Transportation Consortium of South-Central States (Tran-SET)

# Development, Training, Education, and Implementation of Low-cost Sensing Technologies for Bridge Structural Health Monitoring (SHM)

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Project No. 17STUNM02

PI: Dr. Fernando Moreu, Dr. Chris Lippitt (UNM)

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*Developing cost-effective technologies such as drones and augmented reality tools for structural health monitoring*

This research project develops cost-effective technologies for structural health monitoring applications that will be introduced to both practitioners and students. These new technologies, including Arduino, 3D printing, wireless smart sensors, drones, and HoloLens, can be applied towards the maintenance and health monitoring of the transportation infrastructure in the metropolitan and rural areas. These tools can also promote education and workforce development in infrastructure condition assessment for transportation engineering, in collaboration with transportation infrastructure managers. The following topics were taught: fundamentals on transportation structures decay and deterioration; Arduino sensors for transportation infrastructure inspection; the use of drones for structural inspections; and augmented reality tools (HoloLens) to enhance infrastructure inspection.

## Problem Statement

Bridge inspections are time-consuming, expensive, and are often conducted in risky environments with limited access to inspectors. In addition, three significant challenges affect bridge inspections today: (1) bridge inspectors need to visually evaluate all bridge structural elements and thereby are exposed to unsafe environments. This is a major challenge in tall and long steel bridges where elements are difficult to access; (2) Visual observations without measurements cannot quantify defects, and are in general subjective and depend on the experience of the inspector; (3) When infrastructure managers need to quantify the structural properties of bridges being inspected, a significant amount of money must be invested in equipment to collect objective data, such as timber testing equipment for timber bridges or non-destructive testing (NDT) equipment generally used by highly specialized companies.

To solve the aforementioned problem, this project seeks to increase the technical ability of the inspector, with an emphasis on using bridge assessment to inform bridge management decisions. In addition, students and inspectors will be exposed to low-cost technology and sensors that will provide researchers with data to evaluate the effectiveness of such tools for implementation in the transportation industry.

## Summary

This project aims to:

- Develop low-cost sensing design, prototype, testing, and optimization: selecting off-the-shelf available technologies that can be quickly built by transportation engineers.
- Providing guidelines, and educational materials such as videos, and presentations to teach SHM techniques to non-technically trained in electrical engineering or computer science professionals.
- Teach high school students and college students on the use of drones for bridge inspection. Field training to expose different drones to college students at the Albuquerque Balloon Museum and other sites. The team flew the drone with a laser to collect bridge vibrations.
- Develop outreach activities to New Mexico Community College students on structural engineering and civil engineering.

## Findings

After building their self-built Arduino sensors, the high school students tested their setup successfully with the Arduino Integrated Development Environment (IDE) software. Subsequently, they tested their sensors at the Tramway to Sandia Peak to monitor the Structural behavior of the tramway car. At the tramway, the high school students attended a tour into the operating room to watch how the tramway car is operated. They learned the speed at which the tramway car runs while going upwards and while going downwards, the maximum overturning force of pylons, that must be kept under control always. After knowing the interesting facts and the technical background of tramway, the high school students performed inspected the tramway car with their self-built Arduino sensors.

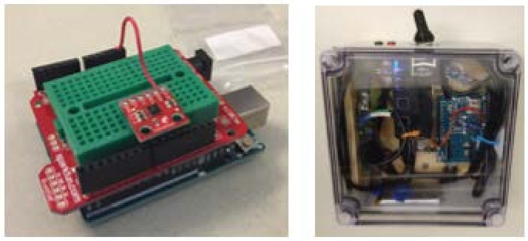

**Figure 1. Low-cost sensor for SHM (basic sensor and complete sensor).**

The mentors instructed the high school students how to perform their experiment. The students placed their sensors on the floor of the tramway car to enable the capture of the movements of the whole car in all the directions, including longitudinal direction (the direction the Tramway car moves forward, the transverse direction (the direction perpendicular to the longitudinal direction), and the gravity direction, (the vertical direction). There are 2 pylons along the path of the tramway car from the foothill to the peak.

**Figure 2. Drone training of high schoolers and undergraduate students by Dr. Lippitt and Dr. Zhang.**

These were the critical locations as when the tramway car passes the pylon, it creates oscillations of the tramway car. The students collected the data along the journey and especially when the tramway car passes the Pylon to compare their results. The vibration is little until the tramway car passed the pylon whereto the speed of the tramway car was reduced to control the dynamic load that could develop on the pylon. The tramway car developed oscillations on the sideways which could be felt or sensed. The data was acquired during the entire journey in the Sandia Peak. After the onward journey to the top of the Sandia Peak was completed, the collected data were processed and analyzed. By the end of the trip, the students were able to interpret the results themselves. The data in the tramway car was collected via the Arduino IDE 1.8.3 software and then visualized using the Fast Fourier Transformation (FFT) in MATLAB. The FFT is used to convert any time history data into Frequency Domain analysis. The tramway car while passing the pylon was swaying around 2 to 4 times every second in both longitudinal and the transverse directions.

## Impacts

New technologies are now mastered by high school students, as well as other faculty and professionals from the summer 2017 training sessions. Industry and government is aware of this initiative and is considering implementing in their staff and their operations for transportation infrastructure assessments. The project also provided opportunities for research and teaching in transportation and related disciplines such as low-cost sensors, augmented reality for inspection of bridges and structures for undergraduate and graduate students. The project improved the performance, skills, or aptitudes of members of students, thereby improving their access to or retention in transportation research, teaching, or other related professions.

## 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 Mr. Christopher Melson (Tran-SET Program Manager) directly at transet@lsu.edu.