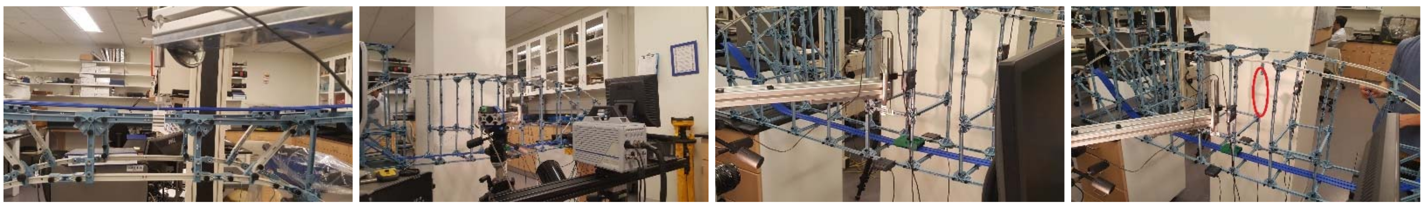
Semi-Annual Progress Report

Project Number and Title: 3.8 Bridge Modal Identification via Video Processing and Quantification of Uncertainties
Research Area: Thrust 3 – New Systems for Longevity and Constructability
PI: *Zhu Mao, University of Massachusetts Lowell*
Co-PI(s): *Co-PIs and home institution(s)*
Reporting Period: *04/01/2019-09/30/2019*
Date: *Date*

Overview: **(Please answer each question individually)**

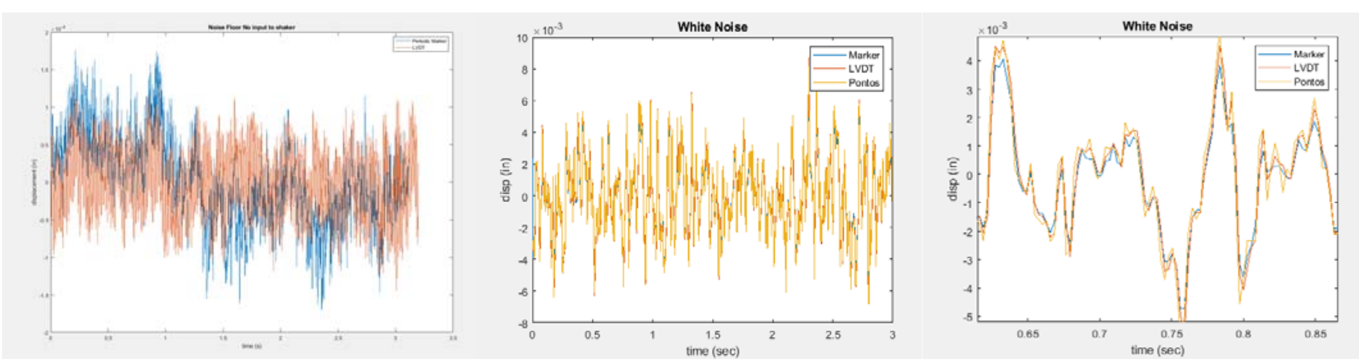
The project aims to investigate the capability of applying non-contact optical sensing and computer vision analysis to identify the structural dynamics and integrity assessment. In this reporting period, we have been focusing on studying the new trackers to facilitate better measurement quality, and applied the customized optical targets onto two lab-scale bridge models. As a benchmark, high fidelity LVDT sensor is employed to provide validation.



(a) (b) (c) (d)

Figure 1. Bridge model testing with customized optical target. (a) and (b): two different bridge models with the setup of LVDT sensor and high speed camera; (c) and (d): zoom in of the optical target and damaged truss.

The customized new optical target has advantage of easy placement and high accuracy. The results in Figure 2-(a) demonstrate a background noise measurement while the target has no external excitation applied. The performance of the approach with the new customized optic tracker is shown as good as the LVDT sensor's, and 10^{-4} inch is a high quality for transportation infrastructure measurements. A contrived test is also conducted to measure displacements due to white noise excitation and on the order of 10^{-3} inch, the result is also compared with commercial optical sensing equipment with different displacement reconstruction algorithm, as shown in the Figure-2(b, c).

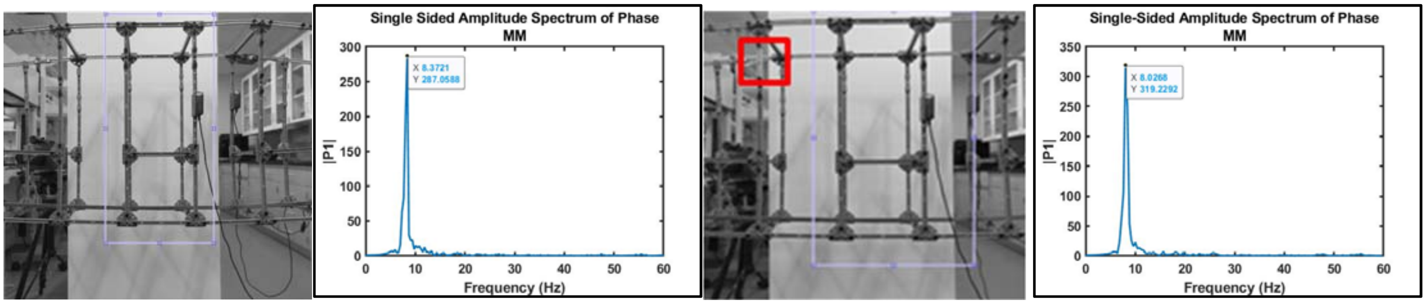


(a) (b) (c)

Figure 2. Comparison of the non-contact measurement with LVDT and commercial sensing equipment Pontos. (a) measurement of the noise floor (10^{-4}) without physical excitation; (b) response due to white noise excitation; (c) zoom in of (b) which indicates nice agreement between the new sensing technique with the state-of-the-art

Optical sensing is applied to extract modal frequency and mode shapes of the testing bridge model, and the modal information of the bridge model in Figure 1-(b) is extracted as shown in Figure 3. In Figure 3-(c), a truss element is disabled to reduce the global stiffness. As a result, the power spectrum shifted to the low frequency side. However, such movement is unsurprisingly insensitive to the environment variability, as well as hard to be utilized for damage localization.

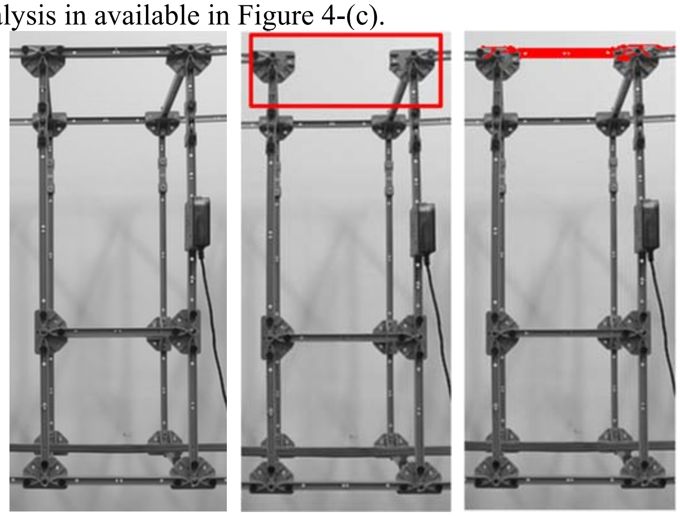
Machine learning based computer vision is also adopted in this reporting period, and such technique automatically identifies the missing component, and highlights the damaged area, as Figure 4 illustrates.



(a) (b) (c) (d)

Figure 3. Extraction of the modal information via phase-based motion extraction. (a) and (b): the video snapshot and extracted power spectrum for undamaged condition; (c) and (d): the video snapshot and extracted power spectrum for damaged condition in the boxed area

Multiple damage scenarios were conducted in this reporting period, and in Figure 4, a truss element is removed as an example. Figure 4-(b) highlighted the area with missing piece, compared to the baseline in Figure 4-(a), and the localized damage via computer vision analysis in available in Figure 4-(c).



(a) (b) (c)

Figure 4. Missing component detection via computer vision. (a) undamaged benchmark; (b) structure with missing truss; (c) computer vision analysis with missing part identified

All the activities in this reporting period is to enhance the non-contact capability in acquiring the system state awareness, and have shown great potential in integrating with other state-of-the-art sensing modalities to make a reliable assessment of transportation infrastructure.

Participants and Collaborators:

The effort is leaded by Professor Zhu Mao, Department of Mechanical Engineering at University of Massachusetts Lowell, and there are a number of mechanical engineering graduate/undergraduate students participated.

Level	Name	Responsibility
Graduated (SU2019)	Aral Sarrafi	Theoretical investigation and supervision the tests
Graduate	Celso doCabo	Key personnel to conduct the theoretical investigation
Graduate	Nick Valente	Idea discussion, and helping on tests
Graduate	Matt Southwick	Idea discussion, and helping on tests
Undergraduate	Brett Daniels	Data acquisition

Major collaborator is Professor Tzuyang Yu, Civil Engineering at UMass Lowell

In the Spring of 2019, the PI taught a graduate-level course MECH.5230 Structural Health Monitoring in regard to the transportation infrastructure reliability and sustainability.

TIDC Transportation Infrastructure Durability Center AT THE UNIVERSITY OF MAINE

Planned Activities:

In the next reporting period, we will focus on the following challenges.

- The lab-scale truss bridge model will be kept utilized as the test bed, to provide realist vibrational data.
- Non-contact sensing will be adopted and more in-depth investigation of selecting pixels, especially a big number of pixels to take advantage of the averages. By doing this, a better estimation of the modal information will be expected, but this is contingent on the data quality at the selected pixels. Trimming and cropping the videos prior to calculating the expected resonance frequencies may also help enhance the performance.
- Applying other sensing modalities, and maybe collaborating with other projects, in identifying frequencies using conventional data acquisition method. This will help design a better band-pass filter in getting mode shapes and motion magnification results. This effort will be cohered with other UMass Lowell faculty on a campus bridge.
- Machine learning algorithms will be preliminarily studied in the next reporting period to provide an option in classifying different damaged types.