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3D Reconstruction Hyperbolic Image of Buried Object Using GPR B-scan Images for Mapping Purposes

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Abstract: Ground Penetrating Radar (GPR) is a non-destructive evaluation and imaging tools for shallow subsurface investigation that based on the transmitting and receiving of electromagnetic when moving along the antenna along the surface. For an unexperienced GPR user, it may have difficulties to understand the raw data of the GPR images due to the data complexity and resemblance of the hyperbola pattern. Thus, this aim of the study is to reconstruct 3D representation of hyperbola images of buried object for underground mapping application. In this framework, Synthetic Aperture Focusing Technique (SAFT) will be used to reconstruct 3D images. Firstly, the raw data of B-scan images undergo zero-time correction and background removal. Then, the projection of each B-scan images to reconstruct 3D image. The obtained 3D images then were stacking together. Finally, the 3D interpolation technique of the stacked images were implemented to obtain 3D reconstruction of hyperbola images. A series of experiments has been conducted on the collected B-scan image of sphere metal ball. The obtained results shows that the SAFT technique not only able to reconstruct the 3D images however it also reveal the location of the buried object that represent by voxel point of 3D images. Thus, the proposed method using SAFT method shows promising 3D reconstruction technique of hyperbola images of buried objects.

Keywords: 3D Reconstruction, Hyperbolic image, Buried objects, Ground penetrating radar, Synthetic aperture focusing Technique

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1. Introduction

Ground Penetrating Radar (GPR) is a non-destructive testing and imaging tools for shallow subsurface investigation that transmits and receive the electromagnetic wave (EM) along the surface [1]. It has been used in many applications related to mapping and locating the underground utilities such as internet cables and telco lines, road inspections and landmines detection. The GPR system transmits high frequency EM that ranging from 100 MHz to 1GHz into shallow subsurface. The EM waves propagate with a velocity that depends on the dielectric property of the medium. If the wave hits a buried object with different material, some of the waves are bounce back to the receiver antenna and then process to create a time-series, known as an A-scan. Consecutive patterns in A-scan can be concatenated to create images of the subsurface, called B-scans. Buried objects exhibit characteristic patterns in B-scan by means of the hyperbola pattern. Even though the recognition of GPR images have achieved a certain level of success, however interpreting the hyperbolic pattern information is still a challenging and ongoing research [2], [3]. Therefore, this paper proposes synthetic aperture focusing technique (SAFT) to reconstruct 3D hyperbolic images. The B-Scan images will be reconstructed into 3D representation using SAFT method.

2. Materials and Methods

Figure 1 shows the procedure of the proposed method. It contains of data collection of GPR images, pre-processing, and extraction of data features, feature reduction and classification. The working procedures of each of the block are explained in the following subsection.

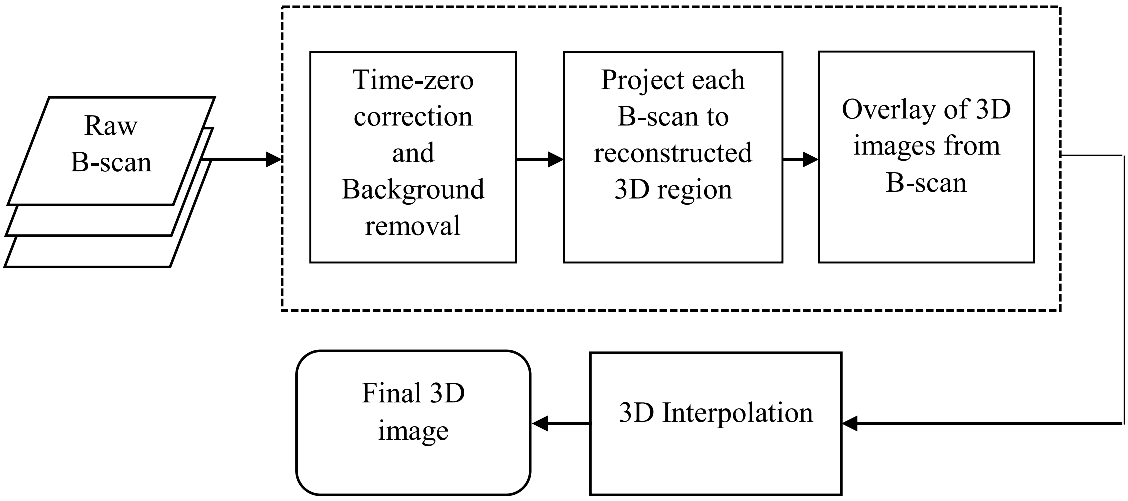

Figure 1: Flowchart of the proposed method

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2.1 Materials And Method

In this work, GPR data acquisition was conducted at Non Destructive Test (NDT) laboratory, Agency Nuclear Malaysia in controlled environment condition with supervision of authorized officer using GPR MALA CX 1.2 GHz. The experimental setup is shown in **Figure 2**. The test bed similar in [4] has been used. The test bed is made of entirely of wood. The presence of any metals may interfere the signal during the scanning process. Metal ball with diameter of 7 cm was used as the buried object. The selected depth is 20 cm. The dry sand was used since it represents the 'best' condition to observe hyperbolic pattern of buried metal ball. In acquiring the GPR data, the scanning process were carried in X and Y direction using standard grid paper of 60 cm x 60 cm with line spacing of 10 cm.

(a) (b) (c)

Figure 2: Experimental setup, (a) the test-rig filled by dry sand, (b) GPR scanning process and (c) the position of metal ball.

The B-Scan images will used to reconstruct 3D model. The algorithm will have to determine transmitter and receiver locations based on calibrated velocity of GPR signals. Two-way travel time between transmitter and receiver when it detects the object will have a calculation in 2D image by using **Eq. 1** [5]:

$$A_p^{ii} = S_{br}^{ii} \left(t = \frac{L_p^{ii}}{Vsignal}\right) \quad \textbf{Eq. 1}$$

In this work, the SAFT using an overlay technique will stack all of the B-scans images (X and Y direction) and being summed to reconstructed 3D image using **Eq. 2**:

$$A_v = \sum_{i=i}^{N} A_v^i \quad \textbf{Eq. 2}$$

The results are presented in the following subsection.

3. Results and Discussion

3.1 Performance Observation of GPR Image

Figure 3 shows the hyperbolic signature based on slicing view in X-axis. Based on the Figure 3 it shows that the horizontal line is refer to the distance (m) and vertical is referred to the time (ns) .This data shows the 2D image co-called *x-cut* slices with interval of 2.5 cm. When it slice through (a), the contrast of hyperbolic is very low as it represent the beginning of the buried object. At (b), (c), (d), (e) and (f) we can see the contrast of hyperbolic is very high compare to (a), because it cut slices through the buried object in the middle. Next, at (g) it show slow contrast and (h) shows the contrast of hyperbolic shape is similar with the neighourhood pixel because there is no buried object underneath.

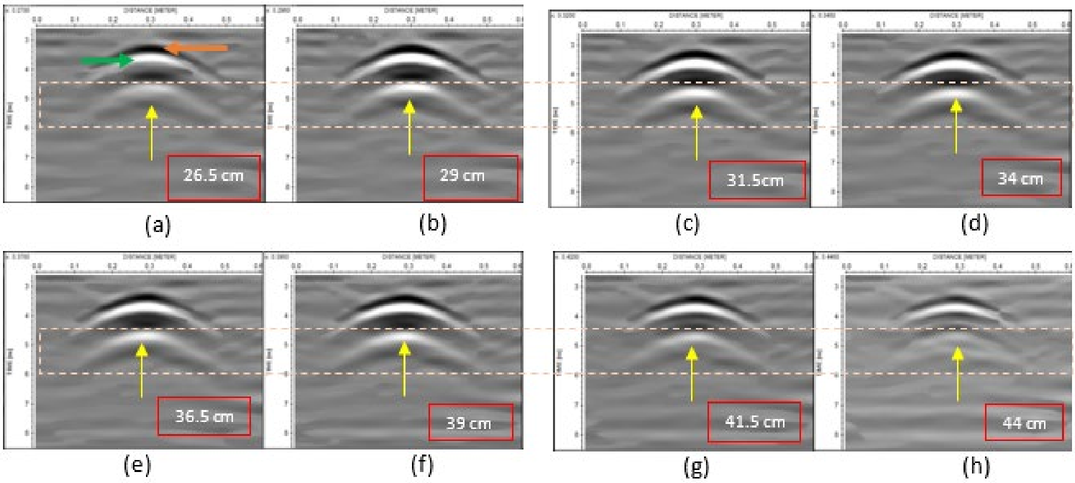


Figure 3: GPR B-scan hyperbolic of sphere metal shape (7 cm diameter), buried 20 cm deep in sand medium. Signal amplitude in time versus longitudinal scanning along x-cut.

Figure 4 shows the 2D image slices in the direction of *y-cut* with slicing interval 2.5 cm. Based on **Figure 4**, it can be noticed that the hyperbola signature of buried metal ball is not appeared in expected hyperbolic shape compared in the direction of x-cut. The x-cut slices in (a), (b), (c) and (d) show almost the same contrast of hyperbolic shape. Meanwhile at (e), (f) and (g) the contrast of hyperbolic is slowly disappear. It may be due to the GPR location was slowly move. At depth of (h) there is no contrast of hyperbola shape because GPR is no longer detect any buried object underneath.

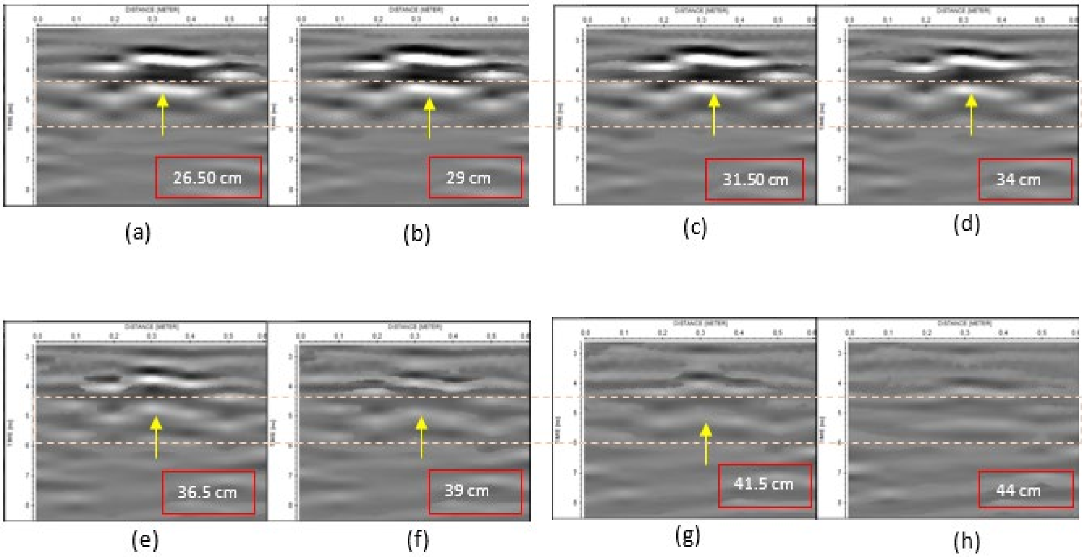
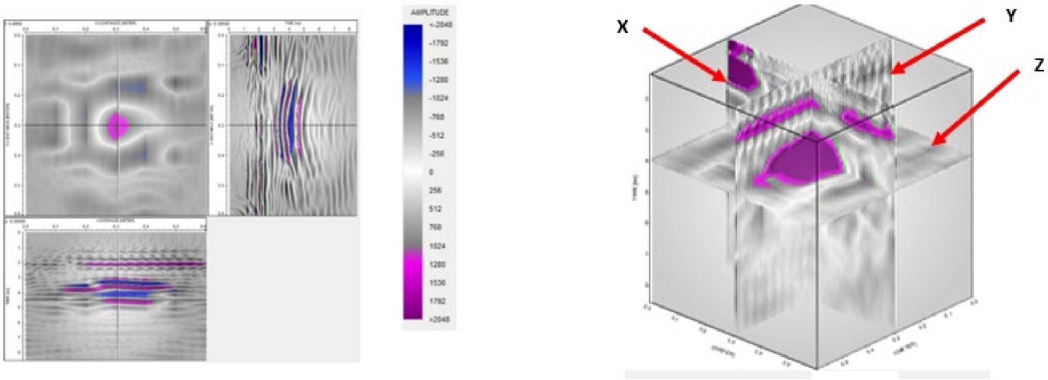


Figure 4: GPR B-scan hyperbolic of sphere metal shape (7 cm diameter), buried 20 cm deep in sand medium. Signal amplitude in time versus longitudinal scanning along y-cut

In this work, the 3D modelling reconstruction was reconstructed by combining multiple slices via using SAFT method, we able to analyse the performance accuracy of 3D modelling in the results. **Figure 5 (a)** shows the projection results based on X- Y- and Z- axis of 3D images. The used of data set (X and Y) that combined together at respective slices to create the z-axis depth. This illustrates that the estimated location of buried metal ball able to give accurate information by reconstructing the image via X- and Y-images. The image has been added with effect of bump mapping and embossing filter to make the image have some texture. **Figure 5 (b)** are interpolation of 3D images combination of x, y and z that being stack together at depth of 20 cm in a 3D representation.



(a) (b)

Figure 5: Reconstruction of z – axis depth of 22 cm, 7 cm diameter of sphere metal ball (left) and Reconstruction of 3D modelling of sphere metal ball at 20 cm depth of x-y-z is stack together (right)

Figure 6 shows the results 3D reconstruction of the estimate location of the buried metal ball using SAFT techniques. It agrees that the simulation results of 3D reconstruction of buried metal ball ables to mimicking the real application with minor error, thus shows a promising result.

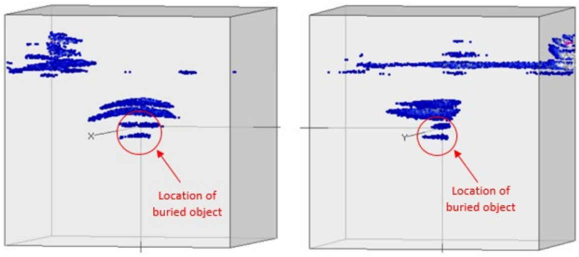


Figure 6: 3D reconstruction of voxel peak amplitude of buried metal ball. X-axis view (left), Y-axis view (right)

4. Conclusion

This paper has presented 3D reconstruction of buried object in GPR images that used Synthetic Aperture Focusing Technique. In this work, the results obtained by slicing in the direction of X- and Y-axis able to exhibit the characteristic of hyperbola signature with respective depth. The slicing at 25 cm depth show high contrast of 2D image contour that represent the buried metal ball. In term of hyperbola signature, both X- and Y-axis illustrated high contrast of hyperbola region at specified depth. The SAFT method that used to visualize 3D images from hyperbolic B-Scan image has three important concern which is reconstruction, overlay of 2D images and 3D interpolation. In reconstruction, a raw B-scan of two perpendicular data (x and y) able to reconstruct each slices using SAFT technique. In second step, SAFT using an overlay technique able to stack all the B-scan images from previous scans and being sum to reconstruct the 3D image. Finally last step, 3D interpolation will combine the voxels of peak amplitude, then finally shallow subsurface 3D images of the sphere metal shape was obtained. From the discussion analysis 3D reconstruction, we knew from x and y data set, it able to give illustrates the shape of buried object even before it was create into 3D modelling. For unexperienced person in GPR it might help those to understand and give an idea what was the object shape are. Especially during an inspection at the site that has so many utilities underground.

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