the defined variables
  - Command Window - Allows for executing commands in the MATLAB environment

MATLAB Environment

- The MATLAB environment consists of the following components:
  - Workspace - Displays all of the defined variables
  - Command Window - Allows for executing commands in the MATLAB environment
  - Command History - Shows a record of the commands used

MATLAB Environment

- The MATLAB environment consists of the following components:
  - Workspace - Displays all of the defined variables
  - Command Window - Allows for executing commands in the MATLAB environment
  - Command History - Shows a record of the commands used
  - File Editor Window - Allows for defining functions, running scripts, etc.

MATLAB Help

- MATLAB Help is a valuable resource for learning MATLAB

MATLAB Help

- MATLAB Help is a valuable resource for learning MATLAB
- Help not only contains theoretical background, but also shows demos and implementation examples

MATLAB Help

- MATLAB Help is a valuable resource for learning MATLAB
- Help not only contains theoretical background, but also shows demos and implementation examples
- Any command description can be found by typing the command in the search field, e.g. `sqrt`

MATLAB Workspace

- The following commands are useful in the MATLAB workspace:

MATLAB Workspace

- The following commands are useful in the MATLAB workspace:
  - `who,whos` - Show the current variables in the workspace

MATLAB Workspace

- The following commands are useful in the MATLAB workspace:
  - `who,whos` - Show the current variables in the workspace
  - `save` - Save the workspace variables to a *.mat file

MATLAB Workspace

- The following commands are useful in the MATLAB workspace:
  - `who,whos` - Show the current variables in the workspace
  - `save` - Save the workspace variables to a *.mat file
  - `load` - Load the variables from a *.mat file

MATLAB Workspace

- The following commands are useful in the MATLAB workspace:
  - `who,whos` - Show the current variables in the workspace
  - `save` - Save the workspace variables to a *.mat file
  - `load` - Load the variables from a *.mat file
  - `clear` - Clear the workspace variables

Matrices

- The matrix is the main data type in MATLAB

Matrices

- The matrix is the main data type in MATLAB
- `A = [1 2 3; 4 5 6; 7 8 9];` creates a matrix `A` of size 3×3

Matrices

- The matrix is the main data type in MATLAB
- `A = [1 2 3; 4 5 6; 7 8 9];` creates a matrix `A` of size 3×3
- Special matrices include the following: `zeros(n,m)`, `ones(n,m)`, `eye(n,m)`, `rand()`, `randn()`

Basic Operations on Matrices

- All operations in MATLAB are defined on matrices: `+`, `-`, `*`, `/`, `^`, `sqrt`, `sin`, `cos`, etc.

Basic Operations on Matrices

- All operations in MATLAB are defined on matrices: `+`, `-`, `*`, `/`, `^`, `sqrt`, `sin`, `cos`, etc.
- Element-wise operations are defined with a preceding dot: `.*`, `./`, `.^`

Basic Operations on Matrices

- All operations in MATLAB are defined on matrices: `+`, `-`, `*`, `/`, `^`, `sqrt`, `sin`, `cos`, etc.
- Element-wise operations are defined with a preceding dot: `.*`, `./`, `.^`
- To find the size of a matrix: `size(A)`

Basic Operations on Matrices

- All operations in MATLAB are defined on matrices: `+`, `-`, `*`, `/`, `^`, `sqrt`, `sin`, `cos`, etc.
- Element-wise operations are defined with a preceding dot: `.*`, `./`, `.^`
- To find the size of a matrix: `size(A)`
- To sum the columns of a matrix: `sum(A)`

Basic Operations on Matrices

- All operations in MATLAB are defined on matrices: `+`, `-`, `*`, `/`, `^`, `sqrt`, `sin`, `cos`, etc.
- Element-wise operations are defined with a preceding dot: `.*`, `./`, `.^`
- To find the size of a matrix: `size(A)`
- To sum the columns of a matrix: `sum(A)`
- To sum all of the elements of a matrix: `sum(sum(A))`

Variable Names

- The following rules must be used when naming variables:

Variable Names

- The following rules must be used when naming variables:
  - 63 characters in length

Variable Names

- The following rules must be used when naming variables:
  - 63 characters in length
  - Begin with a letter

Variable Names

- The following rules must be used when naming variables:
  - 63 characters in length
  - Begin with a letter
  - No blank spaces nor punctuation

Variable Names

- The following rules must be used when naming variables:
  - 63 characters in length
  - Begin with a letter
  - No blank spaces nor punctuation
  - May contain any combination of letters, digits, and underscores

Variable Names

- The following rules must be used when naming variables:
  - 63 characters in length
  - Begin with a letter
  - No blank spaces nor punctuation
  - May contain any combination of letters, digits, and underscores
- Variables are case sensitive and cannot be the same as MATLAB predefined variable names: `true`, `date`, `nan`, `eps`, `pi`, etc.

Logical Operators

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

Logical Operators

- `==`, `<`, `>`, `~=` (not equal), ~ (not)
- `find('condition')` - Returns the indexes of the elements of a matrix that satisfy the given condition

Logical Operators

- ==, <, >, ~= (not equal), ~ (not)
- find('condition') - Returns the indexes of the elements of a matrix that satisfy the given condition
- Example:

```
>> A = [4, 9, 1; 5, 8, 2]
A =
   4 9 1
   5 8 2
>> find(A < 3)
```

Logical Operators

- ==, <, >, ~= (not equal), ~ (not)
- find('condition') - Returns the indexes of the elements of a matrix that satisfy the given condition
- Example:

```
>> A = [4, 9, 1; 5, 8, 2]
A =
  4 9 1
  5 8 2
>> find(A < 3)
 ans =
5
6
```

Flow Control

- MATLAB has five flow control constructs:

Flow Control

- MATLAB has five flow control constructs:
  - The `if` statement

Flow Control

- MATLAB has five flow control constructs:
  - The `if` statement
  - The `switch` statement

Flow Control

- MATLAB has five flow control constructs:
  - The `if` statement
  - The `switch` statement
  - The `for` loop

Flow Control

- MATLAB has five flow control constructs:
  - The `if` statement
  - The `switch` statement
  - The `for` loop
  - The `while` loop

Flow Control

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

if

- The general form of the `if` statement is the following:

```
if expression
  statements
elseif expression
  statements
else
  statements
end
```

switch

- The general form of the `switch` statement is the following:

```
switch switch_expression
  case case_expression_1
    statements
  case case_expression_2
    statements
  otherwise
    statements
end
```

switch

- The general form of the `switch` statement is the following:

```
switch switch_expression
  case case_expression_1
    statements
  case case_expression_2
    statements
  otherwise
    statements
end
```

- Note that unlike C the `switch` statement does not fall through (i.e. breaks are unnecessary)

`for`

- The `for` statement repeats a statement a specific number of times

for

- The `for` statement repeats a statement a specific number of times
- The general form of the `for` statement is the following:

```
for variable == expression
  statements
end
```

`while`

- The `while` statement repeats a statement an indefinite number of times

while

- The `while` statement repeats a statement an indefinite number of times
- The general form of the `while` statement is the following:

```
while expression
  statements
end
```

Scripts and Functions

- There are two kinds of m-files:

Scripts and Functions

- There are two kinds of m-files:
  - Scripts - Operate on data in the workspace and do not accept any input arguments nor do they return output arguments

Scripts and Functions

- There are two kinds of m-files:
  - Scripts - Operate on data in the workspace and do not accept any input arguments nor do they return output arguments
  - Functions - Internal variables are local to the function, input arguments are accepted and output arguments are returned

Functions

- The following function, 'unpackRGBFloat', unpacks RGB float data into separate color values:

```
function [r g b] = unpackRGBFloat(rgbfloatdata)
% UNPACKRGBFLOAT Unpack RGB float data into
% separate color values.

mask = hex2dec('000000FF');
rgb = typecast(rgbfloatdata,'uint32');

r = double(bitand(mask, bitshift(rgb, -16))) / 255;
g = double(bitand(mask, bitshift(rgb, -8))) / 255;
b = double(bitand(mask, rgb)) / 255;

end
```

Visualization

- The following functions can be used for visualizing data:

Visualization

- The following functions can be used for visualizing data:
  - `figure` - Open a new figure

Visualization

- The following functions can be used for visualizing data:
  - `figure` - Open a new figure
  - `hold on, hold off` - Use the same figure or open a new figure

Visualization

- The following functions can be used for visualizing data:
  - `figure` - Open a new figure
  - `hold on, hold off` - Use the same figure or open a new figure
  - `axis([xmin xmax ymin ymax])` - Change scaling of axes

Visualization

- The following functions can be used for visualizing data:
  - `figure` - Open a new figure
  - `hold on, hold off` - Use the same figure or open a new figure
  - `axis([xmin xmax ymin ymax])` - Change scaling of axes
  - `title('figure_title')` - Add a title to the figure

Visualization

- The following functions can be used for visualizing data:
  - `figure` - Open a new figure
  - `hold on, hold off` - Use the same figure or open a new figure
  - `axis([xmin xmax ymin ymax])` - Change scaling of axes
  - `title('figure_title')` - Add a title to the figure
  - `plot(x,y)` - 2D line plot

Visualization

- The following functions can be used for visualizing data:
  - `figure` - Open a new figure
  - `hold on, hold off` - Use the same figure or open a new figure
  - `axis([xmin xmax ymin ymax])` - Change scaling of axes
  - `title('figure_title')` - Add a title to the figure
  - `plot(x,y)` - 2D line plot
  - `scatter3(x,y,z)` - 3D scatter plot

save/clear/load

- The following session variables allow for saving, loading, and clearing the workspace:

save/clear/load

- The following session variables allow for saving, loading, and clearing the workspace:
  - `save mysession` - Creates a mysession.mat file with all the current variables

save/clear/load

- The following session variables allow for saving, loading, and clearing the workspace:
  - `save mysession` - Creates a mysession.mat file with all the current variables
  - `clear all` - Clears all variables in the current session

save/clear/load

- The following session variables allow for saving, loading, and clearing the workspace:
  - `save mysession` - Creates a mysession.mat file with all the current variables
  - `clear all` - Clears all variables in the current session
  - `load mysession` - Loads a previously saved mysession.mat file

MATLAB Toolboxes

- A toolbox is a collection of special functions within MATLAB

MATLAB Toolboxes

- A toolbox is a collection of special functions within MATLAB
- Two very useful toolboxes are the Image Processing and Computer Vision Toolboxes

Image Processing Toolbox

- MATLAB's Image Processing Toolbox is a set of functions that support a wide range of image processing operations including:

Image Processing Toolbox

- MATLAB's Image Processing Toolbox is a set of functions that support a wide range of image processing operations including:
  - Geometric operations

Image Processing Toolbox

- MATLAB's Image Processing Toolbox is a set of functions that support a wide range of image processing operations including:
  - Geometric operations
  - Neighborhood and block operations

Image Processing Toolbox

- MATLAB's Image Processing Toolbox is a set of functions that support a wide range of image processing operations including:
  - Geometric operations
  - Neighborhood and block operations
  - Linear filtering and filter design

Image Processing Toolbox

- MATLAB's Image Processing Toolbox is a set of functions that support a wide range of image processing operations including:
  - Geometric operations
  - Neighborhood and block operations
  - Linear filtering and filter design
  - Transforms

Image Processing Toolbox

- MATLAB's Image Processing Toolbox is a set of functions that support a wide range of image processing operations including:
  - Geometric operations
  - Neighborhood and block operations
  - Linear filtering and filter design
  - Transforms
  - Image analysis and enhancement

Image Processing Toolbox

- MATLAB's Image Processing Toolbox is a set of functions that support 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

Image Processing Toolbox

- MATLAB's Image Processing Toolbox is a set of functions that support 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

Computer Vision Toolbox

- The Computer Vision Toolbox provides the following algorithms, functions, and apps for designing and testing computer vision, 3D vision, and video processing systems:

Computer Vision Toolbox

- The Computer Vision Toolbox provides the following algorithms, functions, and apps for designing and testing computer vision, 3D vision, and video processing systems:
  - Object detection and tracking

Computer Vision Toolbox

- The Computer Vision Toolbox provides the following algorithms, functions, and apps for designing and testing computer vision, 3D vision, and video processing systems:
  - Object detection and tracking
  - Feature detection and extraction

Computer Vision Toolbox

- The Computer Vision Toolbox provides the following algorithms, functions, and apps for designing and testing computer vision, 3D vision, and video processing systems:
  - Object detection and tracking
  - Feature detection and extraction
  - Semantic segmentation

Computer Vision Toolbox

- The Computer Vision Toolbox provides the following algorithms, functions, and apps for designing and testing computer vision, 3D vision, and video processing systems:
  - Object detection and tracking
  - Feature detection and extraction
  - Semantic segmentation
  - 3D reconstruction

Computer Vision Toolbox

- The Computer Vision Toolbox provides the following algorithms, functions, and apps for designing and testing computer vision, 3D vision, and video processing systems:
  - Object detection and tracking
  - Feature detection and extraction
  - Semantic segmentation
  - 3D reconstruction
  - Stereo vision

Computer Vision Toolbox

- The Computer Vision Toolbox provides the following algorithms, functions, and apps for designing and testing computer vision, 3D vision, and video processing systems:
  - Object detection and tracking
  - Feature detection and extraction
  - Semantic segmentation
  - 3D reconstruction
  - Stereo vision
  - Camera calibration

Computer Vision Toolbox

- The Computer Vision Toolbox provides the following algorithms, functions, and apps for designing and testing computer vision, 3D vision, and video processing systems:
  - Object detection and tracking
  - Feature detection and extraction
  - Semantic segmentation
  - 3D reconstruction
  - Stereo vision
  - Camera calibration
  - LIDAR and 3D point cloud processing

Images

- MATLAB can import/export several image formats including PNG, JPEG, TIFF, BMP, etc.

Images

- MATLAB can import/export several image formats including PNG, JPEG, TIFF, BMP, etc.
- Images consist of the following types:

Images

- MATLAB can import/export several image formats including PNG, JPEG, TIFF, BMP, etc.
- Images consist of the following types:
  - Binary images - Each element is either 0 or 1

Images

- MATLAB can import/export several image formats including PNG, JPEG, TIFF, BMP, etc.
- Images consist of the following types:
  - Binary images - Each element is either 0 or 1
  - Intensity images - Each element takes on a value in the range $[0, 1]$

Images

- MATLAB can import/export several image formats including PNG, JPEG, TIFF, BMP, etc.
- Images consist of the following types:
  - Binary images - Each element is either 0 or 1
  - Intensity images - Each element takes on a value in the range $[0, 1]$
  - RGB images - Images are of the form $m \times n \times 3$

Image Import and Export

- The following commands can be used to read, display, and write images:

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

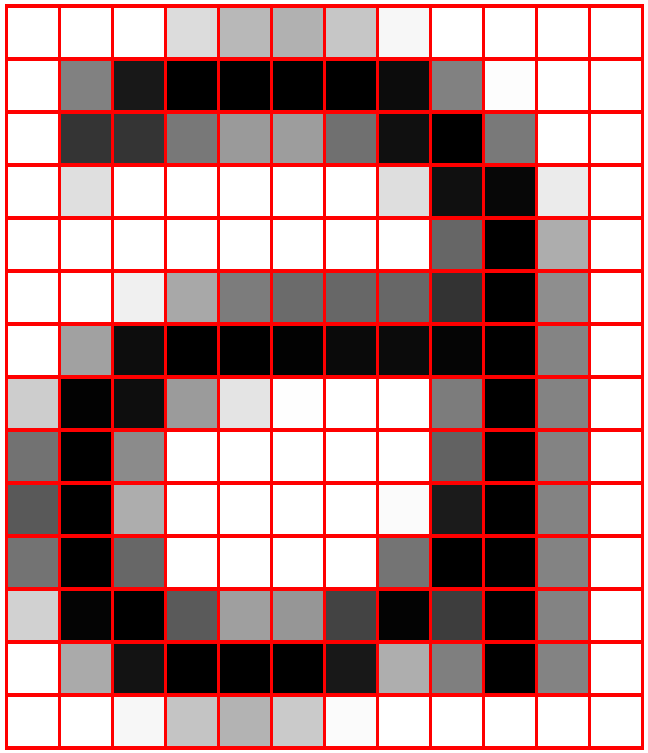
Image Import and Export

- The following commands can be used to read, display, and write images:

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

- Alternatives to `imshow` include `imagesc`, `imtool`, `image`

Images and Matrices



1.0	1.0	1.0	0.9	0.6	0.6	0.6	1.0	1.0	1.0	1.0	1.0
1.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.5	1.0	1.0	1.0
1.0	0.2	0.2	0.5	0.6	0.6	0.5	0.0	0.0	0.5	1.0	1.0
1.0	0.9	1.0	1.0	1.0	1.0	1.0	0.9	0.0	0.0	0.9	1.0
1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.5	0.0	0.5	1.0
1.0	1.0	1.0	0.5	0.5	0.5	0.5	0.5	0.4	0.0	0.5	1.0
1.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	1.0
0.9	0.0	0.0	0.6	1.0	1.0	1.0	1.0	0.5	0.0	0.5	1.0
0.5	0.0	0.6	1.0	1.0	1.0	1.0	1.0	0.5	0.0	0.5	1.0
0.5	0.0	0.7	1.0	1.0	1.0	1.0	1.0	0.0	0.0	0.5	1.0
0.6	0.0	0.6	1.0	1.0	1.0	1.0	0.5	0.0	0.0	0.5	1.0
0.9	0.1	0.0	0.6	0.7	0.7	0.5	0.0	0.5	0.0	0.5	1.0
1.0	0.7	0.1	0.0	0.0	0.0	0.1	0.9	0.8	0.0	0.5	1.0
1.0	1.0	1.0	0.8	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.0

- Images are represented as matrices

Image Conversion Operations

- The following operations can be used to convert an image from one representation to another:

Image Conversion Operations

- The following operations can be used to convert an image from one representation to another:
  - `rgb2gray` - Convert an RGB image to a grayscale image

Image Conversion Operations

- The following operations can be used to convert an image from one representation to another:
  - `rgb2gray` - Convert an RGB image to a grayscale image
  - `im2bw` - Convert an image to its binary representation

Image Conversion Operations

- The following operations can be used to convert an image from one representation to another:
  - `rgb2gray` - Convert an RGB image to a grayscale image
  - `im2bw` - Convert an image to its binary representation
  - `mat2gray` - Convert a matrix to an intensity image

Image Conversion Operations

- The following operations can be used to convert an image from one representation to another:
  - `rgb2gray` - Convert an RGB image to a grayscale image
  - `im2bw` - Convert an image to its binary representation
  - `mat2gray` - Convert a matrix to an intensity image
  - `im2uint8` - Convert an image to an 8-bit unsigned integer representation

Vectors vs. Loops

- MATLAB is fast on vector and matrix operations, but slow with loops

Vectors vs. Loops

- MATLAB is fast on vector and matrix operations, but slow with loops
- Keypoint: try to avoid loops and write vectorized code

Vectorized Loops

- Consider the following example to compute the sine for a range of values:

Vectorized Loops

- Consider the following example to compute the sine for a range of values:
  - Poor style (elapsed time $\approx$ 8.735 sec):

```
i = 0;
for t = 0:.01:1000000
   i = i + 1;
   y(i) = sin(t);
end
```

Vectorized Loops

- Consider the following example to compute the sine for a range of values:
  - Poor style (elapsed time $\approx$ 8.735 sec):

```
i = 0;
for t = 0:.01:1000000
   i = i + 1;
   y(i) = sin(t);
end
```

  - Good style (elapsed time $\approx$ 0.499 sec):

```
t = 0:.01:1000000
y = sin(t);
```

Summary

- MATLAB is a great resource for prototyping image processing and computer vision software

Summary

- MATLAB is a great resource for prototyping image processing and computer vision software
- The toolboxes in MATLAB provide both low and high level functions for implementing programs