POLITECNICO DI MILANO

MEASUREMENTS

Introduction

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Course website

- Measurements on Beep

The group of Measurements and Experimental Techniques of the Mechanical department is in charge of the structural monitoring of the G. Meazza stadium since 2003.

Meazza stadium (S. Siro):

- Description of the structure
- The reason of the involvement of the Politecnico di Milano
- The proposed solution

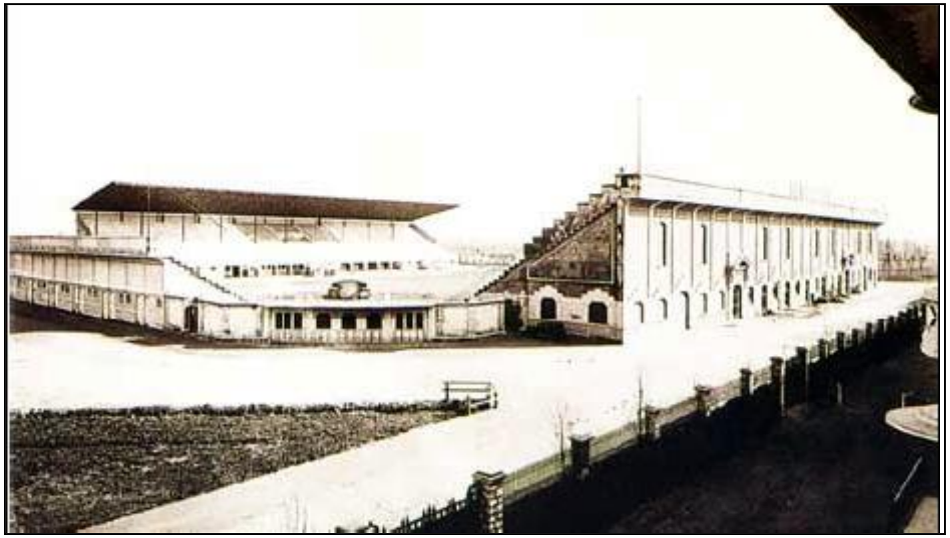
Meazza Stadium

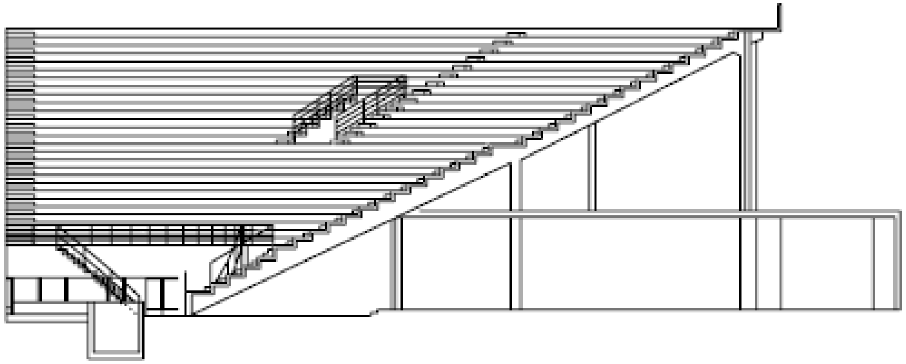
3 independent substructures:

- 1st ring
- 2nd ring
- 3rd ring and the roofing structure

Meazza Stadium – 1st ring

The first ring was built in the 1927: it is the oldest structure, very stiff and allowed to reach the capacity of 35000 seats

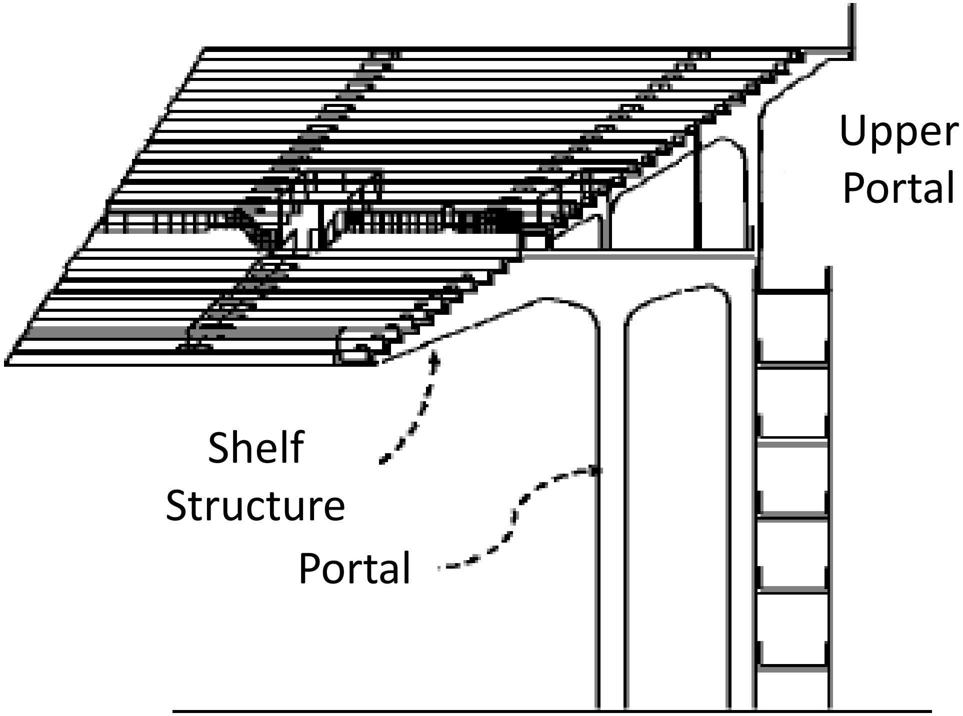




Meazza Stadium – 2nd ring

The Second Ring, built in 1955, is a shelf structure supported by a series of portals. It improved the stadium capacity up to 55000 seats.

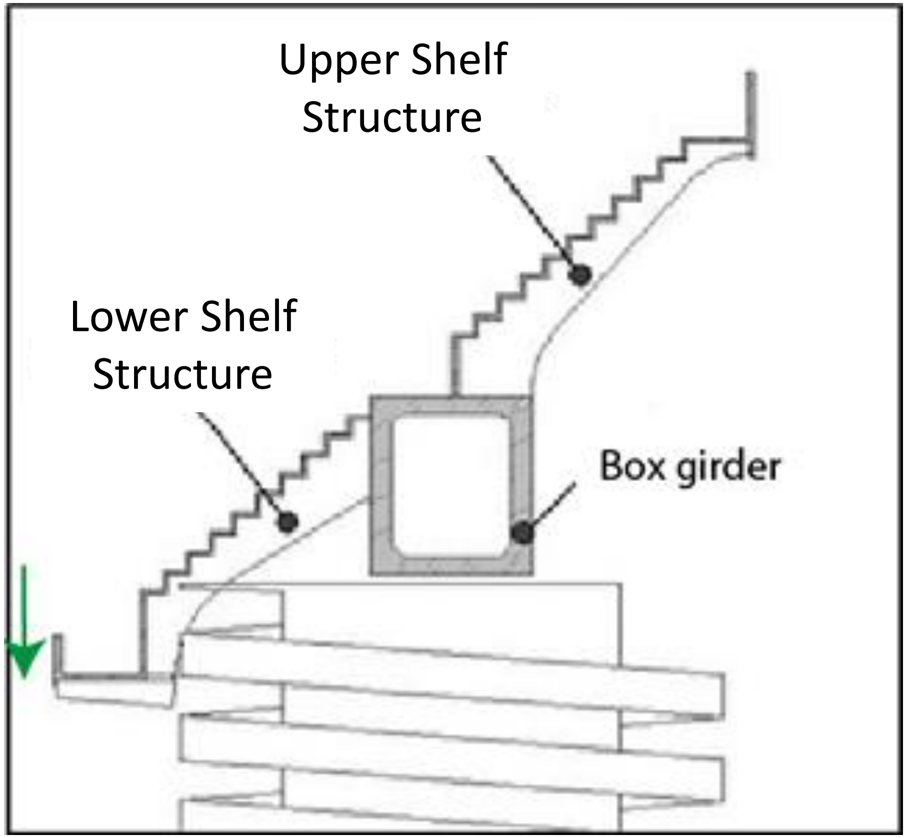
It is subjected to considerable vibrations in horizontal and vertical directions



Meazza Stadium – 3rd ring

Third ring finished in 1990: shelf structures suspended on box girders substained by towers.

It undergoes to considerable vibrations in vertical direction.



Meazza Stadium – 3rd ring

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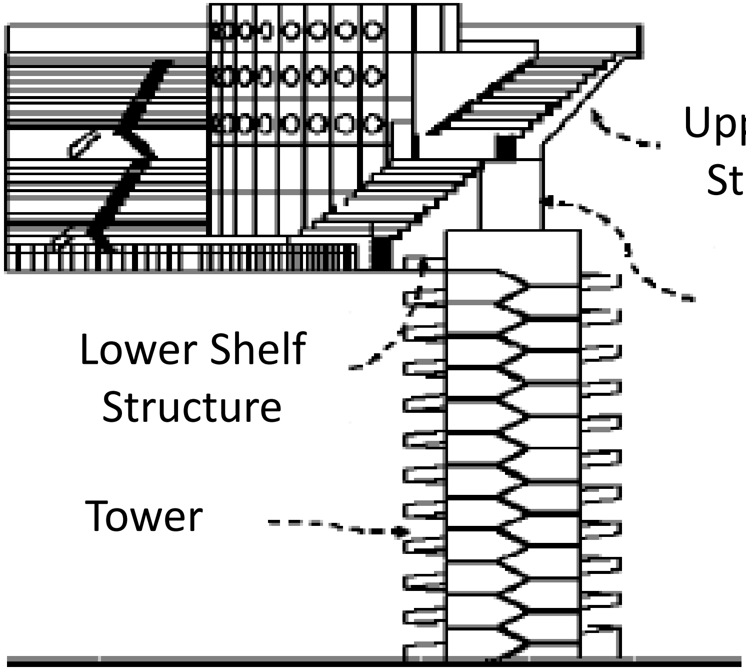
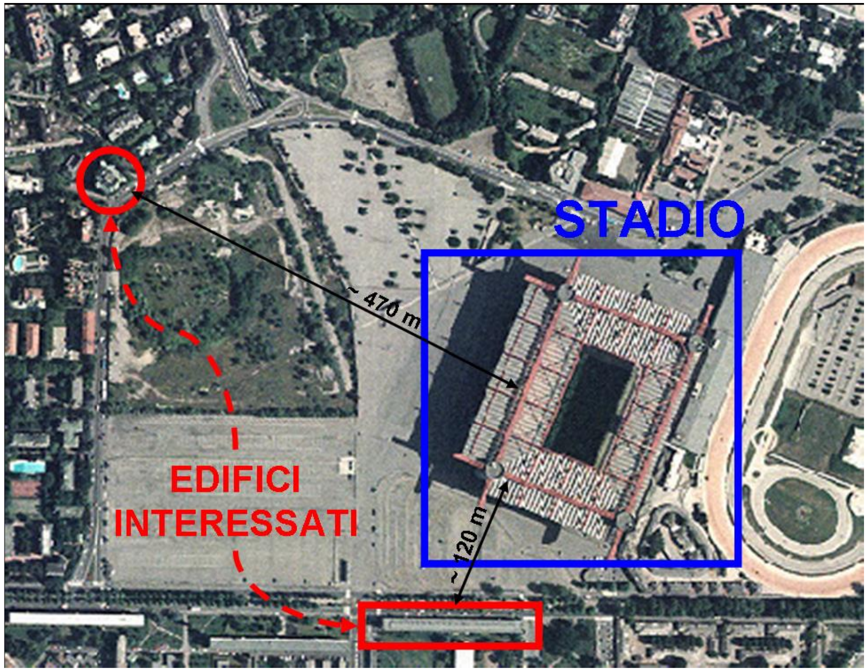
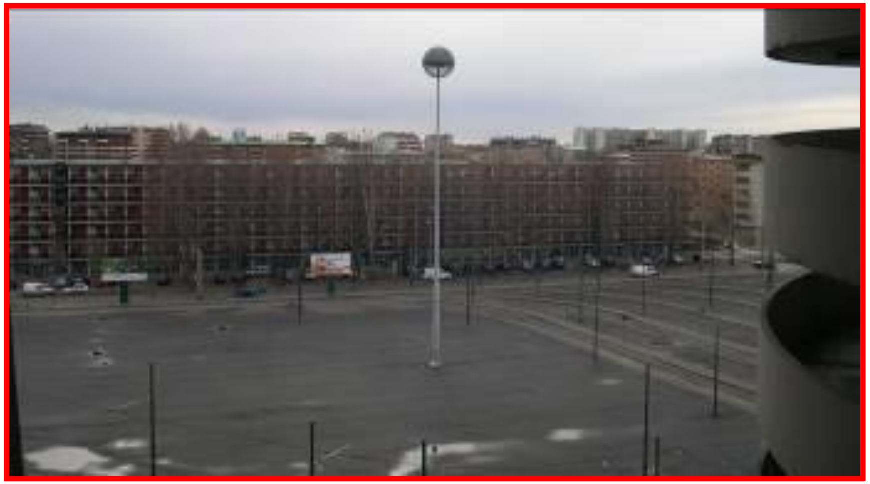


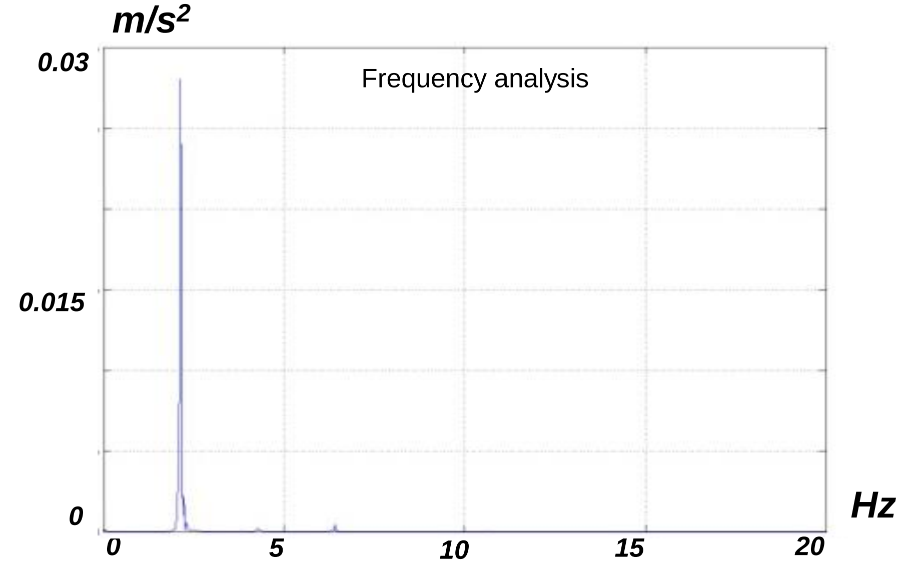
Original Problem: significant vibration level in surrounding buildings

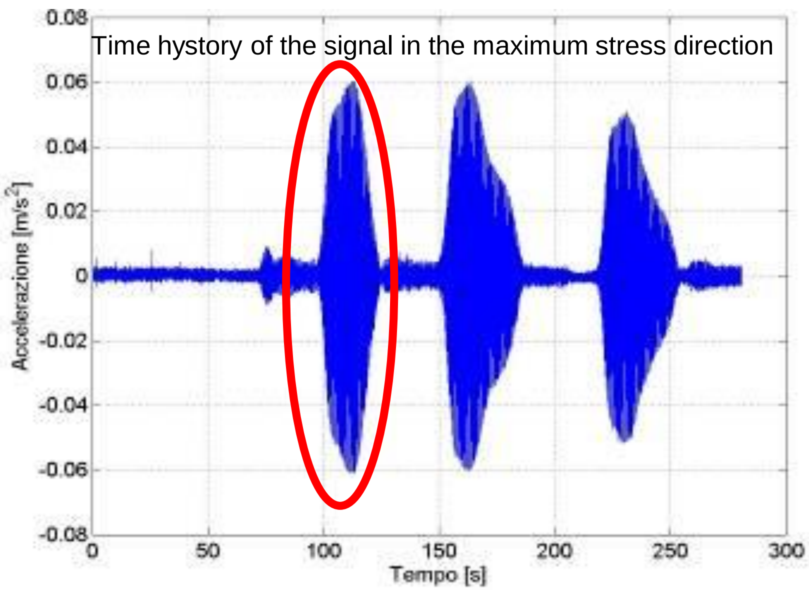
Involved Buildings

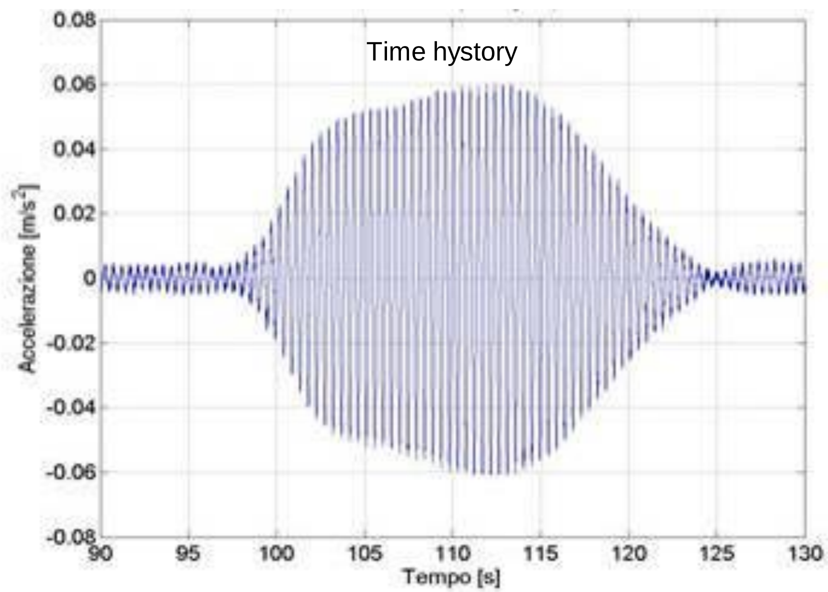




First investigation: measurement of the vibration level in the involved buildings







First investigation: measurement of the vibration level in the involved buildings

The time and frequency domain analysis of the acquired acceleration signals showed:

- a harmonic motion at 2.2Hz
- different acceleration level in different directions: z/x = ¼
- same concert for 3 nights ⇨ same phenomenon

Which could be the cause of this behaviour?

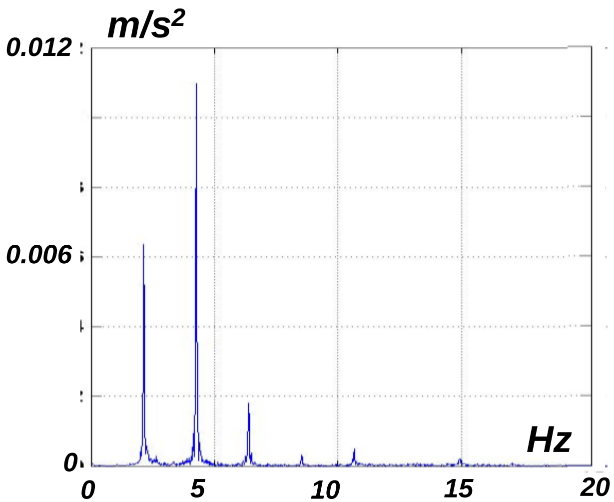
- Sub-woofer?
- Other?

Origin of the phenomenon

Forced motion of the structure induced by the sinchronized motion of the audience at the rithm of the music

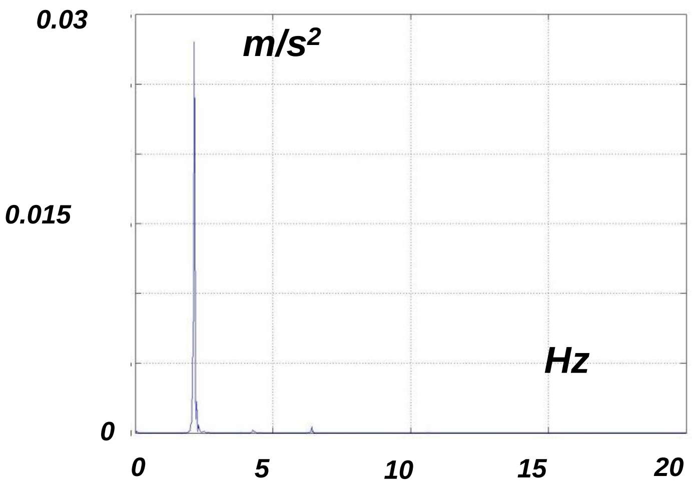
- Synchronized motion of the people coincides with resonance frequency of the stands (about 2.2 Hz); the ground transmits the force to the building, where the accelerometers sense the same harmonic motion

Accelerometer at the base of the tower
Spectrum modulus



x 5

Accelerometer in the residential building
Spectrum modulus



Well-known example of human-structure interaction

A really impressive example is the Norimberga stadium

Proposed solution: permanent and continuous vibration monitoring system

Accelerometers

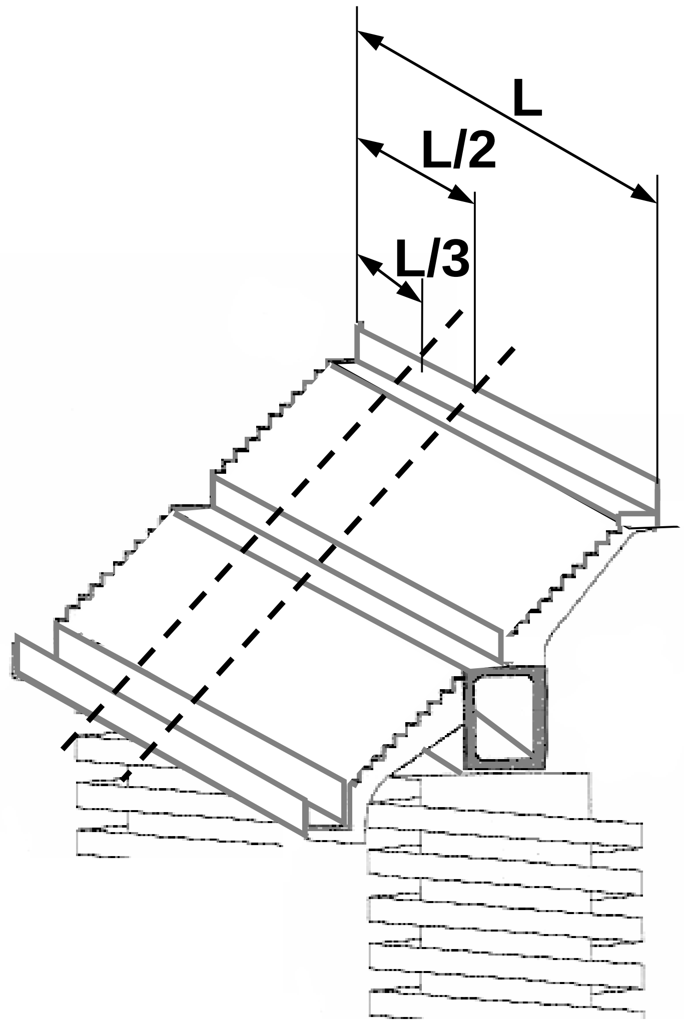
- Servo accelerometers
- High sensitivity
- Low noise floor

Acquisition system

- Redundant
- 16 bit in order to guarantee an high resolution
- Anti-Aliasing filters

Test set-up: sensors layout

The quality and completeness of the information that can be obtained from the monitoring system is highly dependent on the sensors layout. For this reason the choice of the measurement points on the structure is fundamental: they must be placed in order to capt the highest vibration levels and all the main modes of the structure.

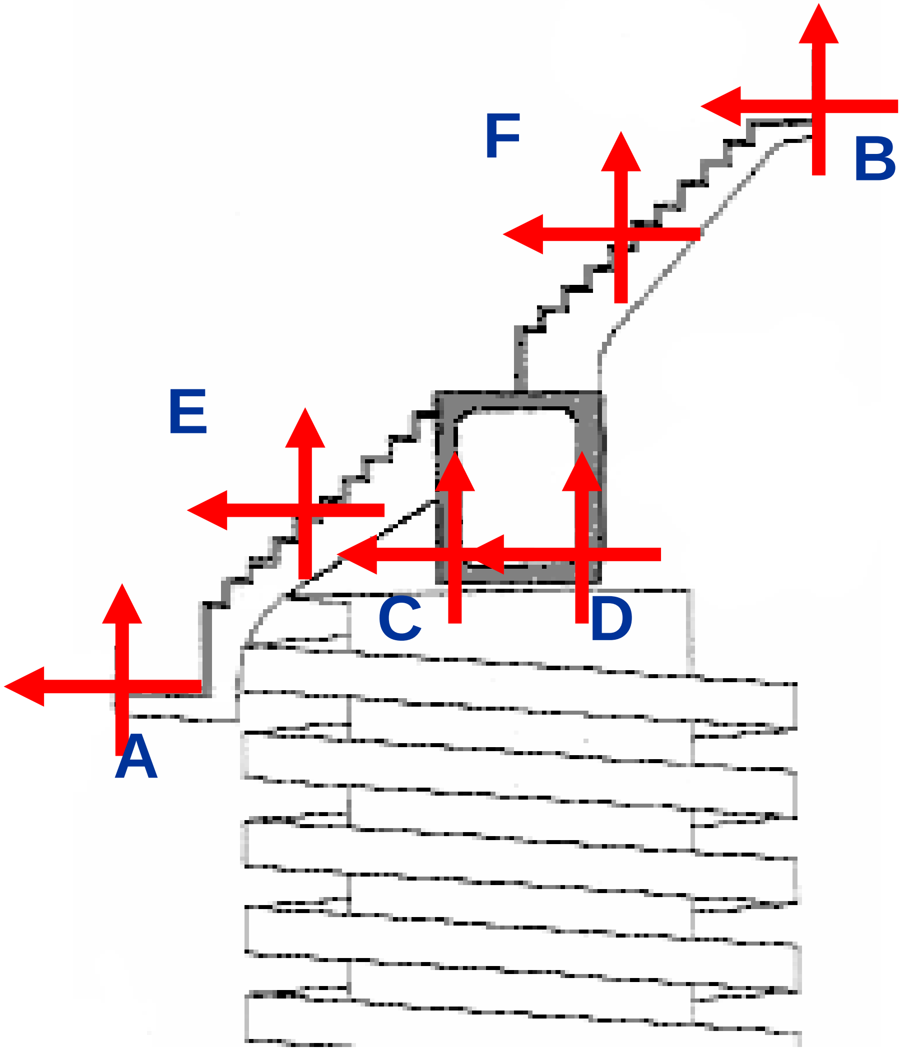


Two sensors for each shelf and for each box girder, in each of the underlined sections

Sensor layout for each section

C

A



Laboratory n. 1

https://beep.metid.polimi.it/ → MEASUREMENTS

Write a Matlab program in a script file that implements the following instructions (the in-built functions that could be used are suggested in red):

1. Displays a dialog window to choose the file to open (*uigetfile*)
2. Loads the file (*cd, load*)
3. Defines how many signals there are in the loaded file (*size*)
4. Derives the sampling time dt knowing the sampling frequency (variable name: «fsamp»)
5. Transforms the signals (V) in engineering units (EU) using the accelerometers senitivity values (variable name: «sens»)
6. Builds the time axis using a for loop (*for*) and defining directly the time vector
7. Plots the signals in the time domain (*plot, subplot*)
8. Displays on the graphs a grid, the legend and the axis title (*grid,legend, xlabel, ylabel,title*) (channels names in variable «channels»)

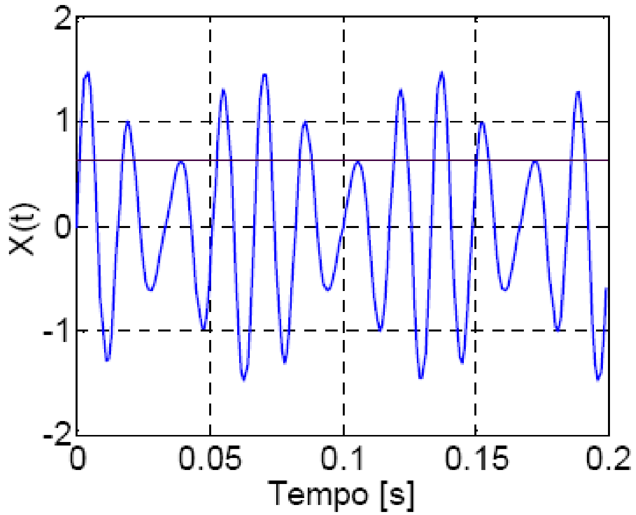
9. Calculates the maximum (using *max* and a recursive cycle), the minimum (*min*), the mean (*mean*), the standard deviation (*std*) and the RMS value for all the channels.
10. Displays on the time histories plot the values calculated in the previous point as lines (line).
11. Saves in a text file (*.txt) all the values of the quantities calculated at point (*save*)

In order understand how to use the in-built functions in Matlab, you can always refer to the Help by clicking on the proper icon (question mark) or by typing on the Matlab Command Window:

«help *function_name»* (e.g. «help min»)

RMS:

It is an index that can be calculated on time signals of a recorded physical quantity (record) and it is related to the mean power of the signal.



Definition:

$$rms = \sqrt{\frac{1}{T}\int_0^T x^2(t)dt}$$

It can be demonstrated that the RMS value can be expressed also as:

$$rms = \sqrt{\mu^2 + \sigma^2}$$

RMS value calculation:

Commands: mean, std, sqrt

$$rms = \sqrt{\mu^2 + \sigma^2}$$

Commands: sum, Pay attention! We have a discrete signal

$$rms = \sqrt{\frac{1}{T}\int_0^T x^2(t)dt}$$

Maximum calculation:

The maximum value of the signal can be calculated by using the in-built function max and with a recursive loop (for) that compares each value of the signal with the following one and memorise the maximum of the two in a temporary variable.

Compare the maximum value obtained with the two methods and display on the screen a message saying if the two values coincide or not (*if, disp*).

Variables available in the file «Data_Lab_1»:

- Data
- channels
- fsamp
- sens

https://virtualdesktop.polimi.it/vpn/index.html

1. Enable the *virtual desktop* service on your own notebook following the guidelines available on the website: http://www.client.polimi.it/en/virtual-desktop/

2. Install the software on your personal computer.

   The university makes available to the students an annual licence of the software that allows:

   - to install Matlab basic package and all optional modules on owned PC (home PC or notebook). Max 4 installations.
   - the distribution of updates

   You can download the software and activate your personal copy by following the instructions on the website:

http://www.software.polimi.it/en/software-download/students/matlab/

Here you can find a basic course for Matlab (Log in with your POLIMI account):

https://matlabacademy.mathworks.com/