Homework 3

Louis Lin

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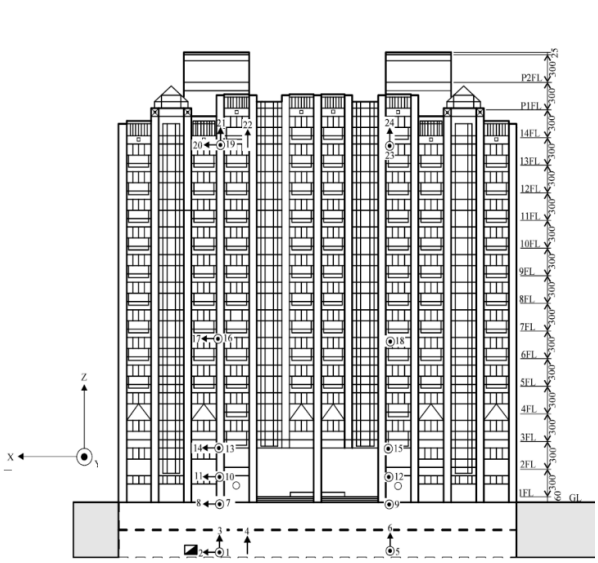
University of California, San Diego

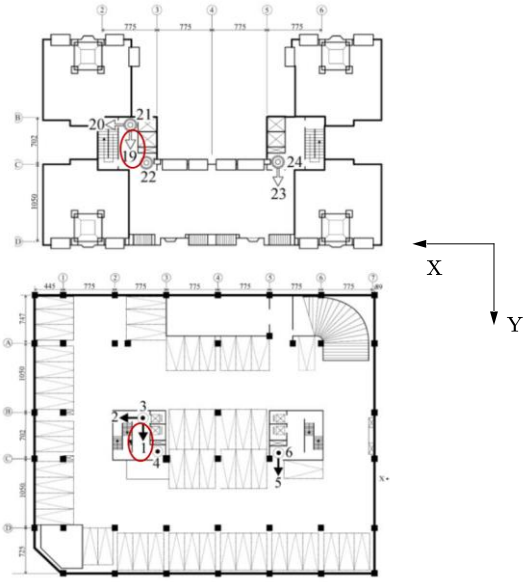
Prof. Chin-Hsiung Loh

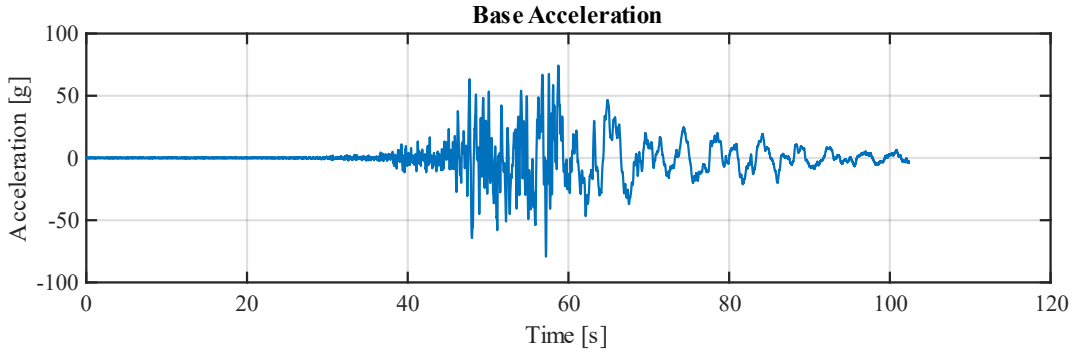
SE 267A Signal Processing and Spectral Analysis

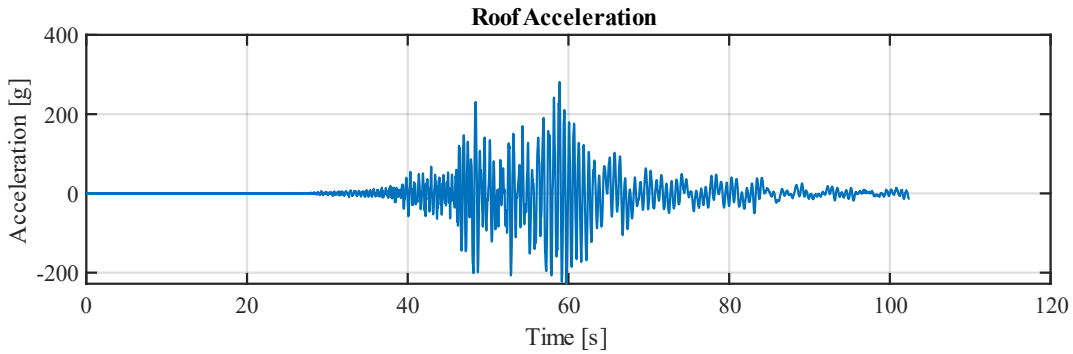
Problem 3

The current homework explores the concept of time lag within a civil structure. The two signals are given from the base and top of a building as shown, where sensor 1 is considered base acceleration and sensor 19 is considered roof acceleration. The signals are given below sampled at 200Hz.

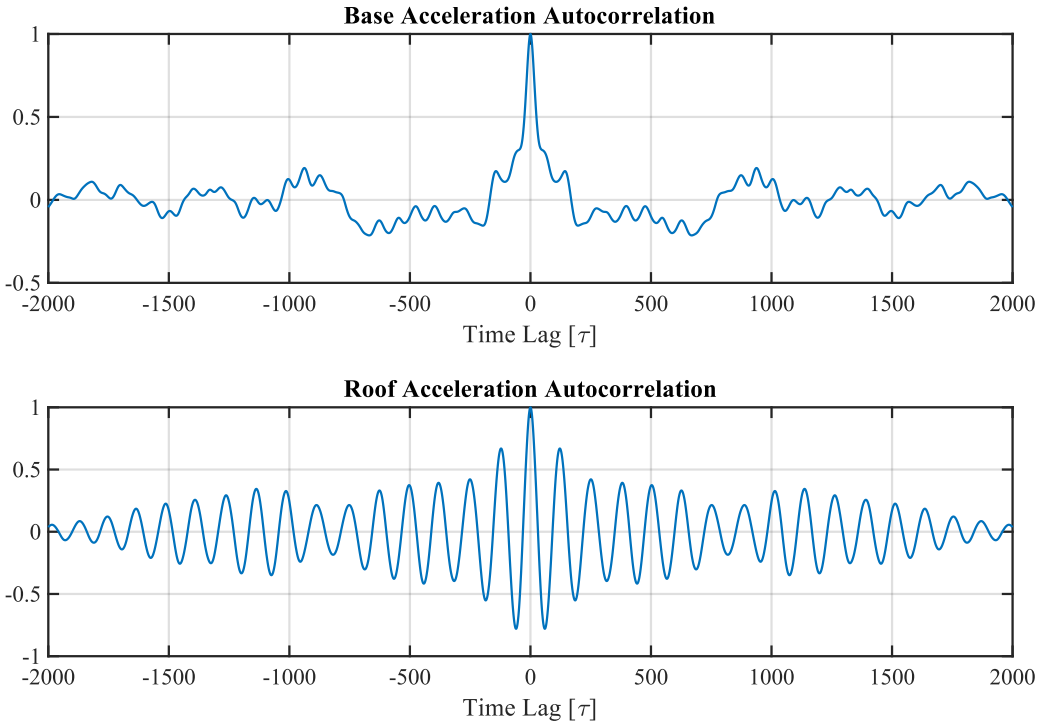




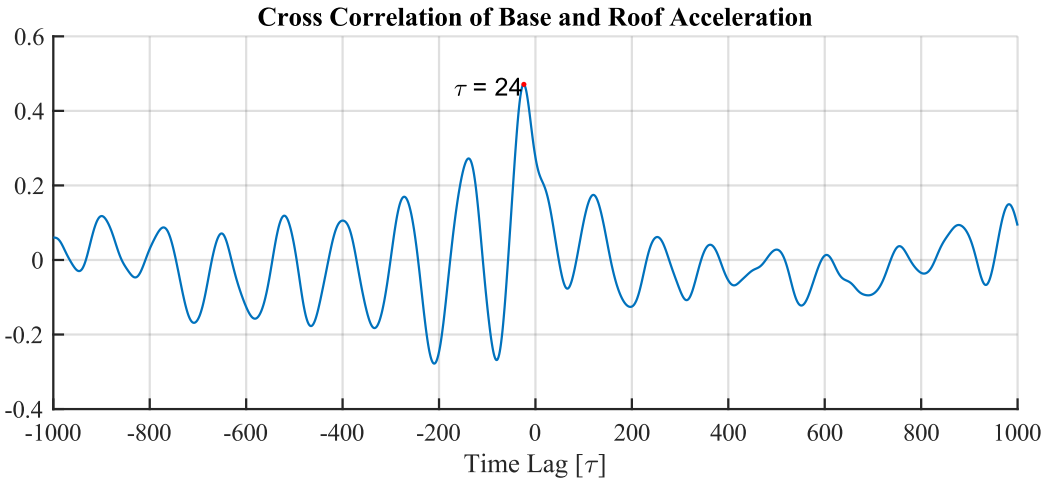




The normalized autocorrelation of the two signals are given below. The autocorrelation represents the convolution of the signal with itself given a specific time lag τ. For autocorrelations, it is symmetric about $\tau = 0$. There is also a peak at this point, since this is where the signal is most correlated with itself, when there is no time lag. If we see the autocorrelation repeat, we may suspect the signal is periodic. It is also seen that the autocorrelation of the signal at the roof level is more sinusoidal given that it has been "filtered" through the dynamics of the building.



The cross correlation between two signals can give clue to the time lag between the two signals in physical space. The τ here represents the number of samples where the signal reaches peak similarity. This peak is found at $\tau = 24$ meaning that the expected time lag between the floor is $\frac{\tau}{f_s} = \frac{24}{200} = 0.12s$. The shear wave velocity through the building is estimated to be $\frac{40\text{m}}{0.12\text{s}} = 333\frac{\text{m}}{\text{s}}$.



```
clear; clc;
%%  Problem 3
clear;
[t, acc_base, acc_roof] = readvars("HW3- building seismic response data.txt");

%% Plot the signals
figure(1); clf; clc; hold on;

nexttile
X = t;
Y = acc_base;
plot(X, Y )
xlabel("Time [s]")
ylabel("Acceleration [g]")
grid
title("Base Acceleration",Interpreter="none")
nexttile
X = t;
Y = acc_roof;
plot(X, Y )
xlabel("Time [s]")
ylabel("Acceleration [g]")
grid
title("Roof Acceleration",Interpreter="none")
print_figure(1, '.\', "Signals",4)

%% Auto Correlation Of Roof Acceleration
fs = 200;

figure(2); clf; clc;
maxlag = fs*10;

nexttile
y = acc_base;
[c,lags] = xcorr(y,y,maxlag ,'normalized');
plot(lags, c)
title("Base Acceleration Autocorrelation")
xlabel("Time Lag [\tau]")
grid

nexttile
y = acc_roof;
[c,lags] = xcorr(y,y,maxlag ,'normalized');
plot(lags, c)
title("Roof Acceleration Autocorrelation")
xlabel("Time Lag [\tau]")
grid
print_figure(2, '.\', "AutoCorrelation",4)
```

```
%% Cross correlation
fs = 200;
maxlag = fs*5;

figure(3); clf; clc;
hold on;

y = acc_roof;
[c,lags] = xcorr(acc_base,acc_roof, maxlag ,'normalized');
plot(lags, c)
title("Cross Correlation of Base and Roof Acceleration")
xlabel("Time Lag [\tau]")
grid

[pk, loc] = findpeaks(c,'npeaks',1,'MinPeakHeight',0.3);
text(lags(loc), pk,"\tau = " +abs(lags(loc)),"horizontalalignment","right")
plot(lags(loc), pk,"r.")
print_figure(3, '.\', "Cross Correlation",2.5)
```

SE167/SE267A Signal Processing & Spectral Analysis

Homework 3 (2022-01-3) **Due date: 2022-01-18**

e-mail your solution to lohc0220@ntu.edu.tw or cloh@ucsd.edu

Problem 3:

Consider two acceleration records $\ddot{x}(t)\ and\ \ddot{y}(t)$, where $\ddot{x}(t)$ is the base acceleration excitation of a structure and $\ddot{y}(t)$ is the roof absolute acceleration response of the structure. The building instrumentation is shown below.

$\ddot{x}(t)$ is the data from **Channel 1,** and $\ddot{y}(t)$ is the data from **Channel 19**.

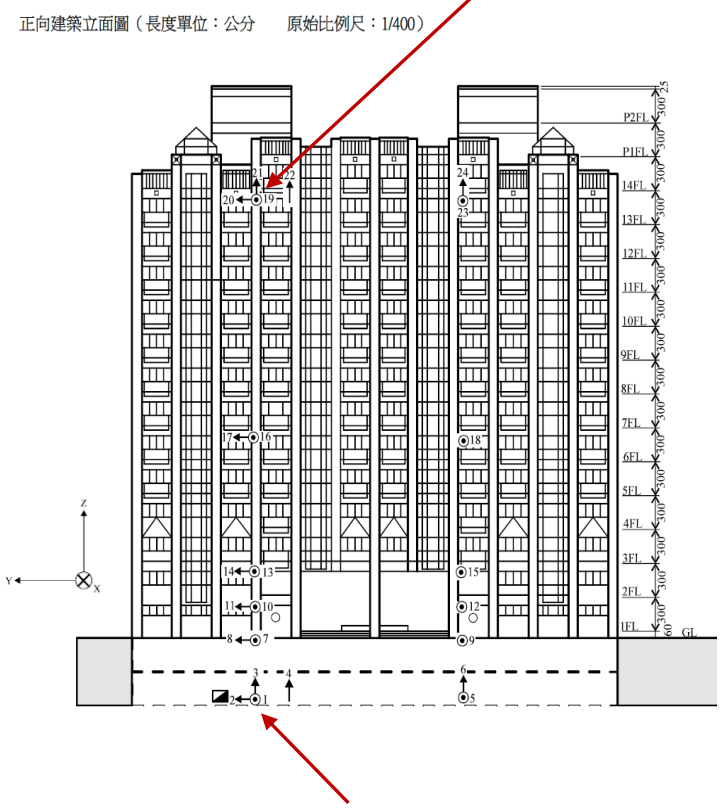
a. Plot the auto-correlation functions of $\ddot{x}(t)\ and\ \ddot{y}(t)$, respectively.

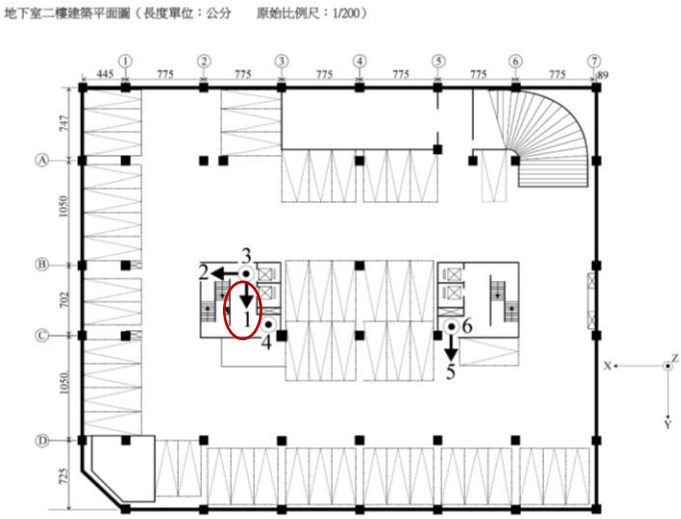
b. Plot the cross-correlation function of $\ddot{x}(t)\ and\ \ddot{y}(t)$. Identify the time lag at the maximum amplitude of the cross-correlation function.

Note: Data is provided in data file Name: Prob-2. Data Sampling rate is 200 Hz.

First column is the time increment, 2nd column is the base excitation and 3rd column is the roof response. The amplitude is "gal".

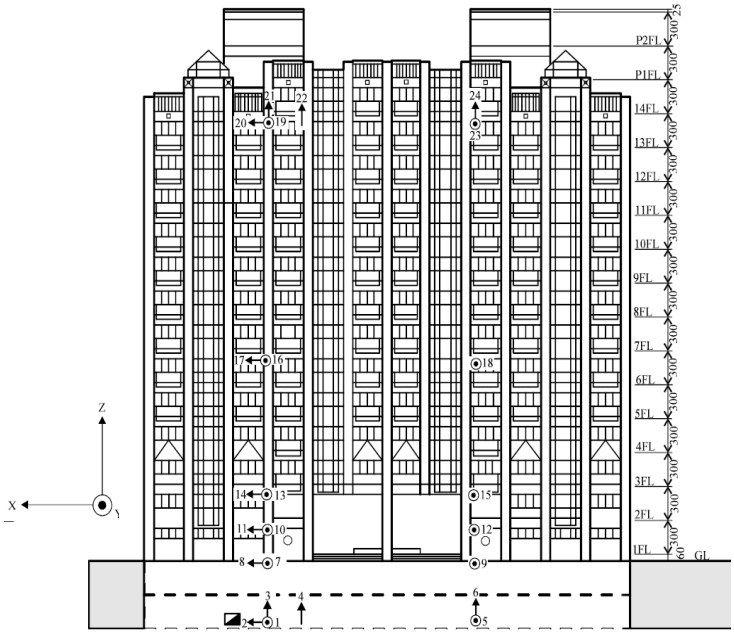
Channel-19: 14th floor (X-direction)





Channel-1: basement (X-direction)

正向建築立面圖（長度單位：公分　　原始比例尺：1/400）



頂樓建築平面圖（長度單位：公分　　原始比例尺：1/200）