

UTC Spotlight

University Transportation Centers Program

This month: March 2018

INSPIRE University Transportation Center, led by Missouri University of Science and Technology, with consortium members City College of New York; East Central College; Georgia Institute of Technology; Lincoln University; Ozarks Technical Community College; St. Louis Community College; University of Colorado at Boulder; University of Nevada-Las Vegas; and University of Nevada-Reno



U.S. Department of Transportation
Office of the Assistant Secretary for
Research and Technology

No. 120

Smart Rock Positioning for Scour Hazard Assessment of Bridges

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.

The main focus of this project is to:

1. design, build, and test a UAV with a ground-referenced global positioning system, a 3-axis magnetometer, a lightweight onboard computer, and one or two batteries for at least a 20-minute operation in field conditions;
2. investigate the effect of UAV operations on magnetic field measurements;
3. evaluate the localization accuracy of one, two, and three smart rocks; and
4. demonstrate the field performance of smart rocks for scour monitoring at bridge sites.

Scour monitoring with fixed and portable instrumentations is one of the most effective measures in mitigating scour hazards. Fixed instrumentation with sensors installed prior to flood events cannot detect scour other than the area instrumented. It is susceptible to the harsh environment during a flood event. Portable instrumentation with sounding rods and sonars is difficult to deploy during a severe flood event due to safety considerations and/or water conditions.

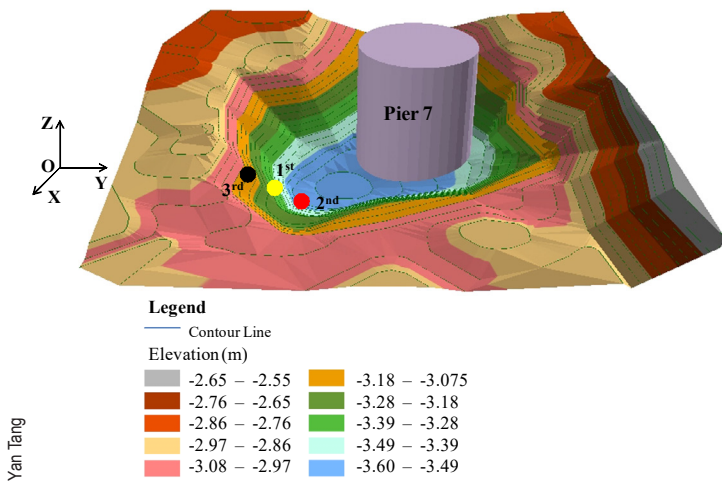
A magnetometer is one type of portable instrumentation. It is unique when combined with the use of movable smart rocks. Smart rocks are deployed prior to a flood event and, as a field agent, directly involved in the process of scour. Each smart rock (see figure 1) is composed of one or more permanent magnets with an aligned gravity-controlled polarization direction and a spherical encasement of fiber-reinforced concrete. The controlled polarization with the south poles of magnets faced upward is designed to minimize the effect of steel reinforcement in bridge piers and decks on magnetic field measurement in field conditions. Spherical smart rocks are easy to roll in field operations. Their design is based on the critical velocity of water flow. With a sufficient number of magnetic field measurements, smart rocks can be localized from a spatial distribution of their surrounding magnetic field changes.



Figure 1: Two gravity-controlled N42 magnets in stack and deployment of one 135-pound smart rock in Roubidoux Creek, Missouri.

Genda Chen and Samuel Edward Okeefe

The smart rock deployed at the Roubidoux Creek Bridge was located successfully and its movement during three field tests was displayed on a three-dimensional contour map of the riverbed (see figure 2). The smart rock moved down the scour hole by 0.182 m during the Dec. 27, 2015, flood. A single N42 magnet can be accurately and reliably located at 6 m distance. With two stacked N42 magnets, the measurement distance can be increased to 7.5 m in an open environment.



Yan Tang

Figure 2: Smart rock movement during three field tests at the Roubidoux Creek Bridge.

The above level of performance largely depends on the availability of a “crane” that extends the sensor from the deck of a bridge to the proximity of a smart rock (see figure 3 left). The use of the crane often requires traffic closure and, more importantly, limits the number of measurement points and thus makes the detection of two or three smart rocks practically impossible.



Genda Chen and Samuel Edward Okeefe

Figure 3: Magnetic field measurement with a sensor installed on a crane moving with the trailer or on a UAV.

To make magnetic field measurement more practical, a sensor and its measurement system are installed on a UAV (see figure 3 right). This setup allows for the rapid collection of a dense array of field intensity data at bridge sites. The large data set will improve the accuracy of smart rock localization and movement prediction.

Although a UAV is mainly made of non-ferrous materials, the electric current that drives motors produces an unwanted magnetic field. The effect of a single motor on its surrounding magnetic field increases slightly with the applied current but decreases rapidly as the measurement distance increases (see figure 4). At 0.92 m distance as used in field tests, the motor effect is negligible up to 9 A. For an octocopter, the negligible motor effect is verified by testing with the propellers reversed so that it remains on ground while in operation. During tests, all the motors are simultaneously controlled to 75% of their maximum operation speed.

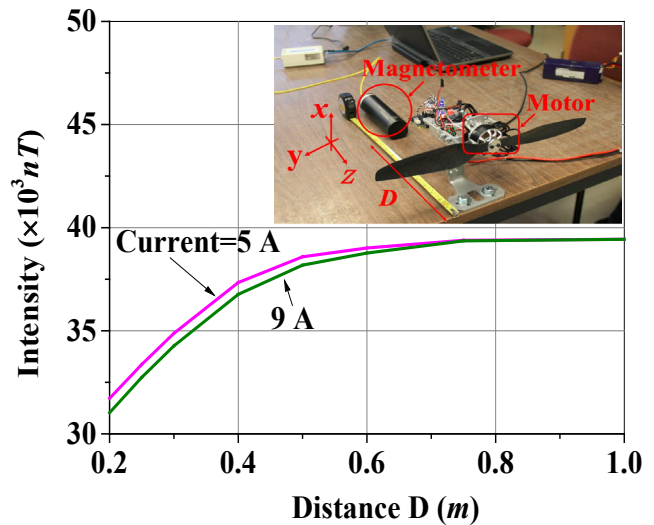


Figure 4: Change in total intensity with measurement distance under various applied currents.

A pooled fund study is currently under development with a few state departments of transportation to engage more engineers and transfer the developed technology into practice through case studies.

This project was based on a previous study funded through the Commercial Remote Sensing and Spatial Information Technologies Program at the U.S. Department of Transportation. The final report is posted at the National Transportation Library (<https://rosap.ntl.bts.gov/view/dot/32116>).

Alex Reven and Zhaochao Li

About This Project



Led by Genda Chen, Ph.D., 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 *UAV-enabled Measurement for Spatial Magnetic Field of Smart Rocks in Bridge Scour Monitoring* project is part of the INSPIRE UTC Research Program. For more information on this and other INSPIRE UTC projects, please contact Dr. Chen at inspire-utc@mst.edu or (573) 341-6114.

This newsletter highlights some recent accomplishments and products from one University Transportation Center. The views presented are those of the authors and not necessarily the views of the Office of the Assistant Secretary for Research and Technology or the U.S. Department of Transportation.

