Introduction to Plotting with Matlab

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Contents

Matlab is a program for solving engineering and mathematical problems. The basic *Matlab* objects are vectors and matrices, so you must be familiar with these before making extensive use of this program.

To start *Matlab* type **matlab**; to quit, type **quit** or **exit**.

Fundamentals

Matlab works with essentially one kind of object, a rectangular numerical matrix. Vectors and scalars are referred to as n-by-1 and 1-by-1 matrices respectively. Here is some basic information on using *Matlab* matrix commands.

- **Entering Matrices**

  The matrix

$$A = \begin{bmatrix} 1 & 3 & 2 \\ 2 & 4 & 1 \\ 6 & 6 & 8 \end{bmatrix}$$

  can be entered into *Matlab* by typing the following three lines. Each line ends by pressing the Return key.

```
A = [1 3 2
     2 4 1
     6 6 8]
```

- **Generating Vectors With Even Space**

  To plot a function, you must first specify the data points at which the function will be evaluated. It is common to choose evenly spaced points and put then in a vector. Here is how you generate a row vector X containing the values from 0 to 10 in increments of 0.2.

  ```
  X = 0 : 0.2 : 10
  ```

- **Array Operations**

  This term is used to refer to element-by-element arithmetic operations on vectors, instead of the usual linear algebra operations denoted by the symbols *, /, or ˆ (exponentiation). Preceding an operator with a period **.** indicates an array or element-by-element operation.

  For example, if X = [1 2 3] and Y = [4 5 6]; then

  $X. * Y$ = [4 10 18].

  Notice that the usual vector product $X * Y$ is undefined.

  The *Matlab* object **ones(m,n)** is useful if you want to add or subtract a constant from each element in a vector. **ones(m,n)** is an m-by-n matrix of ones. Using the vector X from the last example, you write the expression $X + 2$ as follows in *Matlab* notation.

  ```
  X + 2 * ones(1,3)
  ```

  The dimension of **ones** vector must match the other vectors in the computation. The command **size(A)** returns the dimension of a vector or matrix A.

- **On-line Help**

  Matlab has on-line help for all its commands. For example, try any of these commands:

  ```
  help print
  help help
  help general
  ```

Making Plots

Matlab provides a variety of functions for displaying data as 2-D or 3-D graphics.

For 2-D graphics, the basic command is:

```
plot(x1, y1, 'line style', x2, y2, 'line style'...)
```

This command plots vector `x1` versus vector `y1`, vector `x2` versus vector `y2`, etc. on the same graph. Other commands for 2-D graphics are: **polar, bar, stairs, loglog, semilogx,** and **semilogy**.

For 3-D graphics, the most commonly used commands are:

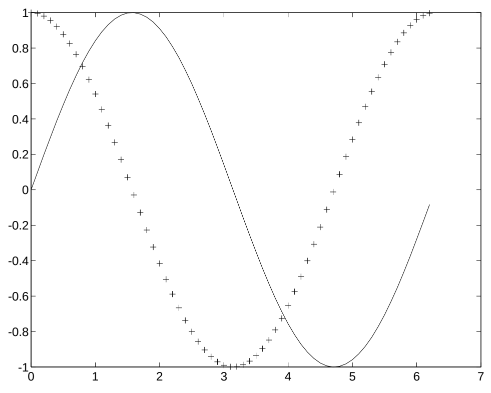
```
plot3(x1, y1, z1, 'line style', x2, y2, z2, 'line style'...)
contour(x,y,Z)
mesh(x,y,Z), surf(x,y,Z)
```

The first statement is a three-dimensional analogue of `plot()` and plots lines and points in 3-D. The second statement produces contour plots of the matrix `Z` using vectors `x` and `y` to control the scaling on the `x-` and `y-` axes. For surface or mesh plots, you use the third statement where `x`, `y` are vectors or matrices and Z is a matrix. Other commands available for 3-D graphics are: **pcolor, image, contour3, fill3, cylinder,** and **sphere**.

Example 1: Plot $y_1 = \sin(x)$ and $y_2 = \cos(x)$ with x in $[0, 2\pi]$ on the same graph. Use a solid line for $\sin(x)$ and the symbol $+$ for $\cos(x)$. The first step is to define a set of values for `x` at which the functions will be defined.

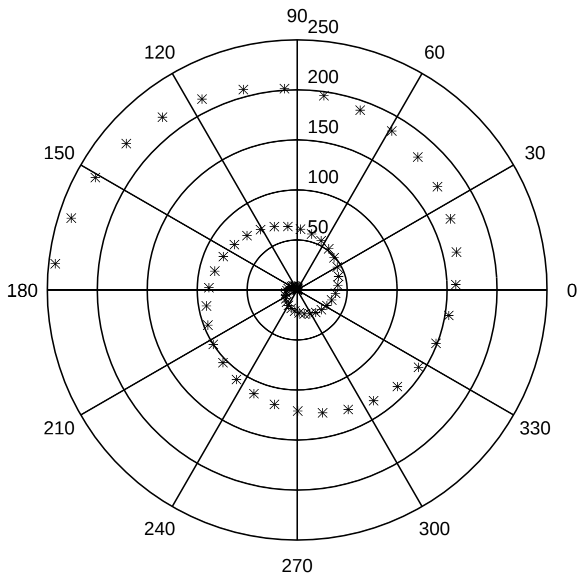
```
x = 0 : 0.1 : 2*pi;
y1 = sin(x);
y2 = cos(x);
plot(x, y1, '-', x, y2, '+')
```

Note: Ordinarily *Matlab* prints the results of each calculation right away. Placing **;** at the end of each line directs *Matlab* to not print the values of each vector.



Example 1

Another way to get multiple plots on the same graph is to use the **hold** command to keep the current graph, while adding new plots. Another **hold** command releases the previous one. For example, the following statements generate the same graph as in **Example 1**. *Matlab* remembers that the vector `x` is already defined.



Example 2

```
plot(x, sin(x), '-')
hold
plot(x, cos(x), '+')
```

The next example shows how *Matlab* generates a spiral using the polar coordinate system.

Example 2: Plot $\rho = \theta^2$ with $0 \le \theta \le 5\pi$ in polar coordinates.

```
theta = 0: 0.2: 5*pi;
rho = theta.^2;
polar(theta, rho, '*')
```

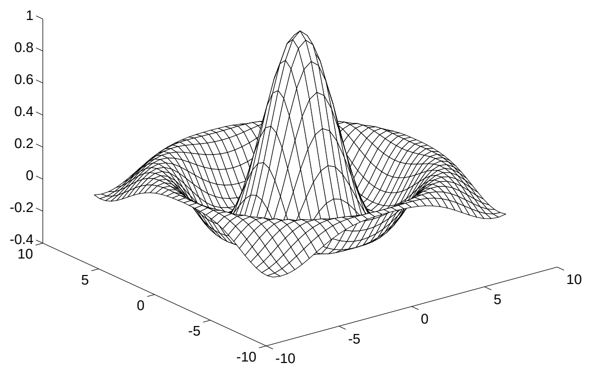
The following example illustrates how to generate a mesh surface in *Matlab*.

Example 3: Plot $z = \sin(r)/r$ with $r = \sqrt{x^2 + y^2}$, $-8 \le x \le 8$, $-8 \le y \le 8$.

The first step in displaying a function of two variables, $z = f(x, y)$, is to use the **meshgrid** function to generate X and Y matrices consisting of repeated rows and columns, respectively, over the domain of the function. The function can then be evaluated and graphed.

```
x = -8: .5: 8;   y = x;
[X,Y] = meshgrid(x,y);
R = sqrt(X.^2 + Y.^2) + eps;   % add eps to prevent R=0
Z = sin(R)./R;
mesh(x, y, Z)                  % or mesh(X,Y,Z)
```

Anything following % on a line is treated as a comment. We added eps (the machine ϵ) to R to prevent overflow.



Example 3

Printing and Saving Graphs

There are two ways to print your plots. The first one sends a copy of your graph directly to the default printer in the Thomson Hall lab. The second lets you save your graph in a file so you can use Unix printing commands to direct it to the printer of your choice.

- Type **print** in the *Matlab* environment to send your current plot to the pre-defined printer. On Math Sciences *Matlab*, the default printer is a laser printer in Thomson Hall. The **print** command generates a full page plot.
- If you want to save graphs in a file, use another printer, change the plot orientation, or use other features of the **print** command, look at the on-line help text within *Matlab*. For example, to save your graph in a PostScript file, use the command:

```
print -dps name-of-file
```

Loading Data Files

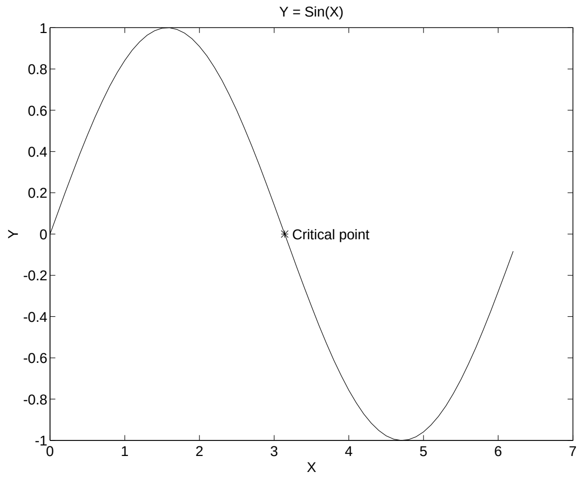
Matlab reads in values from ASCII files using the **load** command. Once the datafile has been read in, you can use any of the *Matlab* graphing commands. Here are some of the things you need to consider when reading in data.

The name of the ASCII datafile must have two parts, separated by a period. The command

```
load filename.extension
```

reads the file *filename.extension*, which can be an ASCII file with a rectangular array of numeric data, arranged in m lines with n values in each line. The result is an m-by-n matrix with the same name as the file with the extension (including the period) stripped.

Here are some examples:



Example 4

`load f.m`	creates a *Matlab* variable named *f*
`load y1`	loads from a file named *y1.mat*
`load func -ascii`	loads from a file named *func*

Title and Labels

You can add a title and labels for the axes with the commands; **title, xlabel, ylabel** and **zlabel**. You can also add contour labels to a contour plot by the command **clabel**. Other text can be added to the graph by using the **text** or **gtext** commands. With **text**, you specify a location where left edge of a text string is placed. With **gtext**, you position the text string with the mouse.

Here is an example which adds titles and labels to the graph of $f(x) = sin(x)$.

Example 4: Plot $y = sin(x); 0 \leq x \leq 2\pi$, with appropriate labels.

```
x = 0: 0.1: 2*pi; plot(x,sin(x))
title('Y = Sin(X)')
xlabel('X');   ylabel('Y')
hold
plot(pi,0,'*')
text(pi + 0.1, 0, 'Critical point')  % or gtext('Critical point')
hold
```

Other Interesting Features of *Matlab* Plotting

Matlab has a lot more capability for graphing or plotting than what has been mentioned here. What follows is a very brief description of three options (multiple graphs in one window, changing the viewpoint for 3-D plots, and controlling axes). *Matlab* also offers ways to turn a sequence of graphs into a movie, control almost every aspect of *graphics objects*, and create image plots. You should read the *Matlab* User's Guide (or some other commercial documentation) for more information.

- **Multiple Plots**

The command **subplot(m,n,p)** breaks the graph (or figure) window into an m-by-n matrix of small rectangular panes. The value of **p** is the pane for the next plot. Panes are numbered from left to right, top to bottom. To return to the default single graph per window, use either **subplot(1,1,1)** or **clf**.

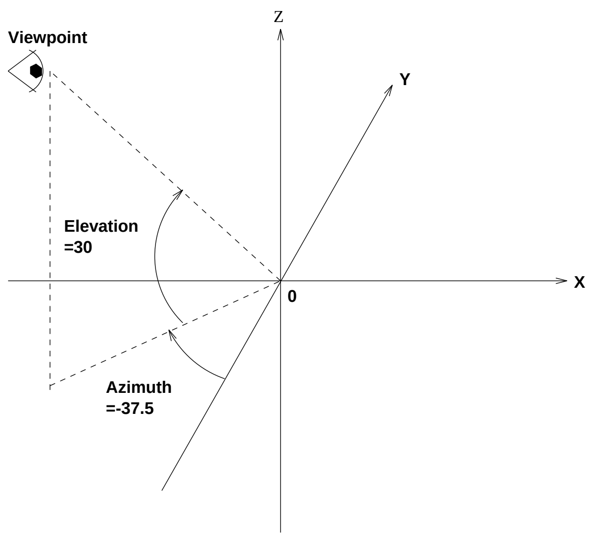
You can have more than one graphics window on an X display. The *Matlab* command, **figure** opens a new window, numbering each new window. You can then use commands such as **clf, figure(h),** or **close** to manipulate the figure windows.

- **Viewpoint**

You can set the angle of view of a 3-D plot with the command:

```
view(az,el)
```

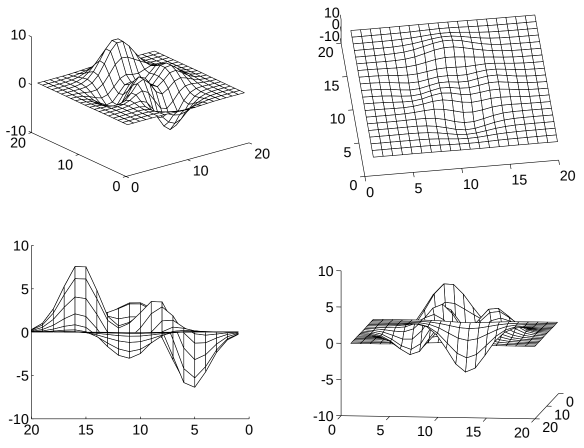
`az` is the azimuth and `el` is the elevation of the viewpoint, both in degrees. See the *viewpoint* figure for an illustration of azimuth and elevation relative to the Cartesian coordiate system.



Default Viewpoint

Example 5: View the internal *Matlab* **peaks** matrix from 4 different viewpoints. The first one, (**view(-37.5,30)**, is the default viewpoint.

```
subplot(2,2,1); mesh(peaks(20)); view(-37.5,30)
subplot(2,2,2); mesh(peaks(20)); view(-7,80)
subplot(2,2,3); mesh(peaks(20)); view(-90,0)
subplot(2,2,4); mesh(peaks(20)); view(-7,-10)
```



Example 5

- **Controlling Axes**

You can control the scaling and appearance of plot axis with the **axis** function. To set scaling for the x- and y- axes on the current 2-D plot, use this command:

```
axis([xmin xmax ymin ymax])
```

To scale the axes on 3-D plot, use this:

```
axis([xmin xmax ymin ymax zmin zmax])
```

In addition,

axis('auto')	returns the axis scaling to its default where the best axis limits are computed automatically;
axis('square')	makes the current axis box square in size, otherwise a circle will look like an oval;
axis('off')	turns off the axes
axis('on')	turns on axis labeling and tic marks.