Quarterly Progress Report

Project Number and Title: C11 Development of a system-level distributed sensing technique for long-term monitoring of concrete and composite bridges
Research Area: Thrust 1: Transportation infrastructure monitoring and assessment for enhanced life
PI: Tzuyang Yu (UML)
Co-PI(s): Susan Faraji (UML), Xingwei Wang (UML), Zhu Mao (UML), Bill Davids (UMaine), Ehsan Ghazanfari (UVM)
Reporting Period: 07/01/2021~09/30/2021
Date: 09/30/2021

Overview:

The research problem we are trying to solve is the long-term monitoring problem of bridges (e.g., concrete and composite bridges), using multiple modes of sensing technology including fiber optic, video motion, and electromagnetic sensors. In the past quarter, we focused our efforts on processing the collected sensor data from a candidate bridge (L-15-076 Rt. 3 Bridge) in Lowell, MA for instrumentation.

Table 1: Task Progress			
Task Number	**Start Date**	**End Date**	**Percent Complete**
Task 1	01/01/20	02/28/20	100%
Task 2	01/01/20	03/31/20	100%
Task 3	01/01/20	07/31/20	100%
Task 4	07/31/20	08/15/20	100%
Task 5	08/15/20	08/20/20	100%
Task 6	08/15/20	12/31/21	45%
Task 7	08/20/20	12/31/21	0%
Task 8	01/01/20	12/31/21	10%

Table 2: Budget Progress		
Entire Project Budget	**Spend Amount**	**Spend Percentage to Date**
$166,304 (Year 1)	$58,206	35%

Characterization of dynamic baseline on the L-15-076 Rt. 3 Bridge (Lowell, MA) – We used a commercial laser Doppler Vibrometer (LDV) system (OptoMat, SWIR laser) to develop the dynamic baseline data of the bridge. Figure 1 shows the L-15-076 Bridge. The LDV was configured at 15.47 m from the mid-span of the bridge. The sampling rate was 4.5 kHz. Traffic-induced vibration of the bridge was measured for two periods (5.5 seconds and 4.1 seconds) of time. Figure 2 shows the LDV measurements of mid-span vibration of the bridge.
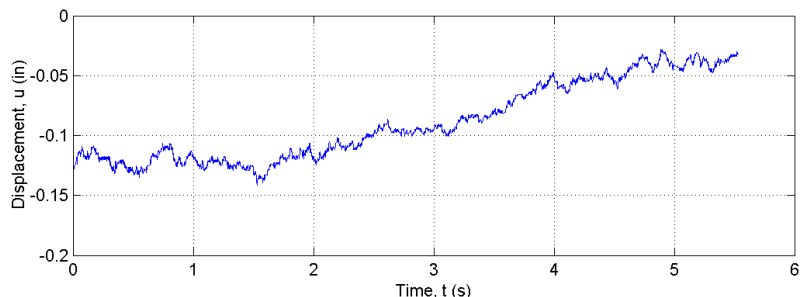

Fig. 1: L-15-076 Rt. 3 Bridge (Lowell)   **Fig. 2: (a)** Mid-span vibration of the bridge – 5.5 sec., displacement
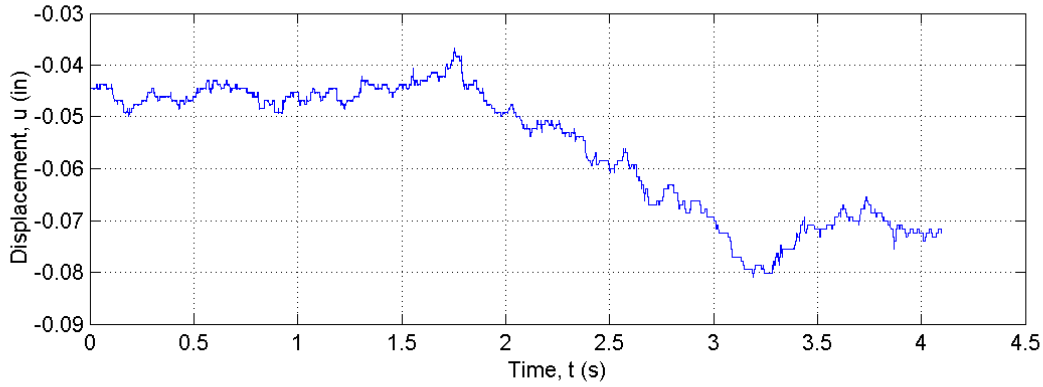
Fig. 2: (b) Mid-span vibration of the bridge – 4.1 sec., displacement

LDV dynamic displacement data were processed by the Fast Fourier Transform (FFT) to extract the modal frequencies in free vibration. Figure 3 shows the frequency spectrum of the 5.5-second displacement data. In Figure 3 (a), the FFT spectrum of the raw displacement data is shown with a large zero-frequency component. After the removal of the zero-frequency component in the FFT spectrum, the result is shown in Figure 3 (b). From Figure 3 (b), the first five modal frequencies are identified to be 0.15 Hz, 0.75 Hz, 1.98 Hz, 2.75 Hz, and 3.97 Hz. These modal frequencies can be used for both structural health monitoring and data fusion tasks of this project.
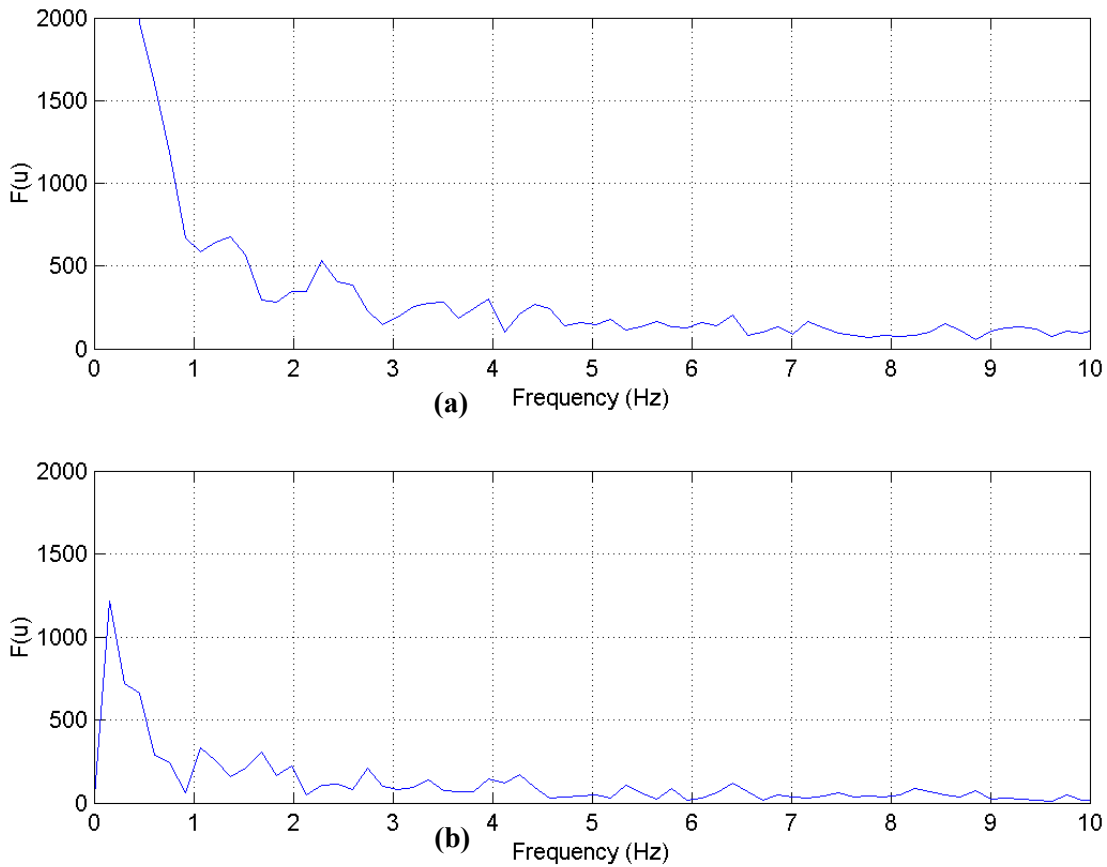

(a)

(b)

Fig. 3: FFT spectra of mid-span displacement of the bridge – 5.5 sec. data

Table 3: Presentations at Conferences, Workshops, Seminars, and Other Events				
Title	**Event**	**Type**	**Location**	**Date(s)**

Table 4: Publications and Submitted Papers and Reports				
Type	**Title**	**Citation**	**Date**	**Status**

Table 4: Presentations at Conferences, Workshops, Seminars, and Other Events				
Title	**Event**	**Type**	**Location**	**Date(s)**

Participants and Collaborators:

Table 5: Active Principal Investigators, faculty, administrators, and Management Team Members			
Individual Name	**Email Address**	**Department**	**Role in Research**
Tzuyang Yu	Tzuyang_Yu@uml.edu	Civil and Environmental Engineering	Project principle investigator (PI) and Institutional Lead at UML; overseeing all project activities
Susan Faraji	Susan_Faraji@uml.edu	Civil and Environmental Engineering	Co-PI, bridge design and analysis
Xingwei Wang	Xingwei_Wang@uml.edu	Electrical and Computer Engineering	Co-PI, development of optical sensors
Zhu Mao	Zhu_Mao@uml.edu	Mechanical Engineering	Co-PI, dynamic health monitoring using motion videos
William Davids	William.Davids@maine.edu	Civil and Environmental Engineering	Co-PI, design and analysis of composite bridges
Ehsan Ghazanfari	Ehsan.Ghazanfari@uvm.edu	Civil and Environmental Engineering	Co-PI, data fusion and analysis

Table 6: Student Participants during the reporting period				
Student Name	**Email Address**	**Class**	**Major**	**Role in research**
Aiyad Alshimaysawee		Ph.D.	Civil and Environmental Engineering	Laboratory and field radar imaging and data processing
Nimun Nak Khun		M.S.	Civil and Environmental Engineering	Field laser radar imaging and data processing
Rui Wu		Ph.D.	Electrical and Computer Engineering	Manufacturing and testing of optical sensors
Celso Do Cabo		Ph.D.	Mechanical Engineering	Assistance in the preparation for bridge field tests
Lidan Cao		Ph.D.	Electrical and Computer Engineering	Manufacturing and testing of optical sensors
Andres Biondi Vaccarriello		Ph.D.	Electrical and Computer Engineering	Manufacturing and testing of optical sensors
Harsh Gandhi		Ph.D.	Civil and Environmental Engineering	Manufacturing of laboratory specimens, data analysis and signal processing
Andrew Schanck		Ph.D.	Civil and Environmental Engineering	Finite element model construction and simulation
Sophe Ying		B.S.	Civil and Environmental Engineering	Assistance in the preparation for bridge field tests
Yaneliz Garcis Ruiz		B.S.	Civil and Environmental Engineering	Assistance in the preparation for bridge field tests

Tiana Robinson		B.S.	Civil and Environmental Engineering	Assistance in the preparation for bridge field tests

Table 7: Research Project Collaborators during the reporting period						
Organization	**Location**	**Contribution to the Project**				
		Financial Support	**In-Kind Support**	**Facilities**	**Collaborative Research**	**Personnel Exchanges**
AIT bridges	Brewer, Maine		X	X	X	X
Saint-Gobain North America	Northborough, Massachusetts		X	X	X	X
MaineDOT	Maine	X		X	X	X
Geophysical Survey Systems Inc. (GSSI)	Nashua, New Hampshire				X	X
MassDOT	Boston		X	X	X	X

Changes:

1) Since September 1, 2021, co-PI Dr. Zhu Mao (Assistant Professor in Mechanical Engineering at UML) has left UML and joined the Department of Mechanical Engineering at Worcester Polytechnic Institute (WPI). He will no longer be working on Project C11 since September 1, 2021.

2) Doctoral student Celso Do Cabo has also left Project C11 with Dr. Mao for WPI since September 1, 2021.

Planned Activities:

Our original plan to return to the Grist Mill Bridge in summer was postponed by the late arrival of a new doctoral student (A. Alshimaysawee) and Dr. Mao's departure. We are planning on installing sensing textiles on a different bridge in Massachusetts.

Task 6: Monitoring of structural performance under service and environmental loads
Task 7: Data fusion, visualization, and interpretation
Task 8: Documentation, reporting, and dissemination