Visualization of Full-Field Coherence Functions for Structural Dynamics Characterization

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Characterizing structural dynamics is critical to monitoring and evaluating the structural health of buildings, bridges, cities, and beyond. An important element of this work involves understanding how structures respond to various forces and impacts. Conventional approaches for capturing and analyzing these responses are time consuming, expensive and typically provide low-spatial resolution. In light of these constraints, a promising new technique employs advanced computer vision and video processing algorithms to extract the complete dynamic data from video recordings. Understanding how to efficiently analyze this rich output data remains a key challenge. Visualization may be the key!

Visualization Problem Breakdown:

- An important element of characterizing structural dynamics involves understanding how structures respond to various excitations.
- When a structure is excited by a force, the input (e.g., impact) has some effect on the output (e.g., structure motion).
- The relationship between input and output is captured by a coherence value.
- Coherence values are analyzed as a function of frequency range.
- A new modal analysis technique employs advanced computer vision and video processing algorithms to capture structural vibration and compute the coherence value (across the frequency range of interest) for every point on a 2D structure.
- For every pixel, a plot of coherence values vs. frequency is calculated (i.e. the coherence function).
- From here, the goal is to characterize the behavior of a structure using as much coherence information as possible, and in particular to identify patterns in the coherence values which indicate non-linear relationships in the structure's motion.
- How can visualization support these tasks???
- How can the coherence function be visualized in a way that helps researchers identify non-linear structural relationships?
- How can visualization solutions be extended for 3D coherence function data?

Data Breakdown:

Data was collected for 3 different structures. There is a directory of data for each structure. There is a 3-story structure, a 4-story structure, and a cantilever beam.

For each structure, the following is provided:

- The original video in .avi format as well as .mat format.
- A hierarchy of phase data presented at different levels in .mat format. The variable of interest in this data is called "phase_delta". Really we will probably ultimately need to apply algorithms in such a way they are applied to all levels, but for the sake of this exercise it is probably ok to only look at single levels.)
    - Each phase delta measurement should have 512 points measured in time. We call these 512 points a "time series."
    - The other two dimensions are the spatial pixel dimensions. The phase_delta data is used for the coherence calculation. You pick one pixel as the input and all the other pixels as the output.
- For the 3-story structure and the 4-story structure there is also accelerometer data.

It is expected that the cantilever beam will have the highest coherence function values because it should be the most linear.

Glossary of Key terms:

Coherence: when an input excitation is applied to a structure, coherence is used to describe the relationship between input excitation and output structural motion. A coherence value of 1 indicates a linear relationship between input and output. Coherence values < 1 indicate non-linear relationships between input and output. The **coherence function** maps coherence as a function of frequency.

Full-field: high spatial resolution.

Modal analysis: characterizing structural dynamics by analyzing the response of structures to various excitations.