"Smart" Attachment for Utility Damage Prevention

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Abstract

Reports about serious injuries and costly damages caused by excavators hitting underground utilities make frequent headlines in the news media. The accidents sometimes result in the death of one or more persons. Thus, excavation represents a dangerous operation that has to be executed with care. The Construction Automation and Robotics Laboratory (CARL) at North Carolina State University (NCSU) has been searching for an answer to the problem. A prototype system has been developed in CARL using nontraditional tactics. It is called a Buried Utility Detection System (BUDS). BUDS differs from the traditional passive metal detection systems which require the existing utility lines to serve as transmitters. BUDS generates and transmits its own magnetic impact and detects the coupling effect with any buried utility line in its detection range. Most importantly, it is installed directly on the excavating machinery and integrated with its operation. Experiments have been carried out with BUDS both in the laboratory and in the field. These experimental results are promising. The work deliberated in this paper presents an ongoing effort for developing an effective and reliable system that can be attached to any type of construction and utility digging equipment for real time underground utility line detection.

Introduction

The hazardous nature of excavation in construction is well documented. The Occupational Safety and Health Administration (OSHA) estimated that the fatality rate was at 50.8 deaths per 100,000 workers per year for 1984-1988. The National Institute of Occupational Safety and Health (NIOSH) estimated that at least 172 persons were killed as a result of all excavation-related accidents. Other reports indicate that excavating equipment hitting buried utility lines causes one death per day. Airplanes have to circle in the sky, and business branches such as banks, investment companies, and travel agencies have been forced to close for a period of time because of excavation mishaps.

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Accurate location of pipes and cables without resorting to pot holing is a problem facing utilities and highway authorities worldwide. Prior to any type of excavation or digging procedure the operator must be aware of what is buried under the ground. At present, utility locators accomplish this task. The locators are informed of what utilities have cables and/or pipes buried in the area and then locate these utilities. The locations of the utilities are then marked, usually by spray painting the ground as shown in Figure 1.

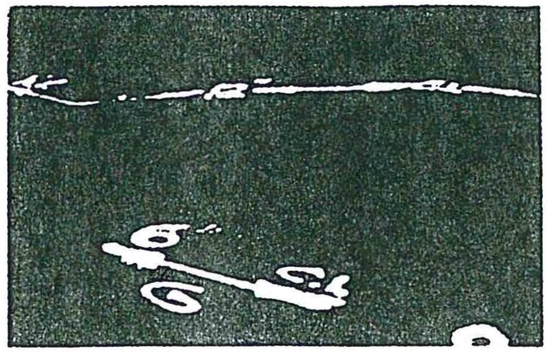
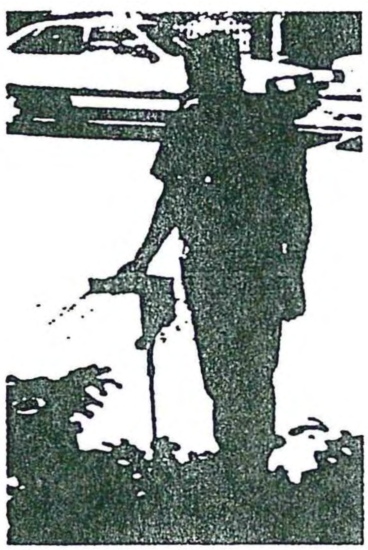
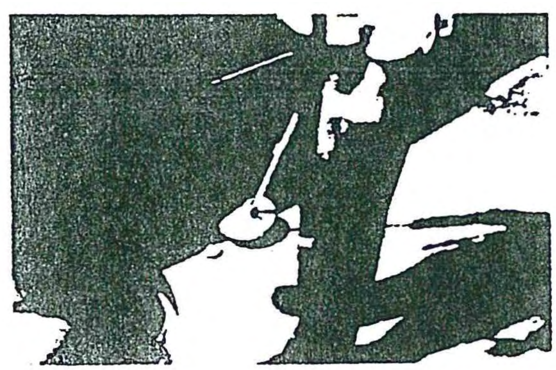


Figure 1: Utility Locating Marks

In order to mark the location of the utilities, they must first be located. There are a number of methods currently being used. The most widely used method is conductive tracing. In this case, a buried utility line is located and traced by applying a distinctive transmitter signal to it and then tracing it with the receiver (see Figure 2a). In conductive tracing, the transmitter is directly attached to the tracer wire (a wire which is buried along with the utility) and ground with a clamp. Once attached, a current is generated along the line and can be detected with a receiver from the surface.





a) **Conductive Tracing** b) **Passive Metal Detection**

Figure 2: Typical Locating Methods

Figure 2b shows a second method of utility detection. This device is a passive metal detector. This hand held device works as a simple metal detector with a buzzer which will change its pitch when it is passed over a metal object.

Besides these two methods, there is a very wide variety of sensing technologies being used and in the process of being developed. The interest in underground detection has many more applications than buried utilities. The advancement of these new sensing technologies is being driven by the need to locate underground objects such as land mines, unexploded ordnance, buried waste disposal and storage drums, rebar, unmarked graves and buried utility lines. Some of the sensing technologies under development include microwave sensors, acoustic sensors, ultrasonic sensors, magnetometers, electromagnetic sensors, ground penetrating radar, micropower impulse radar, and hand held magnetic locators. [UXO Forum 97] [UTS 1996] [Das, et. Al. 1990] [McDonald and Robertson, 1996] [Pawlowski, et.al. 1995] [Sensors & Software, 1997] [Witten Technologies, 1997]

There are many drawbacks to these sensing technologies. They include complex data analysis (or none at all), high cost and some of the systems are very bulky making them difficult to maneuver. Another of the drawbacks of these systems is the fact that they operate only from the surface, thus limiting the possible depth of accurate detection. Thus, utilities buried deeper than the sensing depth cannot be located accurately with these sensing devices. Furthermore, most of these technologies do not give accurate depth readings. Others are virtually unusable in areas with densely populated utilities.

At CARL, a new approach has been studied which integrates micro-processing technology and traditional construction equipment in an innovative way. This paper will first summarize the approach that is most commonly used in utility line detection, the passive metal detection approach. Then a prototype design of the BUDS will be presented, followed by an illustration of the laboratory experiments. Finally, results of the initial field testing of this system will be discussed and analyzed. The intention of this paper is to demonstrate the feasibility of an excavator mounted detection system capable of locating underground utilities in order to avoid costly damages and accidents.

Economic Impact of a Damaged Utility

While reports about accidents due to excavation mishaps abound, models for assessing the economic impact have not been developed. Generally, the total cost of damages is underreported because only the direct costs of the emergency response and of repairing the damage are included. However, the impact is much more widespread, and the costs incurred by parties other than those most directly affected need to be considered in order to accurately measure the total economic impact of utility damages. Heinrich showed (1996), that the total costs associated with an incident reported in the media to cost $15,000 were actually closer to $313,000. The reason for this discrepancy is that the economic impact on shops that lost revenue during a necessary evacuation of a large mall were unaccounted for. The $15,000 covered mainly the cost for the police and the emergency crews. Even the gas lost was not included.

In order to establish a common framework that can be used to analyze utility accidents, an economic impact model was developed. The major costs which occur as a result of damages to utility lines have been broken into direct and indirect costs. Figure 3 presents the major cost factors identified so far.

Figure 3: Economic Impact Model of Utility Outage

The innermost ring represents the direct costs which are incurred at the accident site. The second ring includes the costs to utility consumers. The value for these costs depends heavily on the utility consumers' activities that are affected, the degree to which the affected activities depend upon the impacted utility, the availability of backup sources for the affected utility, and the speed and extent to which customers can resume normal activities following the restoration of the utility service.

As one can see from Figure 3, the five direct cost categories cover mainly the cost for emergency, repair, and physical damages to persons or property. The second group shows several large cost components. They include: a) Lost sales for impacted businesses (i.e., stores, banks, travel agencies), b) legal cost for ensuing lawsuits, c) effects on health and safety of people who depend on the utilities (i.e., people depending on AC, people who are connected to a remote heart monitoring system), and d) spoilage costs for food, beverages, and tobacco.

Even when a particular incident does not involve any deaths, there are still significant costs involved. Since normal industrial, commercial and residential activities are all dependent upon receiving utility services, any disruption in the delivery of utility service will impose costs on all three of these sectors of the economy. The presented model is the beginning of an effort to quantify the effect of such accidents on the economy of a town, city, county, and even an entire state (e.g., lost taxes.)

System Description

BUDS, developed by CARL is an active search system. It consists of an electromagnetic sensor coil, a control box, an actuating device, and a laptop computer with a data collection interface. The sensor coil was developed by Pulse Technology, Ltd. [Metalarm, 1993] [Thorpe and Probert 1996] A single sensor coil is used to both create and sense the induced fields. The advantage of this type of sensing coil is that very little calibration is needed and it is not very sensitive to vibration or noise.

The sensor coil works by first creating a magnetic field about itself. This field is called the 'primary field' and it induces eddy currents into a nearby conductive object, which will create the 'secondary field'. The current in the coil is then removed and both fields then affect the voltage across the coil. Since the 'primary field' depends on constant properties of the sensor circuit, it can be deemed a constant effect. The effect of the 'secondary field' is dependent on properties of the object being detected, such as size, shape, distance and orientation. The decay of this field is what is measured. Specifically, one point in the decay is read and recorded. The main advantage of this type of detection system in this application is its ability to eliminate the effect of existing metal within the environment. By taking advantage of this capability, the sensor coil can be mounted onto a backhoe excavator and be used to detect buried utilities.

Backhoe Mounted Sensor Coil Tests

The system was installed on a John Deere 690C backhoe excavator as shown in Figure 4. The sensor coil was mounted on the stick of the excavator with a hydraulic rotary actuator and a fiberglass ladder. The rotary actuator allowed the operator to move the coil out of the way of the bucket during the excavation procedure. The laptop computer, along with the rest of the electronic circuitry, was installed inside the cab.

Figure 4: Photo of John Deere 690C with BUDS Installed

Tests were conducted to determine if the electromagnetic profile of the backhoe excavator could be eliminated from the sensor coil output. Figure 5 presents the results from experiments conducted on a mockup backhoe. The data was collected as coil output (measured in bits) over time. The coil was first calibrated (zeroed) at a point where the coil was furthest from the backhoe's stick. Next, the coil was rotated through an arc beginning at the point in the arc where the coil was touching the stick through ninety degrees. Zones 1 and 3 represent the coil touching the backhoe's stick. Zones 2 and 4 represent the readings of interest: a pipe or nothing at all. These tests proved that it was possible to use the sensor coil reliably on the full-size backhoe excavator.

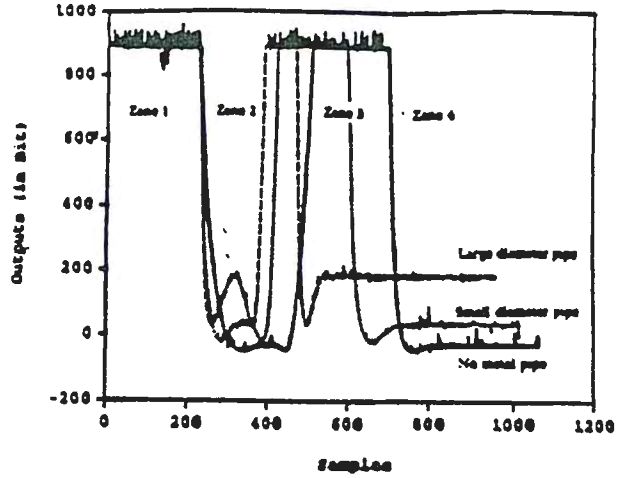


Figure 5: Preliminary Tests with the Sensor Coil Mounted on a Backhoe

Applications to Other Utilities

Underground utilities comprise other things than steel pipes. For this reason, the coil has been tested to see if it can detect other types of utilities. Figure 6 present results from another application. The results of a test where the sensor coil was used in an attempt to detect a fiber optic cable. As can be seen, the fiber optic cable could be reliably detected up to a distance of over two feet.

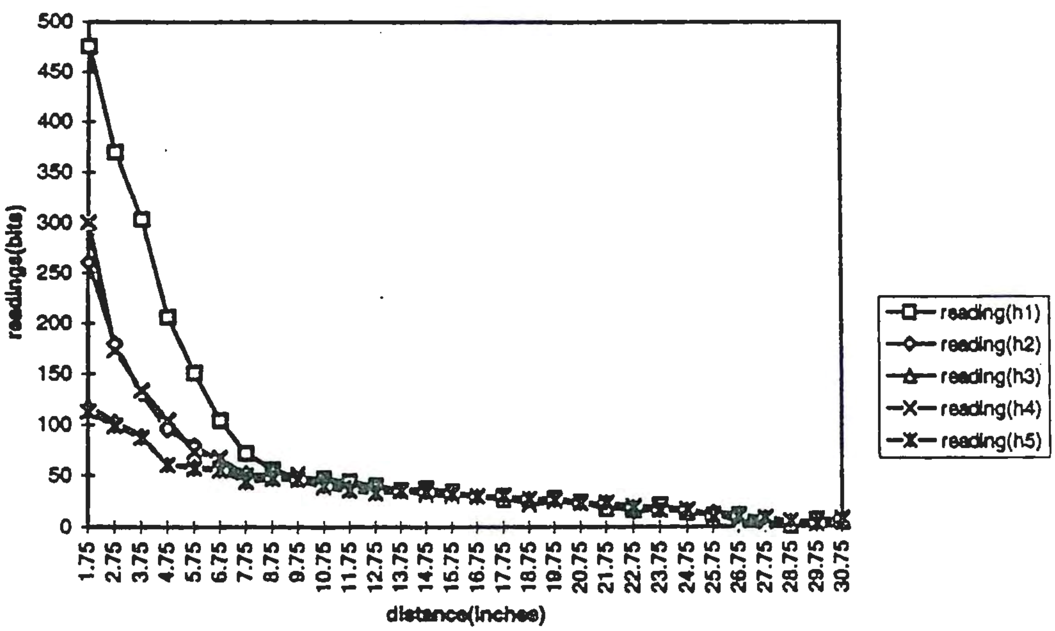


Figure 6: Electromagnetic Profile of a 60 Fiber Optic Cable

Conclusions

This paper presented the successful application of an electromagnetic sensor coil to the application of locating buried utility lines. The coil was mounted directly to the digging/excavating equipment and proven to be reliable. It was also shown that the sensor coil could be used to reliably detect buried copper and fiber optic communication cables. Applying this technology to the digging procedure could greatly reduce/eliminate the chance of damaging utility lines saving lives and money.

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