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INSPIRE UTC Creates Novel Robots that Mimic Human Inspectors for Contact Bridge Inspection

The primary goal of bridge inspection is to ensure that structures are safe for the travelling public. In recent years, inspection data have been increasingly used to support a more proactive approach of asset management such that structures are not only safe but also maintained for a minimal life-cycle cost. The broadening of inspection scope requires a significant shift in practice from fully visual inspection to partially visual inspection supplemented with advanced technologies such as remote sensing and nondestructive evaluation. These technologies enable the implementation of objective decision-making processes in asset management and the understanding of infrastructure resilience.

In current practices, human inspectors (or divers for underwater operation) are required to be physically close (e.g., 0.5 m) to potential defect and damage areas. At close distances, they can tap members for concrete delamination, scrape/cleanse surfaces for steel corrosion, conduct nondestructive tests for steel crack, and examine bridge foundations for flow erosion.

To support new data collection as stipulated in the 2022 National Bridge Inspection Standards, INSPIRE (INSpecting and Preserving Infrastructure through Robotic Exploration) University Transportation Center (UTC) at Missouri University of Science and Technology has developed a mobile, automated bridge inspection facility, referred to Bridge Inspection Robot Deployment Systems (BIRDS). The BIRDS include a series of novel robots that are interactive with bridges for high-quality inspection tasks following four strategies.


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Figure 1. A hybrid flying and traversing vehicle as a stationary inspection platform.

First, a hybrid flying and traversing vehicle is attached to the bottom flange of an I-shaped girder as a steady measurement and observatory station for bridge deck, girder, and pier inspection. Figure 1 shows the prototype of an octocopter, which was tested on June 18, 2024, at the Roubidoux Creek Bridge in Waynesville, MO. The octocopter weighs approximately 40 N[1], flies for seven minutes or traverses for 40 minutes, and is collision-resilient with a protective square composite box. When equipped with RGB and infrared cameras as well as a LiDAR scanner, the octocopter rapidly takes consistent high-fidelity images in an automated, cost-effective way.

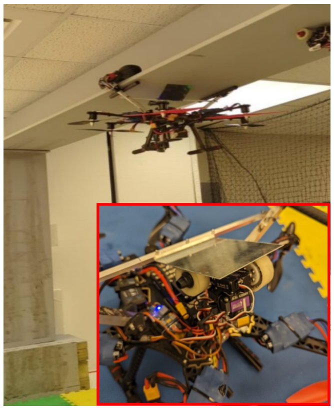
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Figure 2. A mini robot launching off the ramp of a vehicle.

Second, an unmanned aerial vehicle (UAV) carries and launches a lightweight structural crawler to inspect steel members and connections in great details through a microscope or a crack probe. Figure 2 illustrates a mini bicycle climbing robot that is launched off the ramp of a hexacopter. The small robot can travel to crowded areas, inaccessible to the hexacopter, to detect and localize defects such as cracks in welded connections and nonredundant tension members in steel bridges.


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Figure 3. A hybrid flying and stationing vehicle for maintenance tasks and nondestructive tests.

Third, a hybrid flying and stationing vehicle is equipped with an aerial manipulator for local maintenance, such as cleansing, drilling, painting,

[1] An object's weight on Earth is calculated by multiplying the mass of the object by the acceleration due to gravity (g), which is approximately 9.80 m/s². Therefore, an object with a weight of 40 N on Earth corresponds to a mass of 40 N / 9.80 m/s², which is approximately 4.08 kg.

screwing, and sealing tasks, and for nondestructive tests, such as ground penetrating radar of reinforced concrete members, to detect, locate, and quantify defects. Figure 3 presents the top view of an octocopter equipped with a robotic driller that can rotate 90 degrees from a top to side view. The octocopter flies to either a top roof or a side wall for the maintenance tasks.

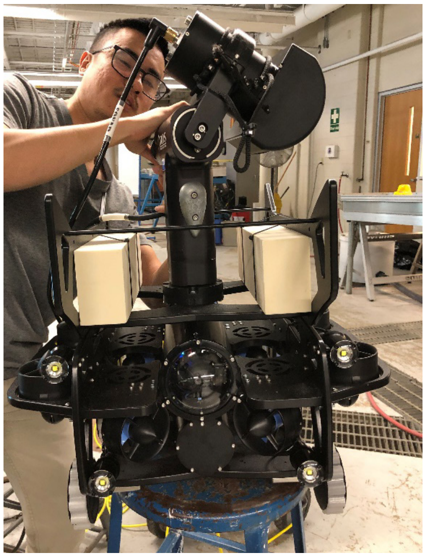
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Figure 4. A hybrid swimming and roving vehicle for bridge foundation scour detection and quantification.

Fourth, a hybrid swimming and roving vehicle is equipped with a sonar system to scan piers and foundations for scour effects. Figure 4 shows a sonar installed on a remotely operated, wheeled vehicle. The vehicle weighs approximately 220 N. It can suspend in water when in the swimming mode or rove a riverbed in the roving mode. The carried sonar can horizontally scan 360 degrees with a 42-degree field of view in the vertical plane. It works at a maximum range of 30 meters with 1.5 cm resolution.

The BIRDS can be used to inspect a bridge following one or more of the three phases:

1. Screening Inspection – Inspectors walk around the bridge when accessible or fly an UAV equipped with RGB and infrared cameras when inaccessible to the inspectors.

2. Probing Inspection – UAV-assisted imaging or near-surface imaging while the hybrid flying and traversing vehicle is attached to an I-shaped girder.

3. Verifying Inspection – Severe damage/defects determined during the probing inspection are confirmed with inspectors' engineering judgement based on visual inspection using augmented reality or crawler-assisted nondestructive evaluation. Depending on the interest and in-house capability, interactive robots-assisted nondestructive testing can be moved to Probing Inspection.

The BIRDS will have significant impact on future bridge preservation of over 617,000 bridges in the U.S. as approximately 60% of them by deck area are girder types. For inspection, the INSPIRE UTC inventions will overcome several challenges facing current visual inspection, such as physical accessibility, human interaction, results inconsistency, and cost effectiveness. For maintenance, the inventions will enable local refurbishment and repair, such as surface painting, bolt screwing, and crack sealing, without requiring the setup of a scaffolding platform.

About This Project

Led by Dr. Genda Chen, Professor and Abbett Distinguished Chair in Civil Engineering and Director of the INSPIRE (INSpecting and Preserving Infrastructure through Robotic Exploration) UTC at Missouri University of Science and Technology, the Bridge Inspection Robot Deployment Systems project is part of the INSPIRE UTC Research Program. For more information on this INSPIRE UTC project, please contact Dr. Genda Chen at inspire-utc@mst.edu or (573) 341-6114.