Fall 2022

INSPIRE Newsletter Fall 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 2 | FALL 2022

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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Director's Message

Greetings colleagues and friends! As we step into the holiday season, I wish you and your family a Happy Thanksgiving, Merry Christmas, and Happy New Year!

This issue features two articles on field application research by INSPIRE UTC researchers. These include (1) Inspection of Steel Bridges Using a Bicycle-like Robot by Dr. Hung La from the University of Nevada at Reno, and (2) Field Validation of a Wireless Bridge Weigh-In Motion System by Dr. Yang Wang from Georgia Institute of Technology.

This issue also features an update 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.

This issue highlights INSPIRE UTC's participation and contribution to the successful completion of the 8th World Conference on Structural Control and Monitoring (8WCSCM), Orlando, FL, which took place on June 5-8, 2022. Dr. Genda Chen chaired a keynote session. INSPIRE UTC Associate Director Dr. Yang Wang from Georgia Institute of Technology and Dr. Chen proposed, organized, and co-chaired a technical session of eight presentation about the INSPIRE UTC theme. Eight center affiliates made the presentations on mixed reality, thermography, and field validation.

This issue also highlights the INSPIRE UTC research impact on transportation workforce, including 22 undergraduate students, 22 graduate students, and seven post doctoral fellows through hands-on research experience. Undergraduate students perform interdisciplinary research related to unmanned systems, rapid air-cushioned vehicles, and augmented reality concepts.

INSPIRE UTC's outreach program extends to a wide variety of activities coordinated by the Kummer Center of STEM Education at Missouri S&T, including a Robotics camp and K-12 grade lab demonstrations using a robotic platform for bridge inspection. The Center also participated in the Expanding Your Horizons camp 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 relevant to the INSPIRE UTC mission. The upcoming webinar being presented by Dr. ZiQiang Chen from the University of Missouri-Kansas City, "Structural Inspection Automation: Research Challenges and 3D Machine Vision Techniques," will discuss low-cost 3D structural elements and damage data collection, human-in-the-loop based structural data collection using augmented reality headsets, and visual simultaneous localization and mapping using virtual reality-based robotic drones.

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's Overwhelming Presence at the June 5-8, 2022, International Conference

The 8th World Conference on Structural Control and Monitoring (8WCSCM, http://www.8wcscm.org/) took place in Orlando, Florida on June 5-8, 2022. Sponsored by the U.S. Panel on Structural Control and Monitoring, the Conference, delivered virtually and in-person, were organized by Dr. Hae-Bum "Andrew" Yun and Dr. F. Necati Catbas from the University of Central Florida.. The INSPIRE UTC had a significant presence at this premier conference that has been held every four years. Led by INSPIRE UTC Director, Dr. Genda Chen, the INSPIRE UTC team of Drs. Liujun Li, Zhenhua Shi, Haibin Zhang, Bo Shang, Tarutal Mondal, and Yanping Zhu from Missouri S&T attended this conference. Dr. Chen also served as Vice President of the U.S. Panel on Structural Control and Monitoring and assisted in the organization of this conference. INSPIRE UTC Co-Director, Dr. Yang Wang from Georgia Institute of Technology, and former INSPIRE UTC faculty investigator, Dr. Ruwen Qin from Stony Brook University, were also among the crowd.

Dr. Chen was invited to chair a keynote session. Drs. Chen and Wang co-organized a technical session on Inspecting and Preserving Infrastructure through Robotic Exploration (INSPIRE) on June 7, 2022. All the INSPIRE UTC associated members made presentations at the conference as listed below:

1. Mondal T. G. and Jahanshahi M. R. "Vision-based Autonomous Inspection of Reinforced Concrete Buildings Leveraging RGB-D Fusion."

2. Li, L., and Chen, G. "Mixed Reality Interface of Geospatial Data towards Efficient, Effective, and Reliable Bridge Inspection."

3. Li, L., Chen, G. and Shang B. "Mixed Reality Enabled Digital Twin for Robot-Assisted Bridge Element Inspection and Maintenance."

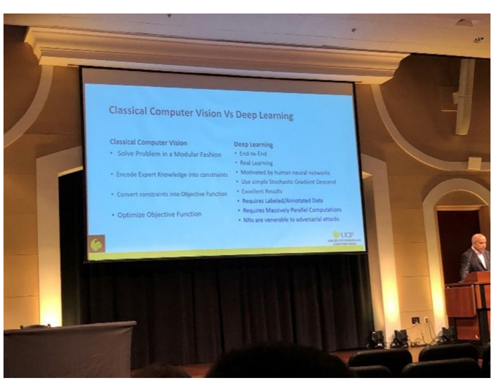
4. Otsuki, Y., Lander, P., and Wang, Y. "Field Validation of a Compact Martlet Wireless Ultrasonic Thickness Measurement System."

5. Shi, Z., Shang, B., Zhang, H., Li, L., Chen, G. "Evaluation of User-friendliness of Several Unmanned Aircraft Systems for Bridge Inspection."

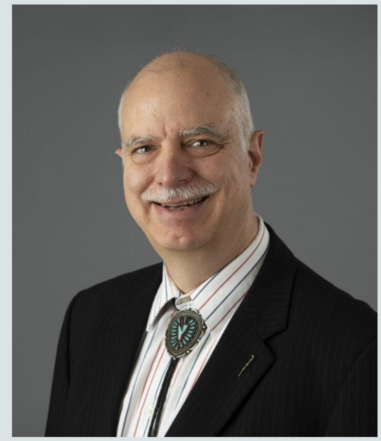
6. Zhang, C., Karim, M., Yin, Z., and Qin, R. "A Deep Neural Network for Multiclass Bridge Element Parsing in Inspection Image Analysis."

7. Zhang, H., Jiao, P., Li, L., Shi, Z., Shang, B., and Chen, G. "Delamination Detection of Concrete Bridge Deck through UAV-based Infrared Thermography."

8. Zhu, Y., and Chen, G. "Cable Force Monitoring by Distributed Fiber Optic Sensor with Two Installation Schemes."



KUMMER INSTITUTE DIRECTOR MESSAGE



Artificial Intelligence and Autonomous Systems are experiencing unprecedented growth, creating opportunities on many levels both in academia and industries. Lucrative jobs are being created at all experience levels, industries are being transformed, and entire new industries are being developed. The field has generated surprising technological breakthroughs. However, so are the technological risks. The most surprising accomplishments have also used unprecedented costs in human effort, financial resources, and energy consumption. Some of the solutions have unintended consequences, such as risks to privacy and fairness. Competition in the field is intense, which can fuel innovation but can also be problematic. Democratizing access to artificial intelligence and autonomous systems is a major challenge and opportunity.

Dr. Donald Wunsch II
Professor and Founding Director of the Kummer Institute Center for Artificial Intelligence and Autonomous Systems

Missouri S&T's Remote Sensing of Underground Pipelines for Gas Leakage

Since July 2021, the Center for Intelligent Infrastructure (CII) at Missouri University of Science and Technology has explored infrared and hyperspectral imaging technologies to detect underground gas leaks using an unmanned aerial vehicle (UAV) equipped with an RGB camera, an infrared camera, a hyperspectral camera and a LiDAR scanner.

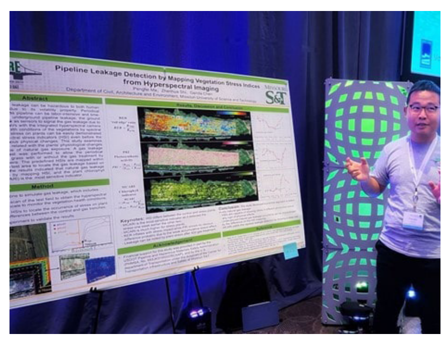
Detecting natural gas leakage from underground pipelines is traditionally a time-consuming and labor-intensive task, especially in vegetation areas. However, ground vegetation can serve as a natural sensor for leakage detection due to its response to changes in the soil microenvironment. Hyperspectral imaging can record plants' biochemical changes, allowing researchers to analyze spectral signatures and identify plant stress.

The CII team built an outdoor lab by burying perforated pipe in trenches, covering the pipes with soil planted with grass, and pumping methane gas through the pipes. They then flew the UAV over the pipeline field and imaged grass leaves for pigment measurement. Prior to each gas treatment, the grasses were mowed to ensure they were at the same height for apple-to-apple comparison over time. The CII team is analyzing the collected data using artificial intelligence (AI) and machine learning to detect and quantify gas leakage.

The U.S. Department of Transportation's Pipeline and Hazardous Materials Safety Administration funded the project, as these efforts are important in smart-city initiatives for resilient communities. The CII team included undergraduate students Kevin Lai and Eric Ssesanga, Ph.D. student and team leader Pengfei Ma, postdoctoral researcher Dr. Bo Shang, research engineer Dr. Zhenhua Shi and associate research professor Dr. Liujun Li. For more information, please contact Dr. Genda Chen, Professor and Robert W. Abbett Distinguished Chair of Civil Engineering and director of the Center for Intelligent Infrastructure, at gchen@mst.edu.

INSPIRE UTC & CII Student Won Second Place in the Poster Competition at Geo-Resolution Conference 2022

The National Geospatial-Intelligence Agency (NGA) and Saint Louis University (SLU) co-sponsor for the Geo-Resolution 2022 recently provided a venue for collaboration between students and geospatial experts in governments, academia, and industry to lay a foundation for innovative solutions to mitigate the effect of climate changes. Led by SLU, Taylor Geospatial Institute (TGI) is a consortium of eight research institutions that share their expertise and critical research facilities. TGI organized a student poster competition at the annual symposium on September 28, 2022 and received 40 posters from students at the consortium member institutions on a wide range of research topics connected to geospatial science. Pengfei Ma, a Ph.D. student under the supervision of Dr. Genda Chen, represented the Center for Intelligent Infrastructure (CII) and INSPIRE University Transportation Center (UTC) at the 2022 poster competition. Pengfei Ma is currently in his fourth year in the Ph.D. Program in the Department of Civil, Architectural, and Environmental Engineering. He has submitted two journal manuscripts for potential publications and is preparing two additional journal manuscripts for submission. All submitted posters and their accompanying videos are available on the TGI website (https://taylorgeospatial.org/geo-resolution-2022-poster-session/).



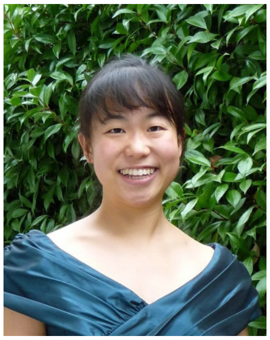
Pengfei Ma presents winning poster at Geo-Resolution Conference 2022

Pengfei Ma, a Ph.D. student in civil engineering at Missouri S&T, won second place for his poster presentation titled "Pipeline Leakage Detection by Mapping Vegetation Stress Indices from Hyperspectral Imaging." Ma is a researcher with the Center for Intelligent Infrastructure and the INSPIRE University Transportation Center. He received a $750 award and certificate.

Original Version Posted October 17, 2022 - Missouri S&T eConnection

NEWS

Dr. Iris Tien awarded the IASSAR Early Achievement Research Prize



Dr. Iris Tien was awarded the prestigious Early Achievement Research Prize by the International Association for Structural Safety and Reliability (IASSAR). IASSAR is an international governing body formed to promote the study, research, and applications of scientific principles of safety, risk, and reliability in the analysis, design, construction, maintenance, and operation of structures and other engineering systems.

The IASSAR Early Achievement Research Prize is awarded to a researcher under the age of 45 for his/her outstanding contributions and accomplishments in the field of structural safety and reliability, and is also a member of the global probabilistic community among international scholars and researchers doing work in the area of structural risk and reliability.

Awarded only once every four years, the IASSAR Early Achievement Research Prize is one of the highest honors one can receive in the field of risk and reliability. Tien is the first woman to receive the award since it became a single prize that is awarded across all areas and subspecialities (including computational stochastic mechanics; stochastic dynamics; system reliability and optimization; stochastic fatigue, fracture, and damage; and system identification) within the field of structural safety and reliability.

Missouri S&T Remote Sensing Team Hits the Road for Bridge Inspections

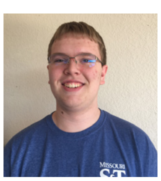
The INSPIRE (Inspecting and Preserving Infrastructure through Robotic Exploration) University Transportation Center at Missouri University of Science and Technology sent a remote-sensing team to inspect 72 highway bridges in New York, Virginia, Georgia, Wisconsin, Missouri, Texas and California. The bridges were selected based on the number of spans, bridge age, construction materials and access.

In Missouri alone, the INSPIRE team inspected 18 steel-girder and prestressed-concrete-girder bridges. Tim Hazlett, a district bridge engineer from the Missouri Department of Transportation spent a day with the team while they inspected bridges in Kansas City. Hazlett commented that drones would be a perfect tool for rapid, close-distance inspection of complex bridges that are traditionally inspected manually.

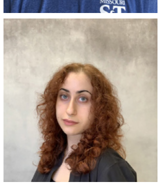
The team uses bridge inspection robot deployment systems (BIRDS) equipped with RGB, infrared, and hyperspectral cameras as well as a LiDAR scanner. These technologies provide faster, cheaper and safer solutions to bridge inspection, helps avoid or minimize traffic lane closure, reach challenging access areas, and improve inspection consistency. The collected images will be used to train artificial intelligence models or machine learning algorithms for bridge condition assessment and to create virtual and augmented reality models for long-term monitoring.

Seven state department of transportation funded the project. Team members are research engineer and team leader Dr. Zhenhua Shi, research consultant Dr. Haibin Zhang, and postdoctoral fellow Dr. Tarutal Mondal. For more information, please contact Dr. Genda Chen, professor and Robert W. Abbett Distinguished Chair of Civil Engineering, at gchen@mst.edu.

Undergraduate Research Students Join CII & INSPIRE UTC



Sean Boland is a freshman in computer science. Sean recently joined INSPIRE UTC as a Head Operations Student Ambassador at INSPIRE UTC. Sean's experience in IT translates well in assisting with technical tasks like newsletters and general troubleshooting. Additionally, Sean was involved in Neosho High School's Robotics Club. Sean's background is suitable for multiple projects including BridgeNet data portal maintenance, artificial intelligence, and machine learning.



Elizabeth Rozhanskiy transferred in the summer from St. Louis Community College (STLCC) and is currently a senior in civil engineering. Elizabeth is a Head Operations Student Ambassador at INSPIRE UTC where she compiles and organizes information, works on semi-annual progress reports and newsletters, and updates content on the center's websites. Elizabeth is involved on campus through the American Society of Civil Engineers (ASCE), Architectural Engineering Institute (AEI), Society of Women Engineers (SWE), and Steel Bridge Design Team.

CII Member Assists with Carbon-Capture Research

Researchers at Missouri S&T will develop a system to capture carbon dioxide and use it for blended cement, ultimately contributing to the decarbonization of the cement industry. The National Science Foundation (NSF) awarded a $1.7 million grant for the project.

"Our goal is to deliver an innovative, integrated and adaptable capture-and-conversion system while producing valuable cement supplements from waste CO2," says Dr. Fateme Rezaei, The Linda and Bipin Doshi Associate Professor of Chemical and Biochemical Engineering at Missouri S&T. "Waste CO2 in industrial flues is considered a valuable resource for a variety of products, including chemicals and fuels."

Rezaei, an internationally known expert in carbon capture, is working with a team of S&T researchers, including Dr. Hongyan Ma, associate professor of civil, architectural and environmental engineering. Ma developed technology through a NSF Innovation Corps project that uses captured CO2 to process industrial wastes such as municipal waste incineration ashes and produce materials that could potentially substitute more than half of the cement used to make concrete.

Rezaei says the United States produces about 90 million metric tons of cement each year, emitting about the same amount of CO2. Portland cement dominates the market, and Rezaei states that if no sustainable alternatives cements are invented, the most promising strategy for decarbonizing the cement industry is to develop additives to make blended cement. Portland cement contains clinker, a material made by liquifying limestone and clay under intense heat in a kiln, mixing it with gypsum and grinding it into a fine powder to use as a binder.

"The White House goal of cutting America's carbon emissions in half by 2020 requires investment in carbon-intensive industrial sectors like cement manufacturing that are hard to decarbonize," says Rezaei. "This strategy could replace clinker in commodity cement with carbon-efficient – or even carbon-negative – minerals."

The S&T research team also includes Dr. Kwame Awuah-Offei, chair of mining and explosives engineering; Dr. Joseph Smith, the Wayne and Gayle Laufer Chair of Energy and professor of chemical and biochemical engineering; and Chengquing Qi, technical center director at Ash Grove Cement Company of Overland Park, Kansas, which is a corporate partner.

The team will explore the fundamental chemistry needed to develop economically viable technology to convert the captured CO2 to blended cement. Rezaei says the research could be applied to other industries that emit CO2, as it can also be used to extract CO2 directly from air.

The NSF award begins January 1, 2023.

Original Version Posted September 15, 2022 - Missouri S&T eConnection

INSPIRE UTC Members Join CUTC Meeting in Big Sky

Members of INSPIRE UTC participated in the annual Council of University Transportation Centers (CUTC) meeting held in Big Sky, Montana in June 2022. The meeting focused on discussions of the current highway system and the potential impact on rural communities involving transporation costs, mobility and safety. Attendees learned how the Small Urban, Rural and Tribal Center on Mobility (SURTCOM) and other UTC's engage partnerships with public and private agencies overcoming financial and institutional obstacles within communities. Additional focus was given on expanding transportation access and increasing road safety by reducing fatalities.

Montana welcomed many attendees with a big surprise and celebrated the opening of the meeting with a show of rain and snow. In fact, the combination of these natural elements accumulated too much runoff water, which washed away part of the only highway connecting Big Sky with Yellowstone National Park. The INSPIRE UTC attendees, Director Genda Chen and Program Coordinator Lisa Winstead, enjoyed the meeting and the Big Sky environment.

INSPECTION OF STEEL BRIDGES USING A BICYCLE-LIKE ROBOT

A steel bridge can be a complex engineering structure made up of various members such as I-beams, hollow tubes, round tubes, cross diaphragms, joints, and bolts. Therefore, developing a universal climbing robot that can work on any steel structure is a challenging task. Several approaches have been introduced including wheeled robots [1], a tank-like robot [2], and naturally inspired mechanisms [3,4]. However, such intricate mechanics may not be suitable in real-world applications on bridge members with complex geometries. This paper presents the latest development of a steel-climbing bicycle robot integrated with an ultrasonic sensing device for an autonomous thickness measurement of steel bridge members and a camera for surface defect detection. The bicycle-like robot has two magnetic wheels controlled by two independent steering actuators. This new design allows the robot to navigate on various steel members along flat, curved, rough, concave, and convex surfaces. The compact ultrasonic test device (developed by the Georgia Tech team led by Dr. Yang Wang) is capable of generating a high-voltage pulse excitation, filtering/amplifying a received ultrasonic signal, and a high-speed analog-to-digital converter at 80 MHz [5,6]. To support the ultrasonic sensing, the robot carries a dual element transducer, an automatic gel couplant dispenser, a position tracking sensor, and a camera. A mounting/retrieving mechanism of the transducer is designed to ensure transducer's firm contact with steel surfaces [7]. The camera view assists an operator in safely navigating the robot to a measurement location, properly dispensing the gel couplant, and firmly pressing the transducer on a measurement surface. The robot also collects visual data and used a deep learning algorithm to detect corroded areas [8]. The automated robot localization provides accurate thickness measurement locations, which are mapped in real-time into a 3D space together with the robot's travel path. The performance of the developed system is validated in several indoor tests and field deployments.

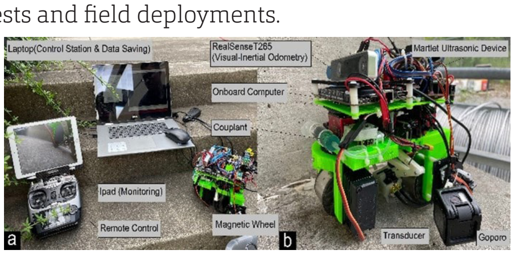


Fig. 1. (a) a ground control station consisting of two independent channels of ground PC and remote controller with a monitor, and (b) a bicycle-like robot integrated with sensors.

Fig. 1 shows the overall robotic inspection system, including the bicycle robot integrated with the ground control station in Fig. 1(a) and the Martlet ultrasonic device (mounted on top of the robot) and other devices in Fig. 1(b). With the transducer deployment mechanism, a 2.25MHz dual-element transducer is installed between the two magnetic wheels to protect the transducer while the robot is in motion. This location is ideal for taking measurement on both flat and curved surfaces. In addition, the robot localization is achieved using an Intel RealSense T265 tracking camera, which can provide real-time positions using a visual-inertial odometry. A GoPro camera is installed next to the rear wheel to stream videos to an iPad through a Bluetooth connection. Depending on the need for robot's traveling or thickness measurement, an operator can remotely control the rotational hinge on the GoPro support to change the camera orientation. This feature makes it possible to switch the GoPro view between the robot's front path and the transducer mounting/measurement position. An onboard computer, Latte Panda Alpha 864, is installed on the robot. When powered by a 700mAh LiPo battery, a human operator can remotely control the robot to work for about 30 minutes. The robot's final weight is 1.2 kg.

Fig. 2. Traversing of a bicycle-like robot along the steel tubes of a pedestrian truss bridge on the University of Nevada, Reno campus.

The robot's onboard computer is connected to the ground PC through a local WiFi network. The onboard computer and the ground PC are networked through a Robot Operating System (ROS), in which the ground PC acts as the master for data collection and visualization. In this implementation, the ultrasonic data received by the Martlet device is transferred to the onboard computer through a Universal Asynchronous Receiver/Transmitter (UART) interface. The location of the thickness measurement and robot position is matched in ROS and visualized in a 3D space in real-time on the ground PC screen. The robot locomotion is maneuvered remotely by a joystick via a radio connection.

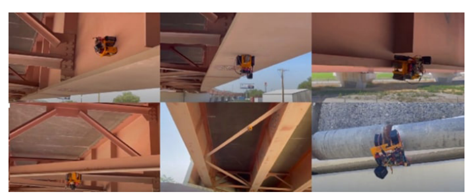


Fig. 3. Robot deployment on an I-80 bridge, Lovelock City, NV, USA: (a, b) traversing upside down on the main I-shape beam), (c) passing an edge of the I-shape beam, (d, e) moving upside down on a T-shape member, and (f) traveling stably on a bridge water draining tube.

The robot was tested on various steel members as shown in Figs. 2-6 and demonstrated to move stably and safely while carrying a camera for imaging/positioning and an ultrasonic device for thickness measurement. Robot locomotion was first assessed on cylindrical members of the bridge as shown in Fig. 2. The robot was then applied to an interstate highway I-80 in Lovelock City, NV, USA. Fig. 3 shows robot's performance in a real-world application scenario with thick dust and rusty steel surfaces. The robot was able to traverse stably on the structure and collect data from this bridge.

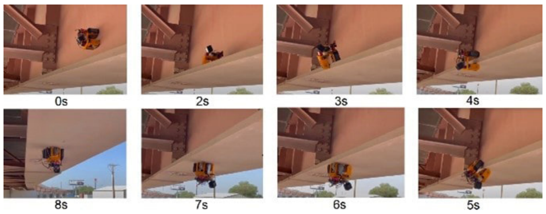


Fig. 4. Smooth traversing of the robot on an edge of the I-shape beam.

The robot reliably passed the extreme cases of I-shape beams including internal and external corners. In applications, thick dusts may reduce the pulling force and friction. A high safety design factor can make the robot to engage with an aging bridge member as shown in Fig. 4.

For corrosion detection of steel members, we examined the performance of Deep Encoder-Decoder Networks [8], as illustrated in Fig. 5. Thousands of images covering different levels of defects and lighting conditions were collected and annotated at a pixel level to train three networks. Up to 99% precision in prediction was achieved.

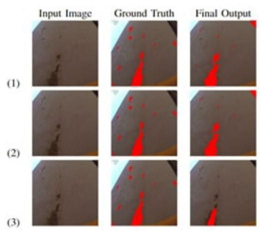


Fig. 5. Applications of three Architecture-Encoder pairs: (1) LinkNet ResNet-18, (2) Unet ResNet-18, and (3) DeepLab ResNet-18, leading to a favorable comparison of input images, ground truths, and final outputs.

For further validation, we performed a field test on the similar steel girder bridge near LaGrange, GA, USA, as shown in Fig. 6. The robot was deployed on the flange and web of the girders to perform thickness measurements at several locations. Fig. 6 shows the robot locomotion and visualizes the traveled path and measurement results at three locations (denoted as red dots). The three measurements (0.596486", 0.580404", and 0.602334") for the web thickness are nearly identical to its nominal thickness (0.60"), which validates the performance of the developed system in a field environment.

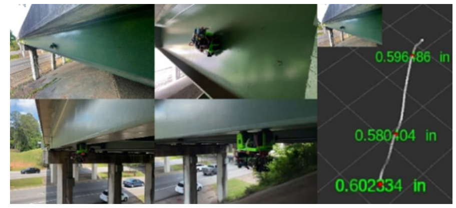


Fig. 6. Real-time synchronization of robot positioning and thickness measurement on a bridge near LaGrange, GA, USA - robot path in white color, thickness measurement points in red dots, and thickness readings in green color.

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[8] H. Ahmed, S. T. Nguyen, D. La, C. P. Le and H. M. La. "Multi-directional Bicycle Robot for Bridge Inspection with Steel Defect Detection System," 2022 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), October 23-27, 2022, Koyto, Japan.

ABOUT THIS PROJECT

Led by Dr. Hung La, Associate Professor at the University of Nevada, Reno, the Climbing Robots with Automated Deployment of Sensors and NDE Devices for Steel Bridge Inspection project is part of the INSPIRE UTC Research Program led by the Missouri University of Science and Technology.

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FIELD VALIDATION OF A WIRELESS BRIDGE WEIGH-IN-MOTION SYSTEM

In the U.S. Department of Transportation's (USDOT) 2017 report, Beyond Traffic 2045, it is noted that heavy truck traffic is increasing and is expected to continue to increase due to an increased demand for freight shipments.[1] This trend heightens the concern of overloaded vehicles, which pose a threat to roadway and infrastructure conditions. Currently, weight enforcement is performed at weigh stations using static scales and sometimes weigh-in-motion (WIM) devices. Traditional weigh stations are inefficient and expensive to maintain. Bridge weigh-in-motion (BWIM) systems use sensors to measure the response of a bridge. By leveraging the latest wireless sensing technology, a BWIM system has the potential to decrease costs and increase the effectiveness of enforcement efforts. The same BWIM sensors also bring the benefits of monitoring the structural condition.

In this project, we developed and validated a low-cost wireless BWIM system. The Martlet wireless sensing system serves as the central technology relied upon to collect the BWIM data.[2] To achieve the goals of the project, efforts to develop the Martlet system were focused on solar energy harvesting, power efficiency improvements, and truck detection methods. The system was installed on an interstate highway bridge in Troup County, GA, as shown in Fig. 1. The four-span highway bridge carries two southbound lanes traffic and passes over GA state route.

Fig. 1. The testbed bridge in Troup County, GA.

The two side spans are simply supported, while the middle two spans are continuous and are longitudinally fixed at the middle bent. All spans consist of steel I-beams that are composite with an 8-inch reinforced concrete deck. For this research, only the middle two spans, Span 2 and Span 3, are instrumented and modeled. The interaction between the side spans and the middle spans are regarded negligible because they are separated by expansion joints.

A controlled BWIM test was performed in 2021 using a loaded Georgia Department of Transportation (GDOT) dump truck with known wheel weights as detailed in Fig. 2. The truck has a single front axle and a tandem rear axle. During the testing, the truck was loaded and had a gross vehicle weight (GVW) of 60,050 lb. The weight of the truck was determined using a portable scale with an accuracy of ±50 lb.

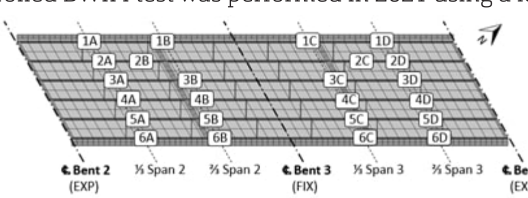

Fig. 3. Labels for sensor groups instrumented under the bridge deck.

Fig. 2 The loaded GDOT dump truck.

For this validation test, a relatively large number of sensors are installed under the bridge deck, although their quantity can be reduced in practice. Each sensor group label as shown in Fig. 3 has two parts: the first is a number (1 through 6) that corresponds to the girder number, and the second is a letter (A through D) that identifies the position along the girder. Every sensor group includes a vertical acceleration channel and a longitudinal strain channel except that girder 1 and 6 nodes include accelerometers only.

The strain gages are bonded directly to bare steel with cyanoacrylate (superglue) and are positioned parallel to the longitudinal direction of the girders so that they measure the major axis bending strain. At each strain gage location, a thermistor is placed alongside the gage. For protection, the strain gages and thermistors are covered with one layer of butyl rubber sealant and a top layer of neoprene rubber. Enclosure of the wireless Martlet unit sits on the bottom flange of the steel girder, as shown in Fig. 4.

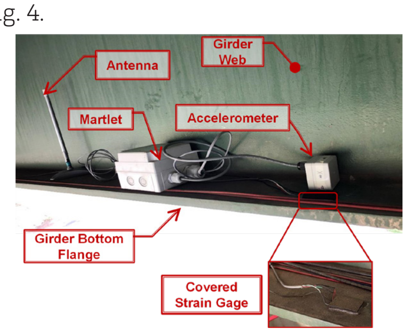

Fig. 4. Photo of one sensor group.

Besides the above sensors under the bridge deck, LIDAR (light detection and ranging) sensors are added above the road surface, as illustrated in Fig. 5, to assist in detecting the truck speed and axle number. Interfaced with Martlets, these one-dimensional LIDAR devices measure the distance to an object by timing the duration it takes for a laser to reflect off the object. Once triggered by a truck entrance, an upstream LIDAR sensor

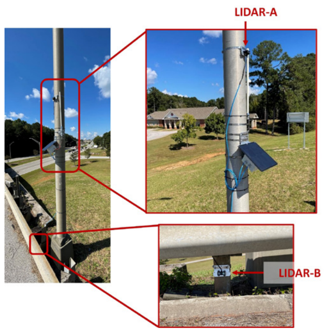

Fig. 5. LIDAR sensors.

before the bridge can wake up the Martlet wireless sensor network.

Tests were performed with the truck passing through either the left or right lane at a pre-set speed. Example plots below show the bridge response at select sensors using the data from one test run when the truck traveled in the left lane at 50 mph. Fig. 6 presents the acceleration recorded from sensor groups 4B and 4C, which are deployed at the locations that are symmetric about Bent 3. The acceleration change around 3 seconds seems indicative of the presence of the test truck. More obviously, the truck causes the bridge to vibrate with increasing magnitudes as it passes over the bridge. As expected, the vibration responses at 4B and 4C are nearly at opposite phases due to their symmetric deployment about Bent 3 and connectivity by a continuous girder.

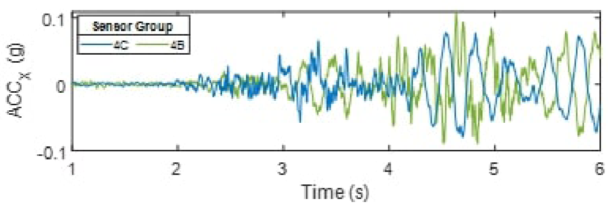

Fig. 6. Vertical accelerations induced by the truck passing through the left lane at 50 mph.

Fig. 7 presents the strain readings from other four sensor groups. The path of the truck follows the peaks of the strain responses. First, the truck crosses over the strain gage at sensor group 5D, then 5C, 5B, and 5A, respectively. When the truck is directly above the sensors, it creates positive bending at the bottom flange of the girder. When at a symmetric position in the other span, the truck leads to negative bending as expected.

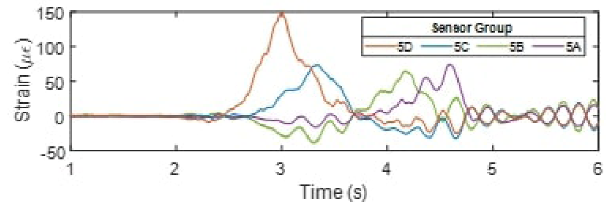

Fig. 7. Bending strains induced by the truck passing through the left lane at 50 mph.

To perform BWIM using the recorded sensor data, a recently developed input estimation algorithm, called the finite input covariance (FIC) estimator is adopted.[3] Using data from the left-lane 50 mph test described above, the FIC estimate has 0.72% error for the front axle weight, and 1.87% error for the tandem axle. The overall GVW error is 1.52% for the left-lane 50 mph test.

In another test with the truck traveling at 50 mph in the right lane, the FIC estimate has -7.65% error for the front axle weight, and 7.7% error for the tandem axle. Although both axle estimates experience larger errors, the overall GVW error remained at 3% due to the cancellation of axle weight errors.

References:

[1] U.S. Department of Transportation, Beyond traffic – trends and choices 2045, U.S. Department of Transportation, Washington, D.C., USA, 2017.

[2] M. Kane, D. Zhu, M. Hirose, X. Dong, B. Winter, M. Häckell, J. P. Lynch, Y. Wang, and A. Swartz, "Development of an extensible dual-core wireless sensing node for cyber-physical systems," in Proc. SPIE 9061, Sensors and Smart Structures Technologies for Civil, Mechanical, and Aerospace Systems San Diego, CA, USA, 2014, p. 90611U.

[3] X. Liu, Y. Wang, and E. I. Verriest, "Simultaneous input-state estimation with direct feedthrough based on a unifying MMSE framework with experimental validation," Mechanical Systems and Signal Processing, vol. 147, p. 107083, 2021

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

Three-member Inspection Crew

The INSPIRE UTC formed a three-member inspection crew to inspect a total of 72 steel- and concrete-girder bridges in seven participating states from the east (New York) to the west (California), and from the north (Wisconsin) to the south (Texas). The crew consists of Drs. Zhenhua Shi, Haibin Zhang, and Tarutal Ghosh Mondal. All three members graduated with a Ph.D. degree in civil engineering. Dr. Shi is currently leading the inspection crew as an engineer-in-training. He is also a Federal Aviation Administration (FAA) approved remote pilot.

Bridge Inspection Robot Deployment Systems

The INSPIRE UTC acquired several types of unmanned vehicles including drones and structural crawlers, most of which are custom-made in the center. Representative vehicles include heavy drones (33.5-lb Headwall M600 Pro and 28.8-lb Geodetic M600 Pro), light commercial drones (3.2-lb Elios2, 3.0-lb Phantom4 Pro, 1.8-lb Skydio2, and 0.7-lb Anafi Parrot), and a magnet-wheeled multidirectional structural crawler. To date, the Headwall M600 Pro, Elios2, Skydio2, Phanton4 Pro, and Anafi Parrot drones have been used during field bridge inspections. The Elios2 is collision-tolerant while both Skydio2 and Phantom4 Pro drones feature collision avoidance. The structural crawler has also been tested on several real-world bridges in the state of Nevada, Georgia, and Missouri.

Remote Sensing

The INSPIRE UTC developed integrated multimodal remote sensing, including optical, thermal, and hyperspectral imaging and LiDAR scanning. Both RGB and hyperspectral images are helpful for the detection and understanding of surface defects. The hyperspectral images are captured from a Headwall Nano-Hyperspec® camera, which operates in the Visible Near Infrared (VNIR) wavelengths (approximately 400-1000 nm [2]). Thermal images are helpful for the probing of undersurface defects, which are taken from a dual-sensor FLIR R640 Pro camera. The LiDAR scanners are used to acquire high-resolution images of a large area to create an accurate 3D reconstruction model for a digital twin platform, which has been increasingly becoming important in the development of smart cities and/or autonomous vehicle industries.

Getting Ready for Field Inspections

By the end of October 2022, the selected bridges in the states of Missouri, Wisconsin, and Virginia have been inspected using the advanced technologies developed in the INSPIRE UTC. The inspection crew recently started to inspect the selected bridges in the state of Georgia and Texas, which will be completed in November and December, respectively. The collected data have been uploaded and curated at the INSPIRE UTC cloud archive and backed up on external hard drives.

Fig. 1 shows a checklist developed for a robot-assisted bridge inspection to ensure smooth operation in field conditions. In addition to documenting the inspection equipment, the checklist includes records for an inspection team of one pilot-in-command and two safety field observers and documents the weather condition from a wireless weather station during the field inspection.

Representative Inspection Results

Bridge ID & Location							
Inspection Date							
Pilot-in-command (PIC)							
Visual Observer 1 (VO)							
Visual Observer 2 (VO)							
iG4		Point Description		Instrument Height		Start Time	End Time
Meteorological Data Recorded Every Hour	Index\Time	Start Time [ ]					End Time [ ]
	Wind Gust (mph)						
	Temperature (F)						
	Humidity (%)						
	Pressure (inHg, relative)						
	Light (W/M^2)						

Items	Check	Items	Check	MISC Items	Check
Binocular	☒	Flight Mission Planning & Uploading	☐	Tape Measure	☐
Camera & Tripod	☐	GNSS Receiver iG4	☐	Tarps	☐
Canopy	☐	Ice Box	☐	Traction Boards/ Tire Chains	☐
Cellphone for Hotspot	☐	MicroSD & Hard Drive Clearance	☐	Traffic Cones	☐
Chairs	☐	Napkin & Hand Sanitizer	☐	UAS/Pilot Permits	☐
Charge All Batteries	☐	PPE: Glasses & Hard Hats	☐	Vests	☐
Drones: ANAFI Parrot ☐ Elios2 ☐ Geodetic M600 ☐ Headwall M600 ☐ Phantom4 ☐ Skydio2 ☐	☐	RT09 Computer & Hard Drive	☐	Walkie-Talkie	☐
Extension Cord	☐	Strobe Light	☐	Water & Food	☐
First Aid Kit	☐	Tables	☐	Weather Station & Pipe Holder	☐

Fig. 1 Robot-assisted bridge inspection checklist

Fig. 2 shows the flight route and waypoints of the Headwall M600 Pro Drone for one of the selected bridges in Wisconsin. The drone was equipped with both thermal and hyperspectral sensors during the inspection. The drone flew at a speed of 2.3 m/s and an elevation of 34.7 m. The flight path was planned along the two sides of the bridge deck to prevent the drone from flying directly over the traffic. The flight height was controlled and set at nearly 50 m above ground level (AGL) to overpass most trees and powerlines and minimize visual distraction to the passing traffic over the bridge. The AGL varies automatically during each flight to accommodate the height variation of the ground surface as shown in Fig. 2. The flight time was controlled by adjusting the flight path and speed to be within 60% of the maximum flight time to allow adequate time for safe landing and maintain long battery life. At least four right turns are recommended for filter tuning to improve the Inertial Measurement Unit (IMU) and GPS performance before the formal inspection begins.

Fig. 3 shows the hyperspectral images of two of the selected Missouri bridges. Compared to three bands in a regular

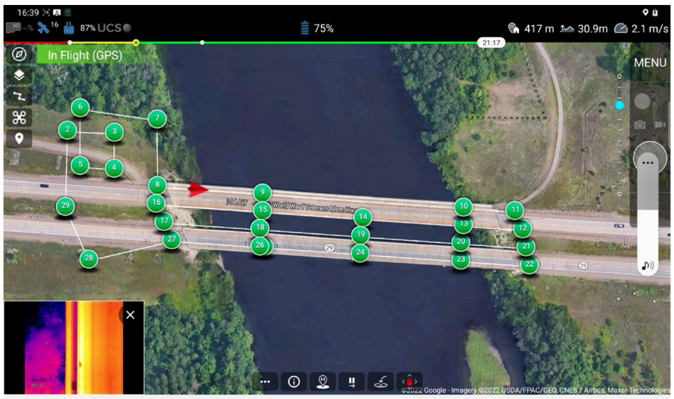


Fig. 2 The Headwall M600 Pro Drone in flight

RGB image, each hyperspectral image contains 273 bands of information about the bridge deck, which is much more informative and sensitive to the change in surface condition of the bridge deck, especially for the long-term monitoring of the bridge performance. The hyperspectral sensor detects how an object reflects and absorbs light (energy) in different wavelengths and stores three-dimensional hypercubes (two spatial dimensions and one spectral dimension) for each pixel. This sensor is a powerful tool for the characterization, discrimination, classification, and detection of any object, such as minerals, vegetations, and building materials. Fig. 3 also displays four spectra corresponding to four points (pixels) on the deck of the left bridge and its nearby tree. Specifically, the three spectra in red, blue, and black colors were taken from the concrete surface of the bridge deck while the spectrum in green color was taken from an area covered with trees next to the bridge. It is clearly seen that the three spectra on the concrete surface show a similar overall trending in the wavelength range except for some local fluctuations. The local fluctuations could be related to the deterioration condition of concrete. On the other hand, the spectral curve in green color is quite different from the previous three spectra in overall trending. This is because the tree and the concrete exhibit totally different light reflection behaviors. In particular, the dramatic increase in reflectance from 640 nm to 720-740 nm likely represents a feature of the green plant due to the presence of chlorophyll. The intensity of reflectance at 720 nm or higher can be sensitive to the health condition of the plant since chlorophyll is related to most of negative effects on the growth and health of plants.

Fig 4 compares the thermal and RGB images of a mock-up, single-span bridge to demonstrate the effectiveness of detecting

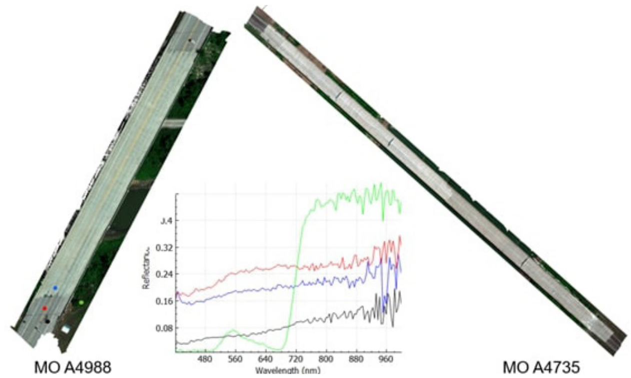


Fig. 3 Hyperspectral images with sample spectra at four points from two of the selected Missouri bridges

subsurface delamination from thermal imaging. The mock-up bridge was designed and constructed with different sizes of embedment (two large defects, 1′ × 1′ each, on the top side and three small defects, 6″ × 6″ each, on the bottom side for each reinforced concrete slab) to simulate delamination in bridge decks. Once there was a certain temperature difference on the deck,thermal imaging was very effective in detecting subsurface delamination. A sense of thermal imaging can be seen in the bottom left corner of Fig 2.

Fig 5 depicts an example side image of a selected bridge in

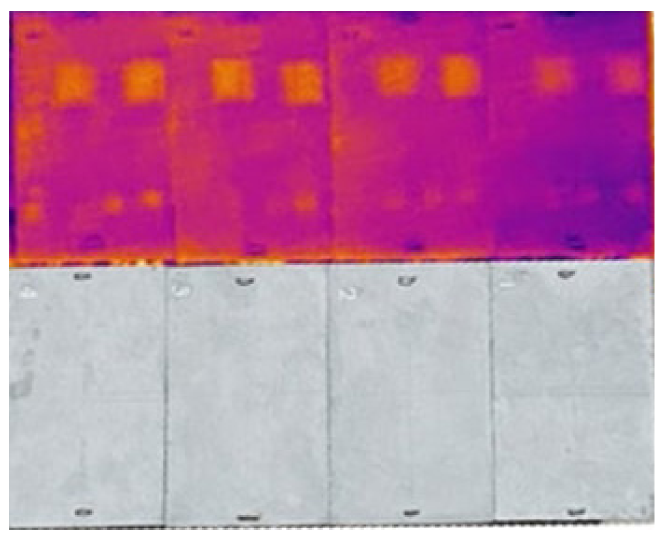


Fig. 4 Thermal and RGB images of a mock-up bridge with embedded defects

Virginia, taken from the Skydio2 drone, while Fig 6 shows an image from the underneath of the deck taken from the Elios2 drone and overlaid with a semi-transparent thermal image. Corrosion of the girder can be clearly seen especially at the support area. The protection cage around the Elios2 enables it to fly in a confined space, which is especially suitable for girder inspection. However, each fully- charged Elios2 lasts approximately 8 min. Due to its susceptibility to winds and magnetic interference from steel girders and due to its relatively short flight time, the Elios2 was supplemented by other types of drones, such as Skydio2 and Phantom4, to complete the inspection of an entire bridge. For drone-inaccessible areas covered by trees and bushes, a high-resolution hand-held Nikon camera was used to manually take images of critical regions, as shown in Fig 7. The ongoing studies reveal that a suite of different tools with different attributes is necessary for a comprehensive and robust bridge inspection in open field conditions.

The case studies in this project are critical to identifying the potential issues in robot-assisted bridge inspection. These issues include, but are not limited to, battery storage, flight mission planning, alternative plans, field station determination, preparation of substitute drones, data backup practices, and emergency situation handling. These case studies can also help develop protocols and guidelines for the process by summarizing experiences and findings. As the expeditions continue, the protocols and guidelines for robot-assisted bridge inspection will continue to be practiced, tested, and developed for a smooth, streamlined, traffic disruption-free robot-assisted bridge inspection.

Fig. 5 Bridge side image taken from the Skydio2

Fig. 6 Underside image of a deck taken from the Elios2 and overlaid with a semi-transparent thermal image

Fig. 7 Details of the bridge support in the image taken from a Nikon camera

References

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

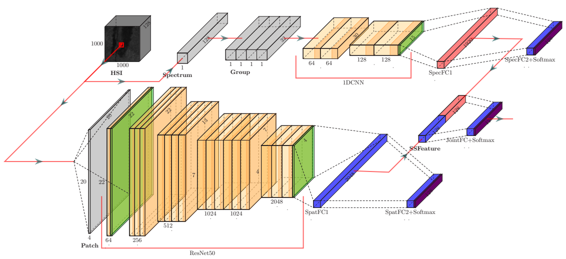
[2] Headwall Photonics Homepage, https://www.headwallphotonics.com.

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 the 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.

INSPIRE WEBINARS

UPCOMING WEBINARS



STRUCTURAL INSPECTION AUTOMATION: RESEARCH CHALLENGES AND 3D MACHINE VISION TECHNIQUES

Present: December 13, 2022, 11:00AM-12:00 PM (CST)
Speaker: **Dr. ZhiQiang Chen**
Associate Professor
University of Missouri, Kansas City
Register: **inspire-utc.mst.edu/webinars**

This presentation plans to discuss that machine vision with optical sensors is the most viable approach as a core component to realizing structural inspection automation. Using an analogy of Tesla cars that rely entirely on vision sensors without using active Radar or LiDAR sensors, the presentation will then elaborate on six automation levels for structural inspection. However, our civil infrastructure stakeholders are much different from those from private automobile sectors, which have poured tremendous investment into collecting and creating semantically rich datasets for developing machine learning algorithms and AI-based software frameworks. On the other hand, large-scale semantically annotated datasets from civil engineering sectors are not expected to be available in the near future. Considering such constraints and aiming at the goal of realizing cost-effective structural inspection automation, the presentation will introduce recent efforts in the following three topics:

1. Low-cost 3D structural element and damage data collection and deep learning based algorithmic benchmarking

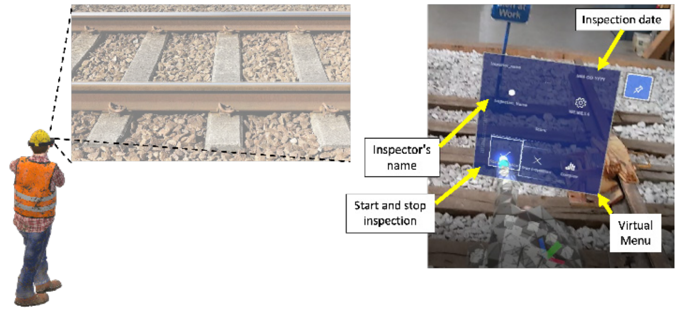
2. Human-in-the-loop based structural data collection using augmented reality headsets.

3. Visual Simultaneous localization and mapping (SLAM) enabled optimal structural element and damage mapping using virtual reality-based robotic drones.

RECENT WEBINARS

RELIABILITY OF BRIDGE INSPECTION TECHNOLOGIES

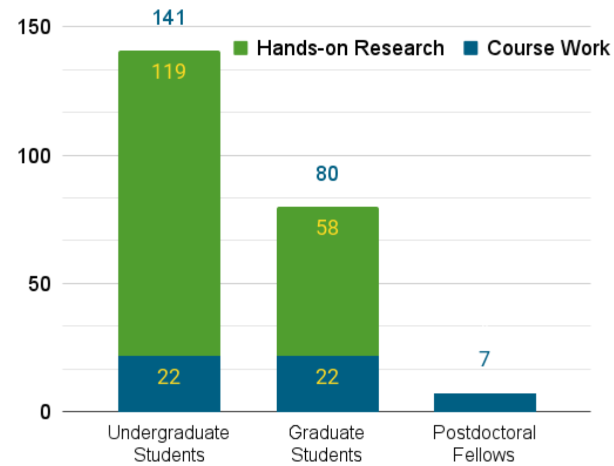
Presented: September 13, 2022, 11:00AM-12:00PM (CST)
Speaker: **Dr. Glenn Washer**
Professor
University of Missouri in Columbia



INTELLIGENT HUMAN-INFRASTRUCTURE INTERFACES FOR INSPECTORS AND DECISION-MAKERS

Presented: June 21, 2022, 10:00AM-11:00 AM (CST)
Speaker: **Dr. Fernando Moreu**
Assistant Professor of Structural Engineering
University of New Mexico at Albuquerque

INSPIRE UTC'S IMPACT ON TRANSPORTATION WORKFORCE



As we approach the last year of USDOT funding in the current phase, the INSPIRE UTC has ramped up its impact on the effectiveness of transportation system, the establishment and strengthening of start-up companies, the expansion of knowledge base around the theme of the center, and transportation workforce. In the future, the transportation system will be more effectively managed by improving inspector safety, reducing inspection time, minimizing interruption to traffic, enhancing data quality, and saving overall costs. The INSPIRE UTC support is critically important to the establishment of a start-up company called Automated Inspection Robots (AIR) Corp. registered in January of 2020 under the leadership of Dr. Hung La from the University of Nevada at Reno. The UTC support is also strengthening the existing spin-off company called InnovBot LLC directed by Dr. Jizhong Xiao from the City College of New York. The body of scientific knowledge in robot-assisted inspection and maintenance is greatly expanded by enabling the development of infrastructure-interactive drones and climbing robots, augmented/virtual reality driven field operation during inspection and maintenance, and artificial intelligence and machine learning informed decision-making to translate big data into useful engineering information in infrastructure asset management. In particular, the INSPIRE UTC has developed transportation workforce by providing direct training of 22 undergraduate students, 22 graduate students, seven postdoctoral fellows and research faculty through hands-on research activities. The INSPIRE UTC has also trained approximately 158 additional undergraduate and graduate students through seven course work.

INSPIRE UTC YEAR 6 FUNDED RESEARCH PROJECTS

The INSPIRE UTC is committed to addressing the research needs and projected research progress outlined in the original center proposal. Project proposals were reviewed and evaluated on 50% technology advances, 35% innovative solutions, and 15% relevance to the goal of the center. In Year 6, the INSPIRE UTC awarded the following research projects:

INSPIRE UTC - Year 6 Projects

Project	Principal Investigator	Co-Principal Investigators
Bridge Inspection Robot Deployment Systems (BIRDS)	**Dr. G. Chen**, Missouri S&T	**Dr. H. La**, University of Nevada-Reno, **Dr. P. Oh**, University of Nevada, Las Vegas, **Dr. Y. Wang**, Georgia Institute of Technology, **Dr. J. Xiao**, The City College of New York
Mixed Reality for Beyond Visual Line-of-Sight Bridge Inspection Using Robot-Assisted Nondestructive Evaluation	**Dr. G. Chen**, Missouri S&T	
QA/QC Guidelines on Drone-based Remote Sensing for Bridge Element Inspection	**Dr. G. Chen**, Missouri S&T	
Mixed Reality Interfaces for Simulation Training and Control	**Dr. S. Louis**, University of Nevada, Reno	
Hyperspectral Imaging and Analysis for Steel Paint Condition Assessment	**Dr. H. Ma**, Missouri S&T	
Integration of Aerial Manipulation, Haptics-based Human-in-the-Loop Control, and Augmented Reality for Bridge Deck Hosing	**Dr. P. Oh**, University of Nevada, Las Vegas	
A Field Deployable Wall-Climbing Robot for Bridge Inspection Using Vision and Impact Sounding Techniques	**Dr. J. Xiao**, The City College of New York	**Dr. A. Agrawal**, The City College of New York
Autonomous Ultrasonic Thickness Measurement by a Magnet-Wheeled Robot	**Dr. Y. Wang**, Georgia Institute of Technology	**Dr. H. La**, University of Nevada, Reno
Data-Driven risk-Informed Bridge Asset Management and Prioritization across Transportation Networks	**Dr. I. Tien**, Georgia Institute of Technology	**Dr. G. Chen**, Missouri S&T
Nondestructive Data Driven Motion Planning for Inspection Robots	**Dr. H. La**, University of Nevada, Reno	**Dr. G. Chen**, Missouri S&T

INSPIRE WEBINARS

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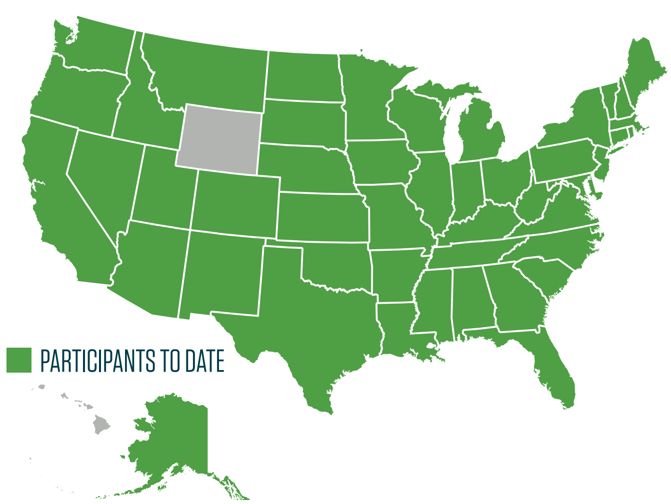
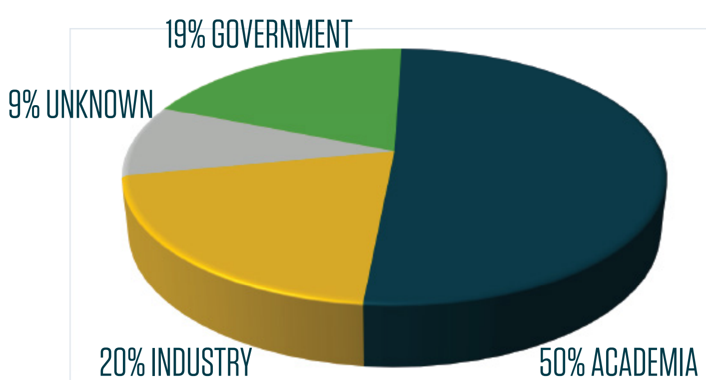
21 WEBINARS | **2,068** PARTICIPANTS | **51** COUNTRIES | **48** US STATES

US PARTICIPATION



SECTOR PARTICIPATION



inspire-utc.mst.edu/webinars

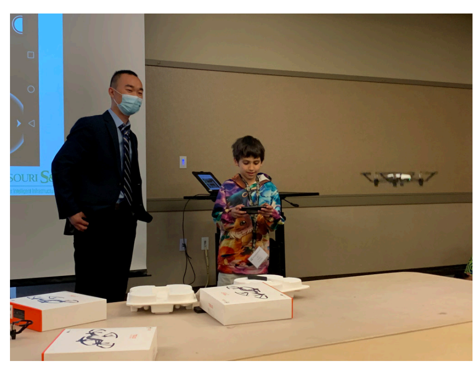
INSPIRE UTC Invites Dixon Elementary 3rd Graders for Interactive Workshop

On April 19, 2022, INSPIRE UTC of Missouri S&T held an one-hour interactive workshop for 51 third grade students from Dixon. The students were given a glimpse of the INSPIRE Center research activities including different types of unmanned aircraft systems (drones) and climbing robots. About 80% of the students lined up for the hands-on experience with a Tello drone, of which approximately 10% were adept to flying the Tello drone. Students managed to fly the drones without incidence. Among many intelligent flight modes of the Tello drone, 8-D flip and 360° automatic rotation with recording modes were also demonstrated.



INSPIRE UTC Hosts Hands-On Workshop for Dixon Elementary 5th Graders

On April 28, 2022, INSPIRE UTC of Missouri S&T hosted an outreach for 66 Dixon 5th graders. The outreach started with a brief introduction of the ongoing research activities at the INSPIRE center. The students were presented a variety of equipment at the center including a large 3-D printer, commercial drones including Tello drone, Phantom4 drone, Skydio2 Pro drone and Elios2 drone, customized drones including "drilling" drone and "BridgeBot" hybrid vehicle, as well as a robotic crawler for climbing steel bridges. The presentation also included instructions on how to fly a Tello drone for the later hands-on experience. Approximately 80% of the students flew Tello drones. Students were required to take off the drone, operate and fly the drone to the center of the room, and then fly the drone back to the initial location. Some students finished the task with some tilted landings. One of the teachers flew the drone at the end to demonstrate the maximum capabilities of the drone.

INSPIRE UTC Holds an Immersive Workshop for Newburg 7th Graders

On May 2, 2022, INSPIRE UTC of Missouri S&T held a workshop for a 7th grade group of 10 students on campus. The students and their guardians were given a glimpse of the research and equipment at the INSPIRE center. Students were also instructed on how to fly the Tello drone for their hands-on experience. Most 7th grade students have drone-flying experience and could fly the Tello drone in a skillful and experienced manner. One student accidentally crashed the Tello drone which became a humorous moment for the group. The lightweight Tello drone has propeller guards to reduce safety concerns.

Jackling Introduction to Engineering Summer Camp

On July 13, 2022, INSPIRE UTC of Missouri S&T hosted the Jackling Introduction to Engineering summer camp for an 8th grade group of 5 students for their visit to the Missouri S&T campus. The students were given a glimpse of the research and projects at the INSPIRE Center directed by Dr. Genda Chen. The demonstrated robot-assisted bridge inspection research involves a variety of tools, including a 3-D printer, HoloLens, a suite of drones, and a steel member crawler (climbing robot) which is designed to be equipped with multiple sensors to efficiently inspect steel bridges for defects detection such as corrosion, cracks, and other deterioration. It is designed with strong magnet wheels with 360-degree rotation capability for all kinds of steel bridge member situations. Students were also instructed on how to fly the Tello drone and HoloLens for their hands-on experience. The Tello drone has propeller guards to improve safety especially for beginners.

For more information, visit:
futurestudents.mst.edu/summer-camps

Aerospace Summer Camp Interested in Drone Operation

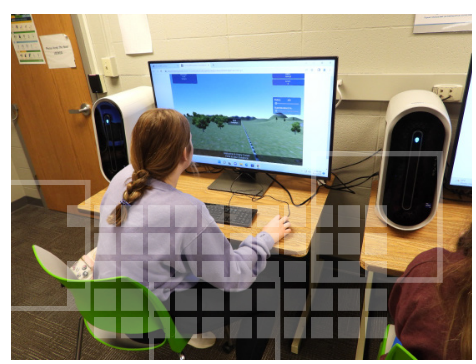
On July 20, 2022, INSPIRE UTC of Missouri S&T hosted outreach activities for 69 students from an aerospace summer camp. The program was divided into three sessions with each session holding an average of 23 students, respectively. The students were given a glimpse of the research activities conducted at the INSPIRE center including several types of unmanned aircraft systems (drones), robotics, and equipment. After the presentation, students were demonstrated how to fly a Tello drone with the opportunity for individual hands-on experience. Some students tried the Intelligence Flight mode, one of which involves flip maneuver. More than 95% of the students lined up to fly the Tello drones. Approximately 20% of students had to focus on how to manuever the drones to avoid crashing. Undergraduate research assistants Derek Edwards and Elizabeth Rozhanskiy presented and assisted with the participants. Students with aerospace interest can relate the drone flight experience with future pursuit of aerospace engineering for aircrafts.



INSPIRE UTC Hosts Driving Simulation Workshop (EYH)

On Sep 23, 2022, The INSPIRE UTC of Missouri S&T hosted a “Traffic Jam” workshop for 28 middle school students for the “Expanding Your Horizons” theme. The workshop was divided into two groups with each containing 14 students. The students were first demonstrated how to drive a car simulator to have a basic sense of driving a vehicle, in which they would learn how to respond to traffic lights, accelerate smoothly, brake to avoid a crash, and reverse when stuck. Each student had an opportunity to practice driving skills on the car simulator. The students were then instructed on how to play five online games that were developed for the “Traffic Jam” topic including Dilemma Zone, Design Road Curves, Time-Space Invaders, Transporters, and Road Crush, before they play the online games on high-performance computers. In the Dilemma Zone game, students were required to stop the green light in a timely manner within the minimum and maximum green light time so that the least number of vehicles would be caught in the dilemma zones. In the Design Road Curves game, students would adjust the radius and superelevation so that the vehicle would stay on the road while making a smooth turn at high speed. In the Time-Space Invader game, students would adjust the offset time so that vehicles being trapped at a red light (indicated as costs) would be reduced to a minimum. In the Transporters game, students would plan a region to connect houses and shopping zones with different roads without congesting traffic. In the Road Crush game, students would design a pavement with four kinds of materials so that the pavement is strong enough to support traffic on it while maintaining a low pavement cost. Dr. Bo Shang provided instruction on the car simulator and photographed during each rotation.

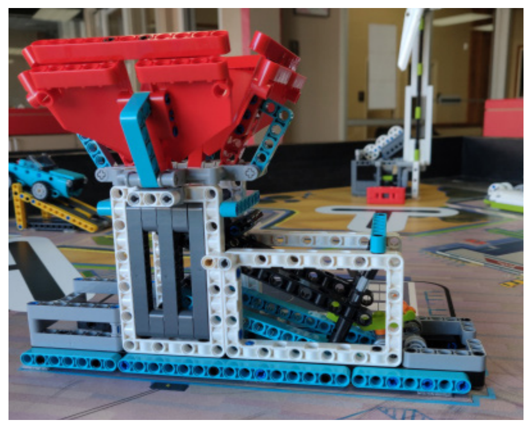




Kaleidoscope Discovery Center Outreach Report for UTC Grant

As of October 17, the Kaleidoscope is at eighty percent recovery from its pre-pandemic outreach activities. The Kaleidoscope has reached approximately 2000 students since summer through robotic and engineering programs in our region and across the state. Last year the FIRST Lego League updated their base robots for the first time in ten years. Although teams can continue to use the older version robots (EV3s), the new Spike Primes encourages block programming which eventually leads into Python, used by the older FIRST Tech and Robotics teams. Thanks to the generous support of this INSPIRE UTC grant, we have been able to upgrade to these robots for the five competitive FLL Lego League Challenge teams.

This year, the Kaleidoscope is supporting five FIRST Lego League Challenge teams (4th-8th grade), two more than last year, currently recruiting FIRST Lego League Explore teams (2nd-4th grade), and is beginning its first Lego League Discover program (PreK-1st) in Rolla after a two-year test in Vienna. All teams are invited to the Lego League Expo held in March 2023 to present their annual projects. This year the K-8th grade robotics theme focuses on energy and encourages participants to learn more about how energy is produced and used in our world.



One of the FIRST Lego League Explore coaches includes one of INSPIRE UTC's members, Dr. Bo Shang. Dr. Shang is a postdoc by day and leads a team of fearsome Lego League Explore warriors on the weekends. It is people like Bo who donate their time and passion for STEM that 'INSPIRE' the next generation of STEM professionals.

The Robotics Room has opened at 612 North Pine Street with an Open House in August. It also serves as a meeting place for four robotics teams, a location for STEM-themed birthday parties, and School Day Off robotics programming.

This summer, thanks in large part to the robotics volunteers throughout the community, the Kaleidoscope ran its first eight weeks of full-time summer camp programming. The program filled a childcare need in the community and simultaneously engaged our AmeriCorps Summer VSAs in robotics summer programming support. Library outreach was re-established after the corona virus hiatus from public programming last year. Children attending these regional library programs themed "Oceans of Possibilities" built robotic Lego sharks with Kaleidoscope volunteers this summer.

The Missouri Future City competition planning is well underway having unprecedently registered 43 teams at time of publication. This year both in-person and resources-only competition will engage over 1750 6th-8th graders in Missouri, including four teams from Arkansas. The Missouri Future City competition started five years ago with six teams participating at the State level. The city-building competition will be held on January 23, 2023 in Butler Carlton Hall on the Missouri S&T campus, and will focus on climate change issues. Engineering professionals are always welcome to participate in the judging of this event.

Kaleidoscope Discovery Center is grateful for the support from the whole INSPIRE UTC community in supporting these STEM outreach activities to our K-8 students locally, regionally, and across the state.

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

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UPCOMING EVENTS

December 13, 2022
Webinar: STRUCTURAL INSPECTION AUTOMATION: RESEARCH CHALLENGES AND 3D MACHINE VISION TECHNIQUES
https://inspire-utc.mst.edu/webinars

January 8-12, 2023
Transportation Research Board (TRB) Annual Meeting, Washington, D.C.
trb.org/AnnualMeeting/Registration.aspx

January 21, 2023
Missouri State Future City Competition, hosted by the Kaleidoscope Discovery Center and Future City Competition, Missouri S&T, Rolla, MO
futurecity.org

Feburary 24-26, 2023
National Society of Black Engineers (NSBE) Pre-College Initiative Weekend, Missouri S&T, Rolla, MO
sdi.mst.edu/precollege

March 11, 2023 (Tentative)
FLL Junior Expo, hosted by the Kaleidoscope Discovery Center, Missouri S&T, Rolla, MO
thekaleidoscope.org/first-robotics

March 12-16, 2023
SOIE Smart Structures & NDE, Long Beach, CA
https://spie.org/conferences-and-exhibitions/smart-structures-nde?SSO=1

inspire-utc.mst.edu/events