Devin Trejo

ECE 3522: Stochastic Processes in Signals and Systems

Department of Electrical and Computer Engineering, Temple University, Philadelphia, PA 1912

I. PROBLEM STATEMENT

In class assignment five we work with random variables (different portions of our speech signal) and compute how similar the two data sets are. In chapter five we introduce covariance and correlation.

A correlation coefficient tells us how closely related two sets of data are. A coefficient of zero says us there is no correlation between the two sets of data. We can say the two sets of data are independent. As we increase positively up to one it tells us both sets of change positively at similar rates. A coefficient of one says the increase exactly meaning the two are exactly correlated. Negative coefficients say the as one data set increase the other decreases. If you obtain -1 it says that as one data set increases the other decreases at the same rate. Covariance is similar except it tells us the magnitude of the change. It still measures how two data sets change with respect to one another.

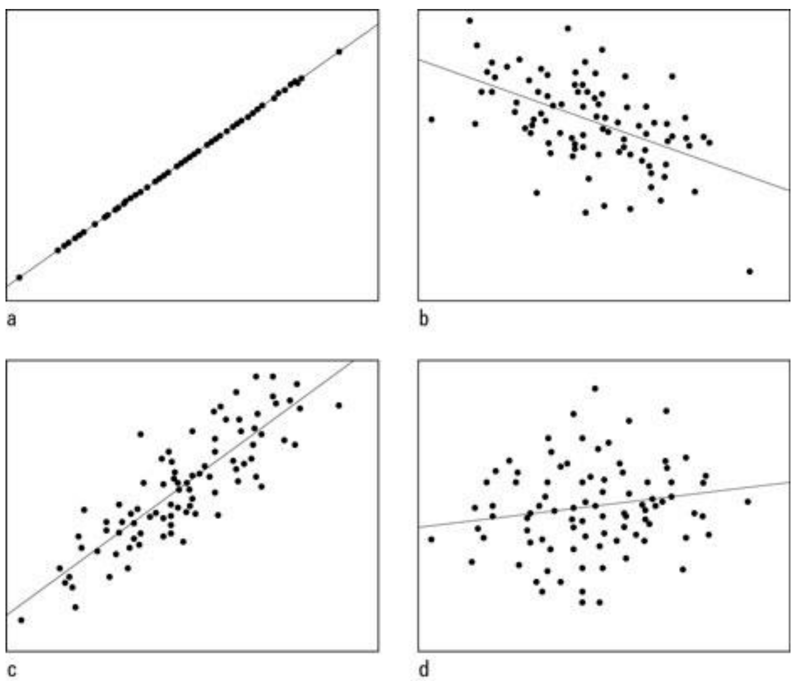

Figure 1: "Scatterplots with correlations of a) +1.00; b) –0.50; c) +0.85; and d) +0.15."

Source: http://www.dummies.com

For the assignment we are tasked with finding the correlation and covariance of our speech signal where one data set is 240 and the other is 240 samples shifted over by k. K ranges from 0 to 512. We find correlation for time = 0.9secs and time = 3.0secs.

Next with find the covariance of the data sets shifted over by i and j samples. We again take 240 samples for each data set. The covariance is given by the two data sets multiplied together and summed for each 240 samples. Covariance is calculated over the signal starting at times starting are 0.9, 3.0 and 1.1 seconds.

II. APPROACH AND RESULTS

To begin we find the correlation of the signal at time =0.9secs. Recall the correlation will range from $-1 \rightarrow 1$ and will be zero if the shifted signal does not appear to have any relationship to the non-shifted portion of the signal. First let us look at our non-shifted portion of the signal or the 240 samples after time = 0.9secs.

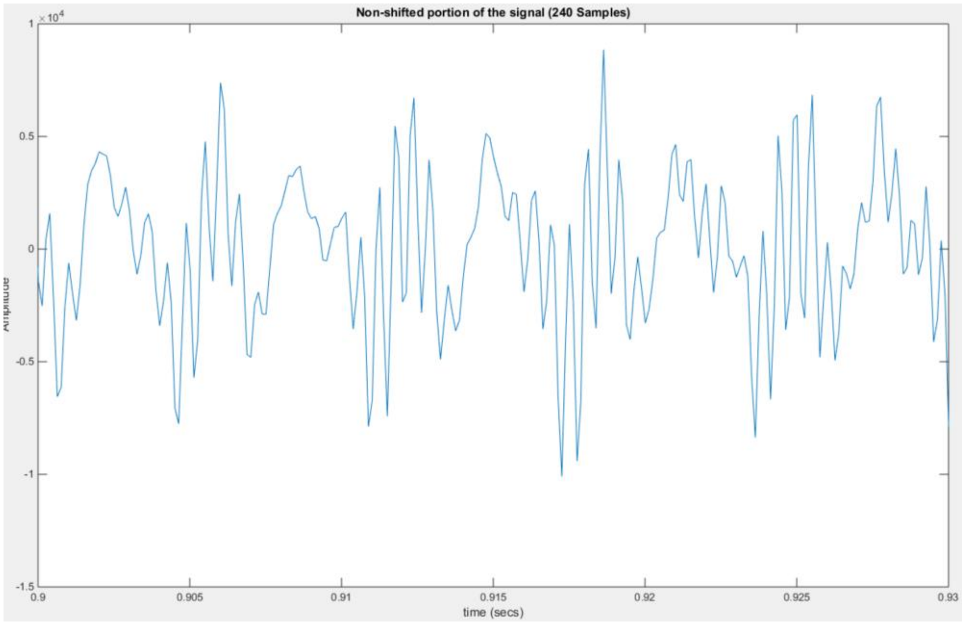

Figure 2:Non-shifted portion of the signal

For this analysis we will take this sample of the signal and compared it with shift k starting at 0 and range up to 512.

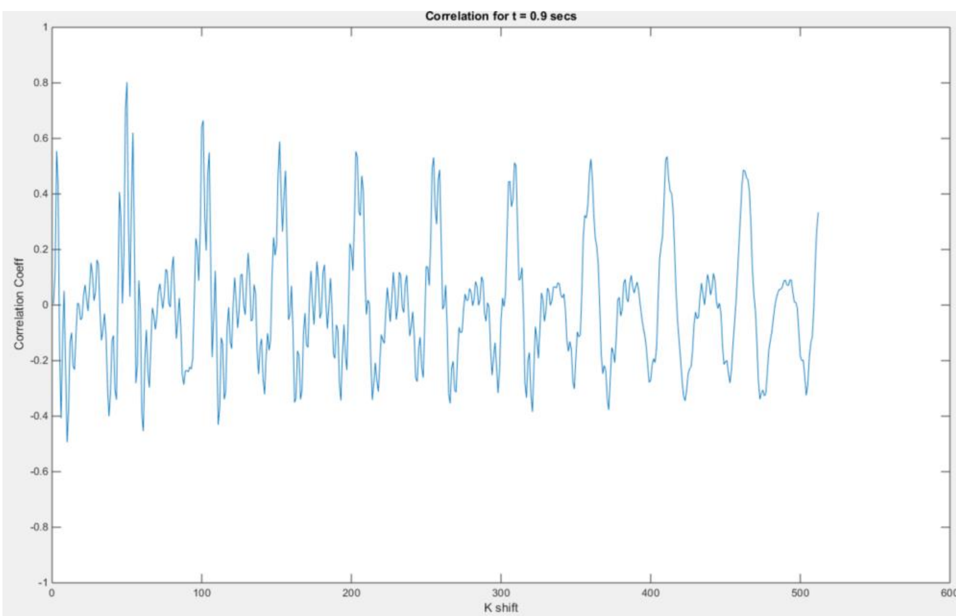

Figure 3: Correlation for time = 0.9seconds with shifts $k = 0 \rightarrow 512$

First characteristics to notice about the correlation is how it appears periodically shift between positive correlation to negative. Given that the composition signal is a sum of sine waves we see that at some point the shift will cause the enough shift so that there is similar sine wave composition between the two compared sample ranges. Take for example when $k = 100$.

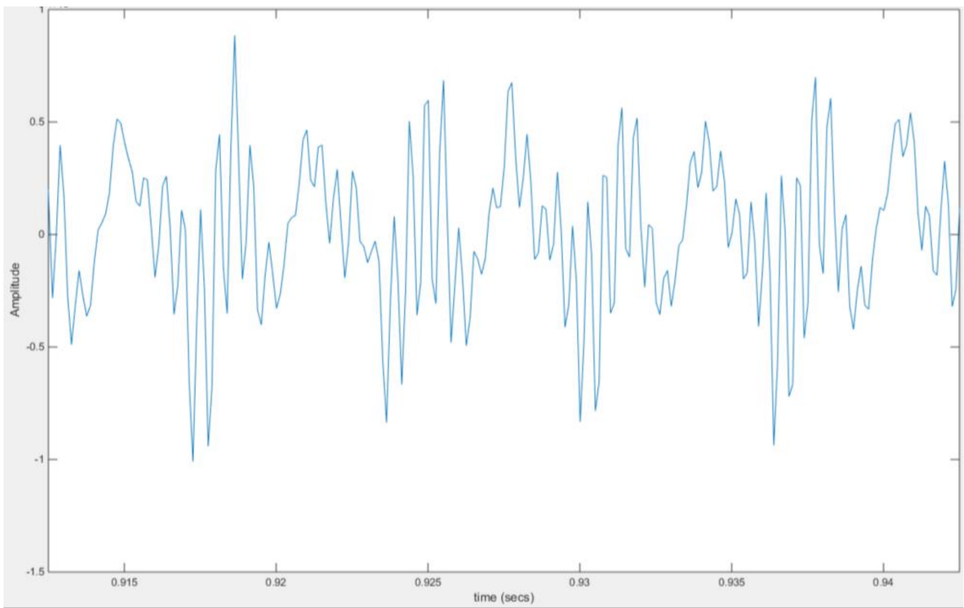

Figure 4: Shifted signal when shift $k = 100$

Compare Figure 2 and Figure 4 we see the two look very similar. This corresponds to a correlation in Figure 3 that approaches 1. Now if we take a look below when there is negative correlation. Notice how when our non-shifted signal is on positive upswing our shifted signal in on negative swing.

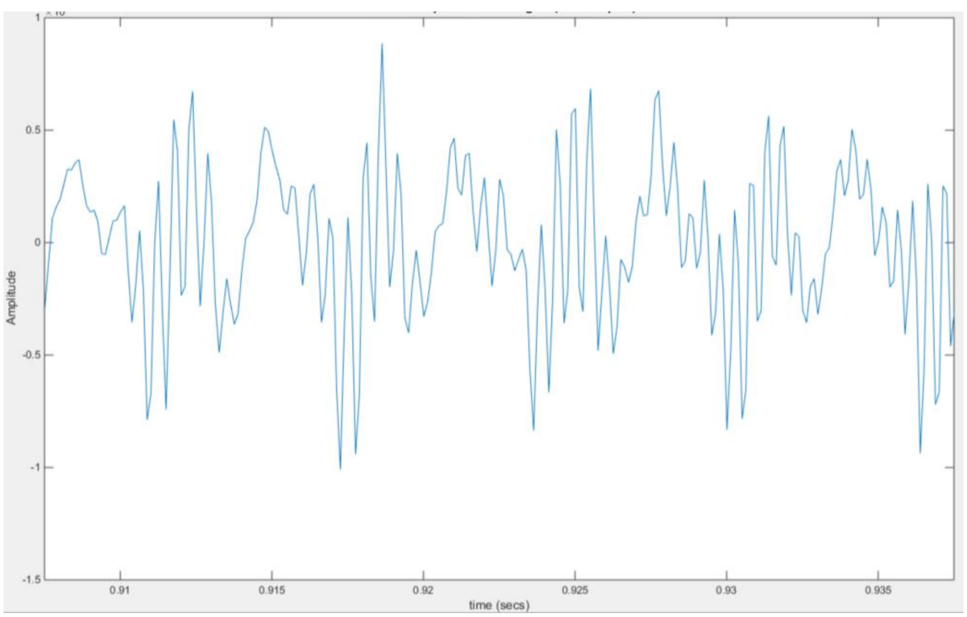

Figure 5: Shifted signal when shift $k = 60$

We perform the same operation for the speech signal when time = 3.0 seconds.

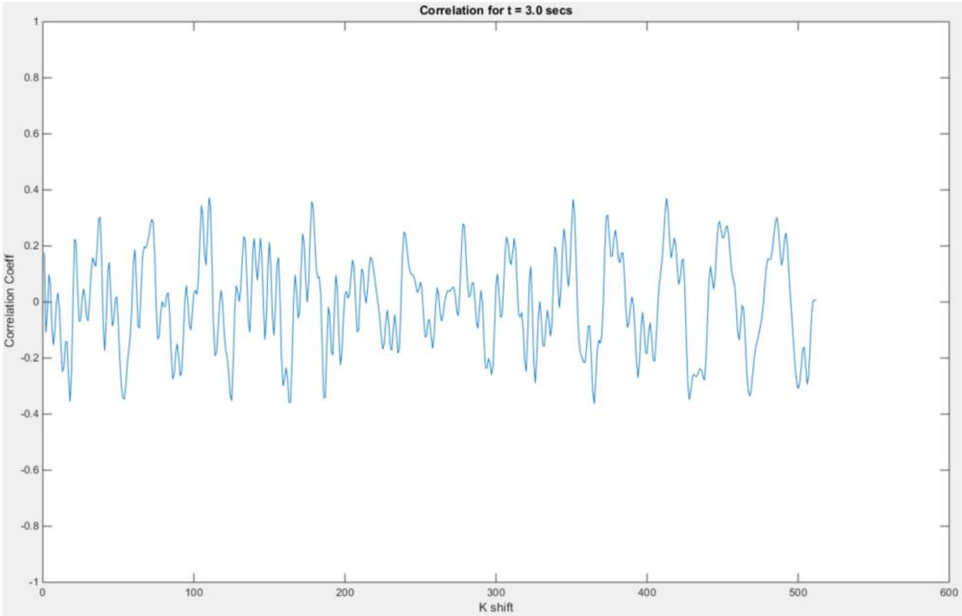

Figure 6: Correlation for time = 3.0 seconds with shifts $k = 0 \rightarrow 512$

In this correlation plot we see the correlation does not swing between -1 and 1 as much. A reasoning behind this characteristic is that at this portion of the signal there is no person speaking. Therefore, there is more random noise composing the signal, which results in very low correlation between the two compared portions of the signal.

Next we move onto covariance for different portions of the signal.

1.0e+07 *

1.0965	0.6488	0.0038
0.6488	1.1159	0.6561
0.0038	0.6561	1.1142
0.1026	-0.0028	0.6482
0.5940	0.0990	-0.0038
0.4989	0.6083	0.1078

Figure 7: Covariance for time = 0.9 seconds

1.0e+05 *

4.4942	3.1924	0.7644
3.1924	4.4938	3.1853
0.7644	3.1853	4.4732
-0.5622	0.7521	3.1581
-0.2863	-0.5737	0.7354
0.3999	-0.2893	-0.5675

Figure 8: Covariance for time = 3.0 seconds

1.0e+05 *

6.1571	5.6534	4.8237
5.6534	6.1095	5.6057
4.8237	5.6057	6.0625
4.0790	4.7931	5.5780
3.4624	4.0498	4.7676
2.7011	3.4359	4.0276
2.0092	2.6757	3.4171

Figure 9: Covariance for time = 1.1 seconds

From these matrices we see the diagonals have the same values. Since the shift of when i and j are the same value example: (0,0), (1,1), (2,2) the sample being pointed to is the same portion of the signal. If we find the covariance between two portions of the same signal we will have maximum covariance. As we hold i constant and increase j our two sampled portions of the signal move further apart. The covariance along our rows and columns therefore should decrease as we move down them.

III. MATLAB CODE

```
clear; clc; close all;

% Let's first open the raw speech data file and store its values in a
% vector fn
%
fp=fopen('rec_01_speech.raw', 'r');
% Test Sine Wave
    %fp=fopen('rec_01_sine.raw', 'r');
fn=fread(fp,inf,'int16');
fclose(fp);

L_speech = length(fn);

% Sample Frequency given
fs = 8000;

% Let us find the min/max val, mean, median, and variance
%
fn_min = min(fn);
fn_max = max(fn);
fn_mean = mean(fn);
fn_median = median(fn);
fn_var = var(fn);
% Print our findings
%
out = sprintf('Speech data: min = %f, max = %f, mean = %f, median = %f, variance = %f
\n'...
    , fn_min, fn_max, fn_mean, fn_median, fn_var);
disp(out);

% ------------------ Speech ------------------

L_speech = length(fn);
timeL = L_speech/fs;

% We can find the legnth of our signal given our sample frequency
%
t= linspace(0, timeL,L_speech);
figure('name','[ECE 3522] Class Assignment [5]');
plot(t, fn);
title('Non-shifted portion of the signal (240 Samples)');
xlabel('time (secs)');
ylabel('Amplitude');
xlim([0.9+60/fs 0.9+(240+60)/fs]);
```

1 To begin we load in our signal (the same method used in previous assignments). Once we have a data organized into variables inside MATLAB we find the mean and variance of the speech signal price and speech signal using MATLAB's built in functions.

```
% Define starting points
%
t_window1 = 0.9;
t_window2 = 3.0;
t_window3 = 1.1;

s_window1 = t_window1*fs;
s_window2 = t_window2*fs;
s_window3 = t_window3*fs;

% Define window size
xL = 239;
yL = 239;
kL = 512;
```

2 The assignment asks us to focus on three different time portions of our signal. Since our signal is organized into sample values we convert these time starting points into sample starting points.

```
%Define index variable
i = 1;

% Find corelation at 0.9secs
for k = 1:kL
    xSam = fn(s_window1:s_window1+xL);
    ySam = fn(s_window1+k+1:s_window1+xL+k+1);

    % Find correlation Coefficient.
    temp = corrcoef(xSam, ySam);
    corCoeff1(i) = temp(2,1);
    i=i+1;
end

k = linspace(0,kL,i-1);

figure('name','[ECE 3522] Class Assignment [5]');
plot(corCoeff1);
title(sprintf('Correlation for t = %0.1f secs', t_window1));
xlabel('K shift');
ylabel('Correlation Coeff');
ylim([-1 1]);
```

3 For finding correlation we define a shift variable k to start from 1 and range up to 512. Our xSam is a static sample that doesn't change sample range. Our ySam is shifted over by k samples. The correlation coefficient is also calculated using built in MatLab function 'corrcoef'. For each shift of k we find the correlation coefficient and store it into a indexed array. Next we simply plot our results.

```
ylim([-1 1]);

% Resest index
i = 1;

% Find corelation at 3.0secs
for k = 1:kL
    xSam = fn(s_window2:s_window2+xL);
    ySam = fn(s_window2+k+1:s_window2+xL+k+1);

    % Find correlation Coefficient.
    temp = corrcoef(xSam, ySam);
    corCoeff2(i) = temp(2,1);
    i=i+1;
end

figure('name','[ECE 3522] Class Assignment [5]');
plot(corCoeff2);
xlabel('K shift');
ylabel('Correlation Coeff');
title(sprintf('Correlation for t = %0.1f secs', t_window2));
ylim([-1 1]);
```

4 Repeat for the previous step for three second portion.

```
% Part 2

% Covariance when t = 0.9secs
for i = 0:1:15
    for j = 0:1:15
        index1 = 1;
        for n = s_window1:1:s_window1+xL
            x1(index1) = fn(n-i)*fn(n-j);
            index1 = index1 + 1;
        end
        coVar1(i+1, j+1) = 1/xL*sum(x1);
    end
end

coVar1
```

5 Finding covariance is similar to the correlation except now we shift over by both sample spaces by i and j. Then we find covariance along all 240 samples in our signal and sum of for each 240 samples. We store our results in a 'coVar' matrix so we can display it in the console later. Note the output will be a 16x16 matrix.

```
% Covariance when t = 3.0secs
for i = 0:1:15
    for j = 0:1:15
        index1 = 1;
        for n = s_window2:s_window2+xL
            x2(index1) = fn(n-i)*fn(n-j);
            index1 = index1 + 1;
        end
        coVar2(i+1, j+1) = 1/xL*sum(x2);
    end
end

coVar2

% Covariance when t = 1.1secs
for i = 0:1:15
    for j = 0:1:15
        index1 = 1;
        for n = s_window3:1:s_window3+xL
            x3(index1) = fn(n-i)*fn(n-j);
            index1 = index1 + 1;
        end
        coVar3(i+1, j+1) = 1/xL*sum(x3);
    end
end

coVar3
```

6 We repeat the steps taken to find covariance for 3.0 seconds and 1.1 seconds.

IV. CONCLUSIONS

As we conclude this class assignment we reflect on what correlation and covariance tell us. First, when given two random sets of variables we can determine if the two are similar characteristics depending on the correlation coefficient. In our assessment of the speech signal we found periodic correlations depending on the shift amount. From looking at Figure 3 we see periodic correlation around every 75 shifts. We said this occurred due to the composition of the speech signal being a sine wave.

Covariance is similar in regard to correlation except we measure how one random variable changes with regard to another. We saw the largest covariance when we compared the same two sample sets (when i and j where equal). As we shifted one sample set further away from the other we saw covariance decrease.