EXECUTIVE SUMMARY

In an effort to develop practical, economical methods for the quantitative nondestructive condition evaluation of bridge conditions, a myriad of non-destructive evaluation (NDE) and structural health monitoring (SHM) methods have been developed with various degree of success. Most of the studied approaches usually include extensive instrumentation set-up that limit their use as a stand-alone maintenance procedure. Despite the numerous achievements made so far, the search for more reliable strategies for damage detection, localization, and quantification in large-scale civil structures is still in progress due to the inherent complexity of the problem and the inevitable variability resulting from measurement errors and environmental factors. In spite of their limited accuracy, visual inspection is the most commonly used practice in monitoring the safety of bridges; but high costs limit its use to infrequent occurrences. In addition, because the intrinsic changes that adversely affect the immediate or future performance of a structural system are usually unknown in advance, continuous and intensive monitoring can be crucial. Real-time SHM can potentially reduce inspection costs, repair costs, and use downtime, all while providing increased public safety.

During the past few decades, several studies have investigated the use of SHM systems based on wired and wireless distributed sensors. The capabilities and robustness of the developed solutions has continuously increased. Yet, one of the identified major challenges towards achieving long-term, autonomous, and continuous structural health monitoring is the powering of the sensors. Embedded and long-term operational requirements preclude the use of batteries, whereas the small volume of the sensor severely limits the energy storage capacity of energy harvesting devices. Therefore, currently there exists a wide gap between the energy that can be scavenged from real-world structures and the energy density required for sensing, computing and communication [1, 2]. Solutions based on classical technologies, which are limited by the power consumption requirements of the sensing systems, will not lead to transformational changes or advance the state of the practice.

In our previous work, we had proposed and successfully demonstrated the proof-of-concept of a self-powered sensor technology that is capable of achieving pico-watt power dissipation [3-8]. The novel ultra-low power technology was developed at Michigan State University. A prototype for a strain sensing system has been tested for pavement monitoring as part of a project funded by the Federal Highway Administration. The sensing system offers several novel features which are not available in other classical SHM methods including: (1) Two orders of magnitude reduction in the operational power requirements. Classical methods of energy harvesting store the generated piezoelectric energy before it is used to power the electronics, thus limiting the efficiency due to power leakage in all the components. Instead, this novel device bypasses all these steps allowing the direct use of the unregulated piezoelectric voltage for computation and data storage; (2) Self-powered continuous sensing (no batteries required); (3) Possibility of deployment in dense networks. Given the small size of the sensors, their projected low-cost, and the fact that they do not rely on batteries, a large number of sensors can be installed near damage sensitive areas allowing for improved resolution and detection capabilities; (4) Autonomous computation and non-volatile storage of sensing variables. The responses from each and every loading event experienced by the structure are recorded; (5) Wireless communication; In order to achieve all the described capabilities, the data is compressed and stored on the sensors as a histogram of cumulative events. Thus, some loss of information is experienced which requires specific data interpretation techniques.