INSPIRE University Transportation Center

2022 Annual Meeting | August 1-2, 2022

Teleconference

MONDAY, AUGUST 1	
Time	**Event**
9:50 am – 10:00 am	**Welcome**
10:00 am – 11:30 am	**Technical Presentations: Sensing and Nondestructive Evaluation**
Dr. Yang Wang	SN-6: Autonomous Ultrasonic Thickness Measurement by a Magnet-Wheeled Robot
Dr. Hongyan Ma	SN-7: Health Inspection of Concrete Pavement and Bridge Members Exposed to Freeze-Thaw Service Environments
Mr. Ying Zhuo	SN-8: Probability of Detection in Corrosion Monitoring with Fe-C Coated LPFG Sensors
11:30 am – 12:00 pm	**Technical Presentations: Inspection and Maintenance**
Dr. Anil Agrawal	IM-3: Smart Sounding System for Autonomous Evaluation of Concrete and Metallic Structures
12:00 pm – 12:30 pm	**Lunch Break**
12:30 pm – 3:30 pm	**Technical Presentations: Autonomous Systems**
Dr. Bo Shang	AS-4: Bridge Inspection Robot Deployment Systems (BIRDS)
Dr. Hung La	AS-5: Nondestructive Data Driven Motion Planning for Inspection Robots
Dr. Jizhong Xiao	AS-6: A Field Deployable Wall-Climbing Robot for Bridge Inspection Using Vision and Impact Sounding Techniques
Dr. Genda Chen	AS-8: Robot-Assisted Underwater Acoustic Imaging for Bridge Scour Evaluation
2:30 pm – 3:00 pm	**Break**
Dr. Paul Oh	AS-9: Integration of Aerial Manipulation, Haptics-based Human-in-the-Loop Control and Augmented Reality for Bridge Deck Hosing
3:30 pm – 4:00 pm	**Technical Presentation: Retrofit and Resilience**
Dr. Iris Tien	RR-2: Data-Driven Risk-Informed Bridge Asset Management and Prioritization across Transportation Networks
4:00 pm – 4:30 pm	**Technical Presentations: Workforce Development**
Dr. Sushil Louis	WD-3: Simulation Training to Work with Bridge Inspection Robots

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TUESDAY, AUGUST 2	
Time	**Event**
10:00 am – 11:00 am	Pooled-Fund Study
11:00 am – 12:00 pm	Semi-Annual Executive Meeting with DOT Members
12:00 pm	Closing Remarks

TECHNICAL PROGRAM

Monday, August 1

9:50 am **WELCOME**

Dr. Genda Chen
Professor and Robert W. Abbett Distinguished Chair, Director INSPIRE University Transportation Center, Missouri S&T

10:00 am **TECHNICAL PRESENTATIONS: SENSING AND NONDESTRUCTIVE EVALUATION**

10:00-10:30 am
Autonomous Ultrasonic Thickness Measurement by a Magnet-Wheeled Robot, Dr. Yang Wang, Georgia Institute of Technology

A wireless sensing device recently developed by PI Wang's group has demonstrated various structural sensing capabilities for bridge applications. In the meantime, a latest robot platform developed by Dr. La's group at the University of Nevada, Reno (UNR) demonstrates promising performance navigating on steel bridge members. Marrying the two state-of-the-art developments, this project will produce a magnet-wheeled robot capable of autonomous nondestructive measurement on steelbridge structures.

The platform can provide valuable information for bridge condition assessment. The Martlet wireless sensing device recently developed by PI Wang's group provides the potential for ultrasonic thickness measurement of steel plates. Meanwhile, the latest robot platform developed by Dr. La's group at University of Nevada, Reno (UNR) demonstrates promising performance for carrying such a wireless ultrasonic measurement device and navigating on steel bridge members.

10:30-11:00 am
Health Inspection of Concrete Pavement and Bridge Members Exposed to Freeze-Thaw Service Environments, Dr. Hongyan Ma, Missouri S&T

This project aims to develop a time-efficient and effective inspection technique (based on hyperspectral imaging and complementary techniques) for damage of concrete pavement and bridge members exposed to F-T environments, which will provide comprehensive information to decision-makers in maintenance/asset management. The focus of the second year of this project will be: (1) to improve the reliability of degree of saturation inspection by supplementing the spectral imaging using surface resistivity, (2) to improve the reliability of concrete deterioration inspection by supplementing the spectral imaging using ultrasound method, and (3) to classify surface deterioration based on the reliable dataset.

After the first year of this research project, the spectra library of chemical components of concrete subjected to different types of F-T deteriorations will be established. In addition, two important correlations between DoS and hyperspectral signatures and between mechanical indicators (e.g., compressive strength and relative dynamic modulus of elasticity) and hyperspectral signatures, will be developed. The obtained knowledge will serve as the basis in the second year to train classifiers and map F-T deteriorations in field concrete pavement and bridge members, as well as to assist in decision-making for maintenance protocols.

11:00-11:30 am
Probability of Detection in Corrosion Monitoring with Fe-C Coated LPFG Sensors, Mr. Ying Zhuo, Missouri S&T

This project aims to develop two statistical methods for determining the probability of detection in corrosion monitoring using long period fiber gratings (LPFG) sensors with thin Fe-C coating, validate these methods from independent laboratory tests, determine the steel mass loss at 90% probability of detection and the largest steel mass loss that may miss from a corrosion inspection at 95% lower confidence bounds, and develop and validate an analytical formulation of the most critical reduction in load capacity of the superstructure of steel-girder bridges based on limited sensor data. The two statistical methods are referred to as the Mass Loss-at-Detection (MLaD) method and the Random-Effects Generalization (REG) method. They will be evaluated in terms of computational efficiency, sensitivity to probability distribution assumptions, and robustness to departure from model assumptions. The one with overall superior performance will be recommended for corrosion monitoring in bridge applications.

11:30 am TECHNICAL PRESENTATION: INSPECTION AND MAINTENANCE

11:30 am-12:00 pm
Smart Sounding System for Autonomous Evaluation of Concrete and Metallic Structures, Dr. Anil Agrawal, The City College of New York

Recent research by the proposers has shown that the sounding, such as chirp signal, can be generated by electronic speakers, and their magnitude and frequency can be controlled. Different from the mechanical impact hammers, the electronic sounding is consistent and can be designed with certain frequency characteristics to excite defects in concrete decks. The focus of this research is on development of “Smart Sounding System” that can be used to inspect underdeck and pier surfaces effectively and autonomously. Previous preliminary research has shown that common defects in concrete structures, such as shallow delamination, generally have a resonant response at a relatively low and narrow frequency band of 1 – 3 kHz, whereas solid areas can be excited at much higher frequency ranges. This observation implies that the sounding energy can be designed and focused on the “delamination frequency band” to increase the response of the delamination signal with respect to those from the solid areas. To further improve the efficiency of the detection, components of the sounding tool can be optimized such that sounding speakers and microphone have a similar resonant frequency close to the dominant frequency of the defect area so that the defect will have the “ringing” effect when excited by the sounding tool. For mapping of the inspection area, the “smart sounding system” can be integrated with advanced tracking camera and GPS device. By using the mapping device, no gridding process will be required, which is time-consuming and labor-intensive in the current practice of impact sounding. Preliminary research by the proposers has also shown that the proposed impact sounding tool can also detect hidden cracks and thickness loss in metallic components, such as girders.

12:00 pm BREAK

12:30 pm TECHNICAL PRESENTATIONS: AUTONOMOUS SYSTEMS

12:30-1:00 pm
Bridge Inspection Robot Deployment Systems (BIRDS), Dr. Bo Shang, Missouri S&T

This project aims to develop and build a mobile test facility, hereafter referred to as Bridge Inspection Robot Deployment Systems (BIRDS), for the field tests of real-world bridges. The BIRDS is equipped with climbing robots, unmanned aerial vehicles, multimodal vehicles, sensors, nondestructive evaluation devices, data acquisition units, batteries, and miscellaneous tools to support field tests. It serves as a field station for data collection and transmission to the base station at the INSPIRE University Transportation Center, and a means of transportation for a crew of two or three inspectors.

1:00-1:30 pm
Nondestructive Data Driven Motion Planning for Inspection Robots, Dr. Hung La, University of Nevada, Reno

During the first four years, the team led by Dr. Hung La of the Advanced Robotics and Automation (ARA) lab, University of Nevada, Reno (UNR), has developed four different climbing robotic prototypes and their control framework to allow the user to manually control these robots to climb on various steel structures. In the final year of this project, the ARA team aims to provide these climbing robotic systems an autonomous navigation function so that they can safely traverse on and visit all steel members of the bridge for efficient inspection.

To achieve this goal, the team plans to (1) develop a method based on geometric features of the steel bridge (e. g., bars/truss, intersection/cross area.) to handle the structure navigation perception; (2) develop a motion planning algorithm to allow the robots to safely navigate on the bridge structure members and efficiently inspect the bridge; (3) test and validate the proposed autonomous motion planning on the ARA robots in both robotics-based simulation environment and real bridges.

1:30-2:00 pm
A Field Deployable Wall-Climbing Robot for Bridge Inspection Using Vision and Impact Sounding Techniques, Dr. Jizhong Xiao, The City College of New York

This Year-2 project will investigate the performance of impact echo methods that uses piezoelectric transducers to detect deep delamination and other types of subsurface flaws. It is expected that the impact echo will not be severely affected by air-wave noise, shall be able to detect and measure the depth of delamination, can be used on concrete floors with asphalt overlays. This project will integrate both impact echo and impact sounding devices in the Impact-Rover and evaluate its performance on concrete slabs. The combination of robotic hardware platform with NDE data analysis software will produce a robotic inspection tool to detect, characterize and map the subsurface defects. The robotic inspection tool can be deployed for bridge inspection, which will meet the INSPIRE UTC goal of making inspection and maintenance more reliable and cost-effective.

This project will produce a field deployable robot (i.e., Impact-Rover-V2) with vertical mobility that carries cameras and impacting mechanism and data collection subsystem. It is envisioned that the robot can detect and evaluate both surface cracks and subsurface defects using the visual inspection and impact sounding/echo technology.

2:00-2:30 pm
Robot-Assisted Underwater Acoustic Imaging for Bridge Scour Evaluation, Dr. Genda Chen, Missouri S&T

Scour is responsible for more than half of the bridges that collapsed in the U.S. over the past four decades. In recent years, the smart rock technology has been developed and validated in field conditions to estimate the maximum depth of a scour hole that has ever been formed around a bridge pier. With a cylindrical magnet (N42), the most sensitive and reliable measurement distance for each smart rock ranges from 1.5 m to 7.5 m. This measurement distance is insufficient in flood seasons when water level reaches to a high elevation. This project aims to develop an underwater acoustic imaging and water depth measuring system with a side-scan sonar and a digital precision altimeter.

A dual-chamber climbing robot that can carry a side-scan sonar or a digital precision altimeter will be prototyped and tested for maneuverability, stability, and functionality under various operation conditions in air or underwater. The technical specifications of an integrated system of the robot and sonar/altimeter will be developed based on laboratory tests. The field performance of the system at a bridge site will be documented in terms of the sensitivity and variability of the side-scan sonar and the digital precision altimeter in scour depth measurement, and stability and maneuverability of the climbing robot.

2:30 pm BREAK

3:00-3:30 pm
Integration of Aerial Manipulation, Haptics-based Human-in-the-Loop Control and Augmented Reality for Bridge Deck Hosing, Dr. Paul Oh, University of Nevada, Las Vegas

This proposal serves to integrate the designs, analyses, and results of the past four years, for bridge deck hosing. Hosing remains an important task in bridge maintenance. The limbs and grippers developed in Year 1 demonstrated hose grasping in Year 2. Analysis yielded a mathematical model that showed that hose reaction forces can be overcome by scaling the drone's footprint (i.e. moment of inertia).

The next logical step would be to integrate these concepts and outcomes to re-visit and thus implement the hosing task. Whipping and push-back are all part of hoseline management. These reaction forces can be dealt with by over-sizing the drone. However, such over-sizing raises costs to build and operate the vehicle. Control of both nozzle pose and hoseline shape can mitigate the need to over-size. Applying Year 3 haptics and Year 4 AR visualization would yield a suitable hosing-drone. The envisioned hosing-drone would cover the operational range needed for bridge deck cleaning.

3:30 pm TECHNICAL PRESENTATION: RETROFIT AND RESILIENCE

3:30-4:00 pm
Data-Driven Risk-Informed Bridge Asset Management and Prioritization across Transportation Networks, Dr. Iris Tien, Georgia Institute of Technology

This project will take a data-driven approach, building deep learning neural network models to detect and characterize bridge deterioration. Based on the observed bridge conditions, outcomes will be defined, serving as the dataset outputs. Deep learning algorithms will then be employed to build models to translate the collected imagery data into classification and characterization of bridge condition and deterioration. To do this, we will undertake four main tasks: (1) Define the dataset outputs based on observed bridge conditions across the set of bridges analyzed; (2) Build learning models to use collected imagery data to classify multiple types of deterioration; (3) Build learning models to use collected imagery data to characterize levels of deterioration across deterioration types; (4) Evaluate generalizability of the models to translate collected imagery data into assessments of bridge deterioration. Outcomes will enable the comparison of assessments across multiple bridges and facilitate the prioritization of resources for maintenance, repair, and rehabilitation decisions across a transportation network.

4:00 pm TECHNICAL PRESENTATIONS: WORKFORCE DEVELOPMENT

4:00-4:30 pm
Simulation Training to Work with Bridge Inspection Robots, Dr. Sushil Louis, University of Nevada, Reno

This project aims to investigate and develop a Simulation Training and Control System (STACS) that helps bridge inspectors equipped with virtual or augmented reality hardware to work together with semi-autonomous and autonomous robots to efficiently and effectively inspect bridge trusses more thoroughly and in less time. Our efforts to date have resulted in a simulation training system for bridge inspection enabling a heterogeneous group of simulated robots to speed up comprehensive bridge inspection.

The PI will investigate and develop techniques to 1) Move STACS towards a Virtual Reality (VR) interface for training and control, 2) connect simulated robots with real robots being developed in other INSPIRE projects, and 3) investigate and develop algorithms, protocols, and autonomy for maximizing inspection speed and completeness for human-robot bridge inspection teams on real bridges.

The same system and command interfaces are being used for training human bridge operators in simulation and in an operational environment. We thus expect a straightforward transition from simulation training to on-site operation as the DOT moves to leverage our system's AI and autonomy development to increase safety and reduce cost. We expect to provide and disseminate a prototype XR-STACS system. The system will feature automated route generation, connectivity to at least two types of robots, and enable multiple views of robots' task achieving progress. XR-STACS will be publicly available on Github and on the INSPIRE site.

4:30 pm ADJOURN

Tuesday, August 2

10:00 am POOLED-FUND STUDY DISCUSSION

10:00-11:00 am

The goals of the pooled-fund initiative are to engage closely with several state Departments of Transportation (DOTs) in the early stage of technology development at the INSPIRE University Transportation Center, and leverage the center resources to develop case studies, protocols, and guidelines that can be adopted by state DOTs for bridge inspection without adversely impacting traffic. The initiative involves the integration, field demonstration and documentation of a robotic system of structural crawlers, unmanned aerial vehicles, a multimodal unmanned vehicle, nondestructive devices, sensors, and data analytics.

Depending on the interest of participating DOTs, the objectives of this initiative include, but are not limited to:

- Development of inspection/operation protocols for various types of bridges with the robotic system integrated into current practice.
- Comparison and correlation of bridge deck inspections from the top and bottom sides of decks to understand the reliability of traffic disruption-free bridge inspection from the underside of decks.
- Design and technical guidelines of measurement devices on a robotic platform for the detection of surface and internal damage/deterioration in structural elements, and for the change in lateral support of foundations.
- Data fusion and analytics of measurements taken from various imaging and sensing systems for consistency and reliability.
- Development of best practices on bridge inspection using the robotic system.

11:00 am SEMI-ANNUAL EXECUTIVE MEETING

11:00 am-12:00 pm
Closed meeting with center-only members (INSPIRE UTC Directors, Associate Directors, External Advisory Committee and Pooled-Fund Study Members)

12:00 pm CLOSING REMARKS
Dr. Genda Chen
Director, INSPIRE University Transportation Center at Missouri S&T