INSPIRE University Transportation Center
2018 Annual Meeting | August 14-15, 2018

Missouri University of Science and Technology
Rolla, Missouri

TUESDAY, AUGUST 14- BUTLER CARLTON HALL (BCH)		
Time	**Event**	**Location**
7:45 am	Registration and Poster Set Up	312 BCH
8:15 am	Welcome	213 BCH
8:30 am	Technical Presentations: Sensing and Nondestructive Evaluation Research	213 BCH
10:00 am	Break	
	Graduate Student Poster Session	312 BCH
	Video Interviews with PIs (Chen, Wang, Xiao)	211B BCH
10:30 am	Technical Presentations: Sensing and Nondestructive Evaluation Research	213 BCH
11:30 am	Technical Presentations: Inspection and Maintenance Research	213 BCH
12:00 pm	Lunch	312 BCH
1:00 pm	Technical Presentation: Autonomous Systems Research	213 BCH
2:30 pm	Break	
	Graduate Student Poster Session	312 BCH
	Free Professional Headshots	312 BCH
	Video Interviews with PIs (Zoughi, Agrawal, Oh)	211B BCH
3:00 pm	Technical Presentations: Workforce Development Research	213 BCH
4:00 pm	Technical Presentations: Retrofit and Resilience Research	213 BCH
4:30 pm	Break	312 BCH
	Graduate Student Poster Session	312 BCH
	Video Interviews with PIs (La, Louis, Tien, Qin)	211B BCH
5:00 pm	Adjourn	
5:10 pm	Pedestrian Bridge Test Demonstration (Outside the Computer Science Bldg.)	

WEDNESDAY, AUGUST 15- 312 BUTLER-CARLTON HALL	
Time	**Event**
8:00 am	**[Closed]** Semi-Annual Executive Meeting with INSPIRE PIs, Co-PIs, and External Advisory Committee (EAC) Members
9:00 am	Break
9:30 am	EAC Panel Discussion
11:00 am	Break
11:15 am	Poster Awards Ceremony
11:30 am	Closing Comments
12:00 pm	Adjourn

TECHNICAL PROGRAM

Tuesday, August 14 – 213 BUTLER-CARLTON HALL

8:15 am WELCOME

Dr. Robert J. Marley
Provost and Executive Vice Chancellor for Academic Affairs, Missouri S&T

8:30 am SENSING AND NONDESTRUCTIVE EVALUATION

8:30-9:00 am
UAV-enabled Measurement for Spatial Magnetic Field of Smart Rocks in Bridge Scour Monitoring, Dr. Genda Chen, Missouri S&T

Foundation scour is the main cause of bridge collapses in the U.S. In 2011, the principal investigator (PI) proposed smart rocks with embedded magnets for bridge scour monitoring. Once deployed around a bridge pier, smart rocks as field agents offer mission-critical information about the maximum depth of a scour hole developed around the bridge foundation – the key parameter that is used to assess foundation stability in engineering design and retrofit. Smart rocks have recently been deployed and tested at three bridge sites in California and Missouri. With multiple measurements, they can be located with an accuracy of 0.5 m. This level of performance, however, largely depends on the availability of a crane that extends the measurement station from the deck of a bridge to the proximity of a smart rock. The use of the crane often requires traffic closure and, more importantly, limits the number of measurement points and thus makes the detection of two or three smart rocks practically impossible.

This project aims to develop a moving unmanned aerial vehicle (UAV) platform for the magnetic field measurement with and without smart rocks, and characterize the field performance of smart rocks so that the smart rock technology can be tested to its full potential for real time monitoring of bridge scour during significant flood events.

9:00-9:30 am
Battery-free Antenna Sensors for Strain and Crack Monitoring of Bridge Structures, Dr. Yang Wang, Georgia Institute of Technology

Fatigue cracks need to be monitored in fatigue critical elements. Previous research by the PI produced a radiofrequency identification (RFID) sensor prototype that can accurately measure tens of micro-strains in laboratory. The antenna sensor was made on a glass microfiber-reinforced polymer substrate. Although accurate for strain measurement and detection of fatigue cracks, the sensor performs less satisfactorily in field conditions since the substrate material (RT/duroid® 5880) is susceptible to thermal effect. In addition, a wireless interrogation distance by a general-purpose commercial RFID reader is limited to the order of meter, which is not desirable with the operation of a UAV. The commercial reader also weighs over 30 N and costs approximately $30k.

This project aims to develop and validate a light antenna sensor (1 kg) with new substrate materials that can be accurately interrogated at a desirable distance (over 30 m) in field applications, and develop and test a customized RFID reader that costs less than $3k for effective monitoring of bridges.

9:30-10:00 am
In-line Long Period Grating and Brillouin Scattering Fiber Optic Sensors for Strain, Temperature, Chloride Concentration, and Steel Mass Loss Measurement in Bridge Applications, Dr. Genda Chen, Missouri S&T

Corrosion is the main reason for costly maintenance of aging transportation infrastructure in the U.S. Since 2008, the PI's group has developed long period fiber grating (LPFG) sensors for point strain and steel mass loss measurements. When attached on a steel bar, a LPFG sensor doped with nano iron/silica particles and polyurethane can monitor the corrosion process of steel. However, the coating of particles with polyurethane was not robust. In addition, chloride concentration is important for the prediction of early corrosion in practice. Compared to grating sensors, Brillouin scattering based sensors have lower spatial resolution but offer a cost-effective solution to the monitoring of large-scale civil infrastructure. Therefore, integrating LPFG sensors into a distributed sensing system for multiple parameter measurements is important in bridge applications. Unlike fiber Bragg grating (FBG) sensors that have been recently applied to civil infrastructure, LPFG sensors and distributed sensing systems are still tested in laboratory. Their packaging is critical in field applications.

This project aims to: (1) Develop a physically and optically protected LPFG strain sensor that is hermetically packaged in a fused silica capillary tube, (2) Develop a Fe-C coated LPFG sensor for life-cycle corrosion monitoring (chloride ion and mass loss) of nearby steel members, (3) Understand how many LPFG sensors of different types and wavelengths can be multiplexed to measure multiple parameters for the monitoring of large-scale bridges, and (4) Understand potential interference between the LPFG sensor interrogation and the pulse pre-pump Brillouin optical time domain analysis (PPP-BOTDA) measurement.

10:00 am BREAK

Graduate Student Poster Session- 312 BCH
Video Interviews with PIs (Chen, Wang, Xiao)- 211B BCH

10:30 am SENSING AND NONDESTRUCTIVE EVALUATION (Cont.)

10:30-11:00 am
3D Microwave Camera for Concrete Delamination and Steel Corrosion Detection, Dr. Reza Zoughi, Missouri S&T

Corrosion of embedded steel reinforcement in concrete leads to concrete cracking and delamination, followed by increased salt and moisture permeation and further damage. Invisibility of the embedded rebar in combination with physical inaccessibility in elevated bridges presents a challenge in the assessment of RC bridge elements.

Wideband (3D) microwave synthetic aperture radar (SAR) imaging techniques that can be integrated into a UAV offer a practical solution to overcome this challenge.

This project aims to develop and optimize a 3D microwave camera for bridge inspection on a UAV platform, quantify its performance for steel corrosion evaluation and concrete delamination detection in reinforced concrete (RC) bridge elements, and build a microwave camera prototype that can be installed on a UAV for field applications.

11:00-11:30 am
Hyperspectral Image Analysis for Mechanical and Chemical Properties of Concrete and Steel Surfaces, Dr. Genda Chen, Missouri S&T

A typical human eye will respond to wavelengths from approximately 400 to 700 nm. A hyperspectral camera can extend the wavelength to as high as 2500 nm. This extension will allow engineers to find objects, identify materials, and detect processes on structural surface, which cannot be done with visual inspection.

This project aims to develop an open-source catalogue of concrete and steel surfaces and their spectral/spatial features (discoloration, characteristic wavelength, roughness, texture, shape, etc.), extract spatial/spectral features of hyperspectral images, and develop/train a multi-class classification or regression classifier through machine learnings (supervised and/or semi-supervised), and validate the classifier as a decision-making tool for the assessment of concrete crack and degradation processes, in-situ concrete properties, and corrosion process in steel bridges.

11:30 am INSPECTION AND MAINTENANCE

11:30 am-12:00 pm
Quantitative Bridge Inspection Ratings Using Autonomous Robotic Systems, Dr. Anil Agrawal, The City College of New York

The 2001 study sponsored by FHWA raised serious concern on the consistency and reliability of visual inspection. Although consistent ratings can be obtained with a good QA/QC program, based on a recent study by the PI, the concern for reliability of defect detection remains. With the adoption of the recent AASHTO Manuel for Bridge Element Inspection, the new inspection approach not only requires rating for bridge elements, but also the location and extent of deterioration. Since autonomous robotic systems generate an enormous amount of inspection data, deducing from the data to a simple rating along with the location and extent of deterioration is a significant challenge. For example, RABITTM has been used to inspect concrete bridge decks with six devices, including ground penetrating radar (GPR), impact-echo and ultrasonic surface wave. However, the probability of detection (POD) for damage has not been fully demonstrated to be significantly improved using multiple devices.

This project aims to develop new fusion strategies of data collected from multiple NDE devices for improved POD based on further understanding and modeling of damage detection mechanisms, and to develop algorithms for the derivation of bridge ratings from identified damage and visual inspection findings.

12:00 pm LUNCH

1:00 pm AUTONOMOUS SYSTEMS

1:00-1:30 pm
Mobile-manipulating UAVs for Sensor Installation, Bridge Inspection and Maintenance, Dr. Paul Oh, University of Nevada, Las Vegas

Mobile manipulating UAVs have great potential for bridge inspection and maintenance. Since 2002, the PI has developed UAVs that could fly through in-and-around buildings and tunnels. Collision avoidance in such cluttered near-Earth environments has been a key challenge. The advent of light-weight, computationally powerful cameras led to breakthroughs in SLAM even though SLAM-based autonomous aerial navigation around bridges remains an unsolved problem.

In 2007, the PI integrated a mobile manipulation function into UAVs, greatly extending the capabilities of UAVs from passive survey of environments with cameras to active interaction with environments using limbs. Mobile-manipulating UAVs have since been demonstrated to successfully turn valves, install sensors, open doors, and drag ropes. Their research and development face several challenges. First, limbs add weight to aircraft. Second, rotorcraft, like a quadcopter, is an under-actuated system whose stability can be easily affected by limb motions. Third, when performing a task like turning a valve, limbs demand compensation for torque-force interactions. Thus, even if battery technologies afford the additional payload of limbs, current knowledge for manipulation with under-actuated systems remains sparse.

This project aims to develop and prototype a mobile-manipulating UAV for bridge maintenance and disaster cleanup through further study on SLAM technology for robust navigation, impedance controllers to ensure UAV's stability with limb motion, and coordinated and cooperative motions of multiple limbs to perform simple tasks like bearings cleaning and crack sealing in concrete bridges. Two strategies will be explored for bridge maintenance: (a) A UAV brings and uses a can of compressed air for bridge cleaning, and (2) Two UAVs airlift, position, and operate hoses from ground, and clean bridges with air or water. The latter can be potentially implemented by including a station-keeping, lighter-than-air UAV like blimp that can airlift a hose and remain airborne for extended periods. The mobile-limbed UAVs can then pull-and-drag the hose into areas that need to be cleaned. The blimp-based approach is attractive because it is easier for a UAV to drop hose lengths rather than pull the hose up in air.

1:30-2:00 pm
Climbing Robots with Automated Deployment of Sensors and NDE Devices for Steel Bridge Inspection, Dr. Hung La, University of Nevada, Reno

The PI was a research scientist/faculty at Rutgers University who successfully developed in 2014 a Robotic Assisted Bridge Inspection Tool (RABIT) for bridge deck inspections. Other bridge elements, such as girders and columns, or even underside of bridge decks are difficult to access and remain a challenge for efficient inspection. Like visual inspection, current practices for bridge maintenance are equally time consuming and expensive. Automation of simple maintenance actions such as bearing cleaning and concrete sealing with robots will lead to a leap forward to the next-generation strategy of bridge maintenance.

This project aims to develop and prototype automated climbing robotic platforms for steel bridge inspection and evaluation with support of visual and 3D LiDAR for navigation in global positioning system (GPS)-denied environments, develop a nondestructive evaluation (NDE) device or sensors deployment strategy with a mechanical limb, and evaluate the condition of steel bridges based on data collected from the device or sensors.

2:00-2:30 pm
Autonomous Wall-climbing Robots for Inspection and Maintenance of Concrete Bridges, Dr. Jizhong Xiao, The City College of New York

Since 2002, the PI's group has developed four generations of wall-climbing robots for NDE inspection of civil infrastructure. These robots combine the advantages of aerodynamic attraction and suction to achieve a desirable balance of strong adhesion and high mobility. They don't require perfect sealing and can thus move on smooth and rough surfaces, such as brick, concrete, stucco, wood, glass, and metal. For example, Rise-Rover uses two drive modules to carry their middle compartment with payload up to 450 N. Ground penetrating radar (GPR)-Rover and Mini GPR-Rover are custom designed to carry a GSSI's GPR antenna for subsurface defect detection and utility survey on concrete structures such as bridges and tunnels. The robots can also carry other devices such as impact echo and ultrasonic flaw detectors for bridge evaluation. To date, all the robots are remotely controlled to scan concrete surfaces.

This project aims to develop motion control and localization methods to make wall-climbing robots a fully autonomous system with automated inspection process using various NDE devices and sensors, and design innovative mechanisms and tools and integrate them into the robots for maintenance actions.

2:30 pm **BREAK**

Graduate Student Poster Session- 312 BCH
Free Professional Headshots for all Attendees- 312 BCH
Video Interviews with PIs (Zoughi, Agrawal, Oh)- 211B BCH

3:00 pm WORKFORCE DEVELOPMENT

3:00-3:30 pm

Training Framework of Robotic Operation and Image Analysis for Decision-Making in Bridge Inspection and Preservation, Dr. Ruwen Qin, Missouri S&T

Inspection and preservation of existing transportation infrastructure to extend their service life is an effective way of mitigating the pressure of steadily growing transportation demands on the aging infrastructure. Their current practice, though, represents one of the most costly operations in state departments of transportation.

The INSPIRE University Transportation Center will develop a remotely-controlled robotic platform that helps with these labor-intensive tasks and allows engineers to focus on decision-making processes. An important mission of INSPIRE is to leverage users' capability of implementing, and interacting with, the robotic platform. Therefore, a long-term plan has been made to create a framework of training engineers and policy makers as well as new workforce on robotic operation and image analysis for the inspection and maintenance of transportation infrastructure. The proposed project, as a component of the plan, involves the prototyping of such a framework based on camera-based bridge inspection and robot-based maintenance.

The overall goal of the project is to create a framework of training engineers and policy makers on robotic operation and image analysis for the inspection and preservation of transportation infrastructure. Specifically, the project aims to (1) provide the method for collecting camera-based bridge inspection data and the algorithms for data processing and pattern recognitions; and (2) create tools for assisting and training users on visually analyzing the processed image data and recognized patterns for inspection and preservation decision-making.

3:30-4:00 pm

Developing a Robotic Simulator and Video Games for Professional and Public Training, Dr. Siming Liu for Dr. Sushil Louis, University of Nevada, Reno

Civil engineers are not educated with robotics. They need to be trained on the job with effective tools. The most recent simulation trainer that the PI has built is currently being used by the United States Navy to train surface warfare officers in decision making under stress. In a crowded in-port environment, the crew on a ship's bridge is trained to probe and identify suspicious boat behavior within the port's traffic pattern. Officers in charge of the simulation training lesson use software for high-level control of dozens of other ships, boats, and aircrafts that quickly react and adapt to the crewed ship's actions based on lower-level programmed autonomy and game-like user interaction. Without this virtual "experience," improperly trained crews put lives in danger. Scenarios that would be catastrophic in reality can also be simulated and, without this training, especially for recovering from error states, operators may inadvertently lose valuable hardware, produce erroneous results, and compromise system and human safety.

This project aims to build a Simulation Training And Control System (STACS) prototype within a 3D simulation game-like environment and develop a realistic training environment. Specific objectives include: (1) Investigate and optimize the design of user interaction and user interfaces within a full 3D game-like environment for training and control, (2) Investigate and optimize the tradeoff between manual and autonomous control of multi-robot teams for bridge inspection, (3) Train bridge inspectors in the use of the proposed multi-robot system, and (4) Provide human operators with complete situational awareness and operational control during an ongoing inspection.

4:00 pm RETROFIT AND RESILIENCE

4:00-4:30 pm
Bridge Resilience Assessment with INSPIRE Data, Dr. Iris Tien, Georgia Institute of Technology

Robotic data collection, both automated and remote, will enable post-disaster assessment of bridge components where it would normally be difficult and potentially dangerous for manual inspection by field workers to do so.

This project aims to develop and validate a new framework that uses the data collected from the robotic exploration of infrastructure, particularly after a disaster, to assess the condition of bridges and prioritize these structures for repair. This will improve the resilience of the transportation system to disasters by targeting bridge repairs and enabling resources to be distributed more effectively across the system for more rapid recovery after a disaster.

4:30 pm BREAK

Graduate Student Poster Session- 312 BCH
Video Interviews with PIs (La, Louis, Tien, Qin)- 211B BCH

5:00 pm ADJOURN

5:10 pm PEDESTRIAN BRIDGE TEST DEMONSTRATION

(Outside the Computer Science Building)

5:10-5:50 pm (Optional)
Demonstration of INSPIRE UTC Technologies Used To Inspect the Computer Science Pedestrian Bridge at Missouri S&T, Dr. Genda Chen and Dr. Reza Zoughi, Missouri S&T

The INSPIRE UTC, with permission and the cooperation of Missouri S&T Facilities Operations, is conducting research testing on the Computer Science Pedestrian Bridge through the end of September 2018. The technologies employed in the Pedestrian Bridge test include: microwave imaging, ground penetrating radar and impact-echo tests, hyperspectral, and thermal imaging.

Wednesday, August 15 – Needles Conference Room- 312 Butler-Carlton Hall

8:00 am **SEMI-ANNUAL EXECUTIVE MEETING**
Closed meeting with INSPIRE UTC PIs, Co-PIs and External Advisory Committee (EAC) Members

9:00 am **BREAK**

9:30 am **EAC PANEL DISCUSSION**

9:30-10:00 am
MoDOT's Current Practice for Bridge Inspection and Local Repair
Bill Stone, Missouri Department of Transportation

10:00-10:30 am
Current Practice for Railroad Bridge Inspection and Local Repair
Kevin Hicks, Union Pacific Railroad

10:30-11:00 am
Element-Level Bridge Inspections, and the Potential Role of INSPIRE UTC Technology
Paul Thompson, Paul D. Thompson

11:00 am **BREAK**

11:15 am **POSTER AWARDS CEREMONY**
Bill Stone, P.E.
Research Administrator, Missouri Department of Transportation
Chair of the Judging Committee

11:30 am **CLOSING COMMENTS**
Dr. Genda Chen
Director, INSPIRE University Transportation Center
Missouri S&T

12:00 pm **ADJOURN**