Study on hybrid model combining super learner and physics-based models for SHM in bridges using low-cost BWIM

Developing quicker, cost-effective alternatives for bridge damage inspection

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Principal Inverstigator(s):

Suyun Ham

University of Texas at Arlington

s.ham@uta.edu

Shih-Ho Chao

University of Texas at Arlington

shchao@uta.edu

Kyeong Rok Ryu

University of Texas at Arlington

kyeongrok.ryu@uta.edu

Lead Institution:

University of Texas at Arlington

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$122,000

Many structural health monitoring (SHM) techniques have been devised over the past decades. However, there is no one-size-fits-all solution that can be applied to all bridges for structural assessments. Bridge-based weight-in-motion systems (BWIM) use the structure's response to estimate vehicles' load distribution. This technology is primarily used to obtain vehicle axle weights efficiently in public. BWIM can be a candidate that overcomes the shortfall of SHM. The use of BWIM systems for SHM has rarely been investigated. The objectives are i) to study and deploy low-cost BWIM sensors for accurate SHM, ii) to evaluate the S-BWIM system, and iii) assessment of the hybrid model capacity combining physics-based mathematical models (PSM) and practical machine-learning (ML) models. A new low-cost BWIM system verified with numerical results will be installed in the local area, Dallas, and Fort Worth (DFW). This study will help Region 6 communities, where low-cost measurements are already used, and prediction models are publicly available for monitoring both traffic loads and bridge conditions. The development of a hybrid model generally adaptable for various conditions of bridges will be a major contribution to the research community. A comparative study of the proposed machine learning algorithm (super learner) with low-cost BWIM sensors will also be implemented in Region 6.

Problem Statement

Bridges are fundamental to infrastructure management. The main challenge is the aging of these transportation infrastructure without tools that perform accurate structural assessments in real-time. Cost-effective and reliable assessment procedures are needed. Many structural health monitoring (SHM) techniques have been devised over the past decades. However, there is no one-size-fits-all solution that can be applied to all bridges. BWIM technology is primarily used to obtain vehicle axle weights efficiently in public. BWIM can be a candidate that overcomes the shortfall of SHM. The use of BWIM systems for SHM has rarely been investigated in literature and few precedents.

Objectives

The main goal of this study is:
1) To study and implement low-cost BWIM sensors that identify damage on bridges
2) to test and evaluate the S-BWIM system for monitoring bridge and improving BWIM accuracy for bridges under different conditions (e.g., weather, traffic)
3) to develop a BWIM detection tool based on a novel hybrid prediction model (super learner) that combines

- physics-based mathematical models (e.g., structural influence line and speed-correction procedure)
- machine-learning models (e.g., artificial neural network and gradient boosting).

Intended Implementation of Research

Education, Workforce Development, and Outreach: Research results will facilitate curriculum improvements at UTA. The research team will draft educational modules to discuss this project with undergraduate and graduate students. The low-cost BWIM sensing application and ML model produced in this project will be used as materials to show real-world applications in Region 6 via multiple courses at UTA. These include 'Sensing and Machine Learning, 'Physics-based Model Design', and 'Advanced Sensors'. The research team will support one Ph.D. student and one M.S. student at UTA for this project. Students from underrepresented populations will be considered a high priority. The research team shall implement the following:

• The approach will help bridge engineers efficiently detect vehicle weight and bridge conditions with acceptable accuracy using low-cost BWIM.

• Incorporated information from the extracted axle weights, GVW and SHM data will improve operations and decisions by traffic and bridge engineers in real-time.

• Online-learning material will be developed to assist current practitioners for realistic workforce development (YouTube and webinar).

Impacts/Benefits of Implementation

The main deliverables of this project include:

• The latest novel hybrid model algorithm combining physic-based/structural–based mathematical model (PSM) and Machine learning (ML), and software to track damage by using low-cost BWIM.

• High-resolution BWIM maps around Region 6.

• An easily accessible decision toolkit for situations based on practical and reliable prediction models for accurate bridge weigh-in-motion (BWIM) technique for public agencies with corresponding utilization strategies.

• Technical papers published in high-rank journals such as Journals of ASCE.

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.