Special issue on Non-conventional sensing techniques for civil infrastructure system monitoring

Preface

The success of structural health monitoring (SHM) heavily relies on the sensors installed for target infrastructure systems. However, conventional sensors do not necessarily provide data need for proper stewardship of aging infrastructure systems. Therefore, new and innovative non-conventional sensors and sensing technologies are in demand for improved and reliable SHM of civil infrastructure.

A special session on “Non-conventional sensing techniques for civil infrastructure system monitoring” was organized at the 7th international conference on structural health monitoring of intelligent infrastructure, SHMII-7 (2015) held in Torino, Italy on July 1-3, 2015. Due to the support by Prof. Chung-Bang Yun, the Editor-in-Chief of Smart Structures and Systems-An international Journal, a special issue for selected papers at this session was established after the conference with the objectives to introduce: (1) advancements in new sensors and sensing technologies specially tailored for SHM of civil infrastructure, and (2) applications of nonconventional sensing and signal processing techniques to SHM. After rigorous peer review, a total of 16 accepted papers are included in this special issue. The following are the excerpts of these contributions.

The paper “Surface Flatness and Distortion Inspection of Precast Concrete Elements Using Laser Scanning Technology” by Wang *et al.* proposes a technique based on laser scanning to track the problems of the traditional methods which were conducted manually or by contact-type devices with time-consuming, labor-intensive and error-prone. The validation experiments show that the proposed technique can evaluate the surface flatness and distortion effectively and accurately. In the paper “Stochastic Modelling and Optimum Inspection and Maintenance Strategy for Fatigue Affected Steel Bridge Members” by Huang *et al.*, the fatigue crack evolution is considered as a stochastic process and the probability of failure caused by fatigue is predicted over the service life of steel bridge members. A multi-objective optimization problem is proposed and solved to determine the optimized inspection and maintenance strategy for the fatigue affected steel bridge members. Furthermore, in the paper “Identification of failure mechanisms for CFRP-confined circular concrete-filled steel tubular columns through acoustic emission signals” by Li *et al.* , the entire destruction process of carbon fiber-reinforced polymer (CFRP)-confined circular concrete-filled steel tubular (CCFT) columns under uniaxial compression is monitored with the AE technique. The damage evolution process and failure mode of CFRP–CCFT columns are studied based on the recorded AE signals, and the characteristic waveforms of different failure modes are efficiently determined via wavelet analysis. In the paper “Piezoelectric Impedance Based Damage Detection in Truss Bridges Based on Time-Frequency ARMA Mode” by Fan *et al.*, a new structural damage detection approach by analyzing the time domain impedance responses is proposed. With the use of the time frequency autoregressive moving average (TFARMA) model, a damage index based on singular value decomposition (SVD) is defined to identify the existence of the structural local damage. The experimental studies demonstrate that the proposed approach is very sensitive and robust in detecting the bolt damage in the gusset plates of steel truss bridges.

Three papers investigate the identification/monitoring/measurement of input force/load. The paper “Data Fusion Based Improved Kalman Filter with Unknown Inputs and without Collocated Acceleration Measurements” by Lei *et al.* aims to circumvent the limitation of the classical Kalman Filter approach for general real time estimation of both structural state and unknown inputs without using collocated acceleration measurements. Data fusion of acceleration and displacement or strain measurements is used to prevent the drifts in the identified structural state and unknown inputs in real time. The paper “Force monitoring of steel cables using vision-based sensing” by Ye *et al.* develops a novel cable force monitoring system integrated with a vision-based multi-point pattern matching algorithm to envisage the disadvantages of traditional cable force measurement methods. The feasibility and accuracy of the developed vision-based force monitoring system has been validated to show that the vision-based system enables non-contact and high-precision force measurement of steel cables and may be a good alternative for cable force monitoring. The paper “Experimental Validation of Smartphones for Human-induced Loads Measurement” by Chen *et al.* presents extensive experiments conducted in two stages to investigate the opportunity of smartphones for their use in structural live load measurements. Shaking table tests are carried out in the first stage using selected popular smartphones. In the second stage, three-dimensional motion capture technology is employed to explore the capacity of smartphones for measuring the movement of individuals in walking, bouncing and jumping activities.

There are two papers studying on the optical fiber based sensing techniques. In the paper “Concrete pavement monitoring with PPP-BOTDA distributed strain and crack sensors” by Bao *et al*., the feasibility of using telecommunication single-mode optical fiber as a distributed fiber optic strain and crack sensor is evaluated. Unlike the conventional point FBG sensors, the PPP-BOTDA sensors can be implemented to measure distributed strains and detect multiple cracks in full-scale concrete panels using commercial single mode optical fibers, providing a cost-effective sensing technology for pavement monitoring. In the paper "Sensing properties of optical fiber sensor to ultrasonic guided waves" by Zhou *et al.*, optical fiber sensors based on Mach-Zehnder interferometer are investigated analytically and then experimentally. The sensing properties of surface bonded optical fiber is analyzed further, used a spiral shape optical fiber sensor to receive the guided waves, and the sensitivity to guided wave of different frequencies by the piezoelectric sensor and optical fiber sensor are compared.

Furthermore, another two papers presenting technologies related to wireless sensing network (WSN). The paper "Electromagnetic Energy Harvesting for Wireless Sensing during Earthquakes" by Shen *et al.* presents a comprehensive study on harvesting energy from earthquake-induced structural vibrations, which is typically of low frequency, to power WSNs. A macroscale pendulum-type electromagnetic harvester (MPEH) is proposed, analyzed and experimentally validated. The experimental results indicate that the proposed models are capable of providing rough estimation for output power and harvested energy. The paper "The effect of non-synchronous sensing on structural identification and its correction" by Feng and Katafygiotis investigates the effect of non-synchronous sensing when using wireless sensors on structural identification and to attempt correcting such errors in order to obtain a better identification result. The effect of synchronization errors in the measured output responses on structural identification and the application of this correction method are demonstrated using simulation examples. The results show that even small synchronization errors in the output responses can distort the identified modal and stiffness parameters remarkably while the parameters identified using the proposed correction method can achieve high accuracy.

Finally, two papers investigate optimization problem for optimal sensor placement. In the paper "A new swarm intelligent optimization algorithm: Pigeon Colony" by Yi *et al.*, a new pigeon colony algorithm (PCA) based on the features of a pigeon colony flying is proposed for solving global numerical optimization problems. Comparative results between the PCA, standard genetic algorithm and particle swarm optimization show that PCA has the best global convergence, smallest cycle indexes, and strongest stability when solving high-dimensional, multi-peak and complicated problems. The paper "Optimal placement of long-gauge sensors for deformation distribution identification" by Zhang *et al.* proposes a novel sensor optimal placement framework using long-gauge fiber optic sensors to identify deformation distribution of tird arch bridges. This work involves the research on the characteristic curve formed by bending macro-strain curve under multiple target load conditions, so as to work outseveralplans of optimal sensor placement accordingly. Compared with traditional sensor placement scheme, an example of tied arch bridge shows that the proposed framework is characterized by the anti-noise and robust performance.

The guest editors expect this special issue will keep the attendees abreast of new non-conventional sensing techniques that can potentially revolutionize the way how infrastructure is monitored. The publishing of this special issue could have not been possible without the effort of all the anonymous reviewers, who have reviewed submitted manuscripts and provided constructive comments on a very timely manner. Also, the guest editors would like to express special thanks to the Editors-in-Chief of Techno-Press, Prof. Chung-Bang Yun for his support of the successful publication of the special issue. Last but not the least, many thanks to all the authors who contributed their precious works to the special issue.

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