<u>Bi-Monthly Progress Report</u>:
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
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Co-PI(s): *Co-PIs and home institution(s)*
Reporting Period: *6/1/2019 – 7/31/2019*
Date: *07/31/2019*

<u>Overview:</u>

The project aims to investigate the capability of applying computer vision analysis and machine learning to identify the structural dynamics through camera measurements. The team has leverage the previous research on phase-based motion magnification to extract the modal information of a bridge in a portable, non-contact, and inexpensive way. Figure 1 below demonstrates the phased-based motion magnification to the videos captured at the Rourke bridge across Merrimack River in the last reporting periods. A more detailed computer-vision based analysis has conducted and on the right of Figure 1, spectrum of the vibrational signal analyzed at the red-boxed areas is provided.

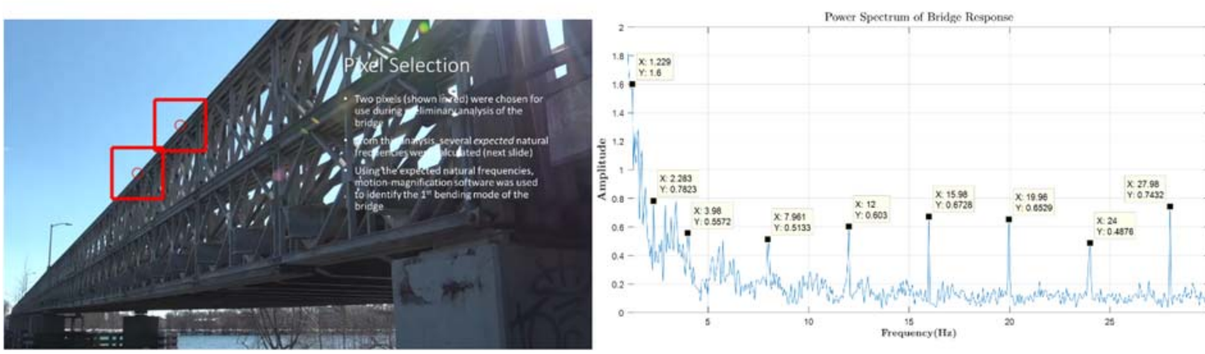

Figure 1: *Recorded image/video data on Rourke bridge and selected pixels*

As mentioned in the previous reports, due to the poor observability, the detection of damages is a challenging task. A lab-scale structure will be adopted at this moment, which is a truss bridge model, to kick off the proof-of-concept pursuit. A finite element model is established in this reporting period, and 7 possible disabled elements are included as potential damages. Corresponding modal information is calculated under the Nastran environment and drifting of resonance frequencies is observed when there is damage involved. Figure 2 shows the sketch of the truss bridge and all the circled elements are the candidate elements involving damages. On the left of Figure 2, first 7 non-repeated modal frequencies are listed and due to the symmetric geography, there are about 4 repetitions for each mode.

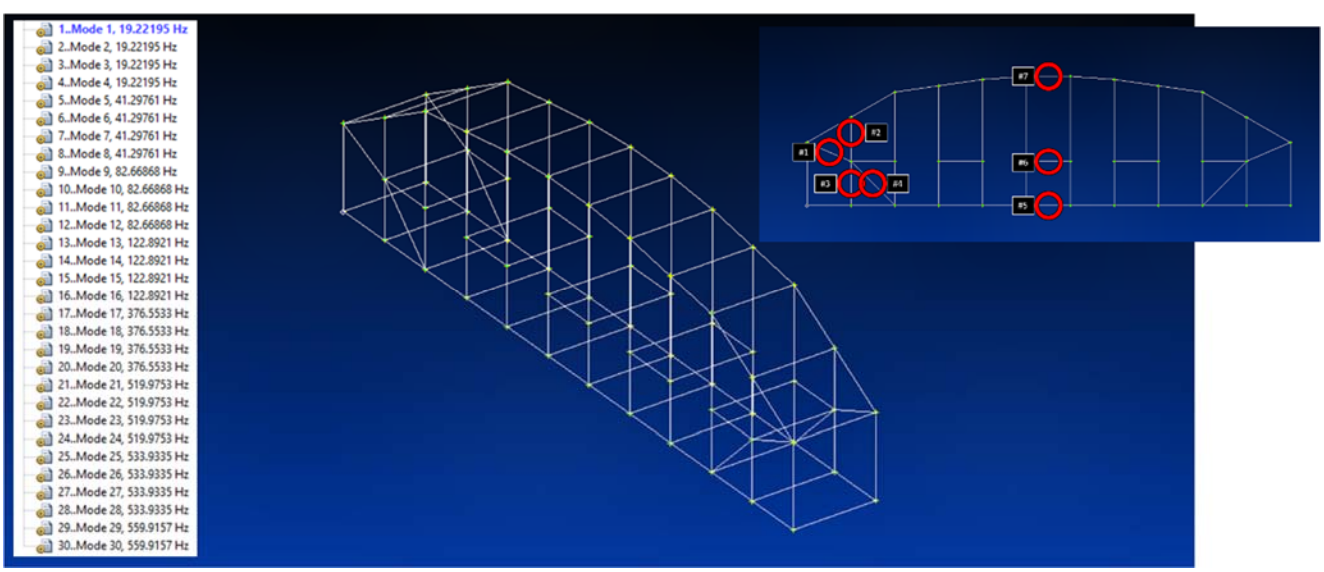

Figure 2: *Contrived truss bridge model and finite element model simulation.*

In Table 1, the deviation of the first 7 modal frequencies from the undamaged baseline is tabulated. Decreasing is highlighted in red while increasing of frequency is marked in green. There are certain damages which do not affect particular modes, so the frequencies do not change. This brings up a challenge that damages may not be easily identified by only comparing the frequencies for such a geometric complexity on most of the bridges. More sophisticated algorithms need to be developed to process the monitoring data and evaluate the condition of bridges.

Table 1: *Undamaged and damaged frequencies of the first 7 unrepeated modes*

[Hz]	Undamaged		Damage A		Damage B		Damage C		Damage D		Damage E		Damage F		Damage G	
Mode 1	19.222	(4)	-0.1315	(1)	-0.0010	(1)	0.0000	(3)	-0.1435	(1)	0.0000	(2)	0.0000	(2)	0.0000	(2)
			0.0000	(3)	0.0000	(3)	+0.0011	(1)	0.0000	(3)	+0.5126	(2)	+0.5118	(2)	+0.5083	(2)
Mode 2	41.298	(4)	-0.4140	(1)	-0.0012	(1)	0.0000	(3)	-0.4082	(1)	0.0000	(2)	0.0000	(2)	0.0000	(2)
			0.0000	(3)	0.0000	(3)	+0.0159	(1)	0.0000	(3)	+0.3276	(2)	+0.3253	(2)	+0.3148	(2)
Mode 3	82.669	(4)	-1.3729	(1)	-0.0032	(1)	0.0000	(3)	-0.7948	(1)	0.0000	(2)	0.0000	(2)	0.0000	(2)
			0.0000	(3)	0.0000	(3)	+0.1644	(1)	0.0000	(3)	+0.0130	(2)	+0.0126	(2)	+0.0110	(2)
Mode 4	122.892	(4)	-15.4660	(1)	-1.4315	(1)	0.0000	(3)	-4.2807	(1)	0.0000	(4)	0.0000	(4)	0.0000	(4)
			0.0000	(3)	0.0000	(3)	+9.2878	(1)	0.0000	(3)						
Mode 5	376.553	(4)	0.0000	(3)	-52.8651	(1)	0.0000	(3)	-127.8458	(1)	0.0000	(4)	0.0000	(4)	0.0000	(4)
			+2.0099	(1)	0.0000	(3)	+63.1682	(1)	0.0000	(3)						
Mode 6	519.975	(4)	0.0000	(4)	0.0000	(4)	0.0000	(4)	0.0000	(4)	0.0000	(2)	0.0000	(2)	0.0000	(2)
											+20.7345	(2)	+3.4536	(2)	+35.0282	(2)
Mode 7	533.934	(4)	0.0000	(3)	0.0000	(3)	0.0000	(3)	-0.0020	(1)	-0.2687	(2)	0.0000	(2)	-0.1664	(2)
			+0.0001	(1)	+0.0020	(1)	+0.0001	(1)	0.0000	(3)	0.0000	(2)	+0.0253	(2)	0.0000	(2)

Planned Activities:

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

- The lab-scale truss bridge model will be utilized as a test bed, and vibrational testing will be conducted in the next reporting period to collect realistic data before identifying the damages.
- 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.
- Machine learning algorithms will be preliminarily studied in the next reporting period to provide an option in classifying different damaged types.