Spring 2022

INSPIRE Newsletter Spring 2022

Missouri University of Science and Technology. INSPIRE - University Transportation Center

TIER 1 UNIVERSITY
TRANSPORTATION CENTER (UTC)

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INSPIRE

INSPECTING AND PRESERVING INFRASTRUCTURE THROUGH ROBOTIC EXPLORATION

VOL. 6 | ISSUE 1 | SPRING

INSPIRE-UTC Biannual Publication

In this issue:

Awarded in December of 2016 by the U.S. Department of Transportation, the five-year **INSPIRE UTC** is a Tier 1 University Transportation Center with a research priority of preserving the existing transportation system as part of the UTC Program (https://www.transportation.gov/utc/2016-utc-grantees) that was authorized under the Fixing America's Surface Transportation Act.

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Missouri S&T
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Ozarks Technical Community College
St. Louis Community College

Director's Message

Greetings colleagues and friends! Since our last newsletter, the INSPIRE University Transportation Center (UTC) has achieved 13,345 members on our email listserv and has hosted various virtual and in-person events for additional interest and outreach. This edition features three articles focusing on Augmented Reality Research by INSPIRE UTC researchers. These include (1) VR Operator Training for Robot Assisted Bridge Inspection, (2) Human-Embodied Drones for Mobile Manipulation in Bridge Inspection and Maintenance, and (3) When AR Meets Bridge Inspection: From Bridge to Cloud.

This edition also features an overview of the Pooled-Fund Study on Traffic Disruption-Free Bridge Inspection Initiative with Robotic Systems. This study involves the integration, field demonstration, and documentation of Bridge Inspection Robot Deployment Systems (BIRDS), including structural crawlers, unmanned aerial vehicles (UAVs), multimode vehicles, nondestructive evaluation (NDE) devices, sensors, and data analytics. Additionally, the edition features an educational module series based on an approach for updating bridge risk assessment using bridge inspection data.

This edition highlights the Transportation Research Board (TRB) Webinar on Robot-Enabled Sensing and Augmented Learning (RE-SEAL) for Bridge Inspection organized by the INSPIRE UTC on behalf of four TRB standing committees. Focused on remote sensing, NDE, and augmented learning through virtual reality and/or artificial intelligence, this webinar that took place on March 29, 2022, attracted 320 registrations.

This issue also highlights graduate and undergraduate students. One graduate student in civil engineering received the Dean's Ph.D. Scholar Award. Seven undergraduates in civil engineering, computer science and computer engineering, and mechanical engineering participate in research related to unmanned systems, rapid air-cushioned vehicles, augmented reality concepts, and administrative duties at the INSPIRE UTC.

Featured outreach includes Kaleidoscope Discovery Center's FIRST Lego League and Missouri Future City Competition, as well as workshops and camps with local middle-school students in STEM Education hosted by the Kummer Center and the annual National Society of Black Engineers pre-college initiative using a driving simulator to recreate scenarios for various driving conditions.

The Center continues to host quarterly webinars that serve to highlight collaborative opportunities and research being conducted at the INSPIRE UTC. The upcoming webinar being presented by Dr. Fernando Moreu from the University of New Mexico at Albuquerque, "Intelligent Human-Infrastructure Interfaces for Inspectors and Decision-Makers," will discuss practical implementations on how the collection of data, analysis and interpretation can transform decisions using Augmented Reality with Wireless Sensors Networks, Artificial Intelligence, Machine Learning, Structural Dynamics, and Inspections.

We hope you enjoy the featured articles and news at INSPIRE UTC and invite you to visit our website at https://inspire-utc.mst.edu for additional information about upcoming events and webinars.

Genda Chen, Ph.D., P.E., F. ASCE, F. SEI, F. ISHMII

Director, INSPIRE University Transportation Center
Director, Center for Intelligent Infrastructure

NEWS

INSPIRE UTC & CII Members Receive Kummer Ignition Grants to Boost Research

Twelve Missouri S&T research teams have received inaugural Kummer Missouri S&T Ignition Grants totaling $365,000. The Ignition Grants are designed to provide resources for Missouri S&T faculty members to build teams that can lead to long-term, externally funded, multi-investigator research programs.

Among the first 12 Kummer Ignition Grant projects and principal investigators are:

"AI and Nanomaterials Enabled Real-Time Dynamic Electro-Chemical Sensing and Analytic System" led by **Dr. Chenglin Wu**, assistant professor of civil, architectural and environmental engineering

"Compound Flooding Risk Assessment and Hazard Resilient Building Design under the Changing Climate to Improve Coastal Resilience" led by **Dr. Grace Yan**, associate professor of civil, architectural and environmental engineering

"Convergent Research and Entrepreneurship towards an Aerial Transportation Ecosystem (CREATE)" by **Dr. Genda Chen**, the Robert W. Abbett Distinguished Professor of Civil Engineering,

"Working Group on Infrastructure Resilience and Adaptation" led by **Dr. Jenny Liu**, professor of civil, architectural and environmental engineering.

The Kummer Missouri S&T Ignition Grant Initiative (IGI) is an annual planning grant created by the office of the vice chancellor for research and innovation to fund new and innovative ideas that will ultimately lead to large research proposals in strategic areas for Missouri S&T. The proposals will integrate multi-disciplinary ideas and ignite teamwork and collaboration to strive toward achieving the visions of the Kummer institute through research and innovation.

The grants support initiatives from Missouri S&T's 2021 Research Road Map. This road map identifies major research constellations selected based on the existing research foundation, projected directions of disciplines, and potential to create a research ecosystem.

Original Version Posted January 4, 2022 - Missouri S&T eConnection

CII Member Interviewed by St. Louis Post-Dispatch

Dr. Grace Yan, associate professor of civil engineering, was interviewed for a St. Louis Post-Dispatch article regarding Dec. 10 tornado damage to an Amazon warehouse in Illinois. Reporter Steph Kukuljan's article was titled "'Not invented for resisting tornadoes': Officials, expert zero in on Amazon warehouse construction," and appeared in media outlets throughout the U.S. She was also interviewed on the topic by reporter Russell Kinsaul for a story that aired on KMOV-TV on December 15, titled "Design of collapsed Amazon warehouse coming under scrutiny."

Original Version Posted January 4, 2022 - Missouri S&T eConnection

VICE CHANCELLOR FOR RESEARCH MESSAGE

It is my pleasure to work with Dr. Chen in supporting the Center of Intelligence Infrastructure (CII) and the INSPIRE University Transportation Center (UTC). Missouri S&T is proud of its long-term association with the UTC program that goes back to 1998. Missouri S&T has led a National UTC, two Tier-1 UTCs, and is currently part of a National UTC (TriDurLE) and a regional UTC (MATC). Transportation Infrastructure Engineering is one of the strategic research and educational areas of Missouri S&T and continues to attract considerable research investment and contribute to workforce development in this critical sector of the US economy. We are very proud of the achievements of the INSPIRE UTC who continues to create knowledge leading to the demonstration, implementation, commercialization, and economic development in the greater area of transportation infrastructure.

Dr. Kamal Khayat
Interim Vice Chancellor for Research and Innovation

INSPIRE UTC & CII Students Receive Dean's Ph.D. Scholar Award

Nine Ph.D. students at Missouri S&T received dean's honors from the College of Engineering and Computing (CEC) during a campus ceremony on Thursday, May 12th.

Three students received the Dean's Graduate Educator Award, which recognizes excellence in teaching by graduate students. Six other students received the Dean's Ph.D. Scholar Award, which recognizes scholarly contributions among the most productive Ph.D. students.

"It is an honor to recognize the outstanding contributions made by our graduate students," says Dr. Francisca Oboh-Ikuenobe, the CEC's associate dean for academic affairs. "The awards reflect the students' commitment to excellence and the mentorship their advisors provide. We are very proud of all the Ph.D. students who were nominated and considered."

The awards involved a highly competitive two-tier selection process where each of the CEC departments independently selected up to three nominees for the college to consider. A committee comprising representatives from five CEC departments selected the winners. Among the Honorees were:

- **Gasser Ali**, civil, architectural and environmental engineering; **Dr. Islam El-adaway**, nominator
- **Eslam Gomaa**, civil, architectural and environmental engineering; **Dr. Mohamed Elgawady**, nominator
- **Yanping Zhu**, civil, architectural and environmental engineering; **Dr. Genda Chen**, nominator and director of INSPIRE UTC.

Missouri University of Science and Technology (Missouri S&T) is a STEM-focused research university of over 7,200 students. Part of the four-campus University of Missouri System and located in Rolla, Missouri, Missouri S&T offers 101 degrees in 40 areas of study and is among the nation's top 10 universities for return on investment, according to Business Insider. S&T also is home to the Kummer Institute, made possible by a $300 million gift from Fred and June Kummer. For more information about Missouri S&T, visit www.mst.edu/.

Dean's Ph.D. Scholar awardees L-R: Yanping Zhu, Gasser Ali, Taihao Han, Ramin Rahimi, Jose Sebastian Uribe Lopez, Francisca Oboh-Ikuenobe, CEC associate dean for academic affairs, is representing Eslam Gomaa. Photo by Missouri S&T.

Original Version Posted May 12, 2022 - Missouri S&T eConnection

UTC Outstanding Student of the Year

Hana Herndon was selected for the UTC Student of the Year (SOY) award at the Transportation Research Board (TRB) meeting. Outstanding Students of the Year awards are to recognize and honor the students supported by the UTC Program. Only U.S. citizens or permanent residents are qualified for this award. OST-R sponsors an annual awards banquet in collaboration with the Council of University Transportation Centers in January of 2021 in Washington, DC. Each Center can nominate or select one outstanding student of the year by the deadline established by the UTC Program Office. The Center must provide the student's information for inclusion in the Student of the Year Awards Program. Each participating Center must award its Student of the Year $1,000 and the costs for the student to attend the award ceremony at the TRB Annual Meeting.

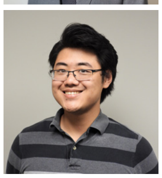
Hana Herndon is a Ph.D. student in the School of Civil and Environmental Engineering at the Georgia Institute of Technology, working under the supervision of Dr. Iris Tien from INSPIRE UTC. Hana graduated with Highest Honors from Georgia Tech in 2021 with a B.S. in Civil Engineering. Hana's undergraduate studies focused on transportation systems and structural engineering, and her graduate research interests include structural health monitoring, structural resilience, and risk analysis. Hana Herndon was selected as an NSF Revolutionizing Engineering Departments (RED) Graduate Fellow, working to revolutionize civil engineering education through the integration of novel data analytics methods and approaches to solve global grand challenges, particularly problems related to increasing infrastructure resilience. Hana is also a recipient of the NSF Graduate Research Fellowship.

NEWS

Undergraduate Research Students Join CII & INSPIRE UTC

Timothy Headrick is a senior in electrical and computer engineering. Tim recently joined INSPIRE UTC as an Undergraduate Research Assistant at CII to help work on UAV devices to monitor city infrastructure. Additionally, he may help with various web development tasks at CII given his work experience at Minerbytes. Tim also helps teach C++ labs at Missouri S&T and is involved in Association for Computing Machinery (ACM) Security and ACM Game Development.

Dawson Jobe is a senior in mechanical engineering. His role in Dr. Genda Chen's INSPIRE UTC research project is to assist in the completion of an unmanned traversing system called TreeFrog to be used to inspect bridges. This system will walk down the side of concrete structures that are partially submerged in water using vacuum suction. Dawson's work will focus on solving mechanical problems that the robot faces as its design is finalized. Ultimately, the system will use a sonar sensor to gather data on the submerged portion of the pillar to be analyzed for defects.

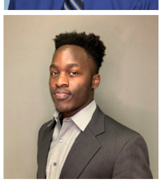


Kevin Lai is a junior in Computer Science. His role at INSPIRE UTC is undergraduate administrative assistant and undergraduate research assistant on augmented reality and web-based interactive training for bridge element classification. Kevin also works as a programmer analyst at the Institute for Applied Nuclear Magnetic Resonance and Undergraduate Student Assistant at the Office of Sponsored Programs.

Rueil Monzambi is a junior in Computer Science with emphasis on machine learning. He is an INSPIRE UTC Undergraduate Research Assistant working on the application of Augmented Reality concepts for bridge inspections. He particularly specializes in computer vision, spatial understanding, and data manipulation and storage. He is also a member of the National Society of Black Engineers (NSBE) and a leader in Cru (formerly called Campus Crusade for Christ).

Jonathan Saelens is a junior in computer engineering. His role at INSPIRE UTC is to manage and improve the electrical wiring as well as assist with the robot operating system (ROS) movement code for Tree Frog, a four-legged vertical climbing robot that uses vacuum suction cups to stick to pillars to survey bridges. He is also involved on campus with the Formula SAE Design Team and will be the Electrical Project Manager for the 2022-2023 season. Jonathan plans to remain at Misosuri S&T after graduation to pursue a master's degree in electrical engineering.

Brandyss Sherman-Hall is a junior in electrical engineering. He is an INSPIRE UTC Undergraduate Research Assistant working on the power supply system for air-cushioned vehicles. His role consists of the design and manufacturing of the vehicle power system using commercial parts or 3D printed parts. Brandyss' involvement on campus extends to being the Electrical Team Lead for the Combat Robotics Design Team.

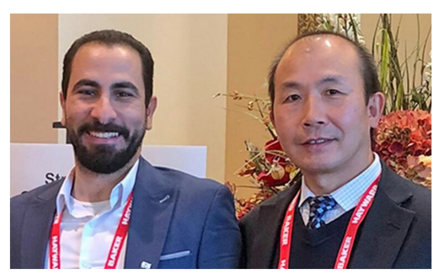


Eric Ssesanga received an A.S. degree in civil engineering from Montgomery College, Maryland, USA and is now a junior in civil engineering at Missouri S&T. He serves a dual role as an INSPIRE UTC Administrative Assistant and Undergraduate Research Assistant. Eric is assisting in expanding the center listserv and designing an innovative high-speed transportation infrastructure system. Eric is involved on campus with the Steel Bridge Design Team and is also a member of the American Society of Civil Engineers (ASCE).

CII Student Receives Best Poster Award at Transportation Conference

The U.S. Department of Transportation's National Center for Transportation Infrastructure Durability and Life-Extension (TriDurLE) organized a student poster competition at the center's annual symposium on December 6. Beshoy Riad, an S&T student, received the best poster award for his poster presentation titled "Implementing the Lightweight Deflectometer for MoDOT Construction Acceptance of Unbound Material Layers." Beshoy is a Ph.D. candidate in civil, architectural and environmental engineering. His advisor is Dr. Xiong Zhang.

Original Version Posted January 4, 2022 - Missouri S&T eConnection



Beshoy Riad and Dr. Xiong Zhang

New Post-Doctoral Fellow Joins CII

Tarutal Ghosh Mondal is currently working as a Post-Doctoral Fellow in the Center for Intelligent Infrastructure (CII) at Missouri University of Science and Technology. Before joining CII, he received his Ph.D. degree in Civil Engineering from Purdue University. His research interests include autonomous sensing and intelligent condition assessment of structures. He is also working in the field of computer vision, deep learning, and augmented reality to develop robust systems for the health monitoring of civil infrastructures.

Research Interests: Robotic inspection, multimodal sensing, computer vision, deep learning, augmented reality, internet of things (IoT), and big data analytics.

As a post doctoral fellow, Tarutal will help develop a deep learning defect detection approach for utility-scale solar farms from drone-based thermal and hyperspectral imaging. This study is to address the challenges of data collection and data processing that existing drone-enabled thermal imaging inspection techniques face. In addition to the infrared and hyperspectral cameras, a Global Positioning System (GPS)/Inertial Measurement Unit (IMU) device will be mounted on a drone for automatic geo-referencing of the defects on solar panels. In the data process task, Tarutal will work toward developing an online user-friendly platform integrated with deep learning models for automatic image analysis and localization.

INSPIRE UTC & CII Members Receive Teaching and Research Awards

Dr. Colin Potts, provost and executive vice chancellor for academic affairs, recognized 27 faculty members for excellence and achievement in teaching, research and service during a faculty awards banquet held December 9, 2021 on campus.

The Faculty Research Award recognizes faculty members who have demonstrated excellence in research and scholarship. Recipients are:

- Dr. Islam El-adaway, professor of civil, architectural, and environmental engineering
- Dr. Chenglin Wu, assistant professor of civil, architectural and environmental engineering.

The Faculty Excellence Award recognizes faculty members who have demonstrated sustained excellence in teaching, research and service. Recipients are:

- Dr. Steven Corns, associate professor of engineering management and systems engineering
- Dr. Grace Yan, associate professor of civil, architectural and environmental engineering.

Dr. Islam El-Adaway

Dr. Chenglin Wu

Dr. Steven Corns

Dr. Guirong Yan

Original Version Posted January 4, 2022 - Missouri S&T eConnection

VR OPERATOR TRAINING FOR ROBOT ASSISTED BRIDGE INSPECTION

Regular reliable bridge inspection is critical to bridge maintenance and public safety. Semi-autonomous bridge inspection robots provide one approach to improving the reliability and regularity of bridge inspection by multiplying human inspectors' effectiveness. Although many challenges remain, recent advances in the design, control, and sensor loading of inspection robots, both flying and crawling, shows the potential for significant advances [1]. Given these advances in the design and control of such individual robots and sensors, this paper addresses two issues within the significant challenge of monitoring and controlling multiple, heterogeneous, semi-autonomous robots during an inspection task. We start by describing a unifying software framework for simulation training and for monitoring and controlling inspection robots. We then attack the problem of optimal routing for crawling robots that must traverse each member of a (steel truss) bridge. Furthermore, these advances enable lessons learned in simulation to inform the design and development of robots, sensors, and human-robot interfaces for operator-in-the-loop automated bridge inspection.

In our formulation of automated bridge inspection, we assume that a human operator oversees and monitors the bridge inspection task while a team of semi-autonomous robots cooperatively traverses and inspects every member of a steel truss bridge. The human operator uses our Simulation Training And Control System (STACS) built on the Unity game engine and implementing our modular software architecture for this task. Figure 1 shows a screenshot of the virtual reality (VR) version of STACS. STACS is designed for dual uses. It provides 1) a simulation training environment for robot assisted bridge inspection and 2) a monitoring and control interface for managing multiple robots.

Figure 1: VR-STACS training simulator and VR interaction.

STACS' component-based software architecture enables easy modifications. We can easily add new robot types and change existing robots' properties such as speed and sensor load. This makes it possible to quickly explore multiple interaction and interface designs in simulation and thus quickly eliminate bad designs to converge on promising ones. For example, we can quickly examine the effect of different physical robot designs on inspection speed and operator cognitive loads. STACS design and architecture provide several advantages. First, we can easily add new robots and change existing robot's physics, sensors, and physical properties. Second, as long as a robot has minimal autonomy to move to a target location, we don't need to teleoperate robots rather just give them a sequence of waypoints to follow on the bridge. Third, the operator's role then reduces to monitoring robots and sensor readings while the robots follow preplanned paths. Thus, the operator intervenes only operate) to get the robot back on track or reroute other robots by pressing a re-route button that results in a new set of routes, provided as a set of waypoints to each functioning robot. Figure 2 shows how you can do this in VR by pointing and specifying a series of waypoints on a virtual bridge while training. Note that an augmented reality (AR) interface enables the same interaction on a real-world bridge.

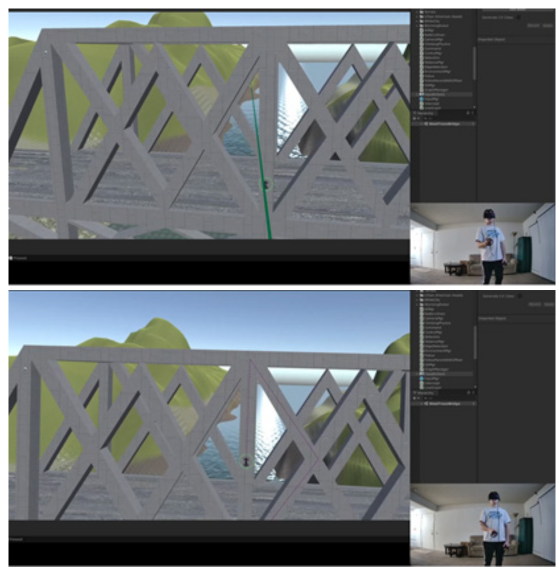


Figure 2: Controlling an individual bridge climbing robot in VR-STACS.

Providing these waypoints means solving the associated routing problem. *Given a team of k robots, can we generate optimal routing for each robot to minimize total inspection time*. This problem maps well to the well-known, but NP-Hard, Min-Max k-Chinese Postman Problem (MM k-CPP) on graphs. Figure 3 shows how to map a Pratt truss to the associated MM k-CPP graph. Being NP-hard, finding the global optimum quickly becomes intractable for any large bridge with many truss members [2]. We thus attack this problem with a new meta-heuristic genetic algorithm (MetaGA) that quickly produces near-optimal balanced tours for k robots. MetaGA tour quality is statistically indistinguishable from best known results on common benchmarks.

Scaling up to the size of real-world bridges, our genetic algorithm produces significantly better (15%) tours in a fraction of the time (0.05) compared to a prior genetic algorithm approach using a direct encoding. These results show the potential of our new

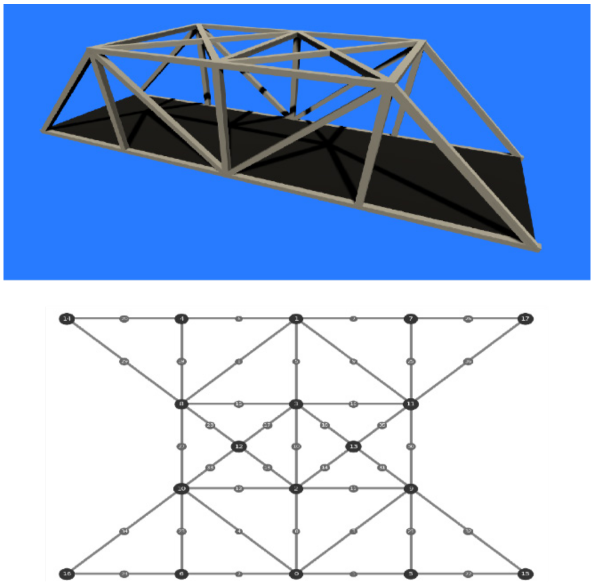


Figure 3: Mapping a Pratt truss to a corresponding graph.

approach for the broad class of arc-routing problems and specifically for quickly generating high-quality tours for robot-assisted real-world bridge inspection tasks.

Figure 4 shows routing produced by our algorithm for a version of the routing problem where four robots start from one bridge abutment. MetaGA routing results in routes being approximately the same length and the routes produced for this K truss are no exception. The shows an overlay of all the routes with thicker and redder lines denoting multiple traverses of the same member. The members incident to the start vertex, on the lower left, have the most overlap.

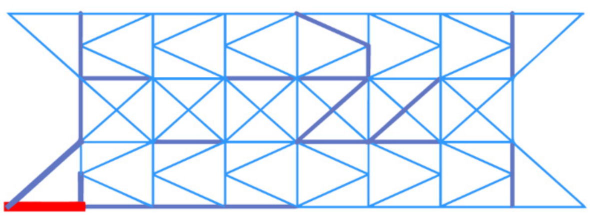


Figure 4: MetaGA tours for 4 robots on a K truss.

Such overlapping is significantly reduced when we evenly distribute robots at all four abutments. Figure 5 shows more efficient (less overlap) routing for eight robots when starting from four abutments compared to them all starting at one.

Integrating these routing results into STACS enables automated bridge and bridge inspection scenario generation for training as well as providing routing and rerouting for real robots in real-world inspection scenarios. We provide videos that show the development and current state of VR-STACS [5] and more detailed descriptions of the research and development described in this article in [3, 4].

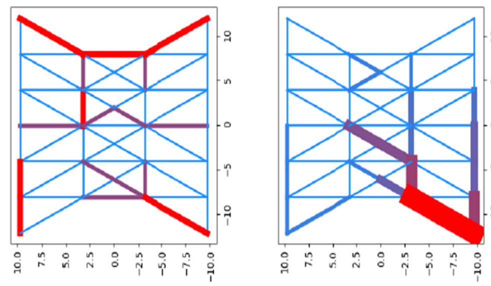


Figure 5: MetaGA produces more efficient (less overlap) inspection routing with four abutments versus one for 8 inspection robots.

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[3] N. Harris, S. Liu, S. J. Louis, B. Dedeurwaerder, J. Peters, and J. H. La, "Simulation Training and Route Optimization for Robotic Bridge Inspection," in Proceedings of the 13th International Workshop on Structural Health Monitoring, 2021.

[4] N. Harris, S. Liu, S. J. Louis, and J. H. La, "A genetic algorithm for multi-robot routing in automated bridge inspection," In Proceedings of the Genetic and Evolutionary Computation Conference Companion, pages 369–370, Prague Czech Republic, July 2019. ACM

[5] J. Peters and S. J. Louis, STACS video playlist at https://youtube.com/playlist?list=PLrXtiYmpe-iuZ1_YIhL6AHMl-DjC0zzFv. April 21, 2022.

ABOUT THIS PROJECT

This review report was prepared with the help of Brian Dedeurwaerder, PhD candidate in Computer Science and Engineering at the University of Nevada, Reno. For more information, please contact Brian at bdedeurwaerder@nevada.unr.edu or Dr. Sushil Louis at sushil@unr.edu

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HUMAN-EMBODIED DRONES FOR MOBILE MANIPULATION IN BRIDGE INSPECTION AND MAINTENANCE

Current drones perform a wide variety of tasks in surveillance, photography, agriculture, package delivery, etc. However, these tasks have been performed passively by human operators. Aerial manipulation shifts this paradigm. Drones with various types of manipulators physically interact with the environment beyond just simply sensing it. Several research groups have demonstrated tasks like valve-turning, structure assembly, and industrial applications [1]. The underlying theory on aerial manipulation is also generally understood by Orsag et al. [2].

The state-of-art aerial manipulation is focused on autonomy. A mobile manipulating drone would autonomously identify an object, configure suitable grasps and plan motions to execute desired tasks. This has been achieved by simplifying object geometries, and motion trajectories (mainly linear). Such autonomous drones could replace some laborous tasks (by human manipulators) in dangerous environments like the underside of a bridge, wind turbine, or power cables. However, such aerial manipulation is not fully implemented in practice as it lacks dexterity for desired tasks.

In bridge inspection and maintenance, expert workers physically interact with objects while performing tasks. They leverage their experiences to assess the performance and dexterously complete the desired tasks accordingly. Haptics and Immersive technologies like Augmented- and Virtual-Reality (AR/VR) would allow one to integrate such experiences in robots. Toward this vision, this article presents a human-embodied drone system. The net effect is such a system could allow a mobile-manipulating drone (MM-UAV) to embody and transport the worker's senses, actions, and presence from one location to another through AR/VR devices. Through such human-embodied drone interface, the worker can both dexterously perform tasks in the surrounding envoironment and socially interact with actual workers on the job site (Figure 1).

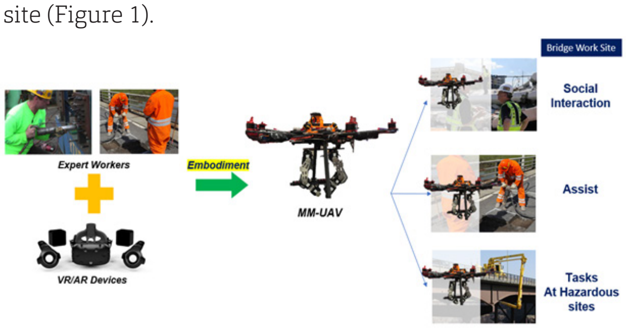

Figure 1: Notional concept of human-embodied drone system.

Two human-embodied drone systems were designed [3-4]. The first system in Figure 2 [3] has a Powerday S550 hexacopter as a drone base. The drone is equipped with a pair of 3 degree-of-freedom (DOF) arms and parallel jaw grippers that mount to the drone. The 3-DOF does not represent human arm motions, but this design suits the payload limit of the drone and provides the desired motion range for the operator to manipulate objects. For a synthetic vision, a camera was attached to a motor on the top of the arms to provide 2D data in real time. The motor tilts the camera by following the operator's head motions. In addition, a 3D model of the test-site was pre-captured and rendered in the VR headset to provide better situational awareness. For immersion, the Microsoft HTC VIVE was selected. The headset gives the operator a virtual representation of the vehicle's environment. The hand controllers provide haptic feedback through scalar-scaled vibrations when gripper sensed reaction forces while interacting with objects.

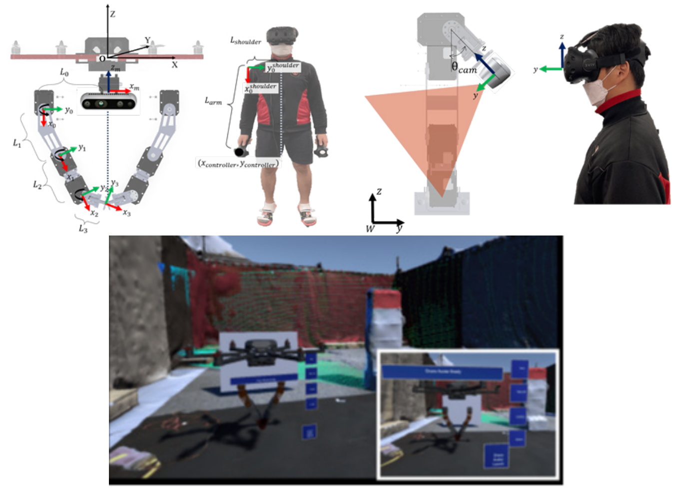

Figure 2: Human arm/head and aerial manipulator kinematic matching (Top), virtual test-site, aerial manipulator rendered in VR headset (Bottom).

To configure the virtual world within a real world environment, a gaming software engine, Unity, and Robot Operating System (ROS) Libraries, ROS# were integrated together.

Finally, Figure 3 demonstrates the flight trials. The real-world flight was conducted in a motion capture arena (bottom of the figure) with a VR station (center of the figure). The VR station is 10 meters from the arena. The aerial manipulator has a cascade PID controller for its stability. The operator accomplishes package delivery through the aerial manipulator from VR station. During the flight, the operator is aware of the task environment through VR headset and can even interact with an onsite worker.

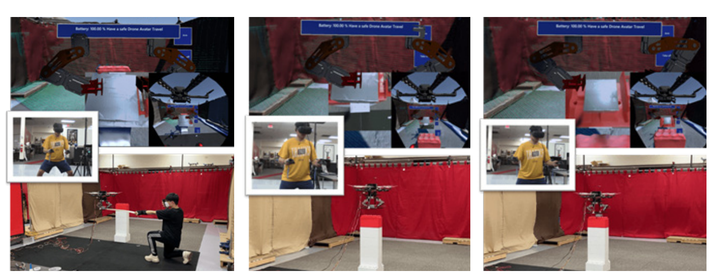

Figure 3: Flight trials for package delivery with onsite worker.

The flight trials showed promising results. However, the tasks were performed vertically by limited DOF of the arms. The 2D-3D integrated vision feedback is not suitable to provide acceptable situational awareness. Furthermore, the package delivery task is not dexterous manipulation.

To address the above challenges, we presented the evolved human-embodied drone system [4] as shown in figure 4.

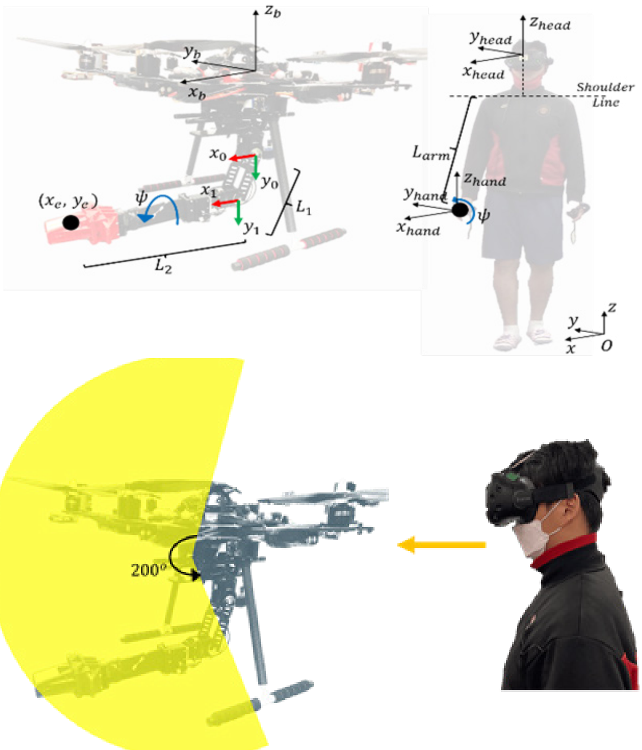

Figure 4: Human-embodied drone system

Here, the synthetic vision which consists of a pre-captured 3Dmodel and a small 2D model created in real-time has been substituted to 200° Field-of-View (FOV) Fisheye camera to provide broader situational awareness in real-time. A dual-arm manipulator was replaced with a 4-DOF arm and a parallel jaw gripper. They allowed the operator to dexterously pinch and grasp objects. In addition, a disturbance observer-based (DoB) controller was implemented to improve the aerial manipulator's stability during the manipulation tasks.

Figure 5 demonstrates the flight trials. Bridge related tasks like peg-in-hole and drilling were selected to be accomplished. Key manipulation was also added to showcase the dexterity of the system.

Figure 5: Flight trials: peg-in-hole (left), drilling (center), key manipulation (Right)

In the future, the following improvements will be pursued. The current controller considers mechanical impedance from the manipulator's physical interaction with the object as disturbance. This can cause mechanical damage when the reaction forces are large. Also, this can prevent the operator from performing accurate haptic assessments in the task. Thus, a force tracking impedance controller will be studied and implemented. In addition, the haptic interface will be upgraded with state-of-the-art sensors and equipment to provide more types of feedback like vibration, temperature, object texture sense to the operator.

References:

[1] F. Ruggiero, V. Lippiello and A. Ollero, "Aerial Manipulation: A Literature Review," in IEEE Robotics and Automation Letters, vol. 3, no. 3, pp. 1957-1964, July 2018, doi: 10.1109/LRA.2018.2808541.

[2] M. Orsag, C. Korpela, P. Y. Oh, and S. Bogdan, "Aerial Manipulation", Springer International Publishing, 2018.

[3] D. Kim and P. Y. Oh, "Toward Avatar-Drone: A Human-Embodied Drone for Aerial Manipulation," 2021 International Conference on Unmanned Aircraft Systems (ICUAS), 2021, pp. 567-574, doi: 10.1109/ICUAS51884.2021.9476704.

[4] D. Kim and P. Y. Oh, "Aerial Manipulation Using a Human-Embodied Drone Interface," 2022 International Conference on Advanced Robotics and Its Social Impacts (ARSO), 2022, (Accepted)

ABOUT THIS PROJECT

This project is led by Dongbin Kim, Adjunct Assistant Professor in Mechanical Engineering at University of Nevada, Las Vegas, under the supervision of Prof. Paul Y. Oh. This Human-Embodied Drone System is part of Mobile-Manipulating UAVs for Sensor Installation, Bridge Inspection and Maintenance, INSPIRE UTC Research Program led by Missouri University of Science and Technology.

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WHEN AR MEETS BRIDGE INSPECTION: FROM BRIDGE TO CLOUD

INTRODUCTION

As bridges in the U.S. National Bridge Inventory continue to deteriorate, biennial inspection becomes more critical and demanding than ever before. The current practice with visual inspection requires the presence of a crew of two inspectors at any bridge site with one for inspection and paperwork and the other for photographing of bridge deterioration and areas of concern. In recent years, inspectors in some states are equipped with mobile tablets (with a flat-screen interface) in a 3D model-based data entry application [1]. The 3D model markup and rendering are often inaccurate and cannot be manipulated by the inspectors to record and visualize defects and element level data (e.g., defect location). This shortcoming can be overcome with the aid of digital technologies in three forms. Virtual reality (VR) immerses users in a digital environment.

Augmented reality (AR) overlays virtual objects on a real-world environment. Mixed reality (MR) can not only overlay but anchor virtual objects to the real world to enable coexistence and interaction between physical and digital objects [2-3]. In bridge applications, MR allows inspectors to recognize their surroundings and digital contents to interact with the real bridge in three dimensions.

AR BRIDGE INSPECTION WORKFLOW

Missouri S&T recently developed with MR Toolkit (MRTK) a MR interface used in a Microsoft's AR headset. As illustrated in Figure 1, this new interface will likely revolutionize the 3D data collection, storage, retrieval, and analysis (or general cloud-based data management) of an entire bridge through wireless communication. It provides an inspector with intraoperative hands-free access to complex data, real environment, and bi-directional communication. As an engine of the MR interface, World Locking System (WLS) toolkit helps lock holograms in place as the user walks around so that space pins can be added to specific locations of the model to align perfectly corresponding features with the physical bridge. The MR bridge environment imports a high-resolution 3D reconstructed and georeferenced bridge model at 5 cm/pixel from a laser scanner and stores and visualizes the meta data such as past inspection report and photos of defects including size, shape, and location. The region of interest (ROI) defects can be compared and annotated as needed by retrieving the historical inspection data and adding the current inspection data. A database is established to automate the bride inspection and reporting process according to the 2019 AASHTO Manual for Bridge Element Inspection. Therefore, the bridge element field inspection efficiency and accuracy can be dramatically improved with the developed MR interface.

A point cloud scan was taken of the bridge on 10th Street in Rolla, MO as shown in Figure 2. The bridge point cloud model was cleaned up in SketchUp, exported to a format supported by Unity, and then imported into the project. The model texture and size were maintained. When the bridge was scaled 1:1 in Unity, it was the same size as the actual bridge. This allowed the bridge model to be overlaid on the actual bridge with virtual and physical features roughly aligned. The model was scaled, rotated, and repositioned in x, y, z directions either manually or by inputting an accurate desirable value to improve the accuracy of bridge alignment.

WLS and its space pin feature was implemented to align local features of the bridges as shown in figure 3. WLS uses an alignment manager called the Frozen Engine to lock the world space as you move around. Space pins were added as small objects that could be individually positioned on physical objects at runtime, and then the Frozen Engine would adjust the view of the model to align. In this way, the bridge model alignment was made much more accurate so that the bridge model can perfectly be anchored with the real bridge for each future revisits.

After the 3D bridge model was overlaid with the real bridge

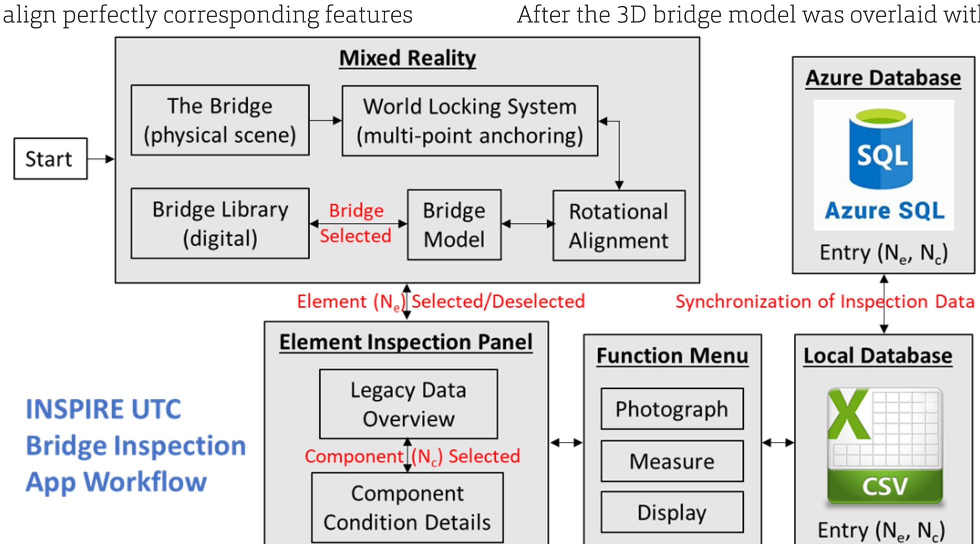

Figure 1: INSPIRE UTC bridge inspection app workflow.

Figure 2: Bridge model manipulated and overlaid.

asset, the Photograph mode can capture the defect areas and localize them correspondingly. The defect pictures and their locations, preliminary bridge element category (subject to later review and confirmation) and its service conditions will be annotated, as illustrated in Fig. 4. The defect meta data will be saved to csv file together with the bridge inspection legacy data for cloud synchronization with Azure SQL database.

The Measure mode allows the user to select the start point and then raycast measurement points in sequence and the dimension measurement along specific surfaces was enabled for bridge element inspections. The Display mode allows defect photo and the distance measured will be displayed for users'

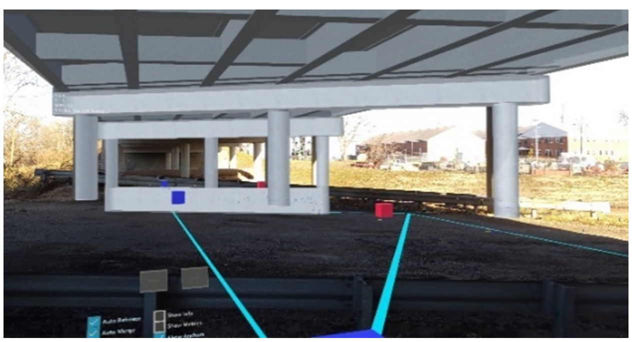

Figure 3: World locking system (WLS) in place.

further analysis. Besides the local database that is being fed information directly from the application at runtime, an Azure cloud database based on SQL that can be accessed whenever there's an internet connection. This allows the operator to work in a remote site, then synchronize the data collected locally to the cloud database. This practice is crucial to prevent data loss and allow data access anytime and anywhere.

Figure 4: Hand-free bridge inspection enabled by AR.

CONCLUSION

The proposed AR approach will accelerate the use of MR devices, such as HoloLens 2, in the bridge element inspection field to improve the quality of visual inspection and bridge asset condition statement for preventative maintenance workflow. The developed MR interface can assist in aspects of bridge inspection education, communication, or operative planning as the pace of MR related technological development will evolve rapidly in the coming years.

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[1] Ahlborn, Theresa M. Wireless data collection retrievals of bridge inspection/management information.2017-02-28

[2] Karaaslan E, Bagci U, Catbas FN. Artificial Intelligence Assisted Infrastructure Assessment using Mixed Reality Systems. Transportation Research Record. 2019;2673(12):413-424. doi:10.1177/0361198119839988

[3] What is the Mixed Reality Toolkit. https://github.com/Microsoft/MixedRealityToolkit-Unity

ABOUT THIS PROJECT

This research article was prepared by Dr. Liujun Li, Associate Research Professor in the Center for Intelligent Infrastructure at Missouri University of Science and Technology, which will serve as part of the study supported by T-REX. Our objective is to create a mixed reality interface of geospatial data to assist inspectors in a more efficient and effective inspection of bridges while improving the consistency and reliability of condition assessment results with hands-free automated measurement and cloud data management and visualization in a geo-referenced augmented reality environment. For more information, please contact Dr. Liujun Li at llpwc@mst.edu or Dr. Genda Chen at gchen@mst.edu.

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2019-2024 POOLED-FUND STUDY #TPF-5(395) ON TRAFFIC DISRUPTION-FREE BRIDGE INSPECTION INITIATIVE WITH ROBOTIC SYSTEMS

Introduction

In the United States, there are over 617,000 bridges in the National Bridge Inventory [1]. According to the 2021 American Society of Civil Engineers (ASCE) Infrastructure Report Card, more than 42% of the bridges are currently at least 50 years old, and 7.5% of the bridges are considered structurally deficient or in "poor" condition. These structurally deficient bridges support 178 million trips every day, a potential safety concern. Overall, the bridges are rated C with Grade A being excellent and Grade F being a complete failure. Other types of infrastructure, such as dams, levees, transits, and schools are even worse as indicated in Figure 1.

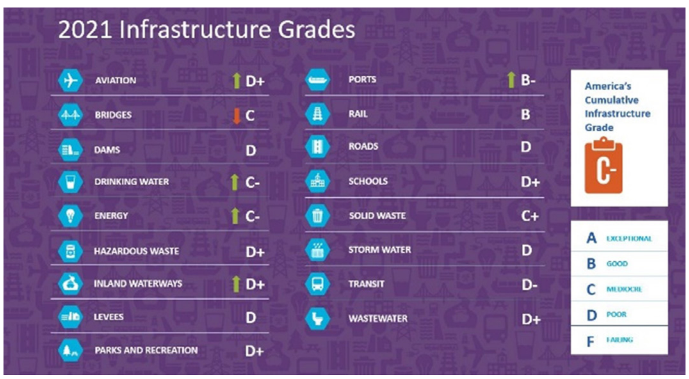


Figure 1: The 2021 infrastructure report card [1].

The current practice of visual inspection is required biennially. Bridge inspection often requires the use of heavy lifting and access equipment, thus increasing operation time and direct costs. When access to the inspected area must be made from bridge decks, the indirect costs associated with road closure multiply. In such a case, travelers may be frustrated with traffic congestion and, both the travelers and inspectors are subject to a safety concern on high volume highways. Moreover, visual inspection is quite subjective and often inconsistent. It is thus of economic, psychological and social importance to develop an alternative platform for faster, safer, cheaper, and consistent bridge inspection with minimum impact on traffic flow.

The INSPIRE University Transportation Center (UTC, https://inspire-utc.mst.edu) at Missouri University of Science and Technology has been developing advanced technologies to aid in next-generation bridge inspection and maintenance. Once integrated, the advanced technologies are referred to Bridge Inspection Robot Deployment Systems (BIRDS). Specifically, structural crawlers, unmanned aerial vehicles (UAVs), and multimodal unmanned vehicles provide mobile platforms for in-depth inspection of elevated bridges. For example, a multimodal unmanned vehicle, called BridgeBot, combines the driving capability of crawlers and the flying capability of UAVs into one system for bridge inspection. The BridgeBot can fly to the underside of a bridge deck, attach to a bridge girder, and provide an inspection platform for installed cameras to take high-resolution images from deficient areas as conventional visual inspection would do.

At the INSPIRE UTC, thermal and hyperspectral images are being developed to assess concrete delamination and steel corrosion of reinforced concrete (RC) bridges. Together with other existing technologies such as ground penetrating radar, impact echo and impact sounding, they provide a suite of measurement tools and methods for the nondestructive evaluation (NDE) of structural damage and deterioration conditions in RC and steel bridges. Innovative sensors such as UAV-based smart rocks for scour monitoring and integrated point and distributed optical fiber systems for strain and corrosion monitoring provide mission-critical data, such as the maximum scour depth, corrosion-induced steel mass loss, and live load induced strains to normalize the NDE data taken over time at spatially distributed points.

Project Objectives and the Scope of Work

The goals of this pooled-fund initiative are to engage closely with state Departments of Transportation (DOTs) in the early stage of technology development at the INSPIRE UTC, and leverage the center resources to develop case studies, protocols, and guidelines that can be adopted by state DOTs for bridge inspection with no or minimal adverse impact on traffic. The initiative involves the integration and field demonstration and documentation of the BIRDS, including structural crawlers, UAVs, multimode vehicles, NDE 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.

To achieve the above objectives, the following tasks are proposed:

1. Bridge selection for manual and automated inspections. De-

velop a selection protocol of bridges that are appropriate for both manual visual inspection and automated NDE. Thus, the performance of robot-assisted NDE can be compared with the current practice of visual inspection. The main parameters considered in this selection include span length, bridge type, accessibility, and importance. For example, river-crossing bridges may be inspected in great depth with advanced technologies, while simple highway bridges with easy access may not require any robotic platform during inspection.

2. Operation of multimodal unmanned systems. Develop a field test facility of the robotic system, the BridgeBot, equipped with two infrared cameras (e.g., dual-sensor FLIR DuoTM Pro) and one impact sounding/echo device for RC elements, and a structural crawler for other bridge elements.
3. Correlation of top and bottom deck inspections. Due to gravity, deterioration on the bottom surface (a safety issue) is more critical than that on the top surface (a serviceability concern). On the bottom side of a bridge deck, deterioration such as concrete cracking, concrete delamination, and reinforcement steel corrosion are easier to detect from underside of the deck. The detection results derived from inspections above and below the deck are compared to understand their correlation or complementary nature.
4. NDE and sensing integration into visual inspection. Develop preliminary guidelines to test NDE devices such as hyperspectral camera for surface mechanical and electrochemical features in RC elements, and test in-line fiber optic sensors for simultaneous measurement of strain, temperature, and mass loss in cross section of reinforcing bars. Normalize/calibrate the NDE test results with those of a few pre-installed fiber optic sensors in structural behavior assessment. All the detected deterioration cases with measurement data are compared with visual inspection results to understand and quantify the improvement in probability of detection compared to the current practice of inspection.
5. Case studies with a representative bridge inventory. Develop an inventory of geographically-distributed test bridges and conduct case studies to implement and demonstrate NDE devices and sensors for the detection of surface and internal damage and deterioration in structural elements, and implement and demonstrate UAV-based smart rocks with embedded magnets for the scour monitoring of bridges. Store and maintain curated data within six months of their collection at the Scholars' Mine of Missouri University of Science and Technology. Share the data with the INSPIRE UTC investigators and, upon approval of state DOTs, the public as appropriate.
6. Protocol and guideline modification. Evaluate and refine as needed the protocols and guidelines of field tests for disruption-free bridge inspections after at least two (2) years of field operation. Imaging and sensing data are fused together to improve the detectability of problem areas with reduced capacity. The test results and corresponding visual inspection results are evaluated and summarized in a mid-term report, based on the probability of detection for structural damage/ deterioration and the improvement of visual inspection practice of bridges.
7. Limited release of protocols, guidelines, and criteria. Conduct a beta version rollout of the protocols, guidelines, and performance criteria at the INSPIRE UTC and the Missouri Local Technical Assistance Program (LTAP) in 4th and 5th years. As part of this rollout, workshops on the workforce development with the developed protocols, guidelines, and field demonstration technologies are conducted. Upon request, in-house workshops are held at participating states once a year.
8. Final reporting and curation of main findings. Prepare and publish a final report on the protocols, guidelines, and performance criteria of field tests with the robotic system at the end of 5th year. Store and maintain curated data and the final report at the Scholars' Mine of Missouri University of Science and Technology. Share the data and the report with the INSPIRE UTC investigators and, upon approval of state DOTs, the public as appropriate.

Selected Bridges for Field Tests

A sample of representative bridges to test robotic technologies in various applications permits data collection efforts within budget constraints:

- Up to nine (9) similar highway bridges/year in three (3) age groups or one long-span bridge/year from each participating state are tested starting in the 3rd year.
- The Long Term Bridge Performance (LTBP) Program data are leveraged to develop deterioration curves.

In this study, the LTBP Bridge Selection Methodology is modified to

1. Determine the most common bridge types that dominate now and are likely to do so in the future: steel-girder bridges and prestressed concrete-girder bridges.
2. Identify representative clusters of each primary bridge type within various regions of the United States: climate/environmental conditions and regional/state maintenance practices and concentrated geographic areas to allow for cost-effective data collection efforts.
3. Determine the level of detail appropriate for data collection efforts for each bridge within geographic clusters: most detailed NDE, structural characterization through field instrumentation, material sampling, and visual inspection for each bridge identified.
4. Perform legacy data mining from plans, inspection reports, maintenance records of all the candidate bridges to determine which bridges represent a geographic cluster with the following specific criteria: state owned, not over a railroad, max. span length between 10 and 50 m, max. of four lanes on bridge, average daily traffic less than 50,000, and built after 1970.

As shown in Figure 2, seven state DOTs including California (CA), Georgia (GA), Missouri (MO), New York (NY), Texas (TX), Virginia

2019-2024 POOLED-FUND STUDY #TPF-5(395) ON TRAFFIC DISRUPTION-FREE BRIDGE INSPECTION INITIATIVE WITH ROBOTIC SYSTEMS

(VA), and Wisconsin (WI), supported and participated in this pooled-fund study. The contractor of this pooled-fund study, Missouri University of Science and Technology, recommended 27 candidate bridges for each state with one exception of Missouri (54 bridges). With state DOT inputs, 9 out of 27 bridges were selected for visual inspection and automated inspections. The selected bridges aged in 3 groups (15-20, 25-30, and 35-40 years).

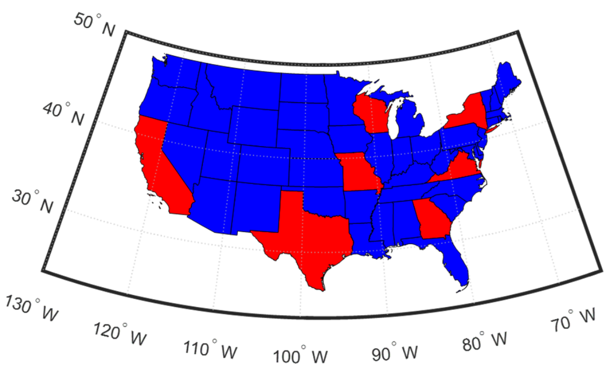


Figure 2: Seven participating states shown in red.

To allow statistical analysis and comparative study, attempts were made to divide the selected bridges into two groups: concrete-girder and steel-girder. Table 1 shows the grouping of seven states in providing different types of bridge testbeds though they may be deviated somewhat by the participating DOTs.

Table 1: Grouping of states to provide two types of girder bridges for this pooled-fund study.

Steel-Girder Bridges	Prestressed Concrete (PC) Girder Bridges
New York	California
Virginia	Georgia
Wisconsin	Texas
Missouri	

System Integration for Field Tests

Currently, the BIRDS is being developed for field tests of the selected bridges mainly from the underside of their decks, which can directly reduce the impact on passing traffic. The BIRDS is equipped with climbing robots, unmanned aerial vehicles, multimodal vehicles, sensors, NDE 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 UTC, and a means of transportation for a crew of two or three inspectors.

Specifically, the BIRDS facility includes a comprehensive set of hardware and software to enable field tests to the extent practically possible with the mobile platforms. Hardware includes a 15-seat van, flying robots (Headwall M600 Pro Drone, Geodetic M600 Pro Drone, Eliso2, Skydio2, and Anafi), climbing robots on steel and concrete members, hybrid robots (BridgeBot for flying and traversing services), sensors (corrosion sensors and smart rocks for bridge scour monitoring), and augmented/virtual reality devices. Software includes analysis tools of data collected from various sensors (e.g., imaging analysis, wavelet analysis, and deep learning). Field tests will start in May of 2022, and be completed till the August of 2024.

Robot-assisted Inspection Protocol

For each bridge, field tests will be done in three phases: 1-Screening, 2-Probing, and 3-Confirming as shown in figure 3:

1. Screening inspection – Inspectors walk around the bridge when accessible or fly an UAV equipped with RGB and infrared cameras when inaccessible.
2. Probing inspection – UAV-assisted optical/thermal/ hyperspectral imaging and LiDAR scanning or crawler-assisted NDE are conducted in the areas of interest with abnormality identified during screening inspection.
3. Confirming inspection – Severe damage/defects determined during the probing inspection are confirmed with inspectors' engineering judgement based on visual inspection or nondestructive testing. If available, surface-mounted or embedded sensors provide in-situ data for the conformation of inspection results.

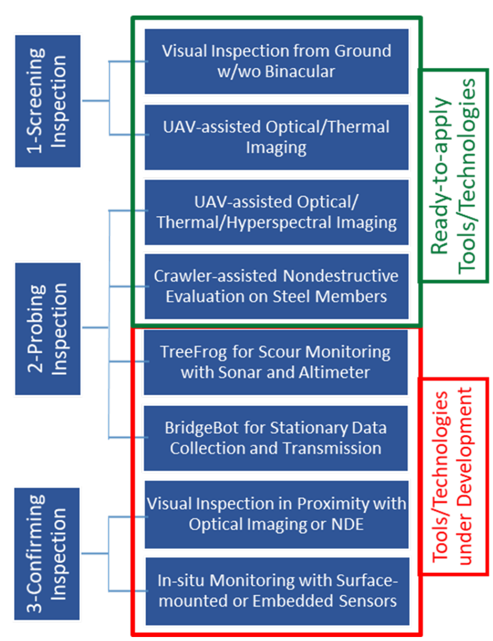


Figure 3: A robot-assisted inspection protocol.

Figure 3 presents an inspection protocol in three phases. The protocol summarizes the maturity of different technologies, which will be deployed once ready. A solar-powered weather station with wireless communication, as shown in Figure 4, provides meteorological data to support the interpretation of acquired inspection data through drone-based remote sensing.

Figure 4: A portable weather station for metereological and environmental data.

Condition Assessment of Bridge Network

To assess the condition of transportation infrastructure with networked bridges and roads, the BIRDS will be applied in combination with a satellite to formulate a multiscale strategy for data collection and analysis, as shown in Fig. 5. The satellite, RGB, LiDAR, infrared, and hyperspectral images as well as robot-assisted nondestructive evaluation and sensor data will be fused to understand both the surface and subsurface conditions of bridges.

Reference

[1] American Society of Civil Engineers. 2021 Infrastructure Report Card.
www.infrastructurereportcard.org

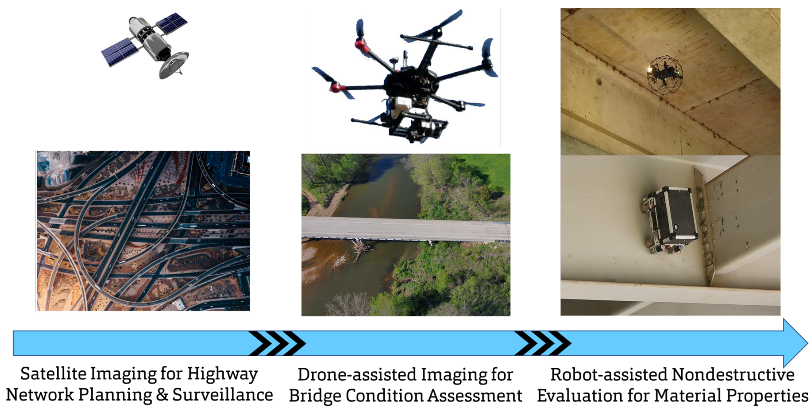


Figure 5: A multiscale sensing system for condition assessment of a bridge network.

ABOUT THIS PROJECT

Led by Dr. Genda Chen, Professor and Abbett Distinguished Chair in Civil Engineering at Missouri University of Science and Technology, this study was led by Missouri Department of Transportation (DOT) and supported by seven DOTs in the state of New York, Virginia, Wisconsin, Georgia, Missouri, Texas, and California. Progress will be reported in this series of newsletters as it becomes available and overall results and findings will be summarized in a final report. For more information on this project, please contact Dr. Chen at inspire-utc@mst.edu or (573) 341-6114.

EDUCATIONAL MODULE SERIES

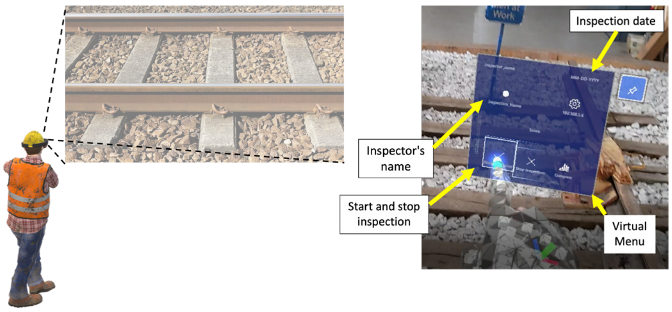
UPDATING BRIDGE RISK ASSESSMENT USING MEASURED CORROSION DATA

BY IRIS TIEN FROM GEORGIA INSTITUTE OF TECHNOLOGY

In this 50-minute lecture, an approach for updating bridge risk assessment using bridge inspection data is introduced. The measurement data is corrosion inspection data as measured by percent mass loss of reinforcement. The focus is on particularly vulnerable bridges, including shear-critical bridges and bridges with short lap splices. Numerical models of these bridges are created, and how the effects of corrosion can be analytically captured in these models is described. The risk of these bridges is then analyzed using probabilistic fragility analyses. The outcomes provide probabilities of exceeding certain bridge damage states given varying loading intensities. The approach gives a way to update assessments of bridge risk based on corrosion inspection data. The analyses provide assessments of bridge risk by varying bridge types, levels of corrosion, damage states, and loading intensities. How such an approach can be used as an application of risk-informed decision-making is also described.

INSPIRE WEBINARS

UPCOMING WEBINARS

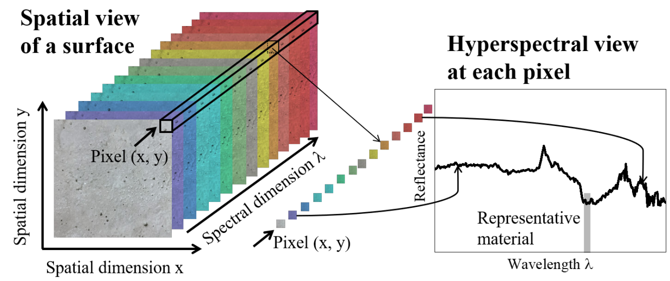


INTELLIGENT HUMAN-INFRASTRUCTURE INTERFACES FOR INSPECTORS AND DECISION-MAKERS

Present: June 21, 2022, 10:00AM-11:00 AM (CST)
Speaker: **Dr. Fernando Moreu**
Assistant Professor of Structural Engineering
University of New Mexico at Albuquerque
Register: **inspire-utc.mst.edu/webinars**

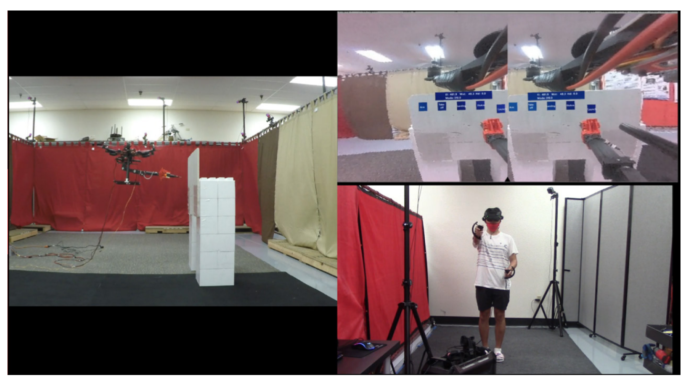
This seminar challenges the traditional conversation about digital twins and machine learning, by proposing a different paradigm for smart cities transformation centered in new human-infrastructure interfaces. This discussion explores the area of human decisions and cognition of the built environment enabling transformations of human interacting with structures in a new environment. To date, new technologies collecting data of the built environment are cheaper, more accurate, diverse, and more accessible than ever before. However, the use and implementation of these new technologies to structural engineers to assess, inspect, or inform actions have been very limited. Decision-makers, owners of infrastructure, policy makers, occupants, and inspectors of infrastructure are often not considered when developing new technologies to inform structural responses or condition. By empowering human-machine interfaces and fostering human involvement and participation (human-in-the-loop), this seminar will present specific practical implementations about how the collection of data, their analysis, and their interpretation can inform (and transform) human decisions. Specific applications include the connection of Augmented Reality with Wireless Sensors Networks, AI, ML, Structural Dynamics, and Inspections.

RECENT WEBINARS



HYPERSPECTRAL IMAGING AND DATA ANALYTICS FOR CIVIL INFRASTRUCTURE INSPECTION

Presented: December 14, 2021, 10:00AM-11:00AM (CST)
Speaker: **Dr. Genda Chen**
Professor and Robert W. Abbett Distinguished Chair in Civil Engineering, Director of INSPIRE UTC, and Director of CII
Missouri University of Science and Technology



TOWARD DEXTEROUS AERIAL MANIPULATION USING EMBODIED HUMAN-INTELLIGENCE FOR BRIDGE INSPECTION AND MAINTENANCE

Presented: March 16, 2022, 10:00AM-11:00AM (CST)
Speaker: **Dr. Dongbin Kim**
Adjunct Assistant Professor in Howard R. Hughes College of Engineering
University of Nevada, Las Vegas (UNLV)

INSPIRE UNIVERSITY TRANSPORTATION CENTER ORGANIZED A TRANSPORTATION RESEARCH BOARD (TRB) WEBINAR

ROBOT-ENABLED SENSING AND AUGMENTED LEARNING (RE-SEAL) FOR BRIDGE INSPECTION

INSPIRE UTC Director, Dr. Genda Chen as a voting member of the TRB Standing Committee on Testing and Evaluation of Transportation Structures [AKB40], worked closely with AKB40, TRB Standing Committee on Structures Maintenance [AKT40], TRB Standing Committee on Bridge and Structure Management [AKT50], and TRB Standing Committee on Bridge Preservation [AKT60] to organize a TRB webinar on RE-SEAL for Bridge Inspection. This webinar delivered on March 29, 2022, covered remote sensing, nondestructive evaluation, and augmented learning through virtual reality and/or artificial intelligence. It attracted 320 registrations of which 244 at peak participated in the webinar. The webinar was coordinated by Deanna P. Sparger from the Office of the Chief Communications Officer at National Academies of Sciences, Engineering, and Medicine. The webinar moderated by **Dr. Sreenivas Alampalli**, a senior principal of Stantec, included three presentations:

- **Dr. Genda Chen** from Missouri University of Science and Technology on Robot-Assisted Bridge Inspection and Maintenance
- **Dr. Hung (Jim) La** from the University of Nevada, Reno, on Climbing Robots for Steel Bridge Inspections
- **Dr. Fernando Moreu** from the University of New Mexico on Augmented Learning through Augmented Reality and Artificial Intelligence

RECENT KEYNOTE/INVITED PRESENTATIONS

- **"Robot-Assisted Bridge Inspection and Maintenance,"** International Workshop on Civil Digital Transformation and Beyond, KAIST, Korea, November 19, 2021, Presented by Dr. Genda Chen.
- **"Advances in Materials for Sustainable Infrastructure: Eco-Efficient Cements, Concrete Durability and Demolition Waste Management,"** School of Civil Engineering, Tianjin University (Online Webinar), December 28, 2021, Presented by Hongyan Ma.
- **"Carbon-Negative Upcycling of Solid Wastes in Construction Materials,"** Missouri Department of Natural Resources Solid Waste Forum, Jefferson City, MO, February 16, 2022, Presented by Hongyan Ma.
- **"Robot-Assisted Bridge Inspection and Maintenance,"** Transportation Research Board (TRB) Webinar on Robot-Enabled Sensing and Augmented Learning (RE-SEAL) for Bridge Inspection on March 29, 2022, Presented by Dr. Genda Chen.
- **"Climbing Robots for Steel Bridge Inspections,"** Transportation Research Board (TRB) Webinar on Robot-Enabled Sensing and Augmented Learning (RE-SEAL) for Bridge Inspection on March 29, 2022, Presented by Hung (Jim) La.

VIEW COMPLETE LIST OF WEBINARS

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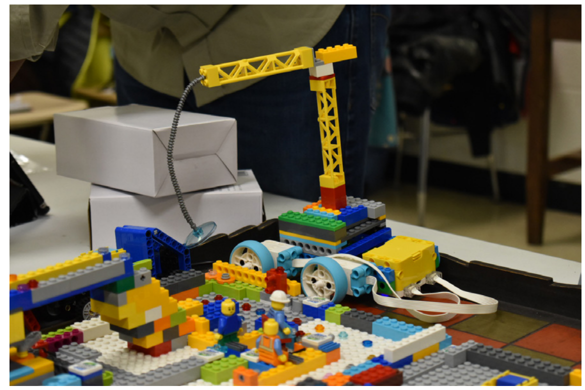
INSPIRE UTC Supports Kaleidoscope Discovery Center's FIRST Lego League and Missouri Future City Competition



As of April 11, the Kaleidoscope has supported robotics and engineering programming in our region and across the state that has reached over 265 students weekly through the FIRST Lego League and the Missouri Future City Competition. Continuing this level of outreach and engagement could not be possible without the generous support from the UTC INSPIRE grant. While some Covid restrictions have been eased, this continues to be a year of restabilizing and rebuilding for many schools and educational programs.

The Kaleidoscope just completed it's tenth FIRST Lego League Expo bringing 1-4th grade students from around the region to Rolla to celebrate and show off their creative designs. This year the Kaleidoscope partnered with Rolla Robotics to host the first formally sanctioned FIRST Expo in this region! Five Kaleidoscope-supported teams from across the region plus two from the St. Louis area followed Covid protocols to meet in person at the Rolla Technical Institute for the March 12 event.

The theme this year dealt with the timely topic of supply chain management. "Cargo Connect" encouraged students to consider how items move across the country and the world to get from their point of creation to their point of use. Volunteers for the event included members of the Kaleidoscope staff, the Rolla Robotics teams, and Missouri S&T National Society for Leadership and Success. The five judges included: Dr. Dave Westenberg (Missouri S&T), Dr. Lisa Liou (Product Innovation and Engineering), Kevin Edwards (Brewer Science), Kevin Daley (Kaleidoscope Discovery Center), and Allison Edmunds (Missouri S&T).

The Kaleidoscope also received grant funding from AmeriCorps not only for a year-long robotics VISTA but also for robotics summer program support. It is the Kaleidoscope's goal to reach 1000 students with robotics programming this summer through volunteers and S&T service groups. In the summer of 2018, the Kaleidoscope reached over 1800 students with similar opportunities. It is our intent to mindfully reestablish this level of robotics outreach post pandemic to help inspire our next generations.

Following up on the teacher/coach/parent coding expertise, the second robotics build and code workshop is scheduled for May 16 to train up summer robotics VISTAs and volunteers to effectively teach these topics. Reaching out to teachers and students this summer will increase the knowledge of all participants going into the fall robotics competition season. Coding continues to create an education barrier in promoting STEM activities to students. The upcoming training requires that participants build and program their own robots. This type of hands-on experience supports all educators promoting STEM education to our students. It is one of the Kaleidoscope's primary objectives.

The Missouri Future City competition was held January 22nd and returned in person on the Missouri S&T campus with Covid protocols in place. Teams of five-ten 6th – 8th grade students presented their visions of Waste Free Cities of the Future to judges from across the state. Ashlarkyliot, the Missouri team from St. Clair Middle School, has advanced to the national competition. Already this year, there are ten teams across the state that have registered for the 2023 competitions, which will encourage their students to solve future city-related problems creatively!

Governor with Future City students from Zelenia

Missouri Future City students were also invited to attend the STEM Day at the Capitol where the team Zelenia from Herculaneum had the opportunity to showcase their model, explain their concepts of a Waste Free City, and even meet the Governor!

On the horizon? The physical location of the robotics space at 612 N Pine Street has been reorganized to allow for families and small groups of students to rent out the Robotics Room to explore new concepts through directed learning opportunities. This space can also be rented to make best use of individual learning options as well as to provide opportunities outside of scheduled class times. Target completion date: June 1, 2022.

For more information, visit: thekaleidoscope.org/first-robotics

INSPIRE UTC Hosts Driving Simulation Workshop

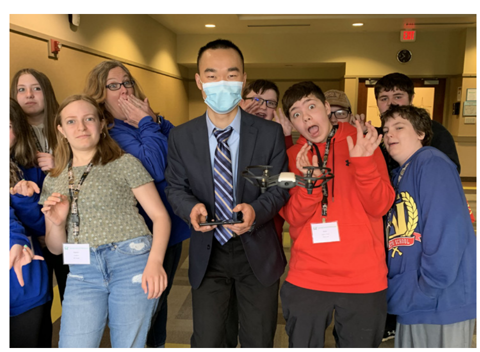
On February 18, 2022, the INSPIRE UTC of Missouri S&T hosted a workshop for a group of about 15 high school students for the precollege initiatives. The workshop aimed at sparking students' interest in learning how to drive and how to drive safely by engaging them in a driver simulator for hands-on experience as well as playing driving simulation games in different simulated environment. The simulated environment includes different scenarios such as urban, rural, and mountain for different driving conditions. Before allocating time and providing opportunity for each student with the hands-on experience and to spark their interest, the workshop addressed several questions including why we need a car simulator, how a car simulator is built, how different your driving experience is from a steering wheel and a keyboard, how challenging it is to drive in different traffic and weather conditions, and how to make a career out of a car simulator while having fun with video games. Most students had fun during the activities.

INSPIRE UTC Hosts Kummer Center for STEM Education

On February 28, 2022, the INSPIRE UTC of Missouri S&T held an outreach for about 15 middle school students. The outreach started by introducing the ongoing research activities at the INSPIRE center including exploring and developing drone and robotic technologies for modern bridge inspections. Andrew Rawlings, who is a senior in mechanical engineering and an undergraduate research assistant at the INSPIRE center, further introduced one type of drone in the center and the climbing robot. Then each student was provided opportunity to fly the drone for hands-on experience. Interestingly, one of the students crashed one of the two flying drones on the wall and took out 20 dollars with the hope to compensate the damage. He was told it's totally expected and not to worry about it. The damaged propellor was quickly found and replaced before the drone could be flew again. The student said he loves to fly the drone before the group left.

INSPIRE UTC Holds Workshop for Newburg Students

The INSPIRE UTC at Missouri S&T hosted 8th graders from Newburg, Missouri. On March 14, 2022, a group of 19 students were on their field trip to visit the INSPIRE UTC. The goal of the workshop is to give a sense of the diverse engineering research that the center is conducting with the hope to spark their interest in STEM. This time the INSPIRE UTC demonstrated a climbing robot and Tello drones. The climbing robot which was designed to climb structural steel frames via its magnetic mechanism, is also able to carry optical and thermal cameras for steel frame inspections. Besides recreational purposes, the Tello drones are used to do drone initial training as well as superficial bridge inspections. Each student operated the climbing robot and flew a Tello drone. Andrew Rawlings, a senior in mechanical engineering and an undergraduate research assistant at the INSPIRE UTC, demonstrated how to flip a drone while flying. The teacher of the 8th graders also showed great interest in the INSPIRE UTC research.



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Lisa Winstead, INSPIRE UTC Program/Project Support Coordinator

UPCOMING EVENTS

June 5-8, 2022
8th World Conference on Structural Control and Monitoring Conference
https://www.8wcscm.org

June 8, 2022
S&T Robotics Camp-Kummer Center for STEM Education
https://inspire-utc.mst.edu/events

June 13-15, 2022
Council of University Transportation Centers (CUTC) Summer Meeting
https://mycutc.org/events/2022-summer-meeting/

June 20-23, 2022
30th ASNT Research Symposium
https://asnt.eventsair.com/asnt-research-symposium-2022/

June 21, 2022
Webinar: INTELLIGENT HUMAN-INFRASTRUCTURE INTERFACES FOR INSPECTORS AND DECISION-MAKERS
https://inspire-utc.mst.edu/webinars

August 2-5, 2022 (Tentative)
INSPIRE UTC Annual Meeting
https://inspire-utc.mst.edu/events/

inspire-utc.mst.edu/events