UCF Stands For Opportunity

CDA6530: Performance Models of Computers and Networks

Chapter 4: Using Matlab for Performance Analysis and Simulation

SCHOOL OF ELECTRICAL ENGINEERING & COMPUTER SCIENCE

Objective

- Learn a useful tool for mathematical analysis and simulation
  - Interpreted language, easy to learn
- Use it to facilitate our simulation projects
- A good tool to plot simulation/experiment results figures for academic papers
  - More powerful than excel
  - Could directly create .eps for Latex

Introduction

- MatLab : **Mat**rix **Lab**oratory
- Numerical Computations with matrices
    - *Every number can be represented as matrix*
- Why Matlab?
    - User Friendly (GUI)
    - Easy to work with
    - Powerful tools for complex mathematics
- Matlab has extensive demo and tutorials to learn by yourself
    - Use help command

Matrices in Matlab

- To enter a matrix

2	5	3
6	4	1

```
>> A = [2 5 3; 6 4 1]
>> B = [1:1.5:6; 2 3 4 5]
>> for i=1:4
        for j=1:3
                C(i,j)=i*j;
        end
    end
 >> D =[];  D=[D;5]; D=[D;6;7]
 >> E = zeros(4, 5)
```

Basic Mathematical Operations

Remember that every variable can be a matrix!

Addition:
>> C = A + B

Subtraction:
>> D = A – B

Multiplication:
>> E = A * B (Matrix multiplication)
>> E = A .* B (Element wise multiplication, A and B same size)

Division:
Left Division and Right Division
>> F = A . / B (Element wise division)
>> F = A / B = A*inv(B)   (A * inverse of B)
>> F = A . \ B (Element wise division)
>> F = A \ B=inv(A)*B   (inverse of A * B)

Generating basic matrices

Matrix with ZEROS:

```
>> A = zeros(m, n)
```

Matrix with ONES:

```
>> B = ones(m, n)
```

IDENTITY Matrix:

```
>> I = eye(m, n)
```

m → Rows
n → Columns
zeros, ones, eye → Matlab *functions*

Obtain Information

- Size(A): return [m n]
- Length(A): length of a vector
  - Length(A) = max(size(A))
- B = A(2:4,3:5)
  - B is the subset of A from row 2 to row 4, column 3 to column 5
- A(:, 2)=[]
  - Delete second column

Basic Matrix Functions

- Inv(A): inverse of A
- Rank(A): rank of matrix A
- A': transpose of A
- Det(A): determinant
- V= eig(A): eigenvalue vector of A
  - [V,D] = eig(A) produces matrices of eigenvalues (D) and eigenvectors (V) of matrix A, so that A*V = V*D

Random Number Generators

- Rand(m,n): matrix with each entry ~ U(0,1)
  - You can use this for the programming project 1
- Randn(m,n): standard normal distribution
  - You cannot use this in programming project 1
  - You must use the polar method I introduced!

Basic 2-D Figure Plot

- Plot(X, Y):
  - Plots vector Y versus vector X
- Hold: next plot action on the same figure
- Title(‘title text here’)
- Xlabel(‘…’), ylabel(‘…’)
- Axis([XMIN XMAX YMIN YMAX])
- Legend(‘…’)
- Grid

- Example demo

Elementary Math Function

- Abs(), sign()
  - Sign(A) = A./abs(A)
- Sin(), cos(), asin(), acos()
- Exp(), log(), log10()
- Ceil(), floor()
- Sqrt()
- Real(), imag()

Elementary Math Function

- Vector operation:
  - Max(), min(): max/min element of a vector
  - Mean(), median()
  - Std(), var(): standard deviation and variance
  - Sum(), prod(): sum/product of elements
  - Sort(): sort in ascending order

Save/Load Data

- Save fname
  - Save all workspace data into fname.mat
  - Save fname x y z
  - Save(fname): when fname is a variable
- Load fname
  - Load fname x y

- No error in data
- You can run simulation intermittently
  - Save/load data between runs

Input/Output for Text Files

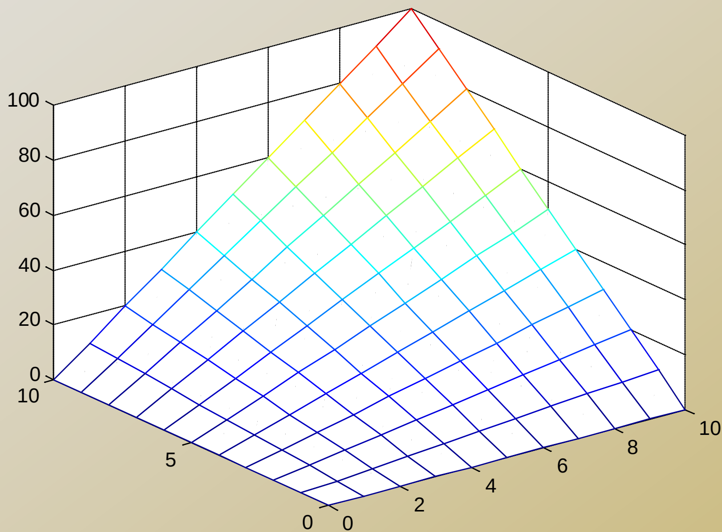
- Input data file for further analysis in Matlab
  - Run simulation using C
    - matlab is slow in doing many loops
  - Use Matlab for post-data processing
    - Matrix calculation, utilize Matlab math functions
  - Simply use Matlab for figure ploting
    - Excel has constraint on data vector length (<300?)
- Functions:
  - [A,B…]= Textread(fname, format)
    - Read formated data
  - Use fprintf(), fscanf() similar to C
    - Note that variables here can be vectors/matrices
    - Show examples here of writing data to text file

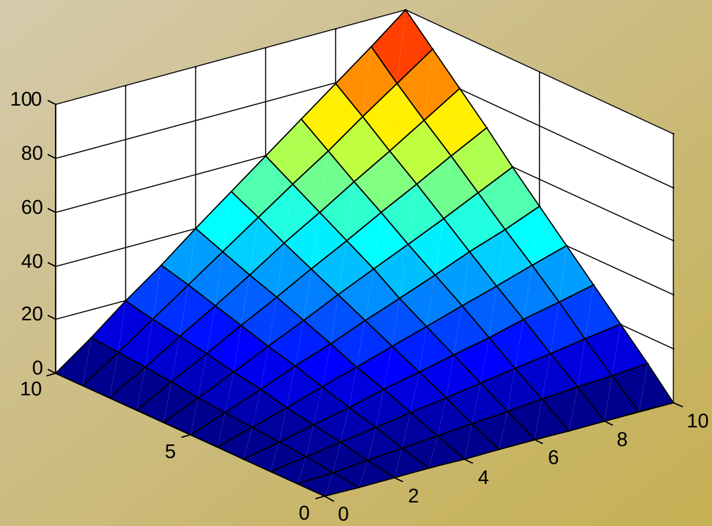
Advanced Graph

- Subplot(m, n, p)
  - breaks the Figure window into an m-by-n matrix of small axes, selects the p-th axes for the current plot, and returns the axis handle.
- Semilogx(), semilogy(), loglog()

3-D plot

- x=[0:10]; y=[0:10]; z=x'*y;
- mesh(x,y,z); figure; surf(x,y,z);





M-file

- Script or function
  - Scripts are m-files containing MATLAB statements
  - Functions are like any other m-file, but they accept arguments
  - It is always recommended to name function file the same as the function name

```
function A = changeSign(B)
% change sign for each element
[m,n] = size(B);  A = zeros(m,n);
for i=1:m
    for j=1:n
        A(i,j)= -B(i,j);
    end
end
return
```

Online Tutorials

- Matlab itself contains many tutorials
- Other online tutorials:
  - http://www.math.siu.edu/matlab/tutorials.html
  - http://www.cs.cmu.edu/~ggordon/780/lectures/matlab_tutorial.pdf
  - Google search “matlab tutorial ppt” to find a lot more

Example on Using Matlab for Markov Chain Steady State Calculation

- Discrete-time Markov Chain transition matrix:

$$\underline{P} = \begin{bmatrix} 0.512 & 0.384 & 0.008 & 0.096 \\ 0.32 & 0.48 & 0.02 & 0.18 \\ 0 & 0 & 0.5 & 0.5 \\ 0 & 0.4 & 0.1 & 0.5 \end{bmatrix}$$

- $\pi P = \pi$, $\pi [1\ 1\ 1 \ldots\ 1]^T = 1$
  - $\pi (P - I) = 0$, But we cannot use it directly
  - Replace first column in (P-I) with $[1\ 1..1]^T$ to be A, then we can solve the linear equation set by $\pi = [1\ 0\ 0\ \ldots\ 0]\ A^{-1}$
- Another way: P*P*P*P……

Tutorial on Matlab Simulink

- Graphical programming language
  - Drag and draw line to program
  - Configure each object for parameters
- Powerful modeling tool
  - Differential Equations
  - Physiological systems
  - Control systems
  - Transfer functions
- M-file can call a simulink model
  - “sim fname”
  - Use current workspace variables
- Simulation results can be saved to workspace variables
  - Thus can be process after simulink

Example: Internet Worm Propagation

$$\frac{dI(t)}{dt} = \frac{\eta}{\Omega} I(t) \cdot [N - I(t)]$$

- N: vulnerable population
- η : worm host average scan rate
- Ω: scanning IP space size

Example 2: RC Circuit

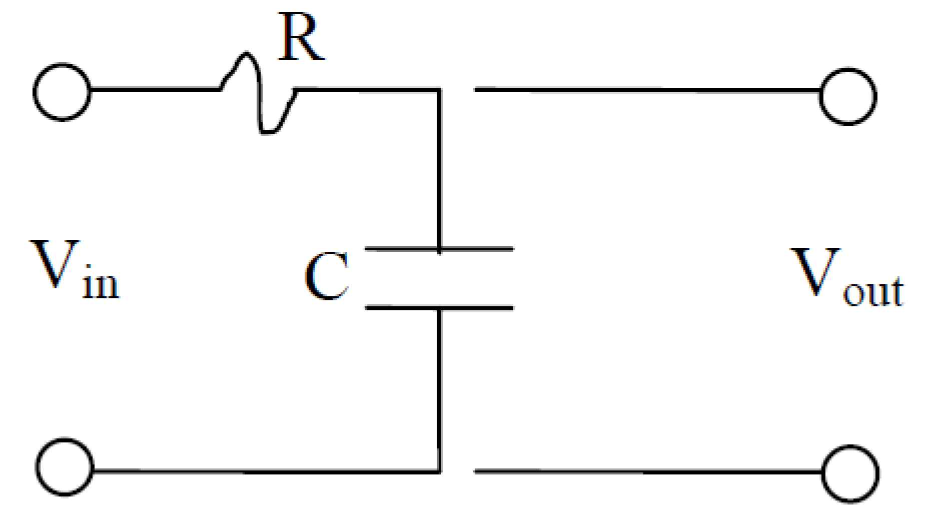


Fig. 1. The RC Circuit.

$$\dot{x} = \frac{1}{RC}\left[f(t) - x\right]$$

Transfer function:

$$X(s) = \frac{F(s)}{1 + RC \cdot s}$$

Save result to workspace variables

- the save format is "structure with time".
- Suppose the workspace variable is X_t.
- Then:
  - X_t.time saves the simulation step times (vector)
  - X_t.signals.values saves the simulation results (vector).
- plot(X_t.time, X_t.signals.values);
- Variable step simulation or fixed step simulation:
  - "to workspace" use "-1" for sample time (inherited)
    - Then X_t.time has variable size
  - "to workspace" use "1" for sample time
    - Then each time tick has one result value