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Verification of underground utilities using GPR

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ABSTRACT

In our day to day construction practices, some of the biggest set backs are observed when an underground utility is damaged. This leads to a tremendous delay in work until the utilities are mended and is not desirable to dig the ground for every utility. Thus, a smart technology is required to detect their location by Non Destructive Testing. Ground Penetrating Radar is a geophysical method of soil exploration which uses electromagnetic waves to provide an image of the subsurface which can be used to identify the utilities underground

Keywords
Ground Penetrating Radar, utility mapping

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Introduction

Rapid population growth all around the globe has led to an increase in demand of basic utility services such as electricity, water, gas, telecommunication and internet services. More and more of these utilities are buried underground layer after layer every day, especially in urban communities. The existing infrastructures buried at unknown locations make the designs and constructions for the new networks and buildings, rather difficult. These utilities become crucial when they are present in environmentally critical and industrial zones. The stakeholders from utility industries often face difficulty in determining the location and depth of these utilities during maintenance and rehabilitation of deteriorated utility. Thus, they are maintaining precise utility records based on the information supplied through continuous on-site investigations.
Although, a lot of these records are inaccurate and unreliable, since most of these utilities were laid many years ago and their records are not updated with the changes that were made to them. GPR can help overcome these challenges owing to many benefits like high speed recording, ability to detect voids and trenches, ability to determine depths and lengths of targets, changeable frequency and real time display unit to view the cross sectional profile of the ground. However, there are certain limitations to this method. A profile of a maximum depth of 16 meters can be obtained, beyond which it is not possible to track utilities. Also, it does not work well in clay, saturated soils and uneven terrains. Apart from it being a very expensive method, interpretation of the data obtained, is complex and expertise is required for the same.

Exisiting Technologies For Pipeline Mapping

A.Existing technologies for locating utilities

1) Pulsed Induction:

Pulsed induction technology is similar to that as general metal detectors. It detects pipes by generating a conductive current at surface and detecting eddy currents induced in a metallic pipe. The accuracy of this method is limited due to poor induction by the transmitter, poor signal strength at the receiver, adjacent utilities or T or elbow joints, and soil that is too dry or overly saturated. Also, it cannot be used for non-metallic pipes. It is most commonly used for detecting gas pipelines as they are metallic. However, in practice error is observed due to nearby metallic objects, foundation of a building or guardrail, etc.

2) Magnetic and Electromagnetic locators:

Magnetic and EM locators measure changes in an induced magnetic field to detect the presence of a ferromagnetic object. The magnetic locators have transmitting and receiving magnetic coils together, while the EM locators have them separated up to several meters. Larger separation provides data from a greater depth, however having lesser spatial resolution.

3) Resistivity Method:

In this method, pipes may be located by measuring the resistivity between the probes and inverting the data. However, the method is tedious and time consuming. It also requires a larger surface area.

4) Acoustic Techniques:

An acoustic pipe tracer sends acoustic signals to the pipe. The receiver detects the sound waves that radiate from the pipe into the surrounding soil. The system operates through a variety of surface materials and is safe for use by an expert. This method is limited for 5 meter depth.

Basic Outline Of Gpr

Ground Penetrating Radar uses electromagnetic waves and can recover electric properties. Since the late 20th century, GPR is being studied meticulously and developed for many applications as it has an advantage of high usability and visualization capabilities. The application of GPR in utility mapping is not fully utilized as it is being used only for retrieving position and depth of the utilities. However, many other attributes like depth, radius, spatial orientation and relative permittivity of the pipes can be obtained as well, based on the geometry of the objects. Thus, with these applications and increasing interests in utility mapping, GPR is becoming an even more important tool.
A GPR has two antennas (transmitting and receiving). The transmitting antenna emits electromagnetic radiation into the sub surface and a reflected wave is generated which is detected by the receiving antenna. The GPR system measures the time “t”, time elapsed between the emission and reception part of the signal returned by the reflection. We can determine the depth of the target using the known propagation speed of microwaves through the ground. A block diagram of a general radar system is shown in Fig. 1.

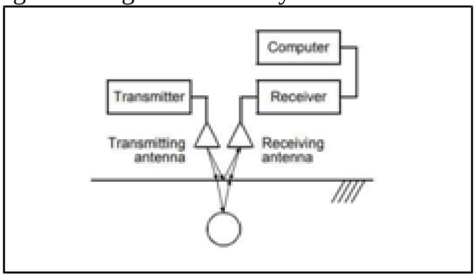

Fig. 1. GPR system consisting of computer-controlled transmitter and receiver

Materials with different dielectric constants will result in different reflection and refractive velocities of the respective waves. Also, different antennas allow different frequencies of radar signals to be emitted.

Cost Structure

Users of GPR require different systems for different needs. Thus, cost of getting a GPR survey varies widely with different parameters. Along with the cost of the GPR machine (owning or renting), there are many other overhead charges which sum up to the total cost of a survey. Some of these charges are - cost of running the machine, payment to the workers, software upgrades, accessories and advanced applications required by the user.
In practice, cost of survey depends on factors like site condition, location, volume of work and depth up to which the survey is to be done. For a survey, the cost may vary in the range of Rs.15000 to Rs.40000 per kilometre.

Methodology

A.data collection

Data collection is the first stage of utility mapping. It is the most important part of the project because if we don’t take the data properly we won’t be able to find the proper location of every pipeline. For collecting the data, we use GPR machinery which consists of a control unit, antennas and a calibrated wheel. The control unit consists of the electronics which trigger pulse of energy into the antenna, thereby transmitting and receiving the signals. It also consists of an in-built computer, from which the raw data available from the receiving signal is collected and eventually stored onto the hard disk. This data is in the form of a continuous linear ray, which, due to the movement of machine across a linear path, forms a sectional profile of continuous rays passing through that section. The inbuilt computer is already equipped with the software which is to be used while data is moved from the machine to a computer for further processing.
The antenna sends a signal underneath the ground surface. These antennas are of different frequencies such as 400 MHz, 200 MHz, 100 MHz, etc. For shallow depth, higher frequencies are used whereas for deeper depths, lower frequencies are used.
Generally, a depth of 3 meters requires a frequency of 400 MHz; 6 meters requires 200 MHz and 10 meters depth requires 100 MHz. Shallow depths provide greater accuracy and hence, their analysis is more accurate and plausible.
We can see the raw data on the screen of control unit on the site itself. Before starting to take the reading, we have to mark elements like manholes, drains and electric poles which are already present on the site, in the record book for reference. We also have to mark the distance at which we are taking the readings. Usually, a benchmark is selected at site which can be used as a reference for various distances.
Physical components of a GPR machine include the handling tools, and most importantly the wheels on which the machine is run. The wheels are calibrated and while the machine is moved across the road, distance is directly measured because of this calibration. For the location of pipelines going along the road we take the readings across the road
(perpendicular) and for the pipelines which are going across the road we take the readings along the road (perpendicular). If we want higher accuracy of depth and location of pipelines, then we have to take the readings at lesser distances across the road. This way, we are able to collect data from site which can be processed and interpreted for further use. In this study, a site at Vadodara is selected. Profiles at a distance of 12 meters are marked and taken readings at. Readings were taken at 32 different profiles.

B.Processingthedata

After taking the data from the site, it is transferred to a computer for processing as it is not appropriate for interpretation. RADAN 7 was used to process the data in computer as it is recommended by GSSI which provided the GPR machine.
The first step in data processing is Time Zero correction. This correction occurs due to the small gap of air which is between the machine and the ground below. This error must be corrected because as the image is actually a production of time required to receive a signal. The time required to receive the signal transmitted is recorded and an equation

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for depth is used for actually plotting depth on the vertical axis. Hence, time zero correction is required, because we are considering the air between the machine and ground, which should not be a part of the data in the first place. A corrected Time Zero provides a more accurate depth calculation because it sets the top of the scan to a close approximation of the ground surface.

The second step in data processing is Background Removal. It is analogous to a filter and is formally called Horizontal Background Removal FIR filter. It removes horizontal bands of noise. This noise can be a result of some horizontal reflectors in the ground or due to low frequency noises. These can prevent us from detecting point reflections of importance. It is also used to remove reflections obtained from water table or because of a boundary between two soil types.

The next step in data processing is static correction. This option offers multiple data filters. It helps in correcting errors of elevation, high frequency noise and phase shifts. It corrects for the errors caused in the data due to extensive processing. After a lot of processing, some of the continuous horizontal layers may appear shifted in time and sometimes discontinuous. Thus the reflections become difficult to be identified from scan to scan which can be corrected using static correction. There are three types of filters available in RADAN 7 which are Boxcar Filter, Triangular Filter, and Custom Filter.

The next step in data processing is Migration. In practice, in an entire profile of soil, many objects overlap one another i.e. deeper objects may be obscured by several objects at a shallow level from the surface of the ground. The diffracted energy from such objects can mask other reflections of interest. This can lead to misinterpretation of the depth, size and geometry of the object. Sometimes it also hides the utilities of importance and makes it difficult to detect their depth. Migration helps in correcting these reflections which appear as hyperbolic tails and show them at their true subsurface positions while collapsing hyperbolic diffractions. This way we can obtain processed data for interpretation. Fig. 2 and Fig. 3 shows examples of unprocessed and processed data.

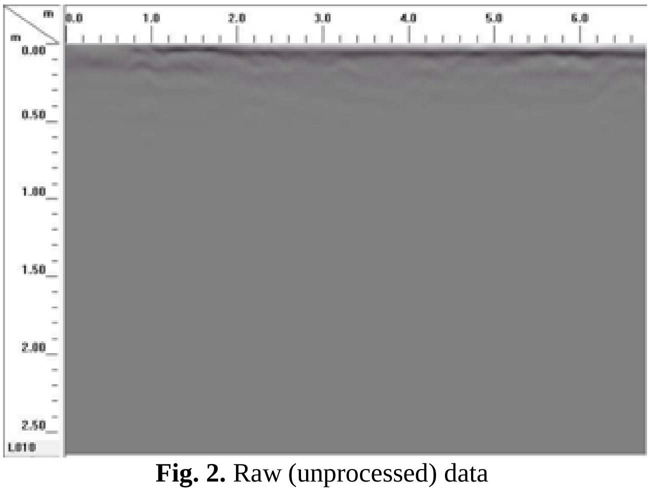

Fig. 2. Raw (unprocessed) data

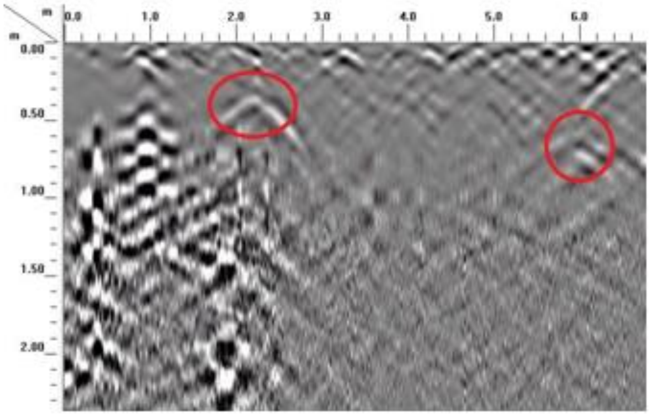

Fig. 3. Processed data

C. Interpretationofprocesseddata

After processing the raw data, the processed data becomes clear to interpret and plot. There are number of profiles taken on the road and we have to interpret every profile one after another to obtain the pipelines. Thus, we have to start from the first profile and see if we can see any hyperbola. We have to mark every evident hyperbolas and note their depth and distance from any reference (divider of the road in this study). Similarly, we have to mark all the hyperbolas or any major disturbances in the data. Disturbances in the data can be a manhole, open drain or any other buried structure. We also have to mark slant dark lines, if any. This may be a buried object. In this way we have to interpret all the profiles.

Now we should try to match the hyperbola which we can see in every profile on the same road. If we can see that the

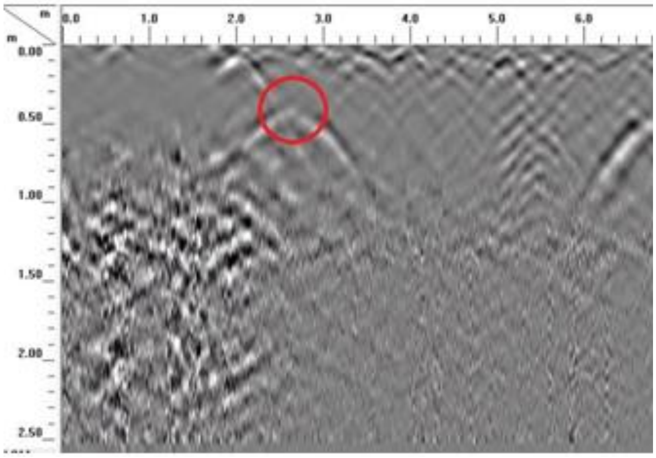

Fig. 4. Location of hyperbola

D. Mappingofutilities

Along with the interpretation of the data, we have to plot the data in AutoCAD layout. We have to mark the points which we will be getting from the data on the profile which are known as 'reflections'. On every profile, we have to mark the reflections in the similar manner. Reflections of different depth are to be marked with different colours. This way, it is easier to join the reflections of similar depth. An example of marked reflections from this study is shown in Fig. 5.

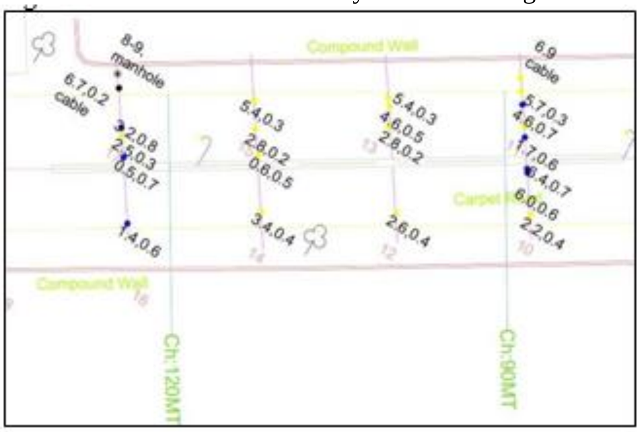

Fig. 5. Marked reflections on layout

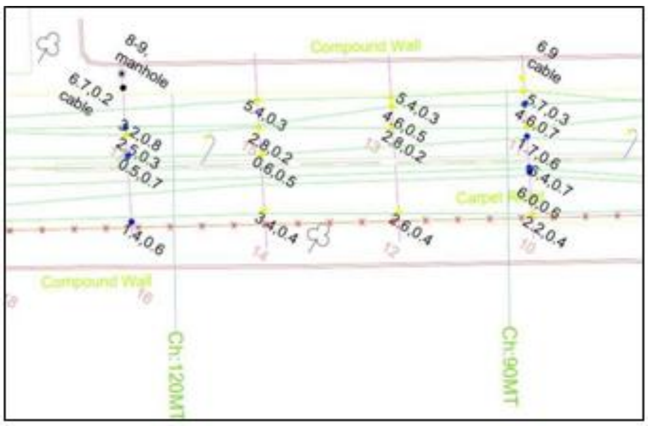

Fig. 6. Marked pipelines

Now if the reflections are same in every profile then we have to join those reflections and make a line representing the pipeline. In this way we have to make lines for every pipeline of the profiles.

Presence of a cable line was observed at the centre of the road for which, reflections were obtained in the profiles which ran fully across the entire road. Evidence of some of the prominent utilities in right lane are shown in Fig. 7 to Fig. 10.

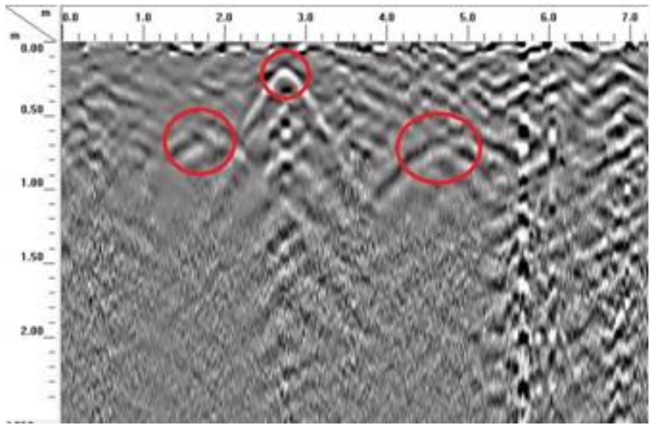

Fig. 7. Profile 11

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presence of unwanted disturbances. These errors need to be corrected logically as the pipelines usually go parallel to the road and there are very less chances of vertical and horizontal deviation of the pipelines. Some technical discussion is required in such cases especially in cases where the roads are changing their direction. Scrutinized site investigation is required to solve the issues generated from the data.

There are a lot more applications to GPR than just measuring the depth and location of the utilities. Also, in this particular study, data obtained for 200 MHz and 100 MHz frequency can also be studied for details about the utilities lying at a greater depth. There are numerous ways of processing data which can applied to the same data for getting different and clearer results.

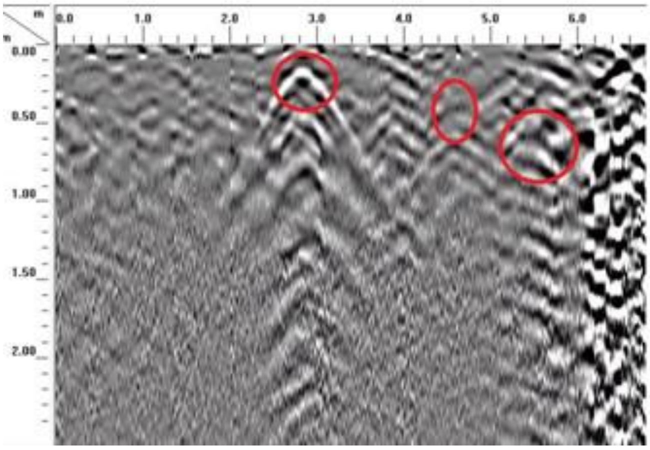

Fig. 8. Profile 13 The results in this study are given in AutoCAD 2D format.

However, there are three other ways to represent the sub surface profile which are 3-D CAD representation, representation on thematic plan and Virtual Realistic Image.

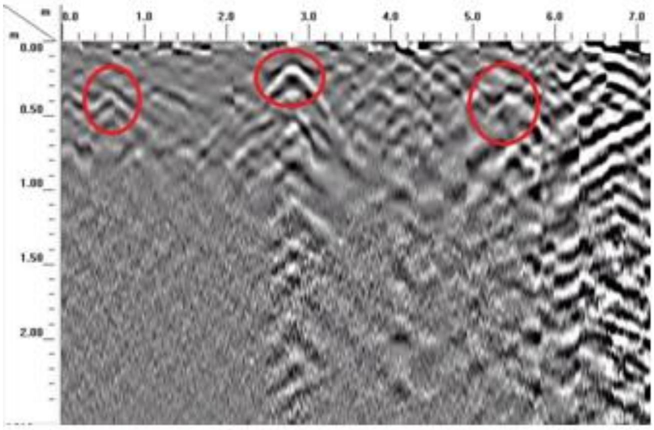

Fig. 9. Profile 15

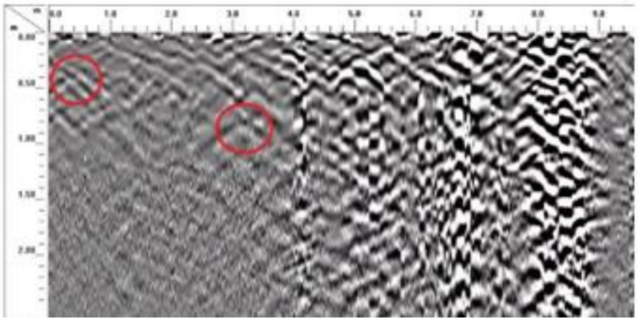

Fig. 10. Profile 17

Conclusion And Future Scope

Using GPR survey for utility mapping, we are available with approximate results for the subsurface profile. These results can provide a satisfactory solution for trenchless testing, along with elimination of delay of work due to accidents. An investment in GPR method for large works is comparatively economical rather than spending a large sum in case of damage.

The results obtained from survey are fairly accurate. However, there is a chance of slight change in location and depth of utilities due to errors in taking readings or due to

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