THE USE OF COMPUTER ASSISTED RADAR TOMOGRAPHY FOR DAMAGE PREVENTION OF UNDERGROUND ASSETS AND AVOIDANCE OF UNDERGROUND HAZARDS

E. Jorgen Bergstrom (jorgen.bergstrom@gel.com)

General Engineering Geophysics
PO Box 30712
Charleston, SC 29417

Abstract

The lack of accurate maps of subsurface utilities and other underground hazards often causes accidents, project delays and increased project cost. Subsurface Utility Engineering (SUE) is an engineering process utilizing state-of-the-art technology to accurately identify, characterize, and map underground utilities and installations prior to the design of new highways and structures or the installment of new underground assets.

Computer Assisted Radar Tomography (CART) is a new technology that can deliver images of the subsurface with an unparalleled level of accuracy and detail. Based on the physics of Ground Penetrating Radar (GPR), CART can image objects of any material, including metallic and non-metallic utilities, valves, drums, trenches, underground storage tanks, paved over manholes and railroad tracks. The CART system is tied to a total station with auto tracking capabilities for precise positioning.

The benefits of CART technology are best realized when the technology is integrated into the SUE process, but CART can also be used as a stand-alone tool for imaging the subsurface. The presented examples show that, in addition to accurately and precisely locating underground assets and hazards, CART can also provide guidance for excavation activities by identifying routes with the least amount of obstacles.

Introduction

Computer Assisted Radar Tomography (CART) is a new Ground Penetrating Radar (GPR) technology. Like traditional GPR, CART can image objects of any material, while collecting a 6.5-foot swath of data with a single pass. The benefits of CART are that high-density data can be collected in a fairly short amount of time to a level of positioning accuracy previously not readily achievable. State-of-the art processing software is then used to create map views and 3-D images of the subsurface. The system eliminates one of the most common classical limitations of GPR in utility detection, which is confusion by signals from non-utility targets (such as rocks). Another classical weakness, limited penetration through clay, concrete and other electrically conductive materials, still exist. However, differences in material's composition and compaction are much easier detected with CART than with standard GPR. As a result, trenches and paved-over patches can be readily detected, thus giving an indication of the location of buried utilities even if the actual utilities are too deep to be imaged.

CART

The CART system is a vehicle for a multi-channel GPR system. It is the culmination of over five years of development from a consortium between Mala GeoScience and leading software developers. A multi-channel system means that several GPR transmitters and receivers operate in harmony over the same ground surface area with the goal of providing images of underground objects not achievable with conventional single channel systems.

The CART system contains 17 antennas (Figure 1) that are housed in a box mounted on a trailer approximately eight feet wide. It is towed in open, relatively level areas. The premise of multi-channel systems is that GPR energy can be beamed at an object underground from several different antennas. Subsequent processing of the data with software that can focus the reflected energy back to a point

underground, or to an object the energy was reflected from creates a reconstructed image of that object. The framework for the software used to process the data originated in the oil industry.

A novel approach with the CART is the continuous tie to a robotic total station (Figure 2). Through its auto tracking capabilities, the total station can track a prism attached to the CART at all times (Figure 3). The path traveled with the CART can then be reconstructed and the data positioned accurately regardless of the shape of the study area. Another benefit with CART is that the data can be dumped seamlessly into AutoCAD and MicroStation for interpretation, editing and comparison with existing base maps (Figure 4).

Interpreting CART data

Through high data density and advanced post-processing techniques, CART can provide images of the subsurface with a level of detail never seen before. Many images are of almost photographic of 17 GPR antennas that quality, accurately showing buried objects' shape and size. However, not all objects are readily visible in the data and require more interpretation to discern. As with GPR, interpretation of these objects is subjective and requires a trained eye. CART data is interpreted by combining plan views and cross sections. Usually the first review of the data is done using plan views (Figure 5). The study area is virtually excavated, revealing utilities, trenches, buried manholes, railroad tracks and other underground obstructions. Cross-sections are then created to verify the interpreted location of underground objects and analyze the data in more detail.

Figure 1: CART consists operate together to create images of the subsurface

Figure 2. A total station with auto-tracking capabilities is used to continuously track the 200MHz moving CART.

Figure 3. CART data collection in progress. The picture shows a tow-mounted 200MHz system and a front- mounted 400MHz system. Note the prism mounted on the rod behind.

Subsurface Utility Engineering Process

Subsurface Utility Engineering (SUE) is a process used to accurately identify and map underground utilities through the use of surface geophysics, surveying, data management and non-destructive excavation techniques. SUE has been recognized as the best available method to map underground

infrastructure and is endorsed by a variety of organizations such as US Department of Transportation, National Transportation Safety Board, US Department of Energy, American Society of Civil Engineers, Associated General Contractors of America, universities and utility companies [1]. A recent study published by Purdue University for the Federal Highway Administration also determined that for every $1 spent on SUE, at least $4.62 was saved on the overall project [2].

Information about subsurface infrastructure can be of varying quality. The highest quality is achieved by exposing a utility with vacuum excavation. In SUE this is referred to as Quality Level A. Applying geophysical methods to identify and map utilities is referred to as Quality Level B. A visual inventory of the above ground infrastructure associated with utilities such as manholes, valve boxes, utility poles, etc and developing a surveyed map of these features is known as Quality Level C. Quality Level D is the most basic level of information obtained and requires a search of all reasonably accessible utility databases. CART has the potential of somewhat redefine Quality Level B by delivering information with a quality that far exceeds the capabilities of conventional methods. More accurate and complete Quality Level B maps using CART will minimize the need for vacuum excavation and thereby reduce project cost.

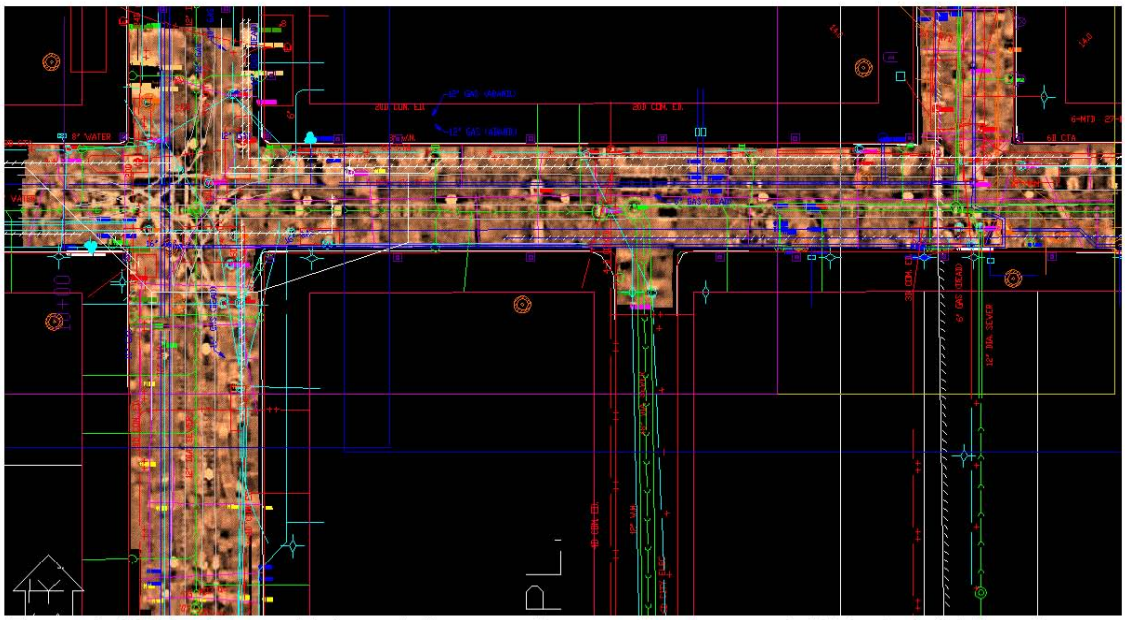

Figure 4. CART data and interpretations can be seamlessly exported into AutoCAD and Microstation for comparisons with existing base maps and editing.

CART in the SUE process

Designing new underground installations in developed areas without accurate information on existing utilities can be a nightmare. Companies involved in these types of projects from design and build perspectives have realized substantial cost saving by requesting a complete inventory of buried utilities to Level B or Level A SUE standard prior to the construction phase. CART has its role in this process, but it is not a panacea. Similar to GPR, CART cannot deliver information on utility types and sizes with satisfactory accuracy, only the horizontal and vertical location of the utilities. Also, in most soils, traditional electromagnetic (EM) line locators will pick up additional small diameter utilities that CART will miss. For these reasons, it is often beneficial to include the CART survey into a complete Level B SUE investigation. Interpretations from the CART investigation can be exported directly into AutoCAD or similar platforms. Utilities identified with conventional GPR and EM locators are surveyed in and are also exported into AutoCAD. The two data sets are then merged to create the best Level B map possible using the best available non-invasive SUE technology. This information is then used as an aid in the

design process to minimize conflicts with existing utilities, construction crew downtime, and utility related accidents (Figure 6). A high quality Level B investigation will minimize the need for vacuum excavation and thereby reduce SUE project cost and time requirement.

CART as a stand-alone method

The benefits of CART are best realized when integrated into the SUE process, but CART can also be used as a stand-alone tool for imaging the subsurface. Some clients may not be interested in knowing what type of utilities they will encounter during the construction work, just their location. Or they may be more interested in just finding the “green spaces” or the routes with the least amount of obstacles (Figure 7). In these situations, the CART can be used as a stand-alone tool. It should be noted, however, that CART alone will not, in many cases, identify all buried utilities.

Conclusions

Having access to accurate maps of subsurface utilities has proven to be a cost saver in project after project involving installing, rerouting, or redesign underground utilities. CART is a new geophysical tool for mapping utilities to SUE Quality Level B standard. However, CART has the potential to somewhat redefine Quality Level B by delivering information of a quality that far exceeds the capabilities of conventional methods. This often minimizes or eliminates the need for vacuum excavation. CART data is interpreted by virtually excavating inch by inch of the subsurface, revealing utilities, trenches, buried manholes, railroad tracks and other underground obstructions. CART data can be used favorably to identify routes with the least amount of crossing utilities and other obstacles.

References

[1] American Society of Civil Engineers, “Standard Guideline for the Collection and Depiction of Existing Subsurface Utility Data”, CI/ASCE 30-02, 2003

[2] Purdue University, “Cost Savings on Highway Projects utilizing Subsurface Utility Engineering”, FHWA Contract Number DTFH61-96-00090, 1999

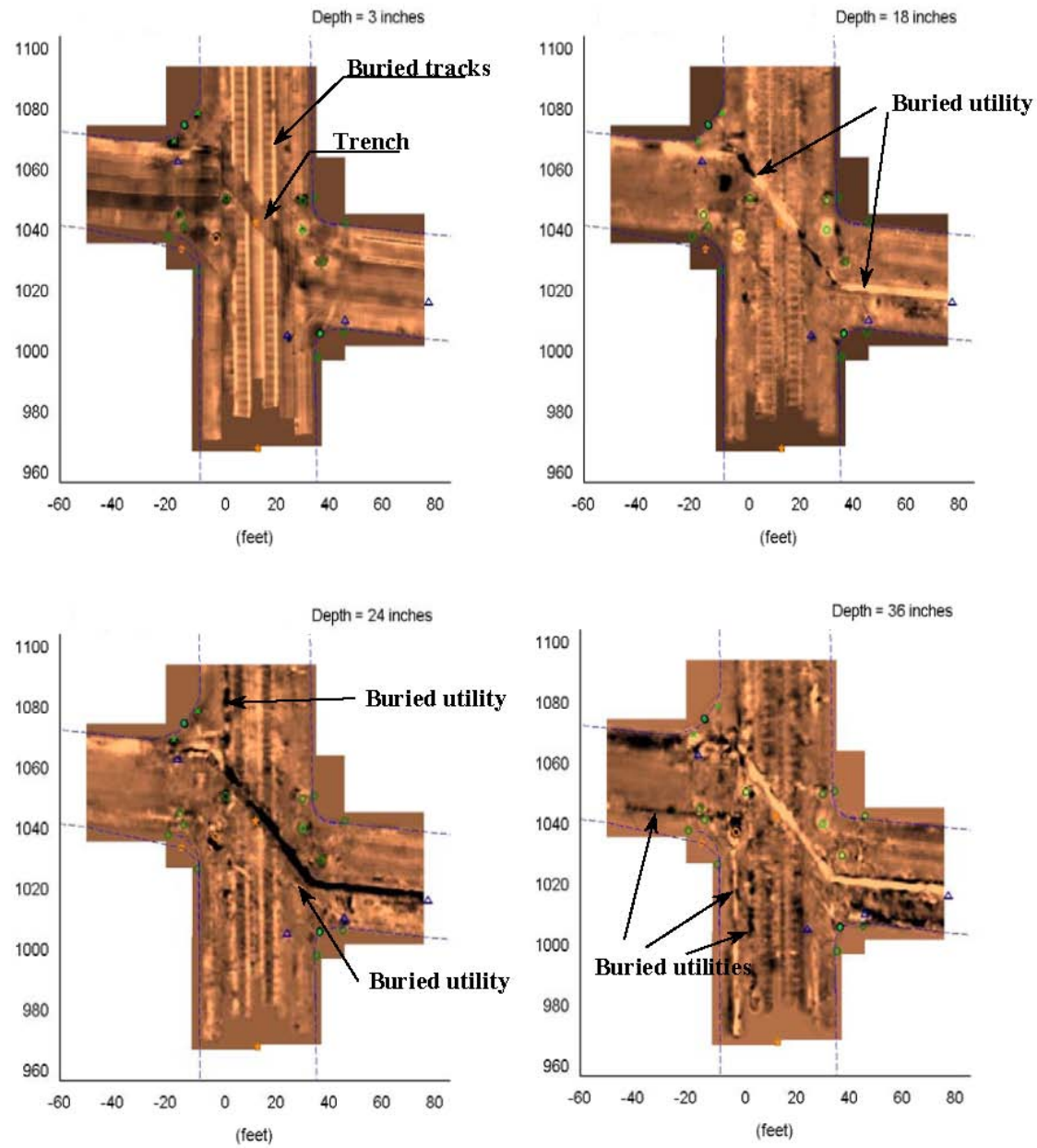

Figure 5. CART Data example showing plan views of various depth slices. This intersection was surveyed in less than two hours.

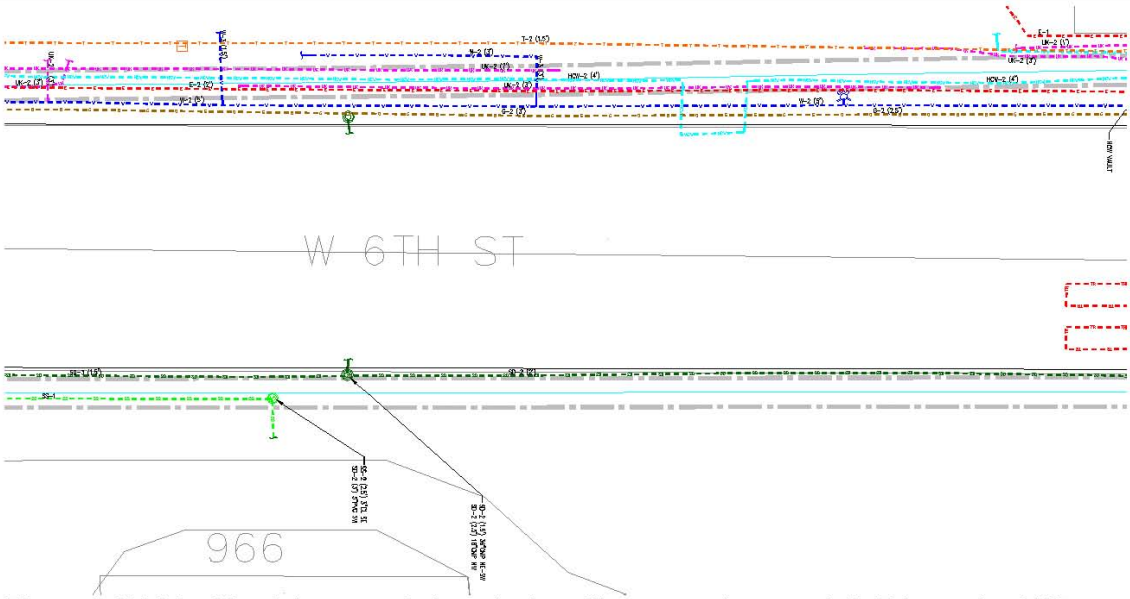

Figure 6. Which side of the street is best for installing a new force main? Prior to the SUE investigation which included CART, the client had planned to install the line on the North (top) side of the street. The SUE investigation revealed numerous conflicts along the proposed route and the client decided to go on the South (bottom) side instead.

Figure 7. CART data revealing the location of numerous utilities at approximately two feet below the surface. Through complete analysis of the data set, new utility routes can be designed with minimum conflicts with existing infrastructure