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Distributed network-based structural health monitoring expert system

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ABSTRACT

Structural Health Monitoring (SHM) is a process of detecting damages to engineering structures. The goal of SHM is to improve both the safety and reliability of infrastructures such as buildings, bridges, and highways. Several efforts have been made to develop improved SHM systems. However, most of these studies only considered vibration as a monitoring parameter without incorporating expert systems based on fuzzy inference. In this work, an expert system was incorporated into SHM for monitoring residential buildings based on building temperature and vibration measurements. The developed system used a Wireless Sensor Network (WSN) with a 2.4 GHz Radio Frequency (RF) band. Results of the system performance evaluation indicated a decrease in reliability from 99% to 50% within a decade of its deployment. In terms of energy conservation, results showed that the system was able to save 30% of energy, thereby increasing its lifetime. The fuzzy expert SHM system is able to detect building conditions with a good level of reliability, energy conservation capability and high accuracy of 94.4% and 100% as the least and best performance, respectively. Hence, direct integration of this system into building structures could aid early detection of building impairment.

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Introduction

Structural health monitoring is a process of constantly watching over civil engineering structures to find an anomaly. The structural engineering community has found that structural health monitoring is a necessary activity to efficiently protect engineering structures (Badejo, 2009; Lynch et al., 2001). SHM systems are designed to efficiently test and monitor the health performance of engineering structures, employing sensors deployed at optimal positions where it can give measurement needed for determining the safety of structures (Bremera et al., 2016). An early SHM method was designed based on manual feedback in which anomaly was reported by means of warning sound, advisory, caution, and maintenance panels. To addressed its shortcoming, various research efforts have been made to develop an improved SHM system with the capability to detect structural defects and inform the owner or authorities (Bremer, et al., 2016; Lynch et al., 2001; Wang et al., 2014; Wang et al., 2017; Wang et al., 2019; Zhang et al., 2012). The goal is to create cities (smart cities) where all their critical infrastructures such as buildings, bridges, and so on can be monitored so that preventive maintenance activities can be planned.

SHM has the following components: sensors, a data transceiver, and a computational unit with processing ability. Recent systems have employed a wireless sensor network (WSN) to transmit measured parameters to the point of processing. WSN is a combination of several battery-powered sensor nodes deployed to acquire parameters for monitoring(Wang et al., 2014). Each node consists of different sensor types to monitor different parameters and transmit data wirelessly between one another to the sink (static or mobile) using existing routing protocols(Wang et al., 2017; Wang et al., 2019). When a mobile sink is employed, topology changes from time to time are managed with a topology management protocol (Zhang et al., 2012).

Damage can be considered as a modification of physical parameters such as mass, stiffness, and damping. A physical parameter can be modified by a motion attributed to a vibration within a building. Environmental factors such as temperature can also affect the status of a building. To increase the efficacy of a damage detection system, we propose the incorporation of an expert system into the SHM. Expert systems are systems that can intelligently make decisions based on available input and knowledge programmed in the input (Angeli, 2010). Expert systems are developed to be able to solve a

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