Title: Structural Anomaly Detection using Edge Intelligence on Vibration-based IoT Sensing

ABSTRACT

Structural anomaly detection is a critical aspect of long-term structural health monitoring for civil infrastructure. It refers to identification of irregularities or deviations in the structural integrity, which is different from data anomaly or loading anomaly. Similar to pulse diagnosis in Chinese Medicine, our team are developing vibration-based structural anomaly detection strategies, built upon advanced digital signal processing and lightweight artificial intelligence. The first strategy is to develop reference-free dynamic displacement estimation and is further extended as interstory drift estimation for rule-based building anomaly detection under earthquake events; also, we develop a data-driven Gaussian Process Regression framework for adaptive bridge anomaly detection under train-crossing events. The second strategy is to develop noise-robust blind source separation with shapelet transform for sudden damage detection, which is a fully automated and universal solution for different structures; it can detect time stamps and locations of multiple sudden damages with low signal-to-noise ratios. The third strategy is to develop semi-supervised deep learning model for train-track anomaly detection. It effectively capturing essential signal features from raw train-induced vibration signals by projecting them into a latent space, which is utilized for both reconstruction and classification of structural anomalies; it is applied to detect wheel flat defect and rail track changes. The impact of these studies is further enhanced by deploying these strategies on wireless IoT sensing systems with an edge intelligence framework, where lightweight artificial intelligence meets edge computing. In particular, a cost-effective IoT prototype developed by our team, aka LiftNode, is utilized to execute the above algorithms onboard and helps to demonstrate the effectiveness and scalability of the proposed solutions. Our research efforts advance the knowledge and close the gaps for long-term structural health monitoring of large-scale civil infrastructure.

BIOGRAPHY

Dr. Fu is an Assistant Professor and MSc (Civil) Director in the School of Civil and Environmental Engineering, Nanyang Technological University (NTU), Singapore. He received B.S. and M.S. in civil engineering from Tongji University in 2012 and 2014, respectively, and earned Ph.D. in civil engineering from the University of Illinois at Urbana-Champaign (UIUC) in 2019. Prior to joining NTU in 2021, he was a research scientist at Embedor Technologies to commercialize the IoT sensor developed in the Ph.D. study, funded by NSF-SBIR. He then became a postdoctoral research associate in the Resilient Extra-Terrestrial Habitats Institute at Purdue University, funded by NASA. His research interests include IoT sensing and digital twin modelling for structural health monitoring. He has published 40+ journal papers, hold 4 patents, and secured research grants of two million SGD as PI or co-PI (with separate accounts) in Singapore. He acted as the key personnel for the development of *Xnode* and enabled wireless construction monitoring of Ain Dubai Ferris Wheel and many railroad bridges in North America. His NTU team is currently working on next-gen wireless SHM systems based on edge intelligence, aka, *LiftNode*. The first version has been deployed in Bukit Panjang Railway tunnel for long-term monitoring.