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Implementation of Wavelet Algorithm to Detect Underground Targets Using GPR

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Abstract
The Detection of targets buried underground viz metallic /nonmetallic is identified using Ground penetrating Radar (GPR) System. [1] The reflections from the targets are obscured due to noise present in the signal, so it is difficult to extract the original signal from the raw GPR data. [2] This paper presents the Wavelet algorithm for identification of various targets like metallic and non-metallic. The experiments are conducted in Civil engineering laboratory, IISc Bangalore. Underground Data is acquired using Mala GPR 800MHz ground coupled antenna was used to identify the targets. By implementation of wavelet algorithm, it is easy to classify the targets. [3]Analyzing some statistical parameters like kurtosis, skewness and entropy are tabulated by comparing the values of [4]mother wavelets like Haar, Debauchees, Symlets etc.

Keywords: GPR, Wavelet, Kurtosis, Entropy, Skewness

1. INTRODUCTION

Railways are the important mode of transport which carry large number of passengers. It requires maintenance of the sleepers and the gauge to prevent derailing of the train. It is a main catastrophe failure in railways. Ballast are the big sized stones which are places below the track, if there are any defects in the ballast lead to misalignment of rails. Ground Penetrating Radar instrument is used to detect the subsurface structures without digging ground with differing electromagnetic properties and can thereby identify the different targets like metallic and nonmetallic. [5]

The signals received from the GPR is not easy to interpret the information of the target. The reflections from the GPR is normally obscured by the noise because it is difficult to differentiate between targets and other materials like soil, rock etc. So, to get a proper peak reflection of the target a DWT (Discrete wavelet transform) method is used to enhance the quality of the target. A number of decomposition levels are used in order to extract the peak reflections of the target. We will get a good peak reflection if a metal target is buried underground compare to nonmetallic objects.

In this work a wavelet transform method is applied to a preprocessed data of the GPR. The statistical parameters like kurtosis, skewness and entropy are calculated and compared with different mother wavelets.

2. LITERATURE SURVEY

A lot of research has been carried out to detect the substructure objects using Ground Penetrating Radar.

This paper [6] focuses on denoising the GPR signal by the implementation of discrete wavelet transform. The data obtained from the GPR is a mixed data. This data contains information about the obscured area with noise and other unwanted signals, which may corrupt the GPR signals. The proposed DDDWT (Double Density discrete wavelet transform) as a mother wavelet was applied to a series of GPR signals, which in turn produced a 2-D denoised GPR image. The proposed DDDWT method was proved to generate more promising results than the traditional Daubechies and Haar wavelets.

This paper [7] extensively discussed the theory of wavelets and its superiority have been explained in precise in this paper. The theory behind grouping or cutting the signal into sizeable data is explained. The paper suggests the use of wavelet analogy over the traditional Fourier methods in obtaining information from any signal. The paper clearly demonstrates the efficiency of using wavelets.

This paper [8] aims to prove that there is a fault in the Sinusoidal PWM inverter fed induction machine during single phasing. Three phases are considered here i.e A,B and C. A single phasing have been performed on phase A and the current components are captured from Phase B and Phase C. Discrete wavelet transform DB4 has been considered as the mother wavelet, this paper attempts to decompose Phase B and

Phase C current values using skewness and kurtosis. The plot of the results of performing skewness and kurtosis for each of the phases are compared. This comparison shows fault in the sine wave.

3. METHODOLOGY

The following steps are used to detect the targets using GPR.

3.1. Model Railway Track

A model track was constructed at IISc of without the rails and sleepers. The model is built with the concrete flooring as the subgrade layer. The track has a length of 4.8m and a breadth of 1.6m. The height of the ballast is 0.6m. The ballast type used is irregular shaped sharp-edged granite stones in good condition. The density was found out to be 980kg/m3. The model track has two sections. One section with buried metal piece and big sized ballast. Another section with clean ballast and a utility pipe.

The metal piece is a rail piece having a length of 0.2m buried with angle of inclination of 45 degrees. The real time model track is built having clean ballast, ballast having metal piece and big stone as shown in the Figure.1 and Figure.2.

Figure.1 Real time Model Track built at IISc

Figure.2 Buried Metal piece target

3.2. Post Processing using Wavelets

GPR signals are non-stationary signals, so it can be analyzed using wavelet algorithm. To detect and classify the buried targets a discrete wavelet transform method is implemented. The proposed block diagram is as shown in Figure.3.

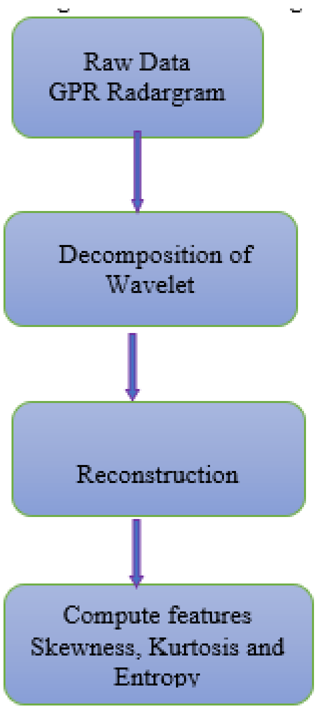

Figure.3 Steps involved in Post processing

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The proposed block diagram simplifies the post processing procedure into 4 crucial parts.

3.2.1.GPR Radargram

The primary step is to obtain the Raw GPR radargram from the GPR instrument. The Raw data consists of a mixture of different signals, the signals are amalgamated with unwanted noises and other high frequency components (which are subjected to errors). The radargram is first pre-processed, after which any other approach can be made to obtain the desired results.

3.2.2. Decomposition of Wavelet

Wavelet theory is implicated to confine the processing data. Smaller data aids in generating clearer results.

Let us consider a signal x of length N. Next the signal x gives a set of detailed and approximation coefficients. Commonly the approximation coefficients are subdivided in to ten level of detail and approximation coefficients. This process is iterated for 10-level of decomposition. The high frequency components represent the detailed coefficient and low frequency component represents the approximation coefficient and then it is followed by a down sampling. The wavelet decomposition algorithm applied is fully recursive as shown in Figure.4.

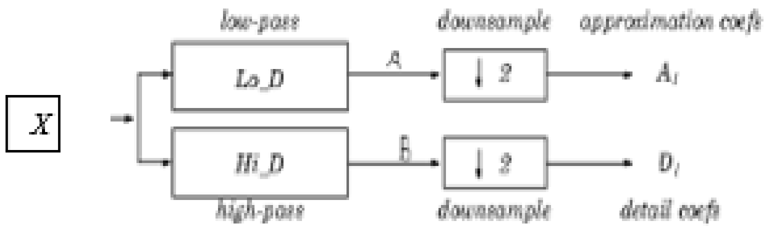


Figure.4 Decomposition of a signal x(t)

Each filter length is 2N. If n is length of X then signal A and B are of length n+2N-1 and then the co-efficient A1 and D1 are of length,

$\left(\frac{n-1}{2}\right)$+N

Then it splits the approximation co-efficient in to two parts, similarly it will proceed up to 10 level of decomposition and so on.

3.2.3 Wavelet Reconstruction.

It is the process of reconstructing the original signal based on the wavelet decomposition structure for N=10 levels. In this approximation coefficients are considered.

3.2.4 Calculation of statistical parameters

In this the statistical parameters such as kurtosis, skewness and entropy are used to analyze the GPR signal. It provides immense information about a particular signal.

Skewness: It is a measure of symmetry. The skewness shows whether the object in range is flat or curved. The skewness of the image shows the slope information leading to a mental sketch of the physical appearance of the buried object. Skewness is given by the equation.

Skewness = $\frac{\sum_{i=1}^{N}(Y_i-\bar{Y})^3/N}{S^3}$ (1)

Where, mean, standard deviation, and data points are represented by $\bar{Y}$,S and N.

Kurtosis: It is the measure of thickness or heaviness of the given signal. The kurtosis magnitude maybe positive or negative. A kurtosis value indicates a amplitude of the reflected signal or a spike in the signal.

Kurtosis =$\frac{\sum_{i=1}^{N}(X_i-\bar{X})^4/N}{S^4}$ (2)

Where standard deviation and data points are represented using S and N.

Entropy: The entropy is nothing but information content of the signal. More the unpredictability of the random variable more the information the signal has. The entropy is given by, Entropy = $-\sum_{j=1}^{N} P(Y_j)\log_2(P(Y_j))$ (3)

Entropy is chosen as a feature vector instead of energy of the signal because energy gives the output which depends only on the amplitudes of the signal. Finally, the extracted features are tabulated and analyzed for classification of target.

Different wavelet transforms such as haar, db2, db3 and sym2, are applied on raw GPR radargram.

4. RESULTS AND DISCUSSION

The GPR radargrams are collected by using Mala GPR machine with an antenna frequency of 800MHZ.The targets used are metal and plastic pipe. We consider different cases like metal, pipe and clean data to analyze the wavelet algorithm.

Case 1: Metal Target with specifications as shown in Table 1.

Table1. Specification of metal target

Antenna	800MHz
Targets used	Metal
Total Distance	1.3m
Distance Interval	0.009712
Last Trace	135
Length of a metal piece buried	0.2m

The raw GPR radargram which is represented as a 2D image is as shown in Figure 5.

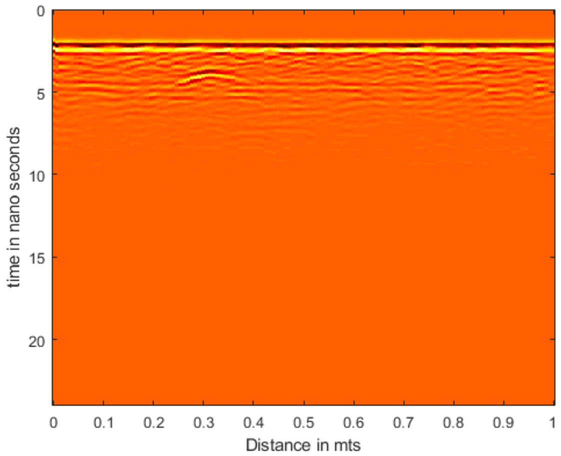
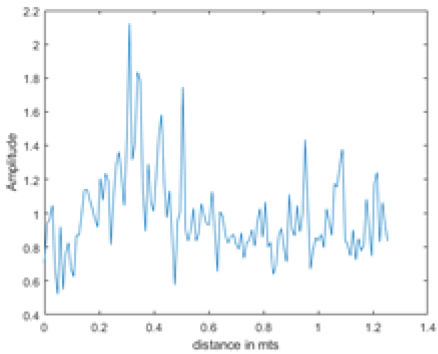


Figure.5B-Scan of a buried metal

GPR signal which is plotted as a function of amplitude versus distance in meters as shown in Figure 6.



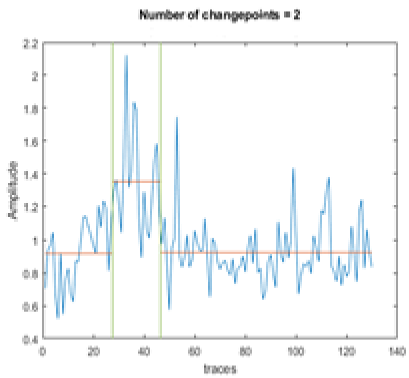


Figure.6 Processed GPR Signal **Figure.7 Metal target detected**

In figure 7, it is possible to detect the metal target because compare to other targets metalhas a high reflection. The target detected from Trace no 25 to Trace 45.

Length of the target is 0.2m(20traces * 009712dis interval = 0.2m)

So, the length of the target will be 0.2m.

The values of skewness, kurtosis and entropy for metal target are easily identified and calculated as shown in Table 2.

Table 2. Different mother wavelets (Target-Metal)

Wavelet	Skewness	entropy	kurtosis
Haar	1.1954	3.6525	5.3774
db2	**1.2128**	**4.3149**	**4.288**
Db3	1.3041	4.3869	4.7827
Sym2	1.2128	4.3149	4.288

Case 2 Target – Clean Data is no objects buried underground. The B- Scan image and GPR signal is as shown in Figure 8 and Figure 9.

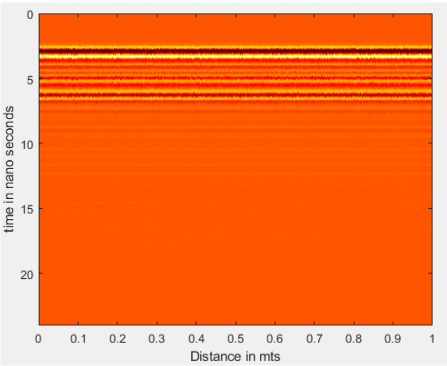


Figure.8 B-Scan of a buried metal

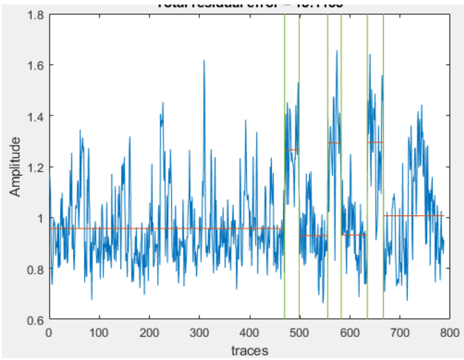


Figure.9 Clean data (nothing buried) detected

The values of clean ballast (data) which is nothing buried underground are tabulated in Table.3.

Table.3 Different mother wavelets (Target- Clean data)

Wavelet	Skewness	entropy	kurtosis
Haar	0.95185	4.2014	3.2331
db2	**1.0288**	**4.5288**	**3.5703**
Db3	1.0452	4.4998	3.3636
Sym2	1.0288	4.5288	3.5703

5. CONCLUSION

TheB- scan Image is represented by processing a raw GPR signal. Then the implementation of wavelet signal processing techniques to the B- scan image. Applied various mother wavelets like Haar, db2, db3 and sym2 for targets. Also calculated three statistical parameters like Skewness, Kurtosis and entropy are tabulated and analyzed. By the comparison, we can conclude that db2 perform better than other wavelets.

6. FUTURE SCOPE

Detection and identification of objects like metal, pipes, big rock etc. by using appropriate algorithm for better visual interpretation of GPR radargrams. Investigation of post processing methods suitable for target mapping.

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