12-741: Data Management
Assignment#1

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Due on: Friday October 29, 11:59pm ET

October 22, 2021

Some notes before you begin:

When answering the following questions, please provide all of your calculations to arrive at the answer (in addition to the answer itself). Your calculations should be very clear and easy to understand. They should include your assumptions, and a step-by-step explanation of how you arrived at the solution. Also, make sure you type your name and AndrewID on the top of each page.

Please make sure to submit PDF files with your answers via Canvas.
Some final recommendations:

- Before finding the answer to each question or looking at the next step in the solution, take some time to think about how you can come up with this on your own.
- Again, make sure you document everything you do, and not just write down the answer to the question. This will both help during grading as well as improving your learning process.
- Do not write down any solution or process that you do not understand. If you feel that you do not understand how to do something, seek some help. The preferred method for this is to post your questions on the discussion board for the course, in Canvas and/or Piazza.

1 Exploring a database (15%)

Find and describe the content of a database related to Civil and Environmental Engineering, of your interest, available to the public in the internet.
In about one page, report the address, describe the content of the database, find out (or estimate) the amount of data in it, and report their format. Describe an application of this database. If you wish, you can also insert a picture of the webpage.

2 Dealing with Time-Series Data (60%)

The file "SeismicResponse.txt" reports the recordings or 8 accelerometers mounted on a building, during an earthquake, in $\frac{m}{s^2}$.

Accelerometers are numbered from a_1 to a_8, and record the horizontal acceleration on two stories, along the X or Y direction. Instruments a_1 to a_4 are on level A, while a_5 to a_8 are on level B, as in the scheme shown in Figure 1.

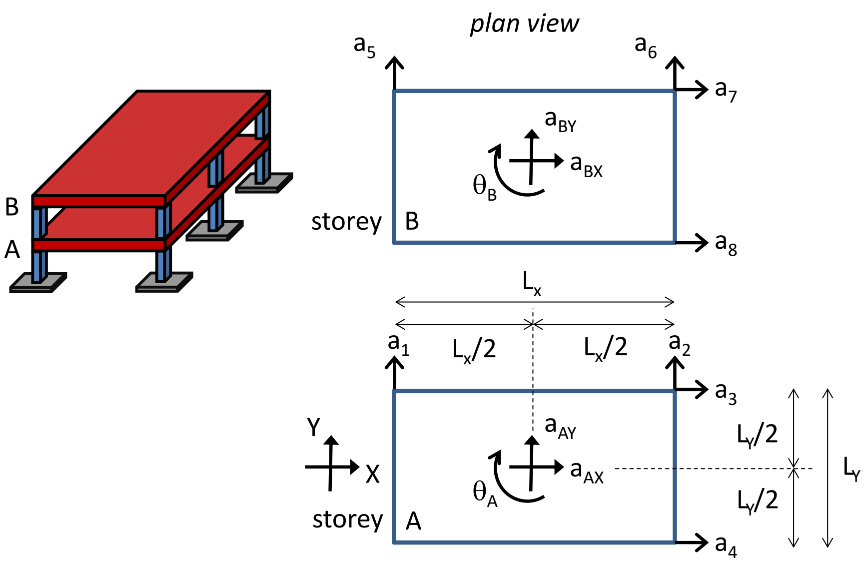

Figure 1: Two-storey building with accelerometers installed.

Dimensions are: $L_x = 30$m, $L_y = 15$m. a_{AX} and a_{BX} indicate the acceleration of the center of the building in the X-direction, for level A and B respectively. a_{AY} and a_{BY} indicate the corresponding quantities in the Y-direction, and θ_A and θ_B the rotation in acceleration.

The file reports 8 columns and 5000 rows. Column i reports the measurements of the i-th accelerometer. Measurements are collected with a sampling period $\Delta_t = 0.01$s. Assume the recording starts as a time $t = 0$.

Assume that each floor behaves at a rigid body in the horizontal frame (while obviously the columns are flexible and allow for relative movement between levels A and B).

USE ONLY SENSORS $a_1, a_2, a_3, a_5, a_6, a_7$. DO NOT USE SENSORS a_4, a_8.

Answer the following questions:

(a) Derive a_{BX} and θ_B, and plot the functions from $t = 18s$ to $t = 20s$, specifying the corresponding physical unit.

(b) Find the maximum absolute value of a_{BX} and reports the time value, in seconds, when it happens.

(c) The inter-story drift is the relative displacement between level A and B. Let us define $a_{IDY} = a_{BY} - a_{AY}$ as inter-story acceleration in the Y direction. Plot the functions from $t = 18$s to $t = 20$s, specifying the corresponding physical unit. Find the maximum of the absolute value of it.

(d) The inter-story velocity is derived as the integral of the inter-story acceleration, and it can be approximated as: $v_{IDY,k} = \sum_{j=1}^{k} a_{IDY,j}\Delta t$, where the subscript j indicates the j-th sample in the time history. The inter-story drift can be similarly defined as the integral of the inter-story velocity: $\delta_{IDY,k} = \sum_{j=1}^{k} v_{IDY,j}\Delta t$. Plot the inter-story drift δ_{IDY}, in the Y direction from $t = 0$s to $t = 50$s, and find its maximum absolute value.

(e) Assume each sensor records the actual physical acceleration, plus a Gaussian white noise (independent for each sensor and sample), with zero mean and standard deviation σ. Assume that in the first 5 seconds of recording the earthquake has not started yet and the sensors record only noise. Estimate σ from the samples, using sensor a_1.

(f) Let us call σ_{IDY} the standard deviation of the noise affecting the time history of a_{IDY}, as you have computed in item (c). Write a formula and derive the numerical value of σ_{IDY}.

(g) The file "SeismicResponse_noNoise.txt" reports the same measurements, without noise. Recompute δ_{IDY} with these new recordings, plot the function (δ_{IDY}) from $t = 0$s to $t = 50$s, and find the maximum of the absolute value of it. Can you explain the difference with respect to the result you obtained in (d)?

Additional questions (no quantitative analysis is required for the following 2 questions). Refer to the data WITH noise in your answers.

(h) Suppose that you want to estimate the maximum of a_{IDY}. You can use the procedure outlined in (c). However, you could also do the following: find the maximum of a_{BY}, the maximum of a_AY, and take the difference between the maxima. Will you get the same result as in (c)? If not, which is the most consistent method?

(i) Can you use also sensors a_4 and a_8 for estimating the movement of the building? (e.g. for estimating θ_A, θ_B?) If so, describe briefly how. Do you think you can get a more accurate result than that obtained without using these sensors?

3 Uncertainty Propagation (25%)

Suppose temperature is measured as $T = 10C$. Assume the measurement is affected by a zero-mean error, with standard deviation 2C. Force is measured as $F = 150$kN, affected by a zero-mean error with standard deviation 40kN.

The stress s on a steel member is defined as:

$$s = a_F F - a_T T + c$$

with $a_F = 0.2 \frac{\text{MPa}}{\text{kN}}, a_T = 3 \frac{\text{MPa}}{\text{C}}, c = 30\text{MPa}$.

Find the mean and standard deviation of s.