Lab 1: Introduction to MATLAB

Signal Processing with MATLAB

- MATLAB ("MATrix LABoratory") is a powerful tool for numerical computation and visualization
- The basic data element is a matrix.
- MATLAB has a large number of built-in functions particularly useful for signal processing.
- This lab introduces a few examples of basic MATLAB programming techniques.

Writing M-files

- Some simple calculations, we can just use Command Window.
- For serious MATLAB use, you need to write M-files, i.e., files with a .m extension, containing MATLAB statements.
    - You need to save the file before being able to run it.
    - DO NOT include space characters when naming an M-file.

Creating vectors

- x = [3 4 7 11] % create a row vector (spaces)
    - if the statement does not end with a semicolon, the results will be printed on the Command Window.
    - If the statement ends with a semicolon, the results will NOT be printed on the Command Window. Two ways to view the results
        - Type the name of the variable in the Command Window.
        - Double click on the name of the variable on the Workspace.
- x = 3:10;
- x = 3:2:21;
- x = 8:-1:0;
- x = linspace(0,1,21) % creates 21 points equally spaced between 0 and 1
- x = 0:0.05:1
- length(x) % returns the number of entries in vector x
- x(3) % return the 3rd element of x. Note that Matlab labels the arrays (vectors and matrices) beginning with 1

Creating vectors...

- Create a vector of the even whole numbers between 31 and 75.
  x=32:2:75
- Let x = [2 5 1 6].
  - Add 16 to each element
    a=x+16;
  - Compute the sum of all elements in x
    b=sum(x);
  - Compute the square root of each element
    c=sqrt(x) or c=x.^(0.5);
  - Compute the square of each element
    c=x.^2 or c=x.*x;
- Element-wise operations: ".*", "./", ".^". Let x = [3 2 6 8]' and y = [4 1 3 5]' (i.e, x and y should be column vectors). Compare the following operations
  - x'*y and y'*x
  - x.*y
  - x*y
  - x.^y

Creating vectors...

- Create a vector x with the elements

$$x_n = (-1)^{n+1}/(2n-1), n = 1, 2, \ldots, 100$$

  and calculate the sum of all elements in x
- Ans:
  n = 1:100;
  x = ((-1).^(n+1)) ./ (2*n - 1); % note the use of .^ and ./
  y = sum(x)
- We can use a for loop to do the task above but it is not efficient.

Plotting Continuous Signals

- MATLAB is dedicated to **discrete signals**. In order to work with a continuous signal, we need to generate enough samples over the interval of interest.
- Plot the exponential signal $x(t) = 2e^{-2t}$ over the interval $t \in [-1, 1]$.
- Plot another exponential signal $x(t) = 2e^{-4t}$ over the interval $t \in [-1, 1]$ on the same figure.
- Plot the sinusoid
$$x_1(t) = \cos(2\pi f_c t)$$
where $f_c = 4000$ Hz for two periods, i.e. $t \in [-T_c, T_c]$ and where T_c is the fundamental period.
Ans:
```
fc =4000; % frequency
Tc = 1/fc; % the fundamental period
t = linspace(-Tc,Tc,200); % 200 time instants from -Tc to Tc
x1 = cos(2*pi*fc*t);
```


Plotting Continuous Signals...

- Plot another sinusoid given by
$$x_2(t) = 1.2\cos(2\pi f_c(t - t_0)) \tag{1}$$
where $f_c = 4000$ Hz and $t_0 = T/4$ for $t \in [-T_c, T_c]$. Note that $x_2(t)$ is an amplitude-scaled and time-shifted version of $x(t)$ in the previous slide.
Ans:
```
t0=Tc/2; % delay
x2 = 1.2*cos(2*pi*fc*(t-t0));
plot(t,x)
```
- Plot the sum: $x_3(t) = x_1(t) + x_2(t)$
Ans: We already have x1 and x2, so the sum can be compute easily
```
x3 = x1+x2;
```

Plotting Continuous Signals...

- It is better to plot x1,x2 and x3 in the same figure.
  Ans: Use the subplot command. Type help subplot in Matlab to know the details.

```
subplot(3,1,1)
plot(t,x1)
xlabel('Time (second)')
ylabel('x1')
subplot(3,1,2)
plot(t,x2)
xlabel('Time (second)')
ylabel('x2')
subplot(3,1,3)
plot(t,x3)
xlabel('Time (second)')
ylabel('x3')
```

- What are your observations?

Task 1

- Plot the discrete sinusoid

$$x[n] = \cos(\frac{1}{6}\pi n) \qquad (2)$$

for $n = 0, 1, 2, \ldots, 20$ and conclude the period of the signal. Verify your observation by theoretical analysis (cf. Lecture 2).

- Plot the discrete sinusoid

$$x[n] = \cos(2n) \qquad (3)$$

to show that this signal is not periodic. Explain the reason.

Task 2

Plot the discrete signal

$$\cos\left(\frac{1}{6}\pi n\right) + \cos\left(\frac{1}{3}\pi n\right)$$

and conclude the period of the signal.

Task 3

- Let $f_0 = 20$ Hz and $T_0 = 1/f_0$. Compute and plot the following signal

$$x(t) = \sum_{n=-N}^{N} a_n e^{j2\pi n f_0 t} \tag{4}$$

where $N = 5$ and a_n is given by

$$a_n = \begin{cases} 0 & n \text{ even} \\ -\frac{j}{2n} & n \text{ odd} \end{cases} \tag{5}$$

for $t \in [0, 2T_0]$.

- Hints:
  - In MATLAB the complex number j can be represented by i,j, or 1i.
  - First create a time vector t from 0 to T_0. The number of sampling points is your choice.
  - You need a for loop to go over n, starting from $-N$, i.e. for n=-N:N .... end
  - For each n, the complex exponential function $e^{j2\pi n f_0 t}$ is represented by exp(i*2*pi*n*f0*t).

Task 4

Let $f_1 = 20Hz$ and $T_1 = 1/f_1$. Compute and plot the following signal

$$f(t) = \frac{8A}{\pi^2}[\sin(w_1 t) - \frac{1}{9}\sin(3w_1 t) + \frac{1}{25}\sin(5w_1 t) - \dots + \frac{(-1)^{\frac{k-1}{2}}}{k^2}\sin(kw_1 t) + \dots]$$

Where k is odd, A is a constant ,k=5, and $t \in [0, 2T_1]$.

Task 5

Increase the value of N in Task 3 to N = 10 and N = 50 and N = 100. Give your comments on the results signal.

Increase the value of k in Task 3 to k = 11 and k = 51 and k = 101. Give your comments on the results signal.

Report

- All the plots you obtained during the lab and the your comments and opinions on the results.
- A summary of what you gained in the lab.
- Each student submits a **single report**.
- To be uploaded via moodle **before 6PM the following day**.
- A penalty 10% of each day will be applied to late submission.
- Poorly written report (grammar and spelling issues will be checked) is subject to deduction.