A SHORT INTRODUCTION TO MATLAB

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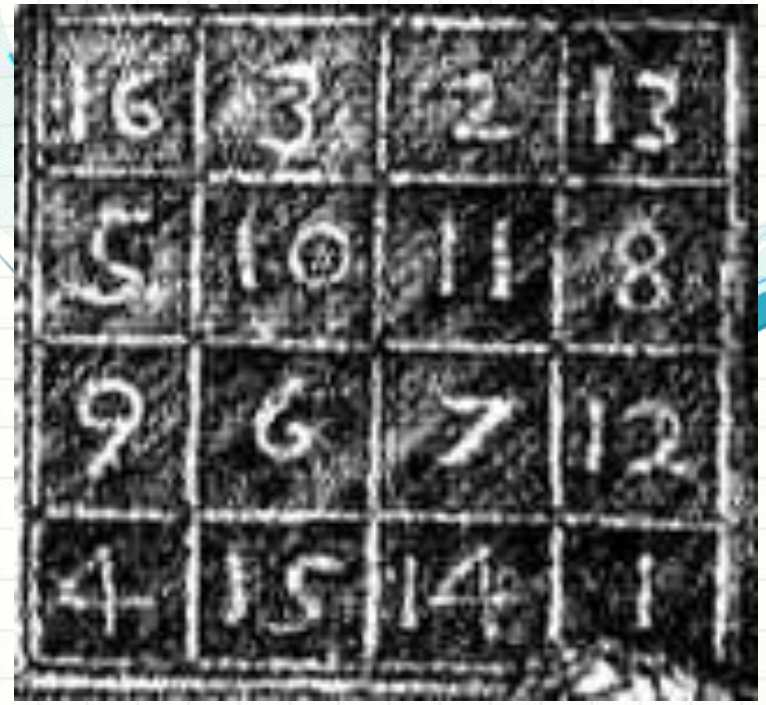


Overview

Matlab=‘Matrix Laboratory’

MATLAB - tool for Engineers/Mathematicians

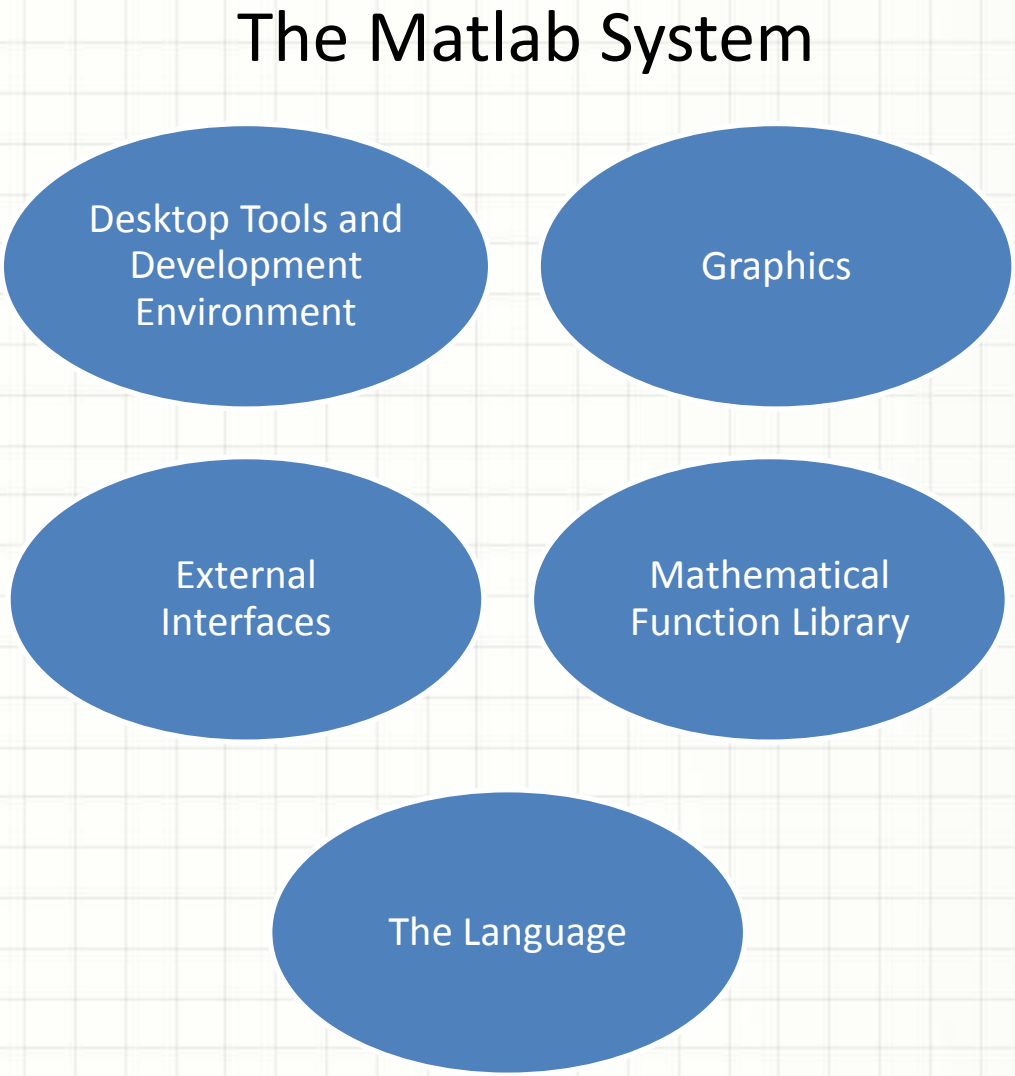
- MAT = Matrix (= a rectangular array of numbers); LAB = Laboratory
- High level language with highly optimized built-in functions.
- Not symbolic like MAPLE but …
- Matlab toolbox: built-in M-files.
- Works in Windows, Macintosh, UNIX environments.
- A standard in universities and the industry.

MATLAB - Typical uses

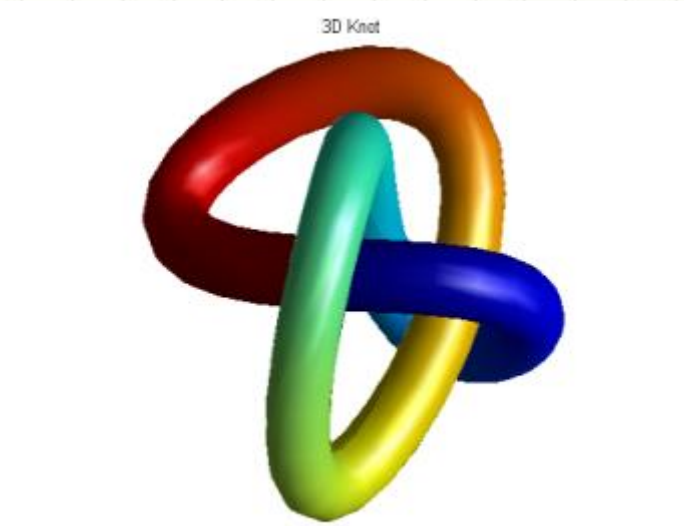
- ✓ Math and computation.
- ✓ Algorithm development, Modeling, Simulation, and Prototyping.
- ✓ Data acquisition, Data analysis, Exploration, and Visualization.
- ✓ Scientific and Engineering Graphics.
- ✓ Application Development, including GUI building.

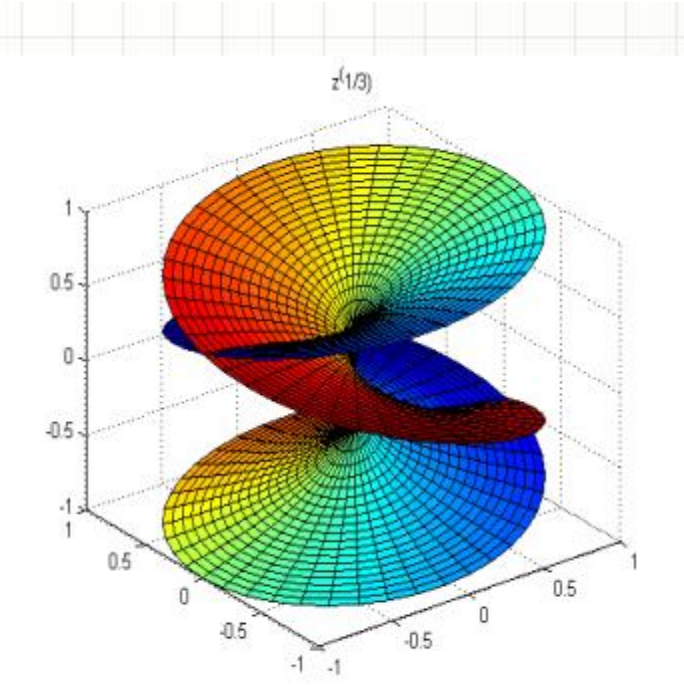
Getting started with Matlab

- Editor, command window, work space.
- Matlab is array based [A(row, column), indices starting at 1].
- Matrix operations are ‘very’ natural.
- We can write scripts and M-files.
- Loading data, doing maths, plot, etc …
- Matlab help.



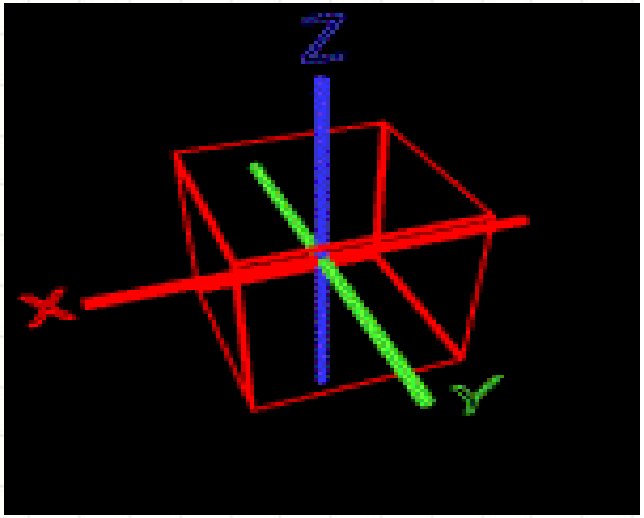
Matlab Graphics

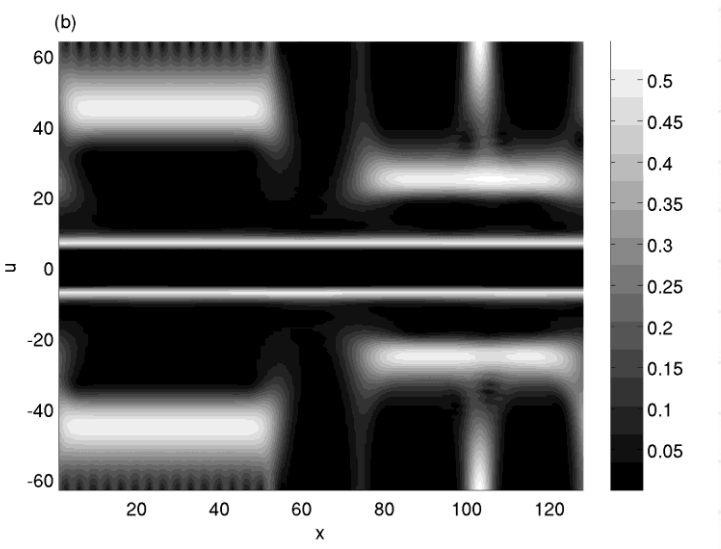


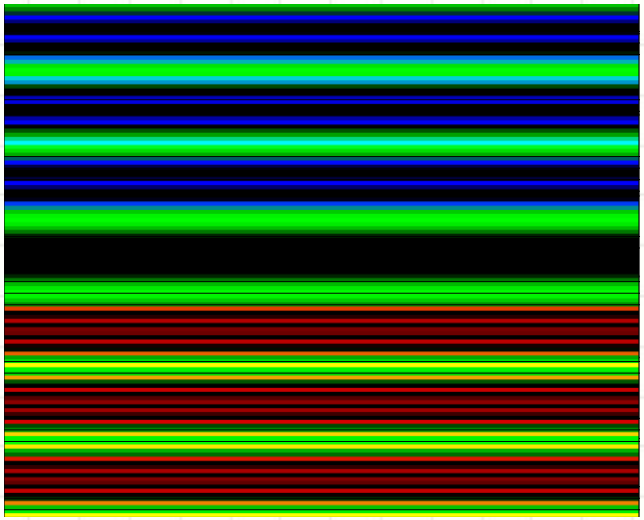


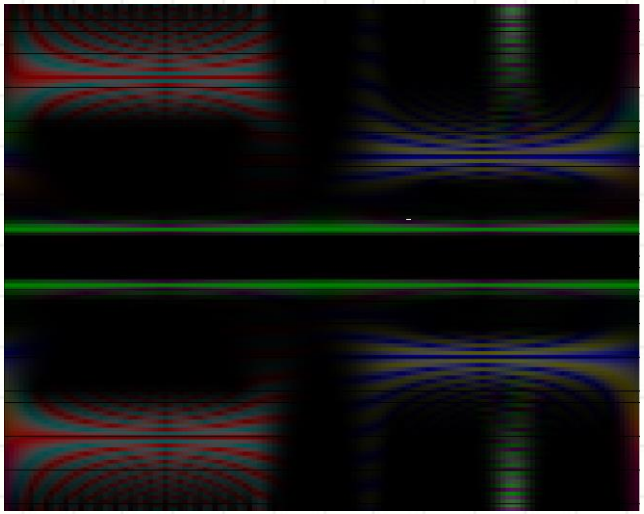
- 2D and 3D data visualization, image processing, animation, and build complete graphical user interfaces.

- Plotting, editing, annotating, printing, exporting, saving, etc …

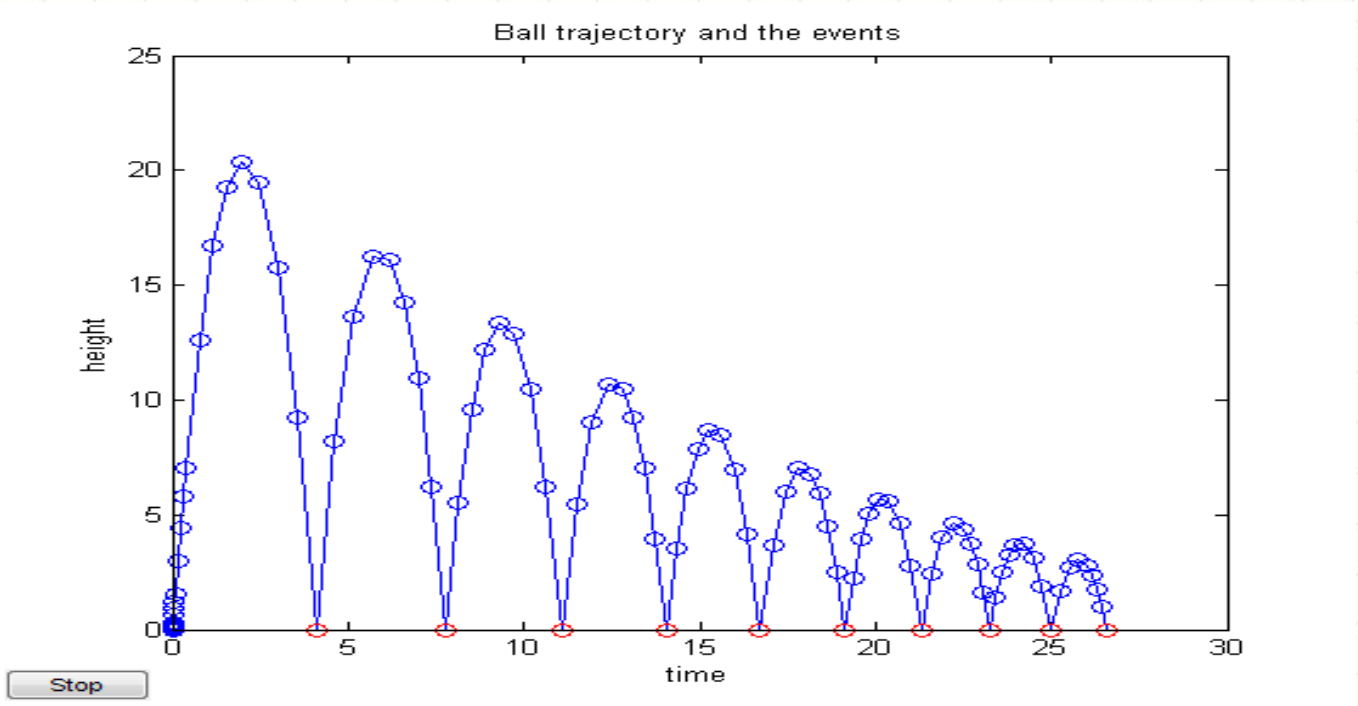

Z
X
Y


(b)
60
40
20
0
-20
-40
-60
u
20
40
60
80
100
120
x
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05





Doing Mathematics in Matlab



- Matrices and array manipulation (e.g. resize, reshape, multiD arrays, ...)
- Linear algebra (e.g. system of linear equations, determinants, singular values, ...)
- Random numbers.
- Polynomials.
- Differential equations.
- Fourier transforms.
- Computational geometry.
- Operation research (e.g. optimization).
- A lot more …

MATLAB TOOLBOXES

- Special purpose and highly optimized built-in M-files.

- Bioinformatics, Curve Fitting, Financial Derivatives, Signal and Image Processing, GA and Neural Networks, Optimization, PDEs, Parallel Computing, and many more …

Quick exercises

- Crate a 4x4 square matrix A and do the following operations:
- ✓ Compute sum of the rows & columns, total sum, min, max, std.
- ✓ Compute the sum of its main and anti diagonals of A.
- ✓ Copy the contents of A to another matrix C; delete the second raw of C and then fill the last column of the resulting matrix with zeros.
- ✓ Use the find command to extract non-zero values in C. Find the number of unique values of C. Clear the matrix C.
- ✓ Compute transpose, determinant, and the eigen values of A.

- ✓ Do SVD on A.
- ✓ Multiply A with random number matrix of same size and apply the FFT; apply the IFFT to get back the original matrix.
- ✓ Repeat the above step and perform wavelet transform.
- ✓ Create a column vector B of length 4 and solve the system Ax = B using the \ operator as well as linsolve.
- ✓ Find the LU factorization (and the permutation matrix) of A.

- Crate a 3x5 matrix from the command prompt and perform the followings:
- ✓ Save the values on your desktop.
- ✓ Load the original matrix with the load command.
- ✓ Plot the last raw.

- Create a table of values with sin, cos, sin x cos, of numbers between 0 and 10 separated in space of 0.1 and do the followings.
- ✓ What is the size of the resulting matrix. Sort the first column.
- ✓ Plot the sin x cos values, do some annotations and save the above figure on the desk top.
- ✓ Export the above figure to the desk top as a tiff file.

- Create a vector t with values between 0 and 2pi separated by space of pi/100 and do the followings:
- ✓ For each discrete point compute sin, shifted sin (by ¼ and ½) values and plot all three against t in one plot. Use different line colors and marker types for each and put the necessary legend.
- ✓ Go to figure pallet and delete the sin curve.

- Create the inline function f(x,y) = sinh(x – y)/(e - cosh(x + y)) and compute f(pi,pi/4), f(0,0).

- 3D plot: Evaluate the function z = sin(R)/R, where R = sqrt(x.^2+y.^2)+eps, over a mesh grid of values -10 < x, y <10 (say in steps of 0.5) and do the followings.
- ✓ Generate a mesh plot of x, y, and z. Insert a color bar. Change different color maps.
- ✓ See how the surface plot looks like.

- Use pcolor for the last 3D plot in the above example. Save the resulting figure as a tiff file on your desktop. Close the figure and load it back from your desktop and display it.

- Multiple plots: use the subplot command to generate surface plots for sin(x) sin(y), sin(x) cos(y), cos(x) sin(y), and cos(x) cos(y) in one figure window (0 < x, y < 2pi, in steps of pi/10).

Writing a Matlab Code

- Flow control (conditional statements, Loops, etc ...).
- Data structures (multi-dimensional data, cell arrays, strings, structures, etc).
- Input/output.
- Scripts and functions.
- Matlab can interact with C and Fortran programs through external interfaces (such as MEX).

Quick exercises

- Crate a 20000x20000 matrix A and compute the total matrix sum using for loops as well as using the function ‘sum’. Compare the speeds.
- Use the for loop to display the magic squares up to fifth order.
- Create and plot the sinc(x) function, for -10 < x < 10, without using the built in `sinc’.
- Create the Fibonacci sequence.

Quick exercises

- Write a Matlab script that does the followings:
- ✓ Clear all variables from your memory and also clear the command window.
- ✓ Generate the magic square A of order 20, compute its rank , inverse and determinant. Find the number of unique elements of A. Save the matrix as a text file on your desktop. Clear the matrix from memory and load it back. Generate a column vector B of length 20 and solve the linear system Ax = B. Generate a 1D as well as a surface plot of A. Take the first two columns of A, sort them and do matrix multiplication (in any order) and dot product . Pick a, b, c and d four distinct elements of A. Compute a/b + c/d using only one division operator.
- ✓ Generate two uniformly distributed random matrices and two normally distributed random matrices of size 100 x 100 each and plot each data in the same figure window (as subplots).
- ✓ Create the function f(x) = sinc(x) and evaluate f at normally distributed random vectors of length 10, 100 , 1000 and 10000. Plot the values separately (use the for loop).

- ✓ Create a time series of length 64 composed of sum of two sin waves with frequency of 2 and 10hrtzs respectively. Apply the FFT and plot the amplitude and phase. Apply a uniformly distributed noise to the sine wave and redo the FFT.
- ✓ For what value of n is ‘e’ best approximated by the function f(n) =(1+1/n)^n. (Hint: generate 10 values of n in logspace between 1 and 20 and evaluate f at each point). Using struct to generate a table of values for n, f(n) and abs(f(n) – e).
- ✓ Create a tri-diagonal matrix T using a vector P (main diagonal) of length n, and vectors Q and R (off diagonal) of length n-1.

Quick exercises

- Write a Matlab function that computes the magic square of any order (if the order is 2, print a warning).
- Write a program that does the followings: filter (in the frequency domain) a noisy sinusoidal function using box car filter of a given width. (Hint: first create a function handle to the noisy sinusoidal function). Plot the box car functions in the frequency domain (what is the fourier transform of a box car function???). Plot the filtered function together with the original noisy function.

Some Maths Examples

- Solve the ODE

$$y'' = -y + \mu(1 - y^2)y', y(0) = y'(0) = 1$$

(Hint: create a system of ODEs and use Matlab ODE solvers).

- Assume f(α,r) = (2μ-2)ΔhR$e^{-D\alpha}$J(1,αR)J(0,αr) is the solution of a certain system where, J is the bessel function of the first kind, D = 25, R = 400, h=23, E = 40*10^6, dp = 1.1*10^4, Δh = -h*dp/E, μ = 0.3. Compute (and plot) the integrals of f wrt α (0<=α<=0.00005) for different values of r, 1<=r<=10.

Quick exercises

- Write a Matlab function that prints “Hello World” as many times based on a user input.

- Redo ‘e’ approximation using f(n) = (1+1/n)^n and generate a text file containing n, f(n) and the absolute error values (Hint: use fprintf).

Graphical user Interfaces; Using the toolboxes; Simulink