Dynamic Analysis of Buildings Using Vibration Data
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Introduction: Structural Analysis Using Ambient and Forced Vibration Data

- **Purpose**
  - **Structural monitoring** allows engineers and scientists to determine how buildings respond to earthquakes and other natural and man-made phenomena.
  - Measured dynamic properties can be used to monitor structural health and to improve standards for design and construction.
  - Research in this field helps ensure safety and structural integrity.

- **Ambient & Forced Vibration Tests**
  - **Ambient vibrations** refer to a building’s natural response to its environment. In ambient tests, the buildings are monitored under typical daily conditions.
  - **Forced vibrations** result from shaking or hitting the building in some unnatural way. In these tests, mechanical shakers or other tools are used to induce vibrations and excite the natural frequencies of the building.

Project Description: Vibration Data Collected on Two Contrasting Buildings

- **ETA-B Blok: Boğaziçi University, Instabul, Turkey**
  - 7 level building, including the basement and roof
  - Completely gutted building undergoing construction, including seismic retrofit
  - 6 different test configurations conducted

- **Engineering I: University of California, Los Angeles, USA**
  - 4 level building starting at the ground floor and including roof
  - Fully functional and operational classrooms, labs, and offices
  - Lots of operating machinery
  - 2 different test configurations conducted

Solution & Findings: Measured Dynamic Properties of Both Buildings

- **Processed Data**
  - **Graphical Analysis of Data**
    - **Acceleration vs. Time** (upper left): shows building vibrations over time measured in g units per second.
    - **Power Spectral Density Plot** (lower left): displays which frequencies excite the building most shown by a series of peaks.
    - **Spectrogram** (below): a three dimensional plot showing the level of energy corresponding to a peak at any given frequency in time.

- **The Effects of Temperature**
  - **Temperature Variation Affects Both the Instrumentation and the Building**
    - Acceleration vs. Time plots like the one at left show temperature drift when displaying data collected over long periods of time or during peak hours of sunlight change.
    - The modal frequencies of a building are also affected by temperature due to slight changes in material properties.
    - The modal frequency fluctuations appear to be correlated with the change in temperature over the time of testing, as shown in the plot at right.

- **ARTeMIS: A Powerful Tool for Data Analysis**
  - **ARTeMIS** is a commercial program that imports and analyzes structural monitoring data to produce three-dimensional animations of the way a structure vibrates at specific frequencies. The movements are shown on a highly exaggerated but proportional scale.
  - By selecting the determined modal frequencies of a building and running an ARTeMIS analysis for those values, the behavior of the building can be visualized. Data models can also be combined to form a multiple-test animation.

- **Future Research**
  - Further analysis of the effects of temperature on building vibration
  - Gather follow up data on ETA-B Blok building after retrofit has been completed to verify improvements in structural integrity

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