Radar System Sees Through Underground Pipes To Detect Potential For Sinkholes

Louisiana Tech University

Sinkholes and ruptured water mains are occurring with alarming frequency throughout the country, creating a sense of urgency for upgrades to the nation's aging drinking and wastewater infrastructure.

According to the American Water Works Association, much of the nation's underground infrastructure is nearing the end of its useful life and needs to be replaced — which will take a significant toll on the budgets of local governments and utilities. The Environmental Protection Agency estimates the cost of replacing more than 1 million miles of drinking water pipeline to be more than $1 trillion, with an additional $298 billion to upgrade sewer and storm-water infrastructure.

Using an electromagnetic scanning technology developed at Louisiana Tech University, Florida-based CUES Inc. is able to help municipalities identify infrastructure most in need of repair and prevent catastrophic failures in underground systems by detecting voids around buried water pipes.

"We can't afford to fix all of our infrastructure at once," says Richard Kordal, Louisiana Tech's director of intellectual property and commercialization. "But this technology gives us the opportunity to triage underground infrastructure and fix pipes that are in critical need of repair first."

Underground Infrastructure

Erez Allouche, Ph.D., P.E., joined the faculty of Louisiana Tech in 2003, just two years before Hurricane Katrina devastated parts of Louisiana.

"When Hurricane Katrina happened there was much hype about the above ground damage, but I had great concern about the damage done to the buried infrastructure that would only come to light 10 years later," says Allouche, associate professor of civil engineering and director of the Trenchless Technology Center.

Allouche applied for and received a $30,000 grant from the National Science Foundation (NSF) to work with local contractors to perform camera inspections on underground pipes and correlate the damage found there to the amount of water damage above ground. However, the commercially available video inspections could provide only limited information about the interior pipe wall and nothing about the environment surrounding the pipe.

"I knew that most of the damage would occur outside the pipe, where the soil washes away," says Allouche.

Underground pipes often develop cracks and crevices, especially when stressed by flood conditions. Over time, soil falls through the cracks and into the pipe, creating a void in the ground space above the pipe that can eventually develop into a sinkhole. Allouche says that by 2006, soil voids began developing throughout storm-ravaged New Orleans.

"People would see a puddle and would worry, is it 2 inches or 2 feet deep?" he says.

Seeing Through Pipe

With no existing technology available to detect sinkholes before they break through the surface, Allouche and his colleagues Arun Jaganathan and Neven Simicevic set out to develop a system that could "see through" pipes to assess the conditions around them. The project dovetailed perfectly with the mission of the Trenchless Technology Center, which is dedicated to rehabilitating underground infrastructure without excavation.

The research team evaluated a variety of technologies for the task, including acoustic and thermal imaging, but ultimately decided on using high-frequency electromagnetic waves also known as ultrawide band (UWB) technology. The use of UWB radio waves (3.1-10.6 GHz), which until 2001 were limited to military applications, has also been adopted by the automotive industry for use as vehicle sensors to warn drivers when other vehicles or objects are getting too close.

"Ours was one of first civilian applications of UWB technology in the U.S.," says Allouche.

Commercial Partner

In CUES, Allouche found a natural commercial partner for developing the technology. CUES, the world's leading manufacturer of closed circuit television video inspection, rehabilitation and pipe profiling equipment, was already an industry sponsor of the Trenchless Technology Center.

“CUES has been manufacturing inspection equipment for nearly 50 years,” says Joe Purtell, vice president.

Kordal says CUES was interested in the project, but knew it would require more research and development funding than the company could provide. So Louisiana Tech and CUES joined forces with Department of Defense contractor Niitek and applied for funding through the National Institute of Science and Technology (NIST), which held a competition to award grants specifically for next-generation infrastructure assessment technologies in 2007.

“The NIST proposal took countless hours, and Joe Purtell worked tirelessly,” says Allouche. “We couldn’t have a better partner than CUES.”

The team was selected and became one of nine grantees, receiving an award of $3.2 million.

“We won a very rare NIST grant that gave the university a lot of visibility,” says Kordal. “It showed that we are doing impressive, cutting-edge research here, and it highlighted the Trenchless Technology Center.”

Additional money from the state of Louisiana and a $400,000 Major Research Instrument Grant from the NSF also boosted the development of the UWB technology.

“The NSF grant enabled us to buy electromagnetic research equipment and that put us on our way,” says Allouche.

The technology development team grew to 10 full-time engineers and technicians working simultaneously on various components, from mechanical design and electronic components to mathematical algorithms. Years of hard work and many, many iterations were followed by testing at the university’s indoor and outdoor test beds and, finally, in cities across the United States.

“The in-field experience of the CUES engineering team led by Tony Winiewicz was instrumental in transferring the technology from a laboratory prototype to a field-ready tool,” says Allouche.

Field Testing

The first field test was conducted in 2012 in Slidell, a city outside New Orleans that had been under water for weeks in the aftermath of Katrina. The team sent the ground-penetrating radar into the city’s water main and sewer pipes, where it emitted signals that passed through the pipes and into the soil surrounding the pipelines. The signals’ reflections were then processed using algorithms and software to dimensionalize the pipes, providing information on defects and the likelihood of voids at various segments of along the lines.

“It was very encouraging that we were able to detect soil voids there,” says Allouche of the successful trial.

Kordal agrees.

“The UWB technology helped the city of Slidell determine that the failure of its crumbling sewer and drainage pipes was a result of the effects of Katrina not normal wear and tear,” adds Kordal.

Louisiana Tech applied for and received a patent on the technology entitled Pipe Survey Method Using UWB Signal (US 8,350,570, issued in January 2013). Kordal helped negotiate the sponsorship agreement and intellectual property plan required for the NIST grant, as well as the exclusive licensing agreement with CUES.

Today, CUES is refining the radar system to make it simple, easy to use and “industrial-hardened.” The company is working with its early adopter clients in the United States and Canada to test the new inspection system, FutureScan.

“Our challenge is to make this system a ubiquitous tool that is added to the tool kit of asset managers and deployed globally,” says Purtell.

FutureScan

The FutureScan radar device, housed in a casing the size of a smartphone box, is strapped on top of CUES’ video inspection robots and integrated into the company’s existing assessment software. As the wheeled robot traverses through a pipeline gathering video footage, FutureScan sends out signals and processes the reflections, providing the operator with a detailed report including a graphical display of pipe anomalies and the likelihood of voids at each segment of the pipeline.

“FutureScan can look through any nonmetalic type of pipe and, depending on soil conditions, see several feet beyond the pipe wall to detect voids or other anomalies,” says Purtell.

The real-time, 360-degree scans can be performed on plastic, vitrified clay pipe, and concrete pipes from 18 to 36 inches in diameter (up to 48 inches in specific conditions) at a speed of 30 feet per minute.

“The information [FutureScan] produces is extremely powerful,” says Allouche. “For the inspection of pipe, this is the best system out there: solid-state electronic equipment and leading-edge algorithms. It’s an extremely advanced system.”

> *FutureScan can accurately measure pipe wall thickness, detect delaminations (composite material failures) and assess the corrosion of steel rebar within reinforced concrete pipe, providing asset managers with a better estimate of the pipe’s remaining useful life.*

“By monitoring the growth of the voids over time, cities can better plan for repairs and only fix what really needs to be fixed,” says Purtell. “We’re anxious to get FutureScan out there to help communities better predict and plan for their capital expenditures.”

Both CUES and Allouche hope that many of the thousands of video inspections conducted in the United States every day will soon include FutureScan, reducing risk for the owners of pipe systems and threats to public health and safety.

"Sinkholes are a real threat — I've personally nearly driven into a few," says Allouche. "I'm proud to be part of a team that developed a system that may potentially save lives and provide people with higher confidence that the ground will not open beneath them."

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