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GPR Preprocessing Methods to Identify Possible Cavities in Lateritic Soil

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***Abstract*—**Lateritic soils is formed by soft sediments, entangled between rigid to soft lateritic rock, and are seeped due to the entry of water in rainy seasons forming cavities which span over large lengths and considerable depth. Mainly in southern and central parts of India the Lateritic soils are formed. The proposed research work aims at the detection of cavities and formation of sink holes in lateritic soil. The data used in this proposed work is obtained from project site in Kannur District, Kerala State, India. To detect the heterogeneities in lateritic soils and formation of cavities, a Geophysical survey method, namely ground penetrating radar (GPR) with 100 MHz and 500 MHz (for confirmative survey) Ground Coupled antennae were used. The proposed work involves two dimensional 2D image pre-processing of the radargram obtained from GPR. The pre-processing involves data editing, time zero correction, Dewow filter, gain control, Background noise removal and edge detection to improve the detection of cavities in lateritic soil. This provides a means for interpreting the raw GPR data.

***Keywords*—**Ground penetrating radar, underground utility mapping,cavity detection and Dewow filter.

I. INTRODUCTION

Lateritic soil is a form of residual soil formed from tropical weathering under circumstances of high rainfall, deep leakage and oxidation. Lateritic soils [1] are well-known for heterogeneity like sink holes and underground cavities. Through geophysical investigation such problems were detected and documented in Kannur district, Kerala. The Ground Penetrating Radar (GPR) is a non-destructive method that uses high frequency radar pulses to image the subsurface. It consists of a transmitting antenna, receiving antenna [2] and a recorder is as presented in figure1.The transmitting antenna sends high frequency radio waves in to the ground, which causes a reflection due to changes in the dielectric properties of the soil and the surrounding medium. These reflections are picked up by the receiving antenna. GPR system has a wide operating frequency range. The frequency of operation decides the amount of signal penetration into the ground. Lower frequencies penetrate deeper into ground making target detection easier, whereas higher frequencies increase the resolution. GPR data representation can be classified in to three categories, as A-scan, B-scan or C-scan respectively.

A-Scan: In this GPR records one dimensional data, with the antennas at a given fixed position shown in figure2.It scans only along x-axis.
B-Scan: It is a two-dimensional image obtained as the horizontal collection from the ensemble of A-scan. The vertical axis is a round trip travel time and horizontal axis is a surface position shown in figure3.
C-Scan: Collecting multiple parallel B-scans one can obtain a three-dimensional data presentation shown in figure4.In C-scan representation one can easily visualize the shape of the target.

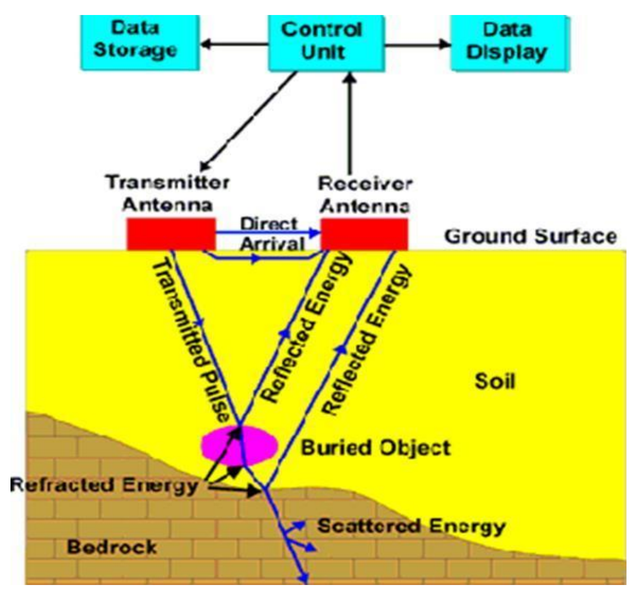

Figure 1. GPR Unit

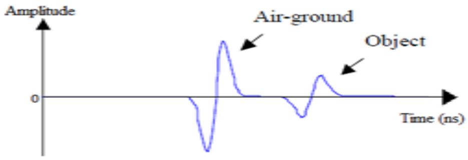

Figure 2. A-scan

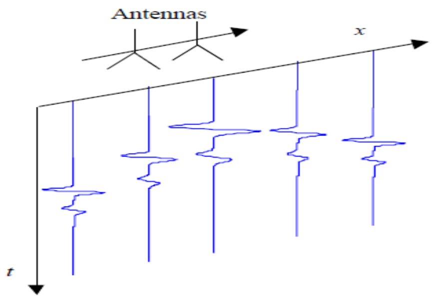

Figure 3. B-scan

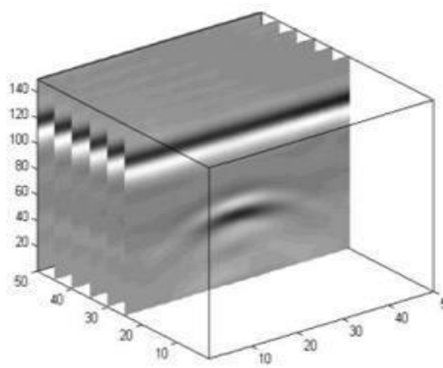

Figure 4. C-scan

II. RELATED WORK

Many researchers have done a lot of works, and improved the conducted Radar surveys using GPR results in radargrams. These have to be post-processed and compared with the conventional survey methods at the trial sites. The post processing techniques such as time-zero correction, infinite impulse response(IIR) filtering, finite impulse response (FIR) filtering and Deconvolution are to be performed to enhance the interpretability of the radargrams of the surveys.[3] The main disadvantage is that it is critical to evaluate the use of antenna frequency and the exactness of the obtained data. A novel technique i.e. hyperbola fitting technique is presented for detecting the underground utility information such as location, depth and radius of buried pipe. Many algorithms [4] such as template matching, least square approach and pattern recognition methods are used. MALA OBJECT MAPPER is a simulation tool which is used to enhance the quality of the GPR radargram. By implementing this method a target i.e. a pipe/cable can be detected accurately with a radius between 45mm to 150mm. The results indicate that the larger the pipe size (150mm), the maximum percentage of accuracy is achieved.

K.L Lee, M.M Mokji [5] developed a Histogram of oriented gradient algorithm for automatic target detection in GPR images. B-scan model was developed which automatically detects the hyperbolic signatures. With this developed algorithm a target detection rate of 93.75% was obtained. Numerous methods have been proposed such as background subtraction or ground bounce removal methods for GPR or for subsurface utility mapping has been performed. [6] Mean, median, SVD, PCA, ICA and Training methods have been evaluated and tested on number of GPR data sets collected with a horn antenna for variety of nonlinear rough surfaces and for various soil moisture contents. In preprocessing stage, GPR imaging influence by the various ground bounce removal techniques. Based on this dependency, variety of ground surfaces have been analyzed by indigenously developed GPR unit and collected data for bare rough ground surface. Another popular approach i.e. set of procedures for data pre-processing of GPR radargram are presented. Raw data taken from GPR are affected by different noises and instability of equipment. The data in this form, are not suitable for the further analysis. Such analyses are heavily depended on the interpreter's experience. The operator should be very critical and careful in choosing the appropriate processing scheme; the same scheme should be used for all traces in localization.[7] By using such simple methods, information about interesting and promising sections of radargram can be obtained.

GPR-Pro [8], is a flexible and user-friendly module developed in MATLAB for processing mainly GPR data. This module can handle the most common GPR data formats. It provides a large number of signal processing algorithms including Principal Component Analysis, FK filtering, data manipulation (matrix algebra), attributes analysis as well as toolboxes for data classification and interpretation. The user can apply different flows on the data keeping always the control of the intermediate and final results. One can easily compare sections and choose the most appropriate flow. To improve the quality of radargram different pre-processing steps are applied to visualize the formation of cavity in lateritic soil.

III. METHODOLOGY

A. Data collection

The Data set was collected using Mala ProEx 100MHz and 500MHz continuous waves, ground coupled antenna GPR system are used for the investigation. The dimension of the test area scanned is 400,000m^2 . The specifications of input image consist of total number of traces of 2529.Each trace is 376 samples with Distance interval 0.019011m and sampling interval 0.97219 nsec.

B. Detection of Cavity

The block diagram of proposed methodology is presented in figure5. The image of the raw GPR radargram is as shown in figure6. The data in this form are not proper for the investigation of targets.[10] These types of data are converted in order to gain essential information.

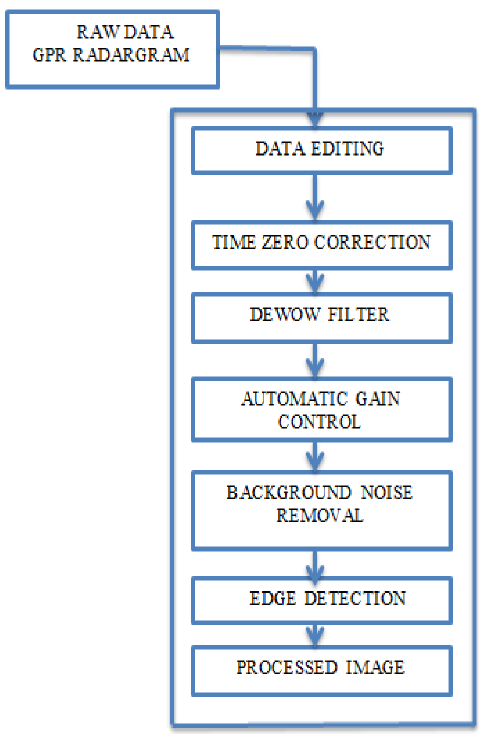

Figure 5. GPR processing flow

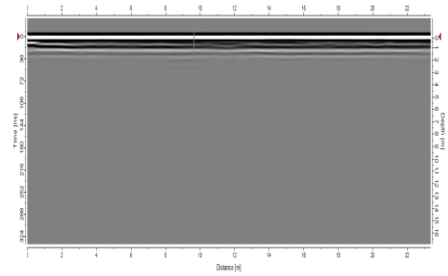
Figure 6. Raw GPR Radargram

The Processing of raw GPR data performed with [9] RAMAC GROUND VISION SOFTWARE tool to convert rad file to ASCII file and imported the data in MATLAB 2016 and represented as an image shown in figure7.

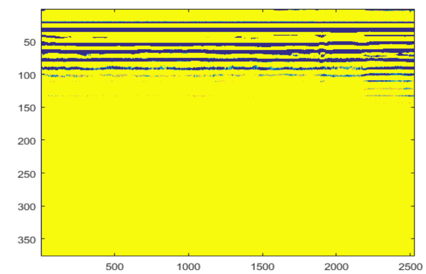

Figure 7. GPR image Representation

Preprocessing is carried out on the image shown in Figure 7. The pre-processing steps are listed below:

1) Time zero correction

Time zero is the first arrival time of the radar signal and is used to adjust a common time zero position point for each trace, before applying processing methods. The area above the grey line is removed, since it contains a very little information for a better processing. [11]. The first step in data processing is to shift each scan of the data so that the top of the scan corresponds to the surface of the cavity formation demonstrated in figure8.

2) Dewow Filter

It is a low pass filter and affects each trace separately. Initially, it calculates the length of a kernel from the relation,

$$\frac{2}{f \cdot \Delta t}$$

where f and Δt are the central frequency (MHz), sampling interval (nsec). This filter calculates the mean of the data within the kernel. Then, the mean value is removed from the initial data as shown in figure9.

3) Gain Control

In this case, spherical and exponential gains were applied to increase imaging quality of reflections for interpretation. In this each data trace is processed such that the average signal is calculated over a time window and then the data point at the center of the window is amplified (or attenuated) by the ratio of preferred output value to the average signal amplitude.

4) Background Noise Removal

Horizontal reflectors visible in the data section sometimes are caused by the antenna ringing. Such horizontal reflectors are also recorded because of the presence of electricity cables, antennas of mobile telephony or industrial noise. The Background Noise Removal filter is applied in order to eliminate such effects as shown in figure11. A new trace is calculated which is equal to the mean of all traces of the section. Then, this mean trace is subtracted from each trace. In the resulting section these effects are minimized.

5) Edge Detection

Edge detection is an image processing technique for finding the boundaries of objects within images. It works by detecting discontinuities in the soil. Edges are classified in to three categories: horizontal (H), vertical (V) and diagonal (D). The filters are basic convolution filters. The Edge filter is used to detect edges by applying a horizontal, vertical and diagonal filter in sequence. All filters are applied to the image and added to detect a cavity in the lateritic soil. By observing hyperbolic signatures in the image, the interpretation of the cavity is identified as shown in figure12.

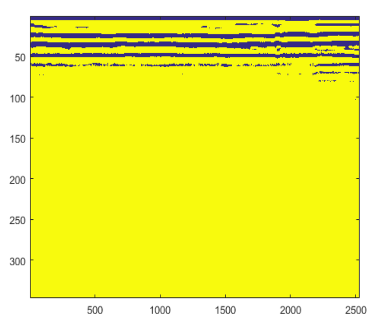

Figure 8. Time zero correction

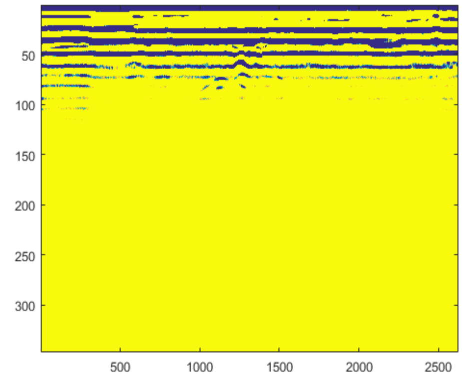

Figure 9. Basic processing-Dewow filter applied

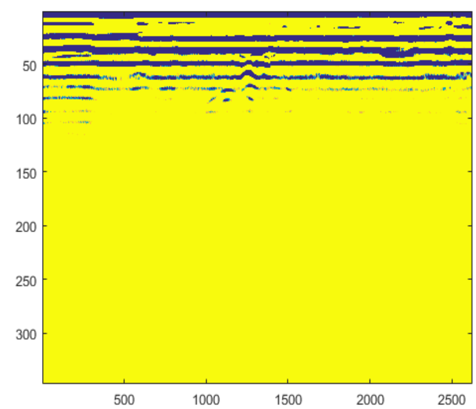

Figure 10. Automatic gain applied

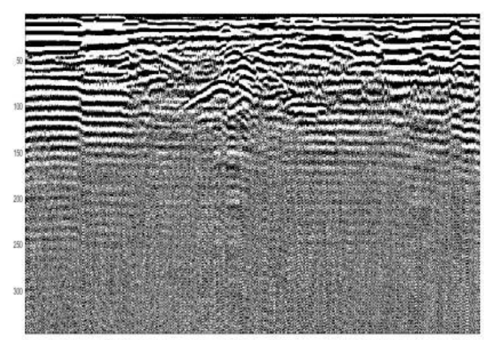

Figure 11. Background removal filter applied

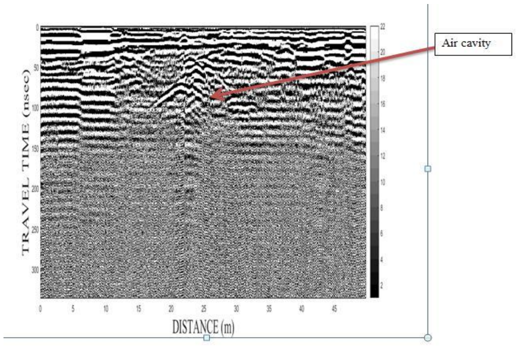

Figure 12. Edge detection filter applied

IV. Results and Discussion

The Proposed methodology is implemented over a GPR radargram collected from IISC, Bengaluru. To identify the cavity formation in lateritic soil are discussed. Preprocessing of the GPR radargram is necessary to improve and enhance the quality of the image. The comparative analysis of the images with and without cavities are as shown in figure 13 and 14. The hyperbolic signatures are significantly identified in the image with cavity in the lateritic soil. This provides useful information to investigate formation of cavities in lateritic soil.

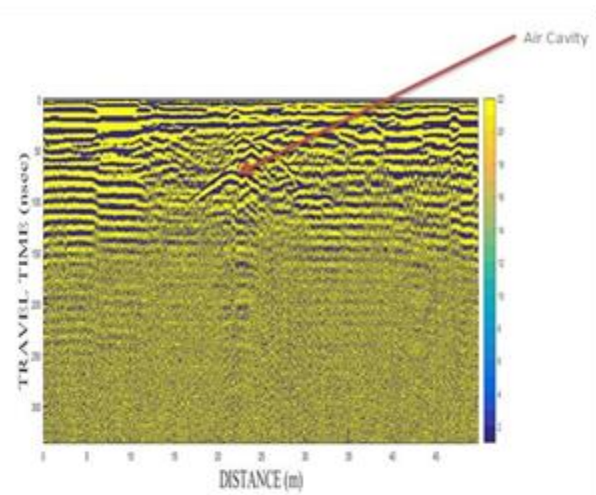

Figure 13. Pre-processing steps applied on GPR data to detect cavity in lateritic soil.

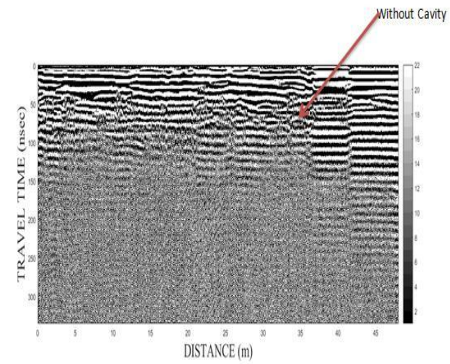

Figure 14. GPR data of without cavity formation in lateritic soil

V. Conclusion and Future Scope

In this work Ground penetrating radar (GPR) is used to perform subsurface investigations. The objective of this work is to present some basic procedures for preprocessing GPR data sets, in detecting the cavity formation in lateritic soil developed in MATLAB 2016.The preprocessing involves time zero correction, Dewow filter, automatic gain control, Background removal and edge detection. Pre-Processing methods which are implemented in this work are found to be suitable to process the raw GPR data and to enhance the interpretability of the cavity formation in the radargram.

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Mrs. S J Savita pursed MTech, from MSRIT, Bengaluru in 2010. She is currently working as Assistant Professor in Department of EIE from RNSIT, Bengaluru since 2007. Main research work focuses on Signal Processing, Image processing algorithms and interpretation of Ground penetrating radar images. She has 10 years of teaching experience.

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