STUDENTS

Predicting Sinkholes in the Road

A new algorithm can identify trouble spots BY **IVAN BERGER**

MANY OF us take for granted the solidity of the ground we walk on. But on occasion the ground can open wide enough to swallow a person, a house, or a street full of cars.

Sinkholes are alarming to witness and can be catastrophic when they appear suddenly on a road or under a home. A new computer algorithm could provide warning signs, to save lives and avoid expensive repairs.

Current detection methods might provide us with clues to where a sinkhole will appear, but these methods require observing minute changes in ground level over time. For example, a roadway subsidence requiring immediate attention might amount to only a half-centimeter shift in a month over an area 3 to 5 meters in diameter. Physically checking roads and highways for such relatively minor warning signs is impractical.

To address the problem, two graduate students at the University of Virginia, in Charlottesville, created an algorithm that analyzes data from existing Earth-sensing satellites, then calculates which changes in ground level probably indicate incipient sinkholes. Andrea Vaccari, an IEEE graduate student member, and research assistant Michael Stuecheli developed the algorithm with the guidance of Scott Acton, an IEEE Fellow and professor of electrical and computer engineering at the university's School of Engineering and Applied Science.

The project was financed with a US $870 000 grant from the U.S. Department of Transportation's Research and Innovative Technology Administration. The funds cover the study of a 40- by 40-kilometer area of the Interstate-81 corridor in Virginia. The Virginia Center for Transportation Innovation and Research, the research branch of the Virginia Department of Transportation (VDOT), chose that area because of its diverse geological conditions, including "karst" terrain, whose soluble subsurface rocks have been found to cause sinkholes.

Karst terrain underlies about 20 percent of the United States. Other common causes of sinkholes include changes in groundwater levels and disturbances in the subsurface structure caused by mining or nearby construction. The problem is widespread. In May alone, sinkholes were reported in more than 20 states.

The algorithm Vaccari and Stuecheli developed uses data from the synthetic aperture radar on board the Italian Space Agency's COSMO-SkyMed earth-observation satellites. The radar data were originally collected for analysis of seismic hazards, environmental disaster monitoring, and agricultural mapping.

The raw satellite data were then processed by Tele-Rilevamento Europa (TRE) Canada, in Vancouver, into high-resolution measurements of ground displacements of about 1 centimeter. TRE is a global company specializing in satellite data to measure geophysical changes in the ground.

"Our algorithm maps those measurements and analyzes them to identify regions not just of subsidence but also of subsidence that is behaving according to a sinkhole model we developed," Vaccari says. "Rather than simply looking at displacement beyond a certain threshold, the goal is to distinguish between places where subsidence continues to increase and those places that, after a single ground settlement, are now stable. It is then up to highway or transportation authorities to decide which areas are considered risky.

"It's too early to make any sweeping claims about the algorithm's predictive ability and accuracy," he continues. "But in tests, the results of our algorithm have correlated pretty well with signs of actual cases of subsidence evaluated by VDOT geologists on the ground."

When VDOT engineering geologists inspected 32 areas pegged by the algorithm as possible trouble spots, they observed strong signs of subsidence in 25 of them.

"We have predicted locations where subsidence is occurring according to a specific sinkhole model," Vaccari says, "and VDOT geologists verified subsidence activity. That's quite encouraging!"

Acton says that it is the first time sinkhole collapses have been predicted. "If we can use remotely sensed data to detect and monitor the subsidence that precedes sinkholes and other major problems," he says, "we can potentially save millions of dollars in highway repairs, reduce highway closures, and enhance public safety."

For now, getting the most from the algorithm requires that the user be familiar with MATLAB software, though there are software routines that can export the results to graphic information systems (GISs) such as Google Earth, says Vaccari. There is a graphical user interface for users without MATLAB experience, but it's a rather basic one, he says.

Adam Campbell, an electrical engineering undergraduate researcher at the University of Virginia, has written a program to let Android devices access the team's project servers and display the 20 subsidences closest to a user's current location, using Google Maps. "We wanted to show that in an actual implementation, our results could be disseminated via smart devices to ground crews," Vaccari says.

The project will soon reach the end of its two-year funding. The team has submitted a new proposal to the U.S. DOT to continue the development and implement it on a larger transportation network. The team's goal is to work first with VDOT and potentially with other state DOTs "to provide hooks to integrate our remote-sensing approach with their GIS, a system that captures and analyzes geographical data, allowing them to use the information within the existing decision support system," Vaccari says.

The team also hopes to extend its algorithm's analyses. "We started with sinkholes because of the challenge of finding them," Vaccari says. "But we plan to extend the approach to monitor natural and man-made features whose locations are known, such as bridges [for settlement] and slopes [for monitoring motion that can be a precursor to a landslide].

"We might possibly also be able to analyze road surface conditions from the satellite data and provide a simple good/bad condition index," he continues. "Should this be proven effective, it would allow the DOTs to target their road inspection and further reduce their costs."

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