EEE 391
Basics of Signal and Systems
Fall 2019-2020
Computer Assignment 1

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Section: *1*

a) According to the last 3 digits of my student ID, there are 3 plots of sinusoidal signals obtained from the indices 6, 9, and 1 respectively:

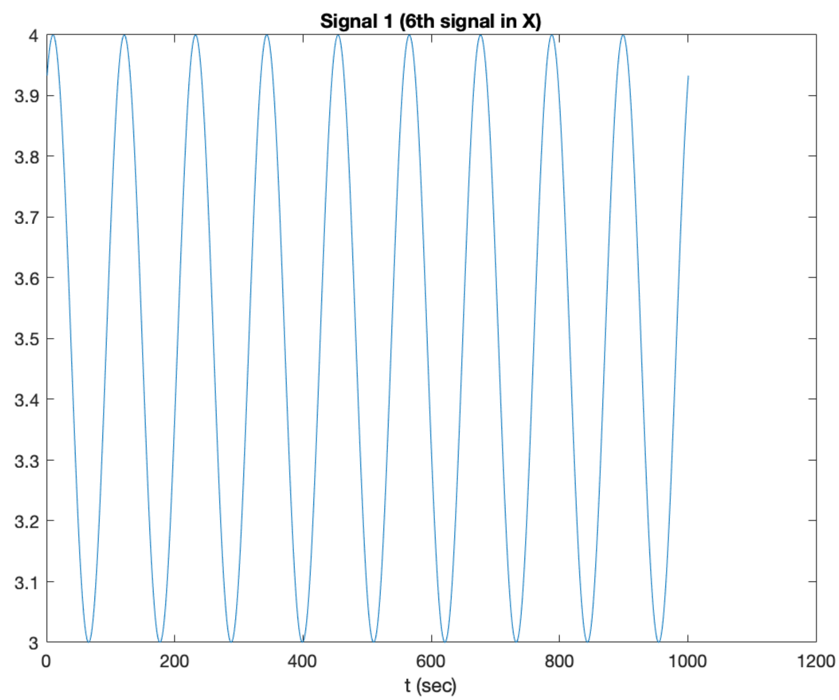

Figure 1. Plot of 6^{th} signal from data matrix

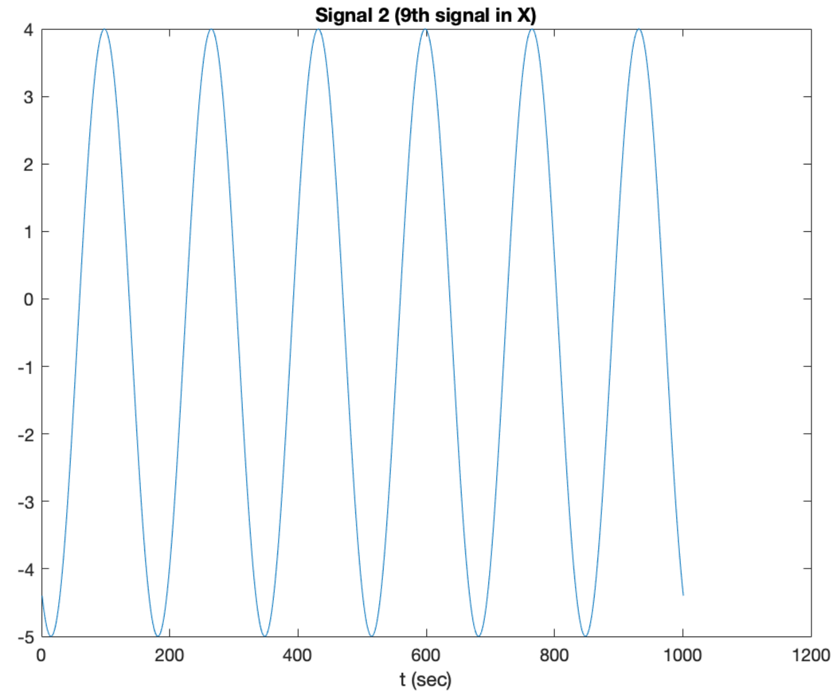

Figure 2. Plot of 9th signal from data matrix

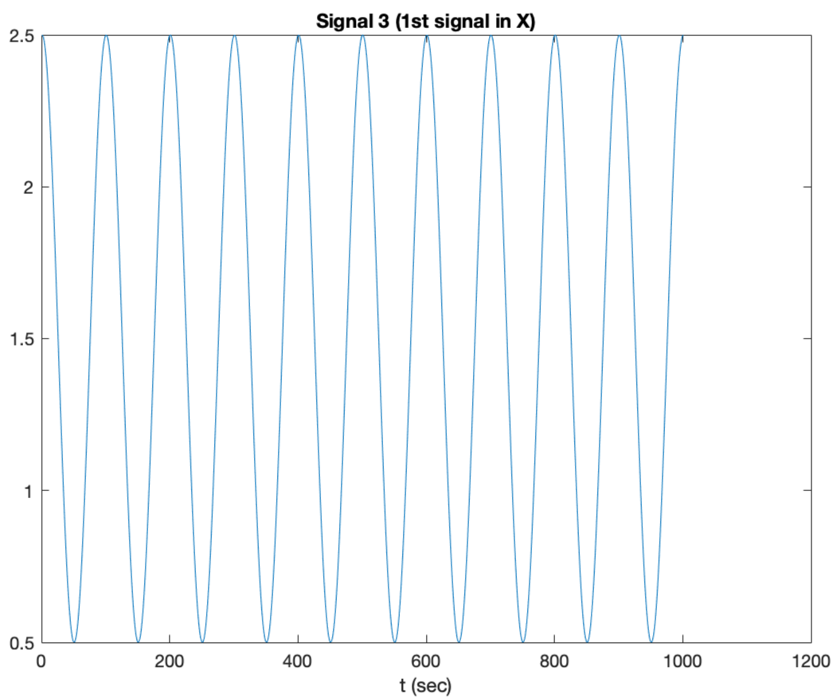

Figure 3. Plot of 1st signal from data matrix

b) Looking at the plots of the signals we can see the parameters of the signals. Here are the steps of estimating the parameters for each continuous signal:

For the first signal (6^{th} signal in data matrix):

- A (amplitude): 0.5
- C (D.C value): 3.5
- T_0 (fundamental period): ~(600 – 400) / 2 = ~100 sec
- f_0 (cyclic frequency): 1 / T = 1 / 100 = ~0.01 Hz
- t_{shift} = ~25 sec
- ϕ (phase shift) = $-\omega_0 t_{shift} = -2\pi f_0 t_{shift} = -0.5\pi$ radians ➔ -90 degrees

For the second signal (9^{th} signal in data matrix):

- A (amplitude): 4.5
- C (D.C value): -0.5
- T_0 (fundamental period): ~(400 – 200) = ~200 sec
- f_0 (cyclic frequency): 1 / T = 1 / 200 = ~0.005 Hz
- t_{shift} = ~100 sec
- ϕ (phase shift) = $-\omega_0 t_{shift} = -2\pi f_0 t_{shift} = -\pi$ radians ➔ -180 degrees

For the third signal (1^{st} signal in data matrix):

- A (amplitude): 1
- C (D.C value): 1.5
- T_0 (fundamental period): ~(400 – 200) / 2 = ~100 sec
- f_0 (cyclic frequency): 1 / T = 1 / 100 = ~0.01 Hz
- t_{shift} = ~100 sec
- ϕ (phase shift) = $-\omega_0 t_{shift} = -2\pi f_0 t_{shift} = -2\pi$ radians ➔ -360 degress

c) Firstly, to find the amplitude, I used *min* and *max* function of MATLAB to obtain the minimum and maximum value of the input signal x. Amplitude is the half distance between these two values, therefore, finding the distance by subtracting minimum value from the maximum value, and dividing the result by 2, the program calculates the value of amplitude. From maximum point below amplitude value or minimum distance above amplitude value is the D.C value.

```
min_value = min(x);                              % Minimum value of signal x
max_value = max(x);                              % Maximum value of signal x

% Calculating Amplitude and DC value
A = round(abs(max_value - min_value) / 2, 2); % Amplitude of signal x
C = round((max_value - A), 2);                   % DC value of the signal x
```

To find the frequency, peak points need to be calculated. Since the peak values in the sampled signal may not be the same from period to period, we need to find the first signal value that exceeds the maximum signal value with removal of A / 1000 and is smaller than the minimum signal value with addition of A / 1000. For these operations, I used *find* function of MATLAB for finding the first indices of the maximum and minimum values of the signals. Since we know the sampling rate, and we can calculate the number of samples by the absolute value of the subtraction between the minimum and maximum index, and multiplied by 2 (since we need a full period), we can calculate the cyclic frequency with the following formulas that we have learned from Chapter 4 of the textbook:

$$T = T_s n$$

$$f = \frac{f_s}{n}$$

where T_s is sampling period, f_s is sampling rate (frequency) and n is the number of samples.

```
max_compare_value = C + A - A / 1000;
min_compare_value = C - A + A / 1000;

max_peak_idxs = find(x > max_compare_value);
min_peak_idxs = find(x < min_compare_value);

first_max_idx = max_peak_idxs(1);
first_min_idx = min_peak_idxs(1);

number_of_samples = abs(first_max_idx - first_min_idx);

f = round(fs / (2 * number_of_samples), 2);
```

For finding the phase shift, distance from the maximum peak to zero need to be found and converted into seconds using sampling rate. Using the time shift we calculate the phase shift with the following formula:

$$\phi \text{ (phase shift)} = -\omega_0 t_{shift} = -2\pi f_0 t_{shift}$$

where f_0 is the cyclic frequency and is t_{shift} time shift. Finally, the result is converted into degrees.

```
t_shift = (first_max_idx - 0) / fs;                % Time shift of signal

phi = -2*pi*f*t_shift;                             % Phase shift
phi = round(phi * (180 / pi), 2);                  % Converting to degrees
```

Displaying the signals after estimating the parameters:

x_1(t) = +3.50 +0.50 cos(56.11 t -0.56)
x_2(t) = -0.50 +4.50 cos(37.38 t -3.66)
x_3(t) = +1.50 +1.00 cos(62.83 t -0.06)

d) Comparing the results, we see that although the amplitude and D.C value of the signals are the same, frequency and the phase values are not quite the same. There is the reason for that; looking through the plots in part b, we estimate the values of parameters assuming that the horizontal axis is time –we assumed the signals as continuous signals. On the other hand, calculating automatically with MATLAB program in part c, we also take the sampling rate into account, therefore, while calculating we have much accurate results compare to looking through the plot and estimate the values.

<u>MATLAB code:</u>

```
%{
    Basics of Signals and Systems (Fall 2019-2020)
    Computer Assignment 1

    @author: Fuad Aghazada
    @id: 21503691
    @date: 27.10.2019
%}

% Loading the data matrix X
load('data.mat', 'X');

% Sampling parameters
sampling_rate = 1000;

% Selecting 3 signals: 6, 9, 1
signal1 = X(6,:);
signal2 = X(9,:);
signal3 = X(1,:);

% Plotting the signals seperately
plot(signal1)
title("Signal 1 (6th signal in X)")
xlabel("t (sec)")

figure

plot(signal2)
title("Signal 2 (9th signal in X)")
xlabel("t (sec)")

figure

plot(signal3)
title("Signal 3 (1st signal in X)")
```

```
xlabel("t (sec)");

% Estimating the parameters of the signals
[C1, A1, f1, phi1] = parameters_of_sin(sampling_rate, signal1);
[C2, A2, f2, phi2] = parameters_of_sin(sampling_rate, signal2);
[C3, A3, f3, phi3] = parameters_of_sin(sampling_rate, signal3);

% Displaying the signal in the given format
display_format = 'x_%d(t) = %+.2f %+.2f cos(%.2f t %+.2f)\n';
fprintf(display_format, 1, C1, A1, 2 * pi * f1, phi1 * (pi / 180));
fprintf(display_format, 2, C2, A2, 2 * pi * f2, phi2 * (pi / 180));
fprintf(display_format, 3, C3, A3, 2 * pi * f3, phi3 * (pi / 180));

% Function for estimating the parameters of the signals
function [C, A, f, phi] = parameters_of_sin(fs, x)

min_value = min(x);                                     % Minimum value of
signal x
max_value = max(x);                                     % Maximum value of
signal x

% Calculating Amplitude and DC value
A = round(abs(max_value - min_value) / 2, 2);           % Amplitude of signal
x
C = round((max_value - A), 2);                          % DC value of the
signal x

% Calculating Cyclic frequency and phase shift
max_compare_value = C + A - A / 1000;                   % Compare value for
finding first max peak
min_compare_value = C - A + A / 1000;                   % Compare value for
finding first min peak

max_peak_idxs = find(x > max_compare_value);            % Vector of indices
in which signal values is greater than max compare value
min_peak_idxs = find(x < min_compare_value);            % Vector of indices
in which signal values is less than min compare value

first_max_idx = max_peak_idxs(1);                       % First max index
among the indices
first_min_idx = min_peak_idxs(1);                       % First min index
among the indices

number_of_samples = abs(first_max_idx - first_min_idx); % Number of samples
in a period

f = round(fs / (2 * number_of_samples), 2);             % Cyclic frequency

t_shift = (first_max_idx - 0) / fs;                     % Time shift of
signal

phi = -2*pi*f*t_shift;                                  % Phase shift
phi = round(phi * (180 / pi), 2);                       % Converting to
degrees

end
```