Spring 2018

INSPIRE Newsletter Spring 2018

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

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INSPIRE

INSPECTING AND PRESERVING INFRASTRUCTURE THROUGH ROBOTIC EXPLORATION

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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 friends and colleagues!

It has been a busy and productive couple of months at the INSPIRE UTC. Since our last update, we have made advancements in each research area, and through outreach and public engagement activities that showcased the work of our 10-university consortium, we have demonstrated to state legislators, community leaders, and students the importance of the University Transportation Center program, and the value that our center's research brings to our communities.

This issue focuses on the robotics research being conducted by our center to develop remotely-controlled mobile platforms for the inspection and preservation of bridges and tunnels. This research strives to enable traffic-disruption-free inspection and maintenance programs in the future. Towards this effort, progress is underway to establish a proposed pooled fund initiative to leverage the center's resources to develop case studies, protocols, and guidelines that can be adopted by state DOTs for bridge inspection without adversely impacting traffic. This will benefit state DOTs by reducing costs and safety risks, and improving efficiencies and eliminating traffic disruption in the inspection and maintenance process.

We recently have begun to engage more undergraduate students by launching a new undergraduate research scholarship program, and by pairing students from consortium member campuses to participate in INSPIRE research projects during the 2018 summer semester.

Plan is also underway to organize the first annual center meeting in Rolla, Missouri. Faculty and students participating in various research projects will make their presentations, exchange ideas, and develop a collaborative path among projects for another productive year in 2019.

We are excited for what lies ahead, and look forward to advancing these new technologies through our research. Thank you to the research faculty for their leadership and hard work on each of the projects aimed at achieving the mission of our center.

We invite you to read featured articles on robotics research and news at the INSPIRE UTC, and visit our website at https://inspire-utc.mst.edu for additional information about our center's research, education, outreach and workforce development efforts.

Sincerely,

Genda Chen, Ph.D., P.E., F. ASCE
Professor and Robert W. Abbett Distinguished Chair in Civil Engineering
Director of the INSPIRE UTC
Missouri University of Science and Technology

UM System Legislative Showcase

The INSPIRE UTC held an exhibit at the inaugural University of Missouri System Legislative Showcase in Jefferson City, Missouri on February 28, 2018. The event highlighted the work of the UM System's four campuses to demonstrate the value that public higher education brings to Missouri citizens and communities.

Under the theme "Protecting Missourians", the INSPIRE UTC, led by Missouri S&T, showcased the work of the 10-university consortium, which addresses various challenges in the highway and railway system, including aging infrastructure. The exhibit highlighted INSPIRE UTC's leadership in research, education, workforce development and technology transfer aimed at infrastructure inspection and preservation solutions with advanced technologies for a sustainable and resilient transportation system.

PRESIDENT'S MESSAGE

Missouri S&T's University Transportation Center is something the entire University and the state of Missouri should be very proud of. In September, I had the honor of attending the kick-off meeting of the consortium and engaging with our state and industry partners to discuss the immense opportunities ahead for the INSPIRE project. This collaboration among universities nationwide is an important investment and a precursor for future investments that need to be made in the country's aging infrastructure. Missouri S&T's expertise in mechanical, aerospace and civil engineering, specifically robotics and vehicle systems, will lead to the development of new and innovative technologies, decision processes and regulations to remain competitive as one of the best UTC's in the nation. I want to commend Professor Genda Chen and his colleagues for their outstanding work. I'm truly INSPIREd by this group, and look forward to seeing the creative breakthroughs it will achieve to address a grand challenge for our state and nation.

Sincerely,

Mun Choi, President
University of Missouri System

UTC SPOTLIGHT features INSPIRE's Smart Rock project

The US Department of Transportation's UTC Spotlight newsletter is a monthly publication that highlights recent accomplishments and products from one university transportation center. The March 2018 edition of the UTC Spotlight features the work of the INSPIRE UTC. Led by Dr. Genda Chen, professor and Robert W. Abbett Distinguished Chair in Civil Engineering and director of the INSPIRE UTC at Missouri S&T, the *UAV-enabled Measurement for Spatial Magnetic Field of Smart Rocks in Bridge Scour Monitoring* project is part of the INSPIRE UTC research program. This project was based on a previous study funded through the Commercial Remote Sensing and Spatial Information Technologies program at the US Department of Transportation.

"Hydraulic effects are responsible for about 60 percent of the more than 1,500 U.S. bridge collapses. Traditionally, divers are sent underwater to inspect bridge foundations and document any riverbed erosion or scour holes that may compromise a foundation's integrity. This project aims to replace divers with smart rocks that automatically roll to the bottom of a scour hole under strong current to assess the scour-hole condition. A magnetometer installed on an unmanned aerial vehicle (UAV), remotely senses the depth of a scour hole by measuring magnetic fields surrounding the smart rocks. The difference in two measurements over time reveals the movement of the smart rocks during that time period, with the vertical movement showing the development of scour hole depth. This critical data is then used by engineers to assess the stability of a foundation due to scour hazards."

Read the full article online at: https://www.transportation.gov/utc/smart-rock-positioning-scour-hazard-assessment-bridges. For more information on this and other INSPIRE UTC projects, visit inspire-utc.mst.edu or contact the center at inspire-utc@mst.edu or 573-341-6114.

RECENT PUBLICATIONS

Aerial Manipulation, a recent publication co-authored by Dr. Paul Oh, Lincy Professor of Unmanned Aerial Systems at the University of Nevada, Las Vegas (UNLV), and associate director of the INSPIRE UTC.

"This text is a thorough treatment of the rapidly growing area of aerial manipulation. It details all the design steps required for the modeling and control of unmanned aerial vehicles (UAV) equipped with robotic manipulators. Starting with the physical basics of rigid-body kinematics, the book gives an in-depth presentation of local and global coordinates, together with the representation of orientation and motion in fixed- and moving-coordinate systems. Coverage of the kinematics and dynamics of unmanned aerial vehicles is developed in a succession of popular UAV configurations for multirotor systems. Such an arrangement, supported by frequent examples and end-of-chapter exercises, leads the reader from simple to more complex UAV configurations. Propulsion-system aerodynamics, essential in UAV design, is analyzed through blade-element and momentum theories, analysis which is followed by a description of drag and ground-aerodynamic effects."

For more information, visit:
https://www.springer.com/us/book/9783319610207

Dr. Paul Oh is the Lincy Professor of Unmanned Aerial Systems in the department of mechanical engineering and director of the Drones and Autonomous Systems Laboratory at the University of Nevada, Las Vegas, and an associate director of the INSPIRE UTC. He has five years of industry experience in the design of target tracking systems, flight simulators, telecommunication network programming, and vehicle assembly. He has over 20 years of research experience in robotics including computer vision, unmanned aerial vehicles and humanoids.

Website:
https://www.unlv.edu/people/paul-oh

AERIAL MANIPULATION DRONES

Drones are aircraft that come in many different forms. The ones people commonly think of are multicopters sold in large chain stores and gift shops. These drones are often equipped with cameras. This allows users to capture aerial footage. Tomorrow's drones however, will likely be equipped with mechanical limbs. The Missouri University of Science and Technology leads a multi-university project called INSPIRE (INSpecting and Preserving Infrastructure through Robotic Exploration). The main focus of this article is to describe work using aerial manipulation to maintain and repair bridges for INSPIRE. Drones equipped with mechanical limbs shift paradigms; they would be able to actively perform work rather than just passively surveil. Such drones present a tool that can disrupt and transform service operations.

Aerial manipulators is a term used to refer to limb-equipped aircraft. Their ancestry stems from multicopter drones that have been commercially available for decades. Costing $5,000 to $50,000 in 2000-2010, they were often very difficult to fly and repair. Today's drones cost from $50 to $5,000. The higher-priced versions tend to fly more stably, longer, farther, and with heavier payload like professional video cameras. Beyond price, parts and service have grown so that such drones are more readily repaired and maintained. The net effect is that today's drones have evolved into consumer electronic products.

The smartphone's economies of scale made cameras, global positioning systems, sensors, batteries and microelectronics cheap, programmable and widely available. This helped to engineer drones at prices and performance that even novices could afford and easily fly.

Reaching mass markets, drone-based businesses began. Examples include package delivery, real estate photography, sport event broadcasting, aerial monitoring of farms, and visual inspection of oil and gas pipes. Beyond simply aircraft, drones entered the digital product line; they became service providers for remote sensing, data analysis, and information ecosystems.

Aircraft have historically evolved from being transportation vehicles to workhorses. For example, cables and hooks were added to helicopters to perform work. Examples include rescue missions, firefighting and construction to handle casualties, retardants, and building materials respectively. Such tasks demand very skilled pilots who ensure the cable does not overswing. Swinging payloads can accidentally smash into neighboring objects. Moreover, unpredictable swinging can cause the helicopter to become unstable and crash.

However, tasks with cables and hooks are limited. The next evolutionary step is to equip drones with mechanical limbs. This would make them true flying robots. Robots by definition physically interact with their environment. The limbs would allow the aircraft to perform physical work like pushing, pulling, loading, unloading, stacking, and packing. Such material-handling tasks demand dexterous manipula-

tion, namely limbs and hands to grab objects, operate hand tools, push buttons, and turn valves.

The research team, formerly at Drexel University (Philadelphia), now at the University of Nevada Las Vegas (UNLV), first conceived the notion of dexterous aerial manipulation in 2008. Mobile-manipulating Unmanned Aerial Vehicles (MM-UAV) was the term they coined to convey this challenging task. Mobile manipulation remains an open research topic in the robotics community. However, case studies primarily focused on mechanical limbs and hands on terrestrial mobile robots.

> "The next evolutionary step is to equip drones with mechanical limbs. This would make them true flying robots. Robots by definition physically interact with their environment. The limbs would allow the aircraft to perform physical work like pushing, pulling, loading, unloading, stacking, and packing."

An industrial robot, like those on automobile assembly lines are fixed; their base is attached to the floor. Programming desired motions are well understood. By contrast, when the base can move, commanding limb and hand (called grippers or end effectors) remains somewhat unsolved. Examples include planetary rovers, bomb disposal robots, and unmanned farm-harvesting vehicles. These ground robots have mechanical limbs mounted on the chassis to collect rock samples, defuse explosives, and pick fruit. The solution often involves a move-stop-manipulate motion sequence; the ground vehicle steers into the desired location, stops, moves its manipulator and then the vehicles goes to the next location.

Mobile manipulation with aerial robots like MM-UAV is significantly more challenging. This is because the vehicle is free-floating. One helpful image is a scuba diver turning an underwater pipe valve. By coordinating hand and leg motions, the diver could turn a valve without standing on the pipe. Without proper body contortions, valve turning would be futile because the diver cannot generate forces and torques in the necessary directions.

For INSPIRE, MM-UAVs need dexterity to perform tasks like bridge deck cleaning and patching. This requires the drone to handle conventional hoses and epoxy applicators. The move-stop-manipulate sequence however would not perform
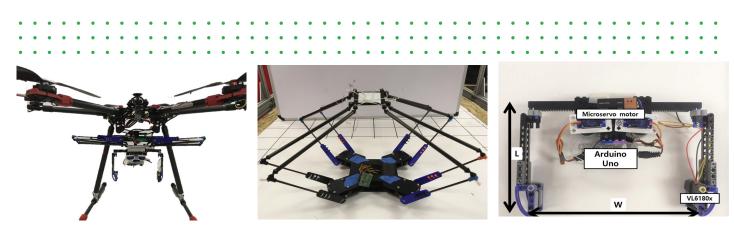
Fig. 1. Parallel-based arm (middle) and gripper (right) in stowed position on rotorcraft (left)

such tasks in a timely manner. Moreover, hoses create a jet when spraying fluid. Also, applying epoxies results in reactionary forces. The net effect is disturbances that make aerial manipulation very challenging.

Currently, the MM-UAV team is designing a suitable limb and gripper. Such an appendage needs to mimic the human upper body. The arm needs the strength to carry the hose, gripper to grasp the nozzle, and wrist to orient spraying. The parallel mechanism design is being used for INSPIRE, yielding promising results. Releasing fluid creates jet forces. But the underlying flight controller counteracts such disturbances.
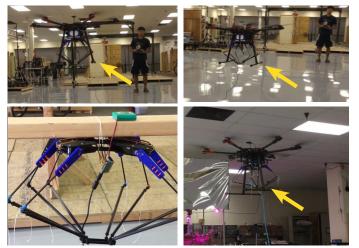
The human arm is a serial mechanism, a linear connection of bones and joints. Mimicking this mechanically however, often results in a heavy appendage. By contrast, parallel mechanisms can be designed to provide similar motions more compactly, with fewer parts and less weight.

The MM-UAV team's future work is hand design. Parallel jar grippers are two-fingered hands often used in industrial pick-and-place robots. The current prototype would securely grasp the hose nozzle or epoxy applicator. Sensors on the gripper would allow controlled adjusting of grasping strength. This is important to regulate spray speed or epoxy spreading.

Fig. 2. Arrows show gripper carrying (water) hose

Fig. 3. Gripper pick-and-place test: approaching object (left) and lifting from table (right)

ABOUT THIS PROJECT:
Led by Dr. Paul Oh, Lincy Professor of Unmanned Aerial Systems at the University of Nevada, Las Vegas (UNLV), and associate director and principal investigator in the INSPIRE (INSpecting and Preserving Infrastructure through Robotic Exploration) UTC, the *Mobile-manipulating UAVs for Sensor Installation, Bridge Inspection, and Maintenance* project is part of the INSPIRE UTC research program.

FOR MORE INFORMATION CONTACT:

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A CLIMBING ROBOT FOR STEEL BRIDGE INSPECTION

Steel structures and steel bridges, constituting a major part in civil infrastructure, require adequate maintenance and health monitoring. In the US, more than fifty thousand steel bridges are either deficient or functionally obsolete, which likely presents a growing threat to people's safety. Traditionally, the steel bridges are inspected manually by rope certified bridge inspectors. Often, it is dangerous for the inspectors to climb up or hang on cables to inspect large bridges with high structures. In addition, reports from visual inspection may vary between inspectors so the structural health condition may not be assessed precisely.

This project aims to develop a climbing robot that can automatically climb up, down, or upside-down on the steel structures and perform an inspection. Through nondestructive evaluation with a camera and a 3D structure sensor installed on the robot, they can build a 3D map of the inspected structure associated with defect (crack, rusted) location. To have the robot adhere strongly on the steel surface, the magnetic wheels are designed. The robot can safely navigate on the structures with support of inertial measurement unit (IMU), hall-effect and infrared (IR) sensors.

> "This project aims to develop a climbing robot that can automatically climb up, down, or upside-down on the steel structures and perform an inspection."

The main focus of this project is to: (i) design, build, and test a climbing robot with a camera, a 3 dimensional structure sensor, an IMU, a lightweight onboard computer, and one or two batteries for at least one hour operation in field conditions, (ii) investigate the adhesion force on magnetic field measurements, (iii) evaluate the steel surface using visual data, and (iv) demonstrate the field performance of the robot for inspection at steel structures.

A robot design with four motorized wheels is proposed, taking the advantage of permanent magnets for adhesion force creation. This allows the robot to adhere to steel surfaces without consum-
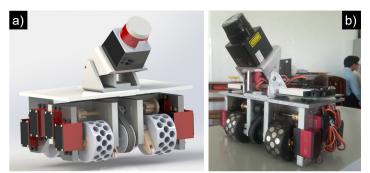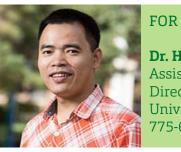

Fig. 1. (a) The 3D design of the climbing robot, and (b) actual implementation of the robot.

ing any power. In addition, cylinder shaped magnets are used for convenience and flexibility in adjusting the attraction force. Moreover, eight high torque servo motors are utilized to drive four wheels for robot navigation and four shafts for robot lifting. A total of 36 Neodymium magnet cylinders embedded in each wheel can create magnetic force up to 14 Kg/wheel. Additionally, a special mechanism has been designed in order to lift either the front or rear wheels off the structure surface if the robot is stuck on rough terrains. Fig. 1 shows the 3D design and implementation of the robot.

Regarding sensing devices, the robot is equipped with multiple imaging sensors: a video camera for image capturing and video streaming, and a time-of-flight (ToF) camera for capturing 3D data. The USB camera at the back of the robot is installed facing downward in order to take images of steel surfaces and feed to the image stitching unit. Besides, the ToF camera is placed so that 3D images received from this camera can assist with robot navigation as well as building a 3D map of the inspected structures.

Apart from cameras, eight Hall Effect sensors are used to detect the presence of a magnetic field to support robot navigation. Moreover, the robot has four IR range sensors mounted at four corners of the robot, which can detect whether there exists a surface underneath (see Fig. 2).

FOR MORE INFORMATION CONTACT:

Dr. Hung La, Ph.D., SM-IEEE
Assistant Professor, Computer Science and Engineering Department
Director, Advanced Robotics and Automation (ARA) Laboratory
University of Nevada Reno
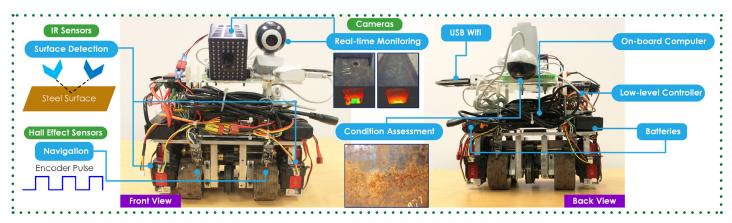775-682-6862 | hla@unr.edu | https://ara.cse.unr.edu

Fig. 2. Robot prototype with integrated sensors: camera, 3D structure sensor, hall-effect and IR sensors.

The robot is controlled by a micro-controller unit (MCU) handling low-level tasks and a more powerful on-board computer for complex processing and communication with the ground station. The on-board computer is an Intel NUC Core i7 computer responsible for capturing video camera and 3D visual images, then sending them to the ground station over wireless LAN connection for data post-processing and logging. It also executes the edge avoidance algorithm with sensors data received from the low-level controller to ensure safe traveling on steel surfaces. The whole robot is powered by two batteries with different voltage levels. One 12V Lithium battery powers the on-board computer and cameras while another 7.4V Lithium battery supplies to all motors. The robot can operate for 1.5 hours with this power setup.
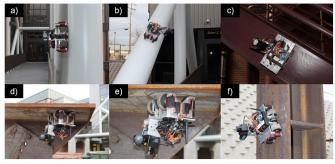

Fig. 3. Field tests of the robot on steel structures and bridge on the UNR campus.

During the experiments, the climbing capability tests are done on a bridge and on several steel structures nearby with coated or unclean surfaces as seen in Fig. 3. Although the steel surface is curved, the robots can still adhere tightly to the steel structures. It also shows strong climbing capability on a rusty steel surface.

During the test, movement of the robot is controlled remotely from ground station while data collected from both video camera and 3D camera are transmitted over wireless connection to the ground station as shown in Fig. 4.

The robot is controlled to move and stop at every certain distance (e.g., 12cm) to capture images of steel surface. To enhance steel surface inspection, acquired images are then stitched together to produce an overall image of steel surface as shown in Fig. 5.

FOR MORE DETAIL, WATCH THE VIDEO AT:
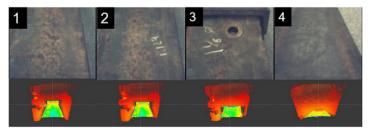**https://www.youtube.com/watch?v=MBsd7thEs88**

Fig. 4. Visual and 3D images acquired from camera and ToF sensor.
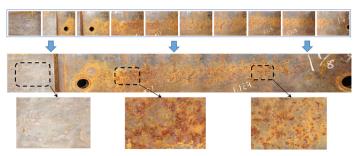

Fig. 5. Image stitching for visual condition assessment.

ABOUT THIS PROJECT:
Led by Dr. Hung La, Assistant Professor at THE University of Nevada, Reno, and principal investigator and associate director of the INSPIRE (INSpecting and Preserving Infrastructure through Robotic Exploration) UTC, the *Climbing Robots with Automated Deployment of Sensors and NDE Devices for Steel Bridge Inspection* project is part of the INSPIRE UTC research program. This project was based on a previous study funded through the I-Corps Teams Program at the National Science Foundation.

AUTOMOMOUS WALL-CLIMBING ROBOTS TO INSPECT CONCRETE BRIDGES

A Federal Highway Administration (FHWA)- sponsored study has found that visual inspection results can have a high level of uncertainty in identifying cracks and damages. In addition to visual inspection of surface flaws, inspectors need to detect subsurface defects (e.g., delamination and voids) using nondestructive evaluation (NDE) instruments such as ground penetration radar (GPR) and impact sounding device to determine the structural integrity of bridges and tunnels. It is an extremely challenging task to access critical locations of infrastructures and perform contact-based nondestructive inspection reliably and safely.

The current practice of full bridge inspection using a hand-held NDE instrument by a "spider-man" with rope access, or by using scaffolding or a Snooper truck is time-consuming, exposes human workers to dangerous situations, and often requires traffic control that is very expensive to carry out.

> "The current practice of full bridge inspection ... is time-consuming, exposes human workers to dangerous situations, and often requires traffic control that is very expensive to carry out. "

In this project, we propose to develop wall-climbing robots that will be deployed to difficult-to-access locations for automatically scanning the concrete surface of bridge structure members with visual and NDE sensors. It is envisioned that the robotic inspection system will be able to carry a camera and GPR antenna to scan the vertical surface of bridge columns and the horizontal surface of bridge girders and decks (both top and bottom sides), reach hard-to-access places, take close-up pictures, record and transmit NDE data to host computer, log GPS coordinates, and record subsurface defect locations for visualization and analysis. Thus, makes the full bridge inspection and repair operations faster, safer, cheaper, and eliminates the need for blocking traffic.

The primary focus of this project is to: (i) design, build, and test wall-climbing robots to carry cameras for visual inspection of surface flaws and NDE sensors (e.g., GPR and impact sounding device) for detection of subsurface defects, (ii) investigate visual inspection methods and image processing algorithms to identify, measure and record the condition state information of

bridge structure members, (iii) investigate motion control and V-SLAM (visual simultaneous localization and mapping) methods to localize defect places and register them in 3D model for better visualization, (iv) evaluate the electromagnetic interference (EMI) between GPR signal and robot circuitry and investigate signal processing methods to eliminate the effects, and (v) demonstrate the field performance of the integrated robotic inspection system at bridge site.
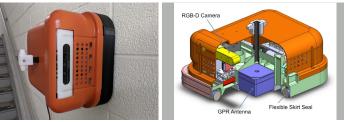

Fig. 1. A wall-climbing robot prototype. GPR-Rover-v2 adhere to vertical wall (left). It carries a RGB-D sensor in front, and a GPR antenna at the bottom, inside a chamber enclosed by the flexible skirt seal (right).

We produce a wall-climbing robot prototype (i.e., GPR-Rover-v2) as shown in Fig. 1. It maintains a constant negative pressure inside a suction chamber by adjusting the propeller speed to achieve a desirable balance of strong adhesion and high mobility. Since it doesn't require perfect sealing as vacuum suction techniques would, it can move on both smooth and rough surfaces, and cross over shallow grooves. It carries a RGB-D camera on a tilt mechanism in the front to adjust the viewing angle. The RGB-D camera not only produces regular Red-Green-Blue (RGB) video images but also provides distance measurement. A GPR antenna is installed inside the chamber enclosed by a flexible skirt seal (Fig.1-right) to scan the contact surface at the bottom.
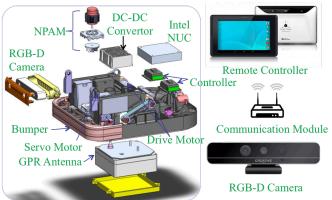

Fig. 2. The electrical components and sensors in GPR-Rover-v2.

The GPR-Rover-v2 consists of a negative pressure adhesive module (NPAM), a pressure sensor, two drive wheels and the associated motors and controllers, one servo motor to adjust the camera tilt angle, a bumper, a DC-DC converter, an Intel NUC computer for on-board image/signal processing (see Fig. 2). The remote control graphic user interface (GUI) on a tablet computer commands the robot motion, adjusts the suction power, controls camera view angle and LED lighting, and displays the first-person-view of the scene transmitted from the video camera through WiFi communication. The GPR transmits the data through power over Ethernet (POE) cable to a host computer for further analysis. The robot has a dimension of 16.5 × 13 × 8 inches with self-weight 12 lbs. It can carry a payload up to 20lbs.

In addition to providing vertical mobility on concrete walls, the robot can perform on-board visual inspection for surface flaw detection, measurement, and registration. We develop a novel deep learning algorithm called InspectionNet based on convolution neural network to detect the cracks and spalling on concrete structures.

First, we create a pixel-level semantic dataset which includes 820 labeled images. To achieve robust modeling, we perform image flipping, rotation, and sub-cropping to do image augmentation for training as well as validation. The training on the dataset for InspectionNet is performed with 12,000 iterations for each defect type.
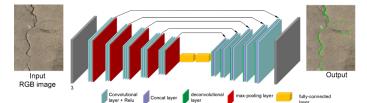
measurement (e.g., the crack width, the area, and depth of spalling) with the help of depth scale information obtained from the RGB-D camera.

Third, we propose a method to obtain the defect locations in reference to the inspection starting position based on our previous work on fast visual odometry and V-SLAM algorithms using an RGB-D camera. The method enables the robot to continuously update its position and orientation with respect to a world coordinate system and reconstruct the 3D model of the concrete structure in the form of point cloud by applying visual SLAM and depth acquisition via the RGB-D camera.

We perform a field test to inspect the bridge tunnel at Riverside Drive and West 155th Street, New York City, NY 10032, whose results are illustrated in Fig. 4. The semantic inspection results (in green) are registered in the concrete structure 3D model for better visualization and also provide a metric measurement for condition assessment and monitoring.

The future research plan is to investigate other NDE technologies (i.e., GPR and impact sounding) to detect and visualize subsurface defects by integrating robotic control and SLAM with NDE signal processing technologies.

Fig. 3. Illustration of InspectionNet architecture for spalling/crack segmentation with pixel level accuracy.

Second, we adopt the U-net style deep neural network to perform end-to-end full pixel level segmentation as shown in Fig. 3. The InspectionNet consists of 25 layers, with the first 15 layers on the left are initialized based on VGG-16 as the pre-feature-extraction layers, and on the right side 10 convolutional layers (5 groups of deconvolution and convolution operation) to do upsampling. The defects are classified as either spalling or cracks with pixel level accuracy, enabling the quantitative
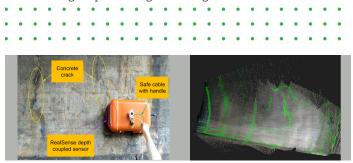

Fig. 4. Field test and results. Deploy the robot on a vertical wall of the bridge (left). Register the defects (green) in 3D point cloud map of the bridge tunnel (right).

ABOUT THIS PROJECT:

Led by Dr. Jizhong Xiao, professor in electrical engineering department at CCNY, and principal investigator in the INSPIRE UTC, the *Autonomous Wall-climbing Robots for Inspection and Maintenance of Concrete Bridges* project is part of the INSPIRE UTC research program. This project was based on previous studies funded through ARO, NSF and FHWA.

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Undergraduate Research

MISSOURI S&T SCHOLARSHIP PROGRAM

The INSPIRE UTC has implemented a new Undergraduate Research Scholarship Program to engage Missouri S&T undergraduate students in research projects conducted by the center. Missouri S&T provides scholarships for undergraduate research through the Opportunities for Undergraduate Research Experience (OURE) program. The INSPIRE UTC provides up to 4 additional scholarships annually for OURE students participating in research projects that are funded by the UTC and led by Missouri S&T faculty. Projects start at the beginning of the summer or fall semester and end at the conclusion of the following spring semester. Participating students will prepare and submit a final research report and poster and present it at the Missouri S&T Undergraduate Research Conference, Undergraduate Research Day at the Capitol event, and INSPIRE UTC Annual Meeting.

MISSOURI S&T/LINCOLN UNIVERSITY SUMMER EXCHANGE

The INSPIRE UTC provides two scholarships each year to support Lincoln University undergraduate students for an 8-week summer research experience on the Missouri S&T campus. The purpose of the program is to provide underrepresented undergraduates attending Lincoln University an opportunity to conduct transportation-related research and learn about graduate education opportunities. Selected students will participate in a research project directed by a member of the INSPIRE UTC faculty. At the conclusion of the program, students will present their research to their fellow S&T peers, faculty mentors, and guests. Participating students will receive a research stipend from the INSPIRE UTC and be provided housing on the Missouri S&T campus for the 8-week summer semester.

For more information, visit:
https://inspire-utc.mst.edu/studentprograms

UNR REU IN COLLABORATIVE HUMAN ROBOT INTERACTION

The University of Nevada, Reno (UNR) offers a Research Experiences for Undergraduates (REU) site focusing on Collaborative Human-Robot Interaction (CHRI). The site will develop new autonomous robot capabilities and supporting network and data science technology to address real-world challenges of operating autonomous systems. The University's Robotics Group is made up of faculty specializing in human-robot interaction, assistive robotics, autonomous robots, field robotics, and wireless communication and cybersecurity. The research will be supported by experienced graduate students who will help mentor undergraduate projects. Students will gain experience with robotics, wireless networks, and assistive technology to optimize collaboration between a robot and human partner(s). Students will participate in a research project, prepare a written report on their project, and present to the University's undergraduate research symposium.

For more information, visit:
https://www.unr.edu/cse/research/intelligent-systems/reu

EXPERIENTIAL LEARNING

Undergraduate students involved in research have the exciting opportunity to be directly involved with technology developments at the forefront of their chosen field of study. Undergraduate research experiences help students prepare for graduate school and provide opportunities to work closely with faculty advisors.

TECHNOLOGY TRANSFER

RECENT WEBINAR

Microwave Materials Characterization and Imaging for Structural Health Monitoring

Presented: March 15, 2018
Speaker: **Dr. Reza Zoughi**
Schlumberger Endowed Professor
Electrical and Computer Engineering
Director, Applied Microwave Nondestructive
Testing Laboratory (amntl)
Missouri University of Science and Technology
Online: https://scholarsmine.mst.edu/inspire_webinars
https://inspire-utc.mst.edu/webinars

The relatively small wavelengths and large bandwidths associated with microwave signals make them great candidates for inspection of construction materials and structures, and for materials characterization and imaging. Signals at these frequencies readily penetrate inside of dielectric materials and composites and interact with their materials characteristics and inner structures. Water molecule is dipolar and possesses a relatively large complex dielectric constant, which is also highly sensitive to the presence of ions that increase its electrical conductivity. Consequently, chemical and physical changes in construction materials affect their complex dielectric constant. This can be measured, and through analytical and empirical dielectric mixing formulae, correlated to those changes. Examples of applications would be, presence of delamination in a bridge deck and pavement, permeation of moisture behind retaining walls or corrosion of reinforcing steel bars which can be imaged with microwave techniques. One of the critical trade-off issues is between the microwave signal penetration into concrete vs. frequency of operation. Dielectric of concrete, particularly when moist, has a relatively high loss factor. As such, lower microwave frequencies are suitable to achieve reasonable penetration. Image resolution degrades as a function of decrease in operating frequency, therefore, a balance must be reached when using these techniques for imaging cement-based materials.

UPCOMING WEBINAR

Climbing Robots for Steel Bridge Inspection and Evaluation

Presented: June 21, 2018, 12 pm (Central)
Speaker: **Dr. Hung La, PhD, SM-IEEE**
Assistant Professor, Computer Science and
Engineering
Director, Advanced Robotics and Automation
(ARA) Laboratory
University of Nevada Reno
Register: https://inspire-utc.mst.edu/webinars

WEBINAR ARCHIVES

2018	Microwave Materials Characterization and Imaging for Structural Health Monitoring By Dr. Reza Zoughi, Missouri S&T
2017	Drone-Enabled Remote Sensing for Transportation Infrastructure Assessment By Colin Brooks, Michigan Tech
	Lab-On-Sensor for Structural Behavior Monitoring: Theory and Applications By Dr. Genda Chen, Missouri S&T

To view past webinars, visit:
https://scholarsmine.mst.edu/inspire_webinars

INSPIRE UTC reaches out to student organizations

On January 29, 2018, Dr. Genda Chen, director of the INSPIRE UTC met with the Missouri S&T student chapter of National Society of Black Engineers (NSBE), and Dr. Suzanna Long, associate director of the INSPIRE UTC met with the Missouri S&T student chapter of the American Society for Engineering Management (ASEM).

Drs. Chen and Long presented the research activities of the center and discussed how students can get involved through undergraduate research.

Kaleidoscope Discovery Center signs a memorandum of understanding with Missouri S&T

On February 27, 2018, Dr. Genda Chen, INSPIRE UTC director attended the formal signing of a memorandum of understanding (MOU) between Missouri S&T and the Kaleidoscope Discovery Center (KDC). The MOU will allow Missouri S&T to formally support the KDC mission to provide every child in the Rolla community with hands-on exposure to advanced programs in engineering, science, technology, the environment, art and mathematics (ESTEAM), and to grow the next generation of leaders in those fields.

The INSPIRE UTC provides robotics outreach support to the KDC to introduce students in the community to the transportation industry, and to raise awareness of the challenges associated with current bridge inspection methods, and the importance of improving these methods through the use of the advanced technologies currently being developed by the INSPIRE UTC.

For more information visit:
https://www.facebook.com/
kaleidoscopediscoverycenter/

INSPIRE UTC researcher supports FIRST Robotics team competitors

Dr. Jizhong Xiao, principal investigator in the INSPIRE UTC, professor of electrical engineering at The City College of New York (CCNY), and director of the CCNY Robotics Lab, and his students are actively supporting robotics education by serving as advisors and coaches to The Titanium Knights 6203, a FIRST robotics team from Bergen County Academies (BCA).

The Titanium Knights 6203 recently participated in the 2018 FIRST Robotics Competition (FRC) and garnished the Event Winner title at the Mid-Atlantic District Mt. Olive event which took place on March 9-11, 2018 in Flanders, NJ.

The mission of *FIRST* is to inspire young people to be science and technology leaders and innovators, by engaging them in exciting mentor-based programs that build science, engineering, and technology skills, that inspire innovation, and that foster well-rounded life capabilities including self-confidence, communication, and leadership.

INSPIRE UTC participates in the National Society of Black Engineers Pre-College Initiative

On February 24, 2018, faculty and students from the INSPIRE UTC and Mid America Transportation Center (MATC) led a hands-on bridge engineering competition for 42 Missouri high school students as part of the National Society of Black Engineers (NSBE) Pre-College Initiative (PCI).

PCI is an on-campus visit program for African-American students who may be considering a future career in math, science, computing or engineering. PCI is sponsored by S&T's student chapter of the National Society of Black Engineers and the Student Diversity Initiatives department. Through information sessions and hands-on workshops students get a chance to explore career options and gain a better understanding of what college life is all about.
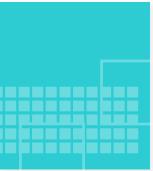
The INSPIRE UTC's workshop was presented by Drs. Ruwen Qin, Grace Yan, and Dincer Konur, PhD students Hongya Qu and Xinzhe Yuan, and engineering management student Wenjin Tao.

Participants were engaged in a hands-on bridge engineering competition, and received first, second and third place awards for their achievement. Students also visited the Virtual Reality Lab for a demonstration of driver's behavior-related transportation research.

Website: https://sdi.mst.edu/precollege

EVENTS

MAY 2018

ICIEA 2018, Wuhan, China

Dr. Jizhong Xiao, principal investigator with the INSPIRE UTC and director of The City College of New York (CCNY) Robotics Lab, will deliver a distinguished lecture on *Mobile Robots Against Gravity for Non-destructive Inspection of Infrastructures* at the 13th IEEE Conference on Industrial Electronics and Applications (ICIEA 2018) to be held in Wuhan, China May 31-June 2, 2018. ICIEA 2018 marks the 13th Anniversary of the ICIEA conferences. As a premier conference, ICIEA provides an excellent forum for scientists, researchers, engineers and industrial practitioners throughout the world to present and discuss the latest technology advancement as well as future directions and trends in industrial electronics.

Website: http://www.ieeeiciea.org/2018/DIL3.html

JUNE 2018

CUTC SUMMER MEETING, Minneapolis, MN

The INSPIRE UTC will attend the Council of University Transportation Centers (CUTC) Summer Meeting on June 4-6, 2018 at the University of Minnesota campus in Minneapolis, MN.

The CUTC is holding the meeting in partnership with the Center for Transportation Studies (CTS) at the University of Minnesota.

Website: http://www.cts.umn.edu/events/2018/CUTCmeeting

JULY 2018

MODOT TRANSPORTATION CAMP AT MISSOURI S&T, Rolla, MO

On July 17, 2018, the INSPIRE UTC will host a one-day transportation camp on the Missouri S&T campus, as part of MoDOT's annual Youth Transportation Conference. Each summer MoDOT selects 30 students from across the state to participate in the camp exposing them to numerous career opportunities in the field of transportation.

Attendees will spend a full day visiting S&T and exploring a variety of topics related to transportation.

Website: http://modot.org/EqualOpportunity/youthcamp.htm

US-JAPAN WORKSHOP, Los Angeles, CA

INSPIRE UTC director, Dr. Genda Chen, will participate by invitation in the 31st US-Japan Bridge Engineering Workshop in Los Angeles, CA July 16-17, 2018. Sponsored by the Federal Highway Administration, the workshop series brings together bridge engineers from the US and Japan to discuss common issues in bridge engineering. This particular workshop will be focused on the four technical topics:

1. Bridges designed for enhanced durability,
2. Bridge instrumentation and health monitoring,
3. Guidelines and use of refined calculations for design and bridge assessment, and
4. Innovative materials for bridge design and construction

Past Workshop: http://www.pwri.go.jp/eng/ujnr/tc/g/30bws/index.htm

AUGUST 2018

INSPIRE UTC ANNUAL MEETING, Rolla, MO

The INSPIRE UTC will hold its annual meeting on the Missouri S&T campus August 13-15, 2018.

Activities will include a pre-meeting step-up workshop for transportation workforce development, research presentations by the INSPIRE UTC faculty, an executive meeting and panel discussion with the INSPIRE UTC external advisory committee and a graduate student poster session and awards ceremony.

Website: http://inspire-utc.mst.edu

SEPTEMBER 2018

2018 US FRONTIERS OF ENGINEERING SYMPOSIUM, Lexington, MA

Dr. Iris Tien, assistant professor of civil engineering at Georgia Institute of Technology, and principal investigator with the INSPIRE UTC, will co-chair the *"Resilient and Reliable Infrastructure"* session at the 2018 U.S. Frontiers of Engineering Symposium in Lexington, MA September 5-7, 2018.

The Frontiers of Engineering Symposium brings together the nation's best engineers from academia, national labs, and industry to explore interdisciplinary ideas to address some of engineering's grand challenges.

Website: https://www.naefrontiers.org/Symposia/USFOE/17105/56883.aspx

9th International Conference on Structural Health Monitoring of Intelligent Infrastructure

TRANSFERRING RESEARCH INTO PRACTICE

AUGUST 4-7, 2019 | St. Louis, Missouri USA

2019 ST. LOUIS
SHMII-9

Organized by
MISSOURI S&T

This conference will showcase technologies and achievements in civil infrastructure, demonstrate the practical value of structural health monitoring research, and raise the public awareness on the needs for further research and applications.

The theme of the conference, **"TRANSFERRING RESEARCH INTO PRACTICE"** calls for the attention and wide participation from researchers, engineers, owners and regulators.

ABSTRACTS DUE JUNE 1, 2018

To submit an abstract, visit:
https://shmii-9.mst.edu