Time & Location: July 15, 2014 at 2:00 PM in Engineering 1 384
Title: An Investigation of Structural Health Monitoring through Compressive Sensing

An avenue of key importance in the construction industry today is Structural Health Monitoring, a concept developed to monitor the quality and longevity of engineering structures. Such a system would help to continuously track health of the structure, indicate the occurrence of damage and give us an idea of its number of useful years. The state of art technique in the field is straightforward - arbitrarily populating a structure with many sensors and extracting information from them. This may be inefficient as it could lead to superfluous data that is expensive to capture and process.

This research aims to explore an alternate technique that optimizes the data acquisition process by eliminating redundant data being sensed and uses just the sufficient data to detect and locate fault present in the structure. For this, Compressive Sensing (CS) is explored as a plausible idea. CS claims that signals can be reconstructed from what was previously believed to be incomplete information by Shannon's theorem, taking only a small amount of random linear non-adaptive measurements. As responses of many physical systems contain a finite basis, CS exploits this feature and determines the sparse solution instead of the traditional least-squares type solution.

Initially, CS is demonstrated by recovering the frequencies of a simple sinusoid. Then, it is compared against conventional Fourier Transform by recovering temporal frequencies and signal reconstruction using the same number of samples for both approaches and comparing errors. Next, feasibility of using CS to detect damage in a 1-DOF system is tested under unforced and forced conditions. In the former scenario, damage is indicated by a change in the natural frequency of vibration of the system after an impact. In the latter, the system is excited harmonically and damage is detected by a change in amplitude of vibration. Since realistic systems are predominantly multi-DOF, CS is tested on a harmonically excited 2-DOF system, where damage is detected by observing the change in amplitude of vibration. To test the robustness of CS in realistic forcing conditions, reconstruction of a chirp signal which contains multiple frequencies is explored.

Damage detection is a spatio-temporal problem. Hence it is important to extend CS to spatial reconstruction. For this reason, modeshape reconstruction of a beam with standard boundary conditions is performed and validated with analytical results from literature. Finally, the operation deflection shapes (ODS) are reconstructed for an SS beam using CS to establish that it is indeed a plausible approach for a less expensive SHM. Modeshape as well as ODS of a beam are examined under undamaged and damaged scenarios. Damage is simulated as a change in stiffness coefficient over a certain beam span. Although the range of modes to be examined heavily depends on the structure in question, literature suggests that for most practical applications, lower modes are more dominant in indicating damage. For ODS on the other hand, damage is indicated by observing the shift in the recovered spatial frequencies and it is confirmed by the reconstructed response.

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Approved for distribution by Tuhin K Das, Committee Chair, on June 26, 2014.
The public is welcome to attend.