DYNAMIC MONITORING OF EXISTENT STRUCTURES USING WSN

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ABSTRACT

Structural Health Monitoring (SHM) represents the present and future of the civil engineering since, until few years ago, structural diagnosis works had been performed with few resources regarding to experimental techniques. In the field of monitoring sensors, the progress of new technologies based on wireless communications and Micro-Electro-Mechanical-Systems (MEMS) are of high interest for replacing the handle difficult wired based sensors. This work aims at exploring the use of Wireless Sensor Networks (WSN) for performing Operational Modal Analysis (OMA) of existent structures.

INTRODUCTION

The structural monitoring is currently used for assessing the operational conditions of the structural systems. Nevertheless, these techniques can be also used as powerful near real-time tools for assisting the decisions that should be taken immediately after the occurrence of extreme events such as earthquakes or unanticipated blast loadings (Farrar and Worden, 2007). When dynamic monitoring techniques are applied for studying cultural heritage buildings, these applications gain much more importance considering the current societal and economical demands as well as the fact that these buildings provide most of the times, the identity to a region or country.

The few experiences reported in the literature regarding to the use of dynamic monitoring systems in existent structures have evidenced serious difficulties for applying conventional equipments and techniques. These difficulties can be summarized as: a) architectonical limitations for the deployment of wired based monitoring systems; and b) elevated costs of the monitoring equipments due to the necessity of high sensitive transducers required for measuring the low amplitude vibrations of these thick walls' buildings.

In SHM, the area where the technology is growing faster is without any doubt the one related to the measurement sensors and data acquisition equipments. Conventional systems are mainly heavy, big sized, expensive and wired based. On the other hand, new technologies like the ones based on wireless communications and MEMS (combination known as Wireless System Networks – WSN) offer interesting possibilities and are being studied as alternatives for replacing the conventional systems.

The use of WSN for structural monitoring was first proposed by Straser and Kiremidjian (1996), Kiremidjian et al. (1997), Straser and Kiremidjian (1998), and Straser et al. (1998). The commercial versions of these platforms were first developed by the University of California-Berkeley and subsequently commercialized by Crossbow (Lynch and Loh, 2006). There are several studies using these systems in bridges (Alamosa Canyon Bridge in USA, Tokyo Rainbow Bridge in Japan, the Geumdang Bridge in Korea, the Gi-Lu cable-stayed bridge in Taiwan and the Golden Gate Bridge in USA). However there are few studies in buildings and even less in existent masonry structures.

EXPERIMENTAL TESTS USING COMMERCIAL AND NEW PROTOTYPE OF WSN PLATFORMS

A single degree of freedom structure represented by an inverted pendulum is one of the simplest examples used by the civil engineers for explaining the fundamentals of the dynamics of structures. In this work, this structure was also used for evaluating the commercial WSN platforms and also a new prototype system that has been especially conceived for fulfilling the demanding requirements of the dynamic monitoring of civil engineering structures. For comparison purposes, both WSN platforms were evaluated considering as references conventional wired based systems consisting in uniaxial piezoelectric accelerometers connected by coaxial cables to a data acquisition system.

The initial tests were meant to observe the performance of commercial off-the shelf WSN solutions (MICA2 platform + MTS400 sensor board). With this purpose, the accuracy of the time series recordings and the resultant frequency domain spectrums of these platforms were evaluated. The results of these tests (Figure 1) indicate the good performance of the commercial WSN platforms for measuring high amplitude vibrations. In this scenario, acceptable correspondence was found with respect to the detected frequencies with both systems (wired and wireless platforms). However, meaningless results were obtained in the mode shape detection task due to the lack of the implementation of synchronization algorithms in the wireless platforms. In low vibration scenarios (signals with amplitudes below 20 mg), as expected, the WSN platforms recorded only noise due to the low resolution of the accelerometers and the ADCs embedded.

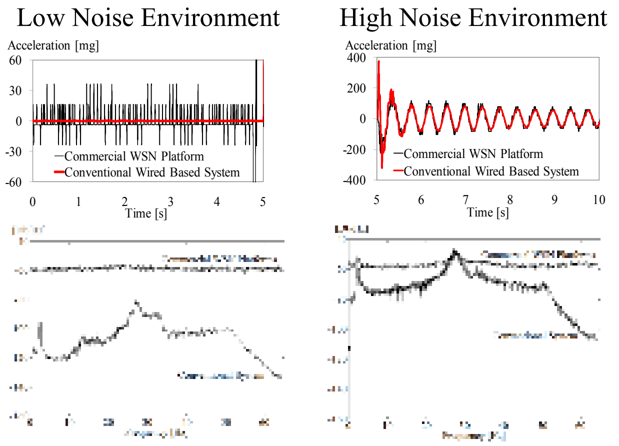

Figure 1: Time and frequency domain validation tests using commercial WSN

Using the developed prototype of WSN platform, a second round of tests was carried out in the pendulum. The results of these tests (Figure 2) show that even for signals with amplitudes below 0.25 mg, the time domain records from the developed system and the conventional wired based accelerometers present remarkable similitude. The resultant frequency domain spectrums also evidence high accuracy. With this respect, even in low noise tests, good agreement was verified.

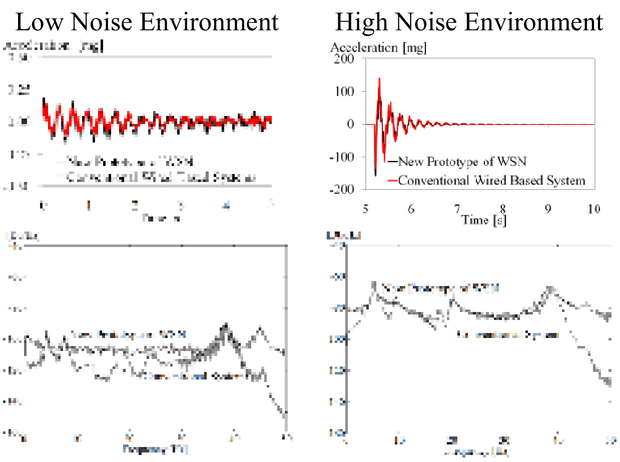

Figure 2: Time and frequency domain validation tests using the developed prototype of WSN

CONCLUSIONS AND FUTURE WORK

The results of the tests carried out using commercial WSN platforms indicated that the use of such sensors, as they are sold, should be carefully considered due to the low resolution of the accelerometers and ADCs embedded as well as the lack of the implementation of communication protocols. On the other hand, the validation tests carried out using the developed prototype of WSN platform indicated that these systems can be positively considered as alternatives for the conventional wired based systems. With the developed systems, accurate estimations of frequencies, dampings and mode shapes could be obtained. Future works may consider further developments in the developed system aiming at improving its reliability in long sampling periods and long term monitoring works.

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