DRISI

Caltrans Division of Research, Innovation and System Information

Research Notes

Next-Gen Monitoring and Evaluation of California Bridges

Developing and deploying a robust and cost-effective wireless sensor network combined with GPS receivers for monitoring a case-study bridge in California.

Geotechnical/ Structures

AUGUST 2015

Project Title:
Next Gen Monitoring and Evaluation of California Bridges

Task Number: 2881

Start Date: February 01, 2015

Completion Date: December 31, 2016

Charly Sikorsky
Research Program Manager
csikorsk@dot.ca.gov

WHAT IS THE NEED?

Despite the decades of research and development in the fields of nondestructive damage evaluation or structural health monitoring, there is currently no definitive approach to estimate the remaining service life or structural capacity of the structure based on measured data. While Caltrans has been one of the leading agencies in deploying instrumentation such as accelerometers, strain gages, and anemometers to monitor bridges in the State, a method to estimate remaining service life from that data remains elusive. The wealth of knowledge collected from such dense instrumentation has helped advance seismic design and retrofit guidance over the years.

However, one of the greatest potentials of the collected data has remained untapped; that is the capability to use the data for real-time or near-real-time assessment of bridges under service loads. This is partially due to the expense associated with installation of traditional wired accelerometers on bridges (both initial and life-time maintenance costs), as well as the lack of a robust damage detection algorithm to evaluate measured data. It may be possible to alleviate this in part due to recent advances in development of inexpensive wireless sensors that provide similar levels of accuracy with a lower initial price and lower life-time cost due to novel and robust designs.

Currently, accelerometers are hard wired giving rise to a cumbersome task for wiring and exposing the sensor system to electro-magnetic interference. This is in addition to the possibility of theft of the copper wire or damage due to environmental exposure. Recent advances in development of inexpensive and accurate wireless accelerometers provides new opportunities to replace the traditional sensors with low-cost modular type alternatives accompanied with portable transceivers for wireless communication.

Wireless sensor networks (WSNs) provide the opportunity for continuous monitoring of the existing and new infrastructure systems, as they offer many attractive possibilities such as ease of installation, wireless communication, possibility of on-board communications, relatively low cost, and small size. With wireless remote transmission capability, real-time visualization of structural response during earthquake and other events is more easily achieved. Furthermore, with elongated life of the deployed sensors there is a great possibility for the long term performance assessment of the bridges under operational conditions.

However, implementations of wireless technologies for condition assessment of civil structures are limited. This is due in part to: 1) the lack of data supporting their utilization as an alternative to wired technologies; and 2) the improper design and integration of WSN to Level III (damage diagnosis, localization, and prognosis) and Level IV (Level III + performance evaluation) condition assessment methodologies.

WHAT ARE WE DOING?

The overall research proposed by the Iowa State University team includes the following steps. First, a well-integrated sensor network consisting of the wireless sensors such as accelerometers and GPS instruments will be designed and then the accuracy and applicability of the array of systems will be validated through an experimental program in a controlled laboratory environment as well as field data acquired from existing wired systems. Next, a robust diagnosis technique for anomaly detection from the monitoring data and rapid assessment of damage and life-cycle operational anomalies resulting from deterioration and minor damages will be developed. Lastly, the fundamentals for an advanced prognosis framework will be proposed.

WHAT IS OUR GOAL?

The objective of this study is to develop an implementable tool by developing and deploying a robust and cost-effective wireless sensor network combined with GPS receivers for monitoring a case-study bridge in California. A reliable Bayesian-based updating scheme to update structural characteristics based on the sensed data, and remaining life-capacity approach that would ensure the accurate evaluation of safety of the bridges in California is also proposed. As part of this work, laboratory tests will be conducted in controlled environments to calibrate the sensors and validate the applicability of the developed framework.

WHAT IS THE BENEFIT?

In this project, the team will identify cost effective wireless sensors including accelerometers, GPS receivers with antenna to measure the carrier phases from the GPS receivers, and consider other wireless device providing relative displacement measures such as tilt-meters. Application of Global Positioning System (GPS) has become an established technique in geodesy and surveying where they can provide absolute displacements with accuracies to a few millimeters. The measurement technique works worldwide, continuously and under all meteorological conditions, and therefore holds promises in monitoring of civil structural systems including bridges (Bishop et al. 1996, Knecht and Manneti 2001, Amiri-Simkooei et al. 2007, Been et al. 2011, and Jo et al. 2013).). The accuracy of the devices will be validated using the lab experiments as well as on-site deployments.

The data collected from such an integrated scheme can then be utilized to i) identify the occurrence of damage, ii) localize the damage, iii) estimate the severity of damage, and finally iv) assess the effect of damage on the remaining life of the structure. These four stages are defined as Level I to IV methods by Stubbs et al. (2000) and have been used extensively in literature to categorize the level of detail involved in system identification methods. In short, such an integrated approach which combines an instrumentation system developed to support the damage identification and localization technique, will enable the Department to estimate remaining service life as well as the safety of the structure (after extreme events).

WHAT IS THE PROGRESS TO DATE?

None, pending start of this task