



Decentralized damage identification using wavelet signal analysis embedded on wireless smart sensors

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ABSTRACT

In this paper, a decentralized damage identification method using wavelet signal analysis tools embedded on wireless smart sensors (Imote2) has been proposed and experimentally validated. The damage identification analysis is decentralized by calculating discrete wavelet coefficients for acceleration in Imote2 sensors and transmitting the wavelet coefficients to a base station for damage identification through wavelet entropy indices. The wavelet entropy is modified to serve as a damage-sensitive signature that can be obtained both at different spatial locations and time stations to indicate existence of damage. It is known that wavelet-based approaches have clear advantages over Fourier transform-based ones for damage identification, since the wavelet transform allows for a wider choice of basis functions. This flexibility allows the wavelet transform to isolate changes in a signal that may be difficult to detect using other transform methods. To assess the reliability of the measurement signals, the wireless sensors have been compared with reference wired sensors. The proposed decentralized method for damage identification is verified via experimental tests using two laboratory structures: a three-story shear building structure and a three-dimensional truss bridge structure.

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1. Introduction

Recent advances in wireless smart sensor technologies have opened up numerous applications in the dynamics-based health monitoring of civil engineering structures [1–3]. Wireless sensors still have some limitations, most notably less reliable data transmission than wired sensing systems, a relatively short communication range, and operational constraints due to limited power; however, numerous field studies have demonstrated that wireless smart sensors can be used to build a reliable and accurate structural health monitoring system [4–6].

Fundamentally, a wireless smart sensor has three capabilities: (1) Sensing, (2) Computing and (3) Communicating. The advent of micro-electro-mechanical system (MEMS) has facilitated the integration of various on-board MEMS-based sensors (e.g. for acceleration, temperature, and humidity) with built-in signal conditioning circuitry on sensor boards. Wireless smart sensors, with their integrated high-speed computing and communication technologies, enable quick and accurate measurement of structural response (e.g. ambient and forced-vibration response) and assessment of structural integrity. The use of wireless smart sensors in

structural health monitoring systems is highly cost-effective, since the wires that would ordinarily be required to connect the sensors to a central data acquisition system are eliminated. This is one of the intriguing benefits of using wireless smart sensors for large-scale civil engineering structures.

During the past several decades, FFT-based natural frequencies and mode shapes have been the dominant parameters used in damage detection and assessment of structural integrity. It is notable that a robust and efficient method using the mode shape can detect and quantify severity of damage [7]. The wavelet and wavelet packet transforms have been recognized as newly emerging signal analysis methods [8]. Compared to the Fourier transform, which uses simple harmonic functions (sine and cosine) as a basis, the wavelet transform allows for a wider choice of basis functions. This flexibility allows the wavelet transform to isolate changes in a signal that may be difficult to detect using other transform methods. This advantage of the wavelet transform is naturally inherited by wavelet-based measures of energy and entropy, and leads to better damage identification. Particularly, wavelets have advantages when the structural dynamic responses are complex and non-stationary. Numerous studies have used wavelet and wavelet packet transforms to detect cracks or structural damage [9–11]. In particular, Ren et al. suggested the use of information entropy [12] as a damage-sensitive feature for detecting damage in structures [13]. They proposed the

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