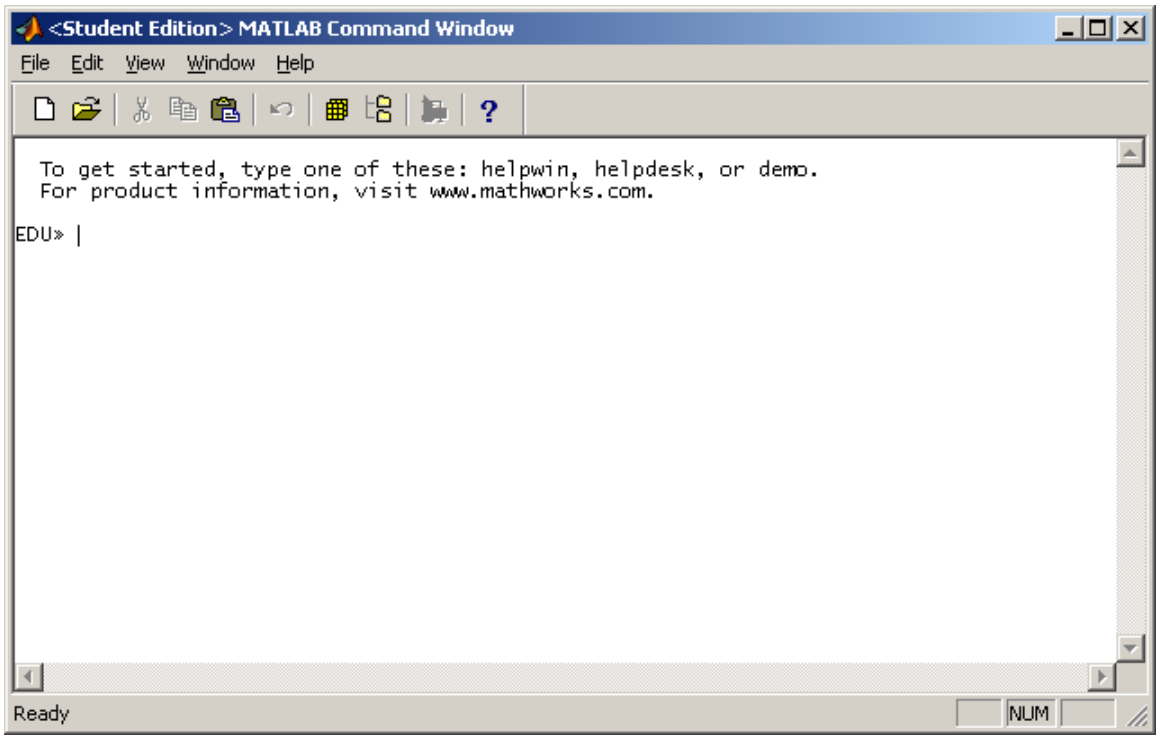
Introduction to Matlab

Matlab (MATrix LABoratory) will be the programming environment of choice for the numerical solutions developed in this textbook due to its wide availability and its ease of use. Matlab provides an interactive screen where commands can be typed and where the software returns output from those commands. The figure below shows the Matlab interactive environment for an earlier Student Edition of the software.



The cursor is shown in this figure in front of the Matlab prompt, in this case, `EDU>>`. One can type commands in front of the prompt and then press the <Enter> key to activate the command and obtain an output from Matlab. For example, Matlab can be used as a calculator to obtain the value of the following expression

$$\frac{2+\frac{3}{4}}{\sqrt{12.5}}$$

by typing the following statement at the prompt: `(2+3/4)/sqrt(12.5)`

Matlab replies with the following output:

```
ans =

    0.7778
```

This results indicates that Matlab calculated the numerical result of the expression typed and stored that value in a *variable* named `ans` (answer). Matlab then showed the contents of variable `ans` in the interactive window.

Please notice that Matlab will replace the contents of variable `ans` with the most recent result everytime that a calculation is performed in the Matlab window. To verify this statement, try the following calculations in Matlab (remember to press <Enter> after each entry):

```
(5+3/4)^2.3/sqrt(5+1/3)

sin(2*pi/3)

log(2.3+sqrt(4.2))
```

These examples illustrate a few interesting facts about Matlab:

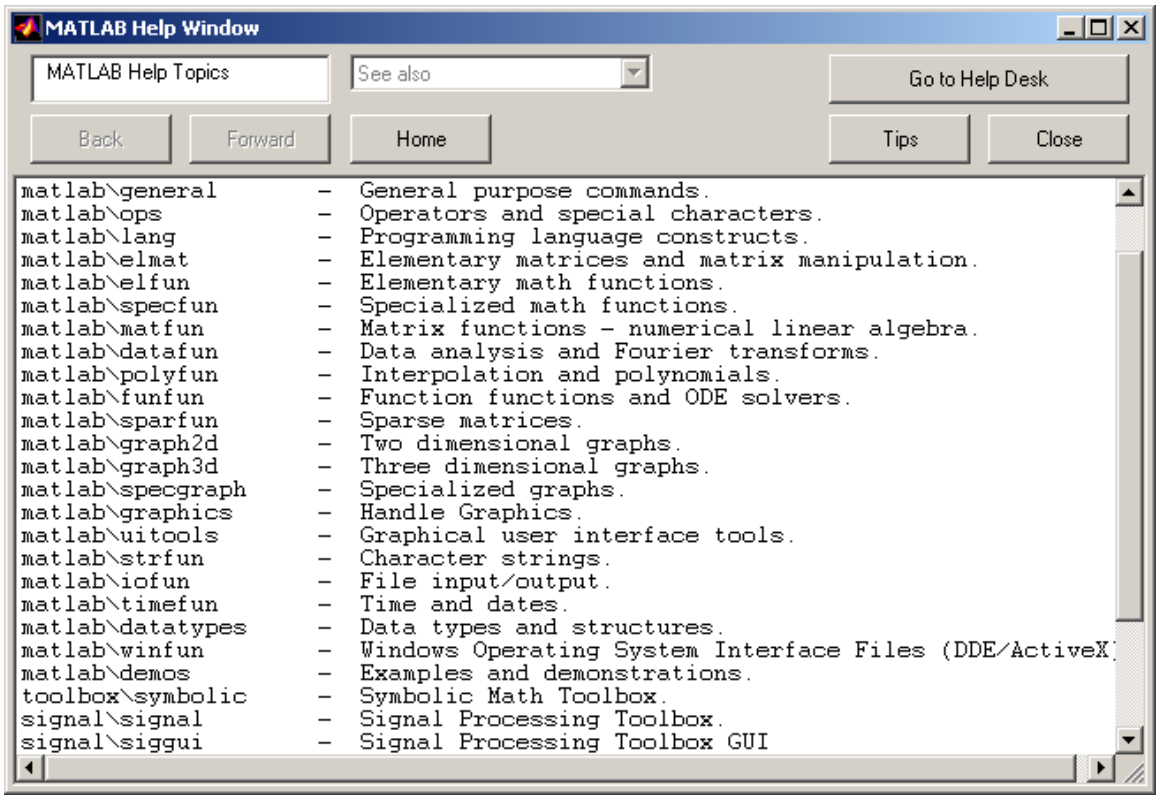
1. The fundamental arithmetic operation symbols are +, -, *, and /
2. To raise a number or expression to a power use the caret symbol ^
3. The ratio of the length of a circle to its diameter, typically referred to as π, is available by typing `pi`.
4. Many classical mathematical functions such as the trigonometric functions sine (`sin`), cosine (`cos`), tangent (`tan`), tand he natural logarithm (log) and exponential (exp) functions are available for calculations.

A few other important issues about using Matlab are listed next:

1. The *Edit* menu includes the options *Undo*, *Copy, Cut*, and *Paste* for editing expressions in the Matlab window. In *Windows*-based systems, you can also use *Cntl-C* and *Cntl-V* to copy and paste.
2. If you have to type a very long expression that requires two or more lines in the Matlab window, you can use the continuation characters (. . .) to specify the command, for example:

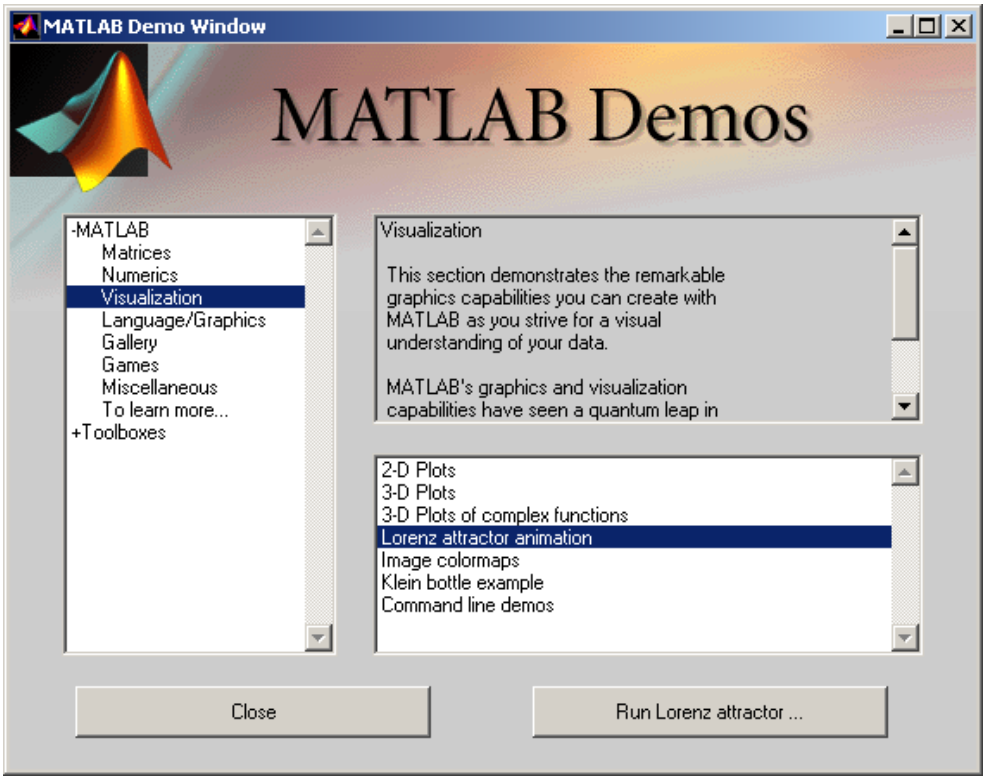
```
EDU» (2.5+3.5*pi+1/log(2.3+sqrt(1.2)))/ ...
     (2.3+sin(3*pi/7)-1/2)

ans =

    5.1582
```

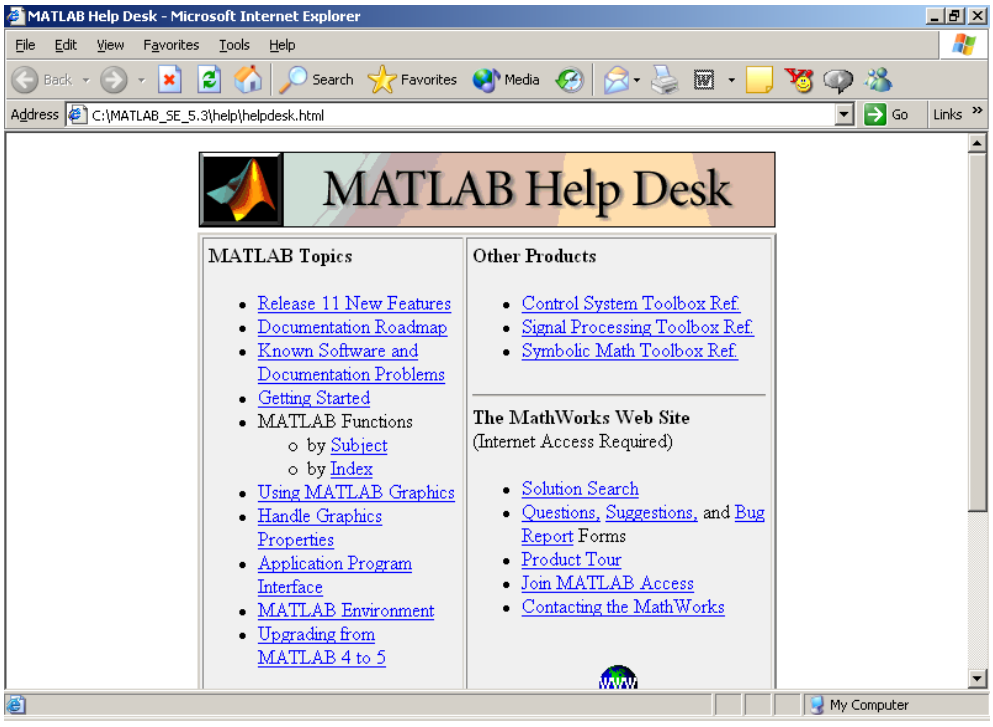
3. The *Help* menu contains several options for finding information about Matlab functions or commands. The option *Help Tips* provides information on the use of the *Help* facility. The option *Help window* produces a text window listing various chapters of help entries grouped according to certain subjects (see figure below). Double-click on any of the chapters to access a listing of functions contained in that chapter. Double click on any of the functions listed to get a help entry on that function. For example, find the help entry for function *plot3* in the help chapter entitled *Matlab\graph3d*.



The option *Examples and Demos* in the *Help* menu activates a Matlab dialog box showing a number of applications of Matlab in various fields of mathematics (see first figure below). Click on the titles shown in the left frame of the dialog box to select a specific collection of examples. Click on a specific application title in the field at the bottom of the dialog box to select that particular example. Press the *Run* button to activate the demonstration. Typically, there will be a new dialog box open with an output figure and a field listing the Matlab commands needed to produce the given result.

The option *Help Desk(HTML)* in the *Help* menu activates an *html* document (a web page) that contains information about the operation of Matlab (see figure below). Click on the link *Documentation Roadmap* to get an overall view of the *Help Desk* contents. Click on the link *Getting Started* to get an overview of Matlab's operation for mathematical calculations and graphics. The frame to the left in the *Getting Started* web page provides an outline of the page contents. Dedicate some time to explore the different chapters thus contained. These chapters and subchapters contain definitions and examples to help you learn the use of Matlab.


MATLAB Demo Window
MATLAB Demos
-MATLAB
Matrices
Numerics
Visualization
Language/Graphics
Gallery
Games
Miscellaneous
To learn more...
+Toolboxes
Visualization
This section demonstrates the remarkable graphics capabilities you can create with MATLAB as you strive for a visual understanding of your data.
MATLAB's graphics and visualization capabilities have seen a quantum leap in
2-D Plots
3-D Plots
3-D Plots of complex functions
Lorenz attractor animation
Image colormaps
Klein bottle example
Command line demos
Close
Run Lorenz attractor ...


MATLAB Help Desk - Microsoft Internet Explorer
File Edit View Favorites Tools Help
Back Search Favorites Media
Address C:\MATLAB_SE_5.3\help\helpdesk.html
Go Links
MATLAB Help Desk
MATLAB Topics
Release 11 New Features
Documentation Roadmap
Known Software and Documentation Problems
Getting Started
MATLAB Functions
by Subject
by Index
Using MATLAB Graphics
Handle Graphics Properties
Application Program Interface
MATLAB Environment
Upgrading from MATLAB 4 to 5
Other Products
Control System Toolbox Ref.
Signal Processing Toolbox Ref.
Symbolic Math Toolbox Ref.
The MathWorks Web Site
(Internet Access Required)
Solution Search
Questions, Suggestions, and Bug Report Forms
Product Tour
Join MATLAB Access
Contacting the MathWorks
My Computer

Using the *Help Desk* to learn about the Matlab environment

This sections offer guidelines on using the *Help Desk* to learn the basics about the Matlab environment.

Open the *Help Desk* web page as described above. Click on the link *Matlab Environment* and follow the outline of the page contents shown in the left-hand field. Click on the links in the contents field to see examples and exercises for any particular section.

It is recommended that you read the contents of the *Matlab Environment* web page while running Matlab so you can reproduce the exercises shown in the *Help Desk*. To facilitate trying the exercises in your own Matlab window, simply copy the commands listed in the *Help Desk* and paste them in your command window.

Read the *Matlab Environment* web page in detail to learn the basic operation of the Command Window, the Editor, and the Figure windows (used to produce graphics).

Using the *Help Desk* to learn Matlab operation

This sections offer guidelines on using the *Help Desk* to learn the use of Matlab on your own.

Open the *Help Desk* web page as described earlier. Click on the link *Getting Started* and follow the outline of the page contents shown in the left-hand field. Click on the links in the contents field to see examples and exercises for any particular section.

It is recommended that you read the contents of the *Getting Started* web page while running Matlab so you can reproduce the exercises shown in the *Help Desk*. To facilitate trying the exercises in your own Matlab window, simply copy the commands listed in the *Help Desk* and paste them in your command window.

Since the *Getting Started* page contains a large variety of concepts and examples, it is recommended that you take a few days to go over all of them while trying the corresponding exercises. The following schedule of reading is recommended based on the amount of material and on the contents of the outline. You may want to keep a notebook handy to summarize the most important commands you learn while reading the *Help Desk* pages.

Day 1 – Introduction

Introduction

- What Is MATLAB?
- The MATLAB System
- About Simulink

Getting Started

- Starting MATLAB
- Matrices and Magic Squares
  - Entering Matrices
  - sum, transpose, and diag

Subscripts
The Colon Operator
The magic Function
Expressions
Variables
Numbers
Operators
Functions
Expressions
Working with Matrices
Generating Matrices
load
M-Files
Concatenation
Deleting Rows and Columns

Day 2 – Command window/graphics

The Command Window
The format Command
Suppressing Output
Long Command Lines
Command Line Editing

Graphics
Creating a Plot
Figure Windows
Adding Plots to an Existing Graph
Subplots
Imaginary and Complex Data
Controlling Axes
Axis Labels and Titles
Mesh and Surface Plots
Visualizing Functions of Two Variables
Images
Printing Graphics

Day 3 – Help / Matlab environment

Help and Online Documentation
The help Command
The Help Window
The lookfor Command
The Help Desk
The doc Command
Printing Online Reference Pages
Link to the MathWorks

The MATLAB Environment
- The Workspace
- save Commands
- The Search Path
- Disk File Manipulation
- The diary Command
- Running External Programs

Day 4 – Matrices / Arrays

More About Matrices and Arrays
- Linear Algebra
- Arrays
- Multivariate Data
- Scalar Expansion
- Logical Subscripting
- The find Function

Day 5 - Flow control

Flow Control
- if
- switch and case
- for
- while
- break

Day 6 - Data/Scripts/Functions

Other Data Structures
- Multidimensional Arrays
- Cell Arrays
- Characters and Text
- Structures

Scripts and Functions
- Scripts
- Functions
- Global Variables
- Command/Function Duality
- The eval Function
- Vectorization
- Preallocation
- Function Functions

Day 7 – Handle graphics

Handle Graphics
- Graphics Objects
- Graphics Objects

Object Handles
Object Creation Functions
Object Properties
set and get
Graphics User Interfaces
Animations
Movies

Learning More

Using the *Help Desk* to learn about Matlab graphics

This sections offer guidelines on using the *Help Desk* to learn the use of Matlab graphics on your own. While some examples of graphics were presented in the contents of the *Getting Started* page, more detailed exampls on graphics are presented in the page entitled *Using Matlab graphics*.

Open the *Help Desk* web page as described in an earlier page. Click on the link *Using Matlab Graphics* and follow the outline of the page contents shown in the left-hand field. Click on the links in the contents field to see examples and exercises for any particular section.

The following schedule of reading is recommended based on the amount of material and on the contents of the outline.

Day 1 – Introduction

Introduction
- High-Level Graphics
- Handle Graphics
- Building Interactive GUIs
- How It All Fits Together
- Where to Begin

Basic Plotting
- Basic Plotting Commands
  - Creating Plots
  - Specifying Line Style
  - Specifying the Color and Size of Lines
  - Adding Plots to an Existing Graph
  - Plotting Only the Data Points
  - Plotting Markers and Lines
  - Line Styles for Black and White Output
  - Setting Default Line Styles

Day 2 – Line plots / Figure windows

Line Plots of Matrix Data
- Plotting Imaginary and Complex Data
- Plotting with Two Y-Axes

Line Plots of 3-D Data
Setting Axis Parameters
Axis Limits and Ticks
Example - Specifying Ticks and Tick Labels
Setting Aspect Ratio
Figure Windows
Displaying Multiple Plots per Figure
Specifying the Target Axes
Default Color Scheme

Day 3 – Labeling graphs

Labeling Graphs
Labeling Individual Axes
Adding Text Strings to a Graph
Positioning Text on Graphs
Text Alignment
Specifying TeX Characters
Using Variables in Text Strings
Example - Aligning Text
Example - Multiline Text

Day 4 - Specialized graphs

Specialized Graphs
Bar and Area Graphs
Types of Bar Graphs
Stacked Bar Graphs to Show Contributing Amounts
Specifying X-Axis Data
Overlaying Plots on Bar Graphs
Area Graphs
Comparing Datasets with Area Graphs
Pie Charts
Removing a Piece from a Pie Charts
Histograms
Histograms in Cartesian Coordinate Systems
Histograms in Polar Coordinate Systems
Specifying Number of Bins

Day 5 – Discrete / velocity data graphs

Discrete Data Graphs
Two-Dimensional Stem Plots
Combining Stem Plots with Line Plots
Three-Dimensional Stem Plots
Stairstep Plots
Direction and Velocity Vector Graphs

Compass Plots
Feather Plots
Two-Dimensional Quiver Plots
Three-Dimensional Quiver Plots

Day 6 – Contour / interactive plots

Contour Plots

Creating Simple Contour Plots
Labeling Contours
Filled Contours
Drawing a Single Contour Line at a Desired Level
The Contouring Algorithm
Changing the Offset of a Contour
Displaying Contours in Polar Coordinates

Interactive Plotting

Animation
Movies
Erase Modes

Day 7 – Three dimensional graphs

Creating 3-D Graphs

Representing a Matrix as a Surface
Mesh and Surface Plots
Visualizing Functions of Two Variables
Surface Plots of Nonuniformly Sampled Data
Parametric Surfaces
Hidden Line Removal
Coloring Mesh and Surface Plots
Colormaps
Indexed Colors - Direct and Scaled Colormapping
Example - Mapping Surface Curvature to Color
Altering Colormaps
Truecolor
Texture Mapping

Day 8 – Defining the view

Defining the View

Setting the Viewpoint
Defining Scenes with Camera Graphics
Camera Graphics Commands
Example - Dollying the Camera
Example - Creating a Fly-Through
Low-Level Camera Properties

Default Viewpoint Selection
Moving In and Out on the Scene
Making the Scene Larger or Smaller
Revolving Around the Scene
Rotation without Resizing of Graphics Objects
Rotation About the Viewing Axis
View Projection Types
Projection Types and Camera Location

Day 9 - Axes aspect ratio

Understanding Axes Aspect Ratio
Specifying Axis Scaling
Specifying Aspect Ratio
Example - axis Command Options
Additional Commands for Setting Aspect Ratio
Low-Level Aspect Ratio Properties
Default Aspect Ratio Selection
Overriding Stretch-to-Fill
Effects of Setting Aspect Ratio Properties
Example - Displaying Real Objects

Day 10 - Lighting

Lighting as a Visualization Tool
Lighting Commands
Light Objects
Adding Lights to a Scene
Properties that Affect Lighting
Selecting a Lighting Method
Reflectance Characteristics of Graphics Objects
Specular and Diffuse Reflection
Ambient Light
Specular Exponent
Specular Color Reflectance
Back Face Lighting
Positioning Lights in Data Space

Day 11 – Volume visualization

Volume Visualization Techniques
Volume Visualization Commands
Visualizing Scalar Volume Data
Example - Visualizing MRI Data
Exploring Volumes with Slice Planes
Example - Slicing Fluid Flow Data
Modifying the Color Mapping

Connecting Equal Values with Isosurfaces
Isocaps Add Context to Visualizations
Defining Isocaps
Visualizing Vector Volume Data
Stream Line Plots of Vector Data
Vector Data Displayed with Cone Plots

Day 12 – Patches in 3D

Creating 3-D Models with Patches

Behavior of the patch Function
Creating a Single Polygon
Multi-Faceted Patches
Example - Defining a Cube
Specifying Patch Coloring
Face and Edge Coloring
Example - Specifying Flat Edge and Face Coloring
Coloring Edges with Shared Vertices
How MATLAB Interprets Patch Color Data
Indexed Color Data
Truecolor Patches
Interpolating in Indexed Color vs. Truecolor

Day 13 – Bit-mapped images

Displaying Bit-Mapped Images

Images in MATLAB
Bit Depth Support
Data Types
Image Types
Indexed Images
Intensity Images
RGB (Truecolor) Images
Working with 8-Bit and 16-Bit Images
8-Bit and 16-Bit Indexed Images
8-Bit and 16-Bit Intensity Images
8-Bit and 16-Bit RGB Images
Mathematical Operations Support for uint8 and uint16
Other 8-Bit and 16-Bit Array Support
Summary of Image Types and Numeric Classes
Reading, Writing, and Querying Graphics Image Files
Reading a Graphics Image
Writing a Graphics Image
Obtaining Information About Graphics Files
Displaying Graphics Images
Summary of Image Types and Display Methods

Day 14 – Printing graphs

Printing MATLAB Graphics