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

The Matlab System

• 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 ...
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 eigenvalues 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.
Create 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 $2\pi$ separated by space of $\pi/100$ and do the followings:

- For each discrete point compute $\sin$, shifted $\sin$ (by $\frac{1}{4}$ and $\frac{1}{2}$) 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 $f(x,y) = \frac{\sinh(x - y)}{e - \cosh(x + y)}$ and compute $f(\pi, \pi/4)$, $f(0,0)$. 
3D plot: Evaluate the function \( z = \frac{\sin(R)}{R} \), where \( R = \sqrt{x^2+y^2} + \text{eps} \), 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 \( (0 < x, y < 2\pi, \text{in steps of } \pi/10) \).
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 10 hertz 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 \( f(n) = (1 + \frac{1}{n})^n \). (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

\[ y'' = -y + \mu (1 - y^2) y', \quad y(0) = y'(0) = 1 \]

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

- Assume \( f(\alpha, r) = (2\mu - 2)\Delta h Re^{-D\alpha} J(1, \alpha R) J(0, \alpha r) \) is the solution of a certain system where, \( J \) is the bessel function of the first kind, \( D = 25, \quad R = 400, \quad h = 23, \quad E = 40 \times 10^6, \quad dp = 1.1 \times 10^4, \quad \Delta h = -h*dp/E, \quad \mu = 0.3. \) Compute (and plot) the integrals of \( f \) wrt \( \alpha \) \((0 <= \alpha <= 0.00005)\) 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