1-1-2007

3D Ground Penetrating Imaging Radar

Purdue ECT Team
Purdue University, ectinfo@ecn.purdue.edu

DOI: 10.5703/1288284315882

3D Ground Penetrating Imaging Radar

The Need

GPiR (ground-penetrating imaging radar) is a new technology for mapping the shallow subsurface, including society's underground infrastructure. Applications for this technology include efficient and precise mapping of buried utilities on a large scale; inspection of the subsurface prior to construction; comparison of "as-builts" to construction plans; inspection of bridge decks and roadbeds; environmental monitoring and assessment; near-surface geological assessment; and "non-invasive" archeology.

The Technology

GPiR is locating underground infrastructure more reliably and accurately than standard techniques using metal detectors. By providing accurate coverage in 3D, GPiR will move the utility industry towards noninvasive management of underground infrastructure, avoiding the hazards and inconvenience of digging; it will also improve construction planning and engineering by showing what lies below the surface before the shovels hit the ground.

This technology has incorporated a complete system for underground imaging: 1) an array of antennas to make underground mapping by radar feasible on a large scale; 2) advanced signal processing—using 3D imaging techniques adapted from seismic imaging in oil exploration—to convert radar echoes into 3D underground images; 3) precise positioning of the images relative to ground features by monitoring sensors with a survey geodimeter (laser theodolite), 4) advanced image processing to extract and display underground features in 3D and archive the results in CAD or GIS.

A commercial GPiR system, called the CART Imaging System* ("CART" stands for "Computer Assisted Radar Tomography") from Witten Technologies, Inc.(WTI), has been tested for more than a year in surveys in major cities of the US and Europe. (Ref. There is another company named Geophysical Survey Systems, Inc. providing 3D GPR technology applications). The CART system uses a highly-efficient GPR array, which can be towed by a vehicle(Figure 1) or pushed in front of a modified commercial lawnmower (Figure 2) at speeds up to about 1 km/h (30 cm/s). The standard CART system uses a fixed array of 9 transmitters and 8 receivers (Figure 3). Each radar element in the array is a standard ultra-wideband GPR that broadcasts an impulse with

http://dx.doi.org/10.5703/1288284315882

a frequency spectrum from about 50 to 400 MHz (A system with higher-frequency elements, having a spectrum between 100 and 650 MHz, has also been tested.).

FIGURE 1 GPR ARRAY

The array is controlled by special electronics that fires the transmitter elements and controls the receivers in sequence to create 16 standard bi-static GPR channels covering a 2 m swath on the ground (Figure 2 right). In this standard "bi-static" mode of operation, each transmitter fires twice in sequence, with each firing being recorded by an adjacent receiver. A multi-static mode, in which each transmitter fires once in sequence and is recorded by all the receivers, is also possible.

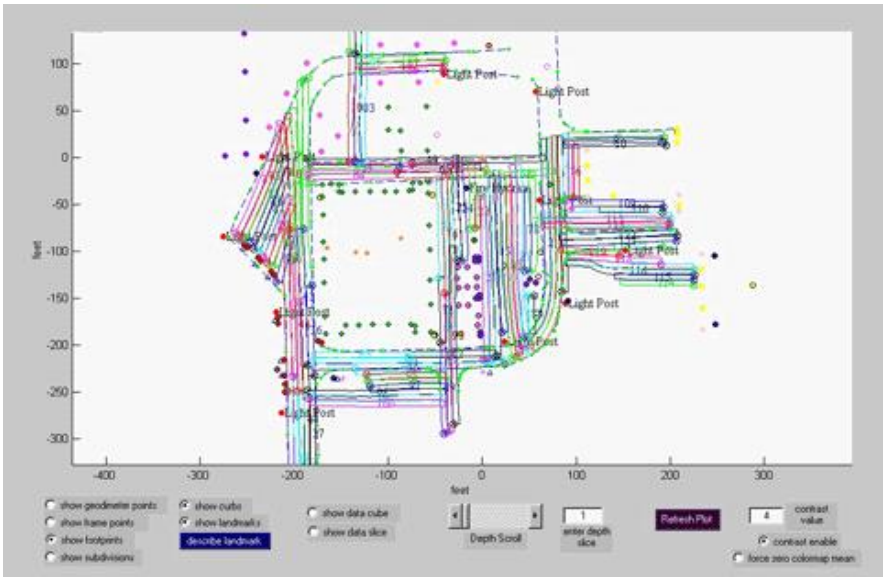

FIGURE 2 PROCESSING SOFTWARE

http://dx.doi.org/10.5703/1288284315882

The CART's 3D images clearly show the approximate size, shape and depth of buried pipes and other underground structures, such as trench walls or concrete footings. CART images also contain information about the material composition of buried structures (metal vs. plastic) and soil conditions. Special image processing software is used to extract and highlight utility lines and conduits.

BENEFITS

Underground mapping during the engineering and planning phase of underground construction saves money and increases safety during actual construction. The Federal Highway Administration has demonstrated in numerous studies that every $1 spent in underground mapping of utilities and other obstructions before highway construction saves up to $5 in construction costs (see Cost Savings on Highway Projects Utilizing Subsurface Utility Engineering, Report FHWA-HIF-00-014 Purdue U, 1999).

GPiR is the most comprehensive and efficient geophysical technology for noninvasive mapping of the underground down to depths of about 6 to 10 feet. By producing a continuous 3D image of the subsurface, GPiR can identify the best locations for test pits or vacuum excavation "potholes" to positively identify utilities in place and can fill in gaps between holes. GPiR can also be used to quickly develop base maps in areas where records of underground structure are missing or poor.

The digital images and maps created by GPiR can also be archived for future use in determining possible changes in infrastructure over time by repeated surveys at the same location.

STATUS

In developing this CART system, the initial research project was carried at Schlumberger-Doll Research from 1998 to 2000. The Electric Power Research Institute (EPRI) sponsored the research, with co-funding from the Gas Technology Institute providing (GTI). In May, 2000, the project was spun off by Schlumberger and merged with Witten Technologies, Inc., to combine the imaging software developed at Schlumberger with WTI’s array radar, which is being commercialized as the CART Imaging System. The new system has been used at Con Edison, PSE&G, Seattle City Light, TxU, DLC, JEA, PEPCO, OPPD, and other non-utility locations. The market for GPiR will be utilities, construction companies, and government agencies charged with managing society’s subsurface infrastructure. Application case: WTI is conducting CART surveys around the former World Trade Center (WTC) in New York City. The 3D radar images are used as one of the means to reconcile utility maps, to help reduce the number of testpits dug, to assist in finding clear lanes and ultimately to help rebuild the infrastructure faster. As of February 13, 2002 WTI aurveyed 25 days (nights) for a total area of about 300,000 sq-ft. Before September 11, 2001 55,000 sq. ft were surveyed for ConEdison(Consolidated Edison Company of New York, A provider of electric service in NY city). Since then an additional 250,000 sq-ft was surveyed.

http://dx.doi.org/10.5703/1288284315882

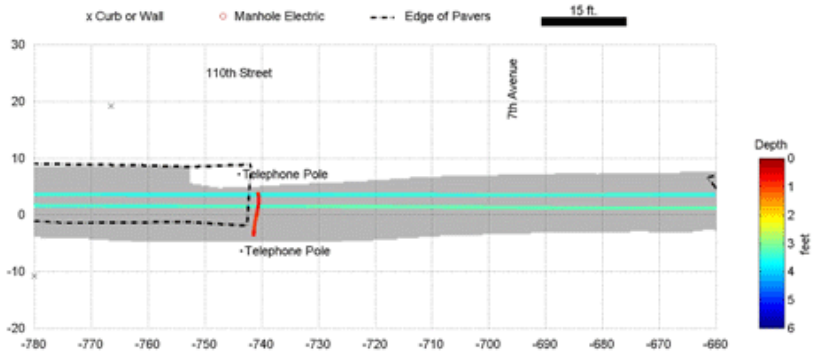

FIGURE 3 MANHATTAN, NY CASE

Commercial underground mapping services with The CART Imaging System are available from Witten Technologies and other licensed service providers. About a dozen units are available around the world. Cost depends on the area surveyed and surface conditions, but is typically between $0.15 to $.40 per sq ft. A good average cost is about $.25 per square foot.

BARRIERS

GPiR has limited depth of penetration in some dense clay (conductive) soils. Increases in power levels, made possible by new FCC regulations on GPR and other ultra-wideband radar, will help to remove this limitation in coming years. Improvements in hardware and signal processing should allow reliable results down to depths of 6 to 10 ft in nearly all soil conditions. Combination of imaging radar with low-frequency electromagnetic induction (EMI) technology will eventually allow imaging down to depths of more than 30 ft. Non-invasive technology such as GPiR can not yet differentiate different types of buried utilities or conduits, nor can it measure sizes precisely (eg, the difference between 2-inch and 8-inch conduits is clearly visible, but not between 2-inch and 2.25-inch conduits). Use of GPiR technology at present requires that the radar unit be scanned over the site with the antennas within about 1 ft of ground level. This makes the technology impractical for extremely rough terrains or densely vegetated areas. Different ways of mounting the radar array on mobile platforms, including airborne platforms, and improvements in power and signal processing will eventually make remove these restrictions.

POINT OF CONTACT

Michael Oristaglio. President, Witten Technologies, Inc.,
Tel: (617) 236-0019 Fax: (617) 236-0032 Website: http://www.wittentech.com
Geophysical Survey Systems, Inc.
Tel: (603) 893-1109 Fax: (603) 889-3984 Website: http://www.geophysical.com

http://dx.doi.org/10.5703/1288284315882

REFERENCES

1. Witten Technologies, Inc. Web site http://www.wittentech.com>
2. ENR article 10/23/2000 http://enr.ecnext.com
3. Nova Award 2002 information

REVIEWERS

Peer reviewed as an emerging construction technology

DISCLAIMER

Purdue University does not endorse this technology or represents that the information presented can be relied upon without further investigation.

PUBLISHER

Emerging Construction Technologies, Division of Construction Engineering and Management, Purdue University, West Lafayette, Indiana

http://dx.doi.org/10.5703/1288284315882