STRUCTURAL HEALTH MONITORING SYSTEMS USING WIRELESS SENSOR NETWORKS

Tat Fu[1], Krishna Chintalapudi[2], Jeongyeup Paek[2], Erik A. Johnson[1] and Ramesh Govindan[2]

[1]Dept. Civil and Env. Engineering
University of Southern California
Los Angeles, CA 90089
JohnsonE@usc.edu

[2]Computer Science Department
University of Southern California
Los Angeles, CA 90089

A conventional large-scale structural health monitoring (SHM) system requires very extensive wiring and cabling that is quite costly [1]. Wireless sensor networks can significantly reduce this cost while allowing for highly dense and flexible sensor placement. However, wireless sensor networks are constrained in both energy usage and radio bandwidth. Being battery powered, the longevity of wireless sensor networks depends critically on the energy expended in radio transmissions, while bandwidth limits the amount of data transmission in a given time period. In other words, wireless sensors networks prefer less data transmission, requiring some level of on-node processing for a viable wireless SHM system. Existing damage localization schemes typically collect structural response data from various locations in the structure and transmit this large amount of data to a centralized location. Such schemes handicap the longevity of wireless sensor networks by drawing considerable energy for radio transmission. Moreover, radio bandwidth further complicates transmitting a large amount of data such as structural response time histories.

This paper discusses the development of a software infrastructure for wireless SHM and a distributed damage localization algorithm that leverages local data processing to avoid transmitting voluminous structural response data over the radio. NetSHM is a software infrastructure developed to allow structural health engineers to implement SHM algorithms in a high level language — *e.g.*, C or MATLAB — and test them without delving into the details of the underlying sensor network. In NetSHM, a hierarchical arrangement between sensor nodes and gateways is formed to allow for highly dense deployments with a large number of sensors or actuators. The wireless sensor nodes deployed in an ad-hoc manner can self-organize and provide basic necessary services such as reliable data delivery and time-synchronization. Currently, NetSHM can provide accurate time-synchronization to within 100 μs, suitable for capturing mode shapes for frequencies up to ~30 Hz.

The distributed damage detection algorithm has two phases: estimate natural frequencies of the structure and estimate mode shapes and attenuation rates. A set of natural frequencies is generated at each node by examining the power spectral density locally; this limited information is then transmitted through the network and aggregated into a global set of natural frequencies. The second phase then locally filters each signal to find the local amplitude, phase and attenuation rate for each mode; these are then aggregated within the network to find a global modal parameter estimates. The algorithm is tested on a laboratory-scale experiment with results comparable to the centralized Eigensystem Realization Algorithm (ERA) [2]. The algorithm is then deployed on a three-dimensional ceiling structure to test the algorithms in a more complicated structure.

References

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Keywords: structural health monitoring, SHM, wireless sensor network, distributed algorithm