Integrate infrastructure performance monitoring using automatic crack evaluation system and convolutional neural network

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Principal Inverstigator(s):

Suyun Ham

The University of Texas at Arlington

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The University of Texas at Arlington

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Developing automatic fault evaluation systems for the improvements of infrastructure maintenance

The proper maintenance and operation of deteriorating infrastructures require timely detection and precise diagnosis of any dangerous damage and accurate estimation of possible structural performance degradation induced by the damage. Although NDT and SHM has been well-studied, there still exist technical challenges in the current NDT system. The challenges include raveling condition survey with time-consuming and labor-intensive field tests, operating slowly caused traffic disruptions, focusing on mostly external surface conditions, not considering structural performance that is not readily available for engineers, decision-makers, and stakeholders. The overall goal of this study is to develop a framework integrating infrastructure performance evaluation using advanced evaluation system so-called automatic crack evaluation system (ACES) and advanced machine learning (ML) techniques (e.g., convolutional neural network (CNN)), which ultimately enable reliable traffic disruption-free assessment, provide structural performance data incorporating with the damage, and help accurate prediction of structural damage with proper damage classification.

Problem Statement

The maintenance of transportation infrastructures (e.g., bridges) has become a major concern for safety and economic loss with many factors such as increasing traffic volumes, deterioration. In particular, deterioration (e.g., external and internal damages) of infrastructures can significantly impact infrastructure service life and often require extensive repairs or replacements. For improving service life, a structure survey of its condition is required for transportation agencies not only to ensure roadway safety but also to provide proper time for appropriate preservation and rehabilitation treatments. Structural health monitoring (SHM) and nondestructive testing (NDT) techniques have been widely studied and utilized in infrastructure evaluation for maintenance over the past decades. There are limitations of the traditional SHM and NDT, including manual inspection, visual-based methods which are time-consuming, labor-intensive, and error-prone to realize in some situations. Advanced sending NDT and SHM has gained attention for addressing the limitations: advanced sensing (e.g., smartphones, automated vehicles) for surface condition assessments acoustic-ultrasound, electrochemical sensors, and Fiber Bragg grating sensors. There are also current NDT techniques focusing on crack evaluation: a damage monitoring system with GIS and acceleration, crack development study, in-situ monitoring. Previous attempts have persistent issues to identify the damage, especially "internal" deteriorations (e.g., delamination, cracks) requiring lane closure due to their slow speed or stationary measurement on a bridge (e.g., chain drag, impact-echo, contact 3D tomography).

For performing accurate structural assessments in a real-time manner, currently, PI developed rapid disruption-Free damage inspection without interrupting traffic so-called automatic crack evaluation system (ACES) with the current state bridge inspection project. The noncontact manner in the system enables faster, easier, and more accurate evaluations for improving timely maintenance. The rapidly obtained mechanical waves propagate through infrastructure elements (e.g., bridge decks) to provide a 2-D or 3-D damage image similar to an MRI, to show a hidden damage map.

Objectives

The main objectives of this study are:

- to establish ACES data with the high-speed reference-free damage detecting system and state-of-art signal processing algorithms to enhance damage recognition capability and speed;
- to perform FE modeling for an efficient structural performance incorporating ACES data; and
- to develop a framework leveraging advanced ML that provides a quick decision of its structure performance to make reliable asset management decisions.

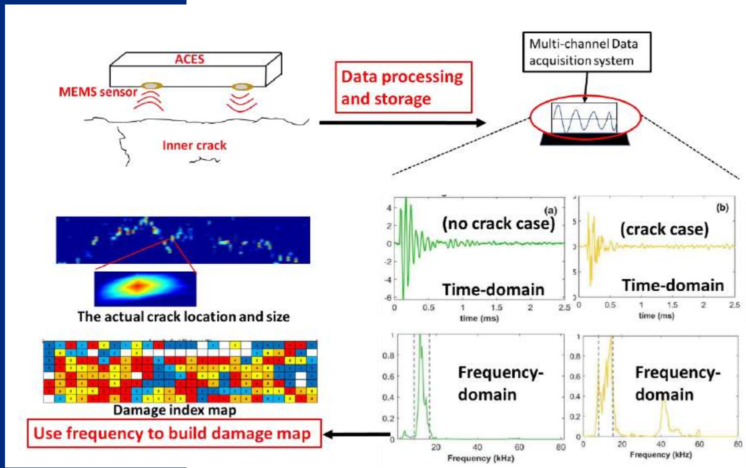

Figure 1. The concept of ACES data collecting and post-processing

Intended Implementation of Research

The significant outcome is to develop a highly reliable and efficient NDT system leveraging state-of-the-art prediction models for the improvements of infrastructure maintenance. If successfully achieved, after the deep-learning training of FE results with damage location, CNN help to understand and provide a quick solution of total infrastructure evaluation effectively. Ultimately, the proposed systems will in-turn, provide an effective monitoring system and ideal asset management strategies to extend the service life of the transportation infrastructure. Thus, the study will meet transportation departments' goals and objectives for transportation safety in urban and rural areas. The technology can be applicable for other data analysis or classification problems as well as a specialization for being able to pick out or detect patterns by CNN. This cutting-edge neural network technique has proven its statistical power in identifying the unknown state of objects, including image classification and natural language process. Findings will support curriculum improvements at UTA. The research team will develop educational modules to discuss this project with undergraduate and graduate students at UTA.

The inspection application and ML model produced in this project will be used as class materials to show real-world applications in Region 6 area in multiple courses at UTA, such as 'Sensing and Machine Learning, 'Physics-based Model Design', and 'Advanced Sensors'. The research team will support one Ph.D. student and one MS. student at UTA under this project. Students from underrepresented populations will be considered a high priority.

Anticipated Impacts/Benefits of Implementation

There is a need for rapid and accurate damage evaluation due to the limitation of previous research efforts presenting slow damage evaluation techniques and missing integration of structural performance incorporating with the damage. Developing assessment framework using ACES leveraging advanced ML framework and asset management plans, this study will have positive impacts on the communities of Region 6. The broader impacts will be by leading efficient and effective transportation planning and operation in Region 6. As understanding current practice in evaluation and monitoring of transportation infrastructure capabilities is critical in achieving the expanded transportation aspects, the proposed project contributes to provide innovative strategies for assisting investment in new sensor, data collection, structural performance assessment using deep-learning technology, and next-generation visualization technology.

Web links

- Tran-SET's website
  https://transet.lsu.edu/research-in-progress/

Tran-SET

Tran-SET is Region 6's University Transportation Center. It is a collaborative partnership between 11 institutions (see below) across 5 states (AR, LA, NM, OK, and TX). Tran-SET is led by Louisiana State University. It was established in late November 2016 "to address the accelerated deterioration of transportation infrastructure through the development, evaluation, and implementation of cutting-edge technologies, novel materials, and innovative construction management processes".

Learn More

For more information about Tran-SET, please visit our website, LinkedIn, Twitter, Facebook, and YouTube pages. Also, please feel free to contact Dr. Momen Mousa (Tran-SET Program Manager) directly at transet@lsu.edu.