

4B2-4

# Experimental Study of Feature Extraction from GPR Data for Landmine Discrimination

Takaaki Tanaka, Yusuke Kimura, <sup>#</sup>Masahiko Nishimoto, and Hikaru Kitajima

Graduate School of Science and Technology, Kumamoto University

2-39-1 Kurokami, Kumamoto 860-8555, Japan, nisimoto@cs.kumamoto-u.ac.jp

## 1. Introduction

Since many civilians are killed or injured by buried small anti-personnel (AP) landmines in the post-war countries every year, detection and clearance of buried small AP landmines is a very important issue. Ground Penetrating Radar (GPR) is a very promising sensor as it can detect plastic as well as low metal contents landmines. However, the GPR is not sufficiently reliable in detecting shallowly buried landmines because of the following two reasons: 1) extraction of return signal from the landmine is very difficult because returns from the landmines and that from ground surface overlap in time; 2) the GPR also receives returns from other subsurface objects such as rocks, tree roots, or metal fragments in the ground, which leads to high levels of false alarms. In order to reduce the false alarms, the development of reliable classification techniques that can accurately discriminate between landmines and other objects is needed [1]-[3]. We have proposed some features for AP landmine discrimination and have evaluated the performance through Monte Carlo simulations using data samples generated by a two-dimensional FDTD method [4][5]. However, because the simulations have been carried out under an ideal situation, experimental confirmation using measured GPR data is necessary. In this report we describe an experimental study of the feature extraction from measured GPR data in order to evaluate availability of the present features for landmine discrimination.

## 2. GPR Measurement System

Figure 1 shows the GPR measurement system used in our experiment. Using a vector network analyzer the return signals are measured at multi frequency points, and time domain data are obtained by applying a Fourier transform. The transmitting and receiving antenna system is constructed by using two Vivaldi antennas as shown in Fig. 2. As a landmine model, we use a plastic dummy of Type-72 AP blast mine with a rubber cap as shown in Fig. 3. This model has a bun-shape with the diameter of 7.8 cm and with the height 4.0 cm. Inside of the model, lower half part is filled with silica sand instead of TNT powder, and upper half part has the air gap. The small iron screw at the center of the model is a substitute for a firing pin. Figure 4 shows an incident pulse that has narrow width and sharp peaks. Parameters that determine the pulse width and bandwidth are selected so that the pulse has most of its energy in the frequency band between 0.5GHz to 5GHz. Although the shape of the late part of the incident pulse is deformed due to the frequency characteristics of the antenna system, sharp and narrow peaks can be clearly observed. Using this system, we measure the GPR data that includes the response from the buried dummy in a little damp sand. Figure 5 is the picture of the surface roughness. Peak-to-peak value of the uneven surface height is around 2 cm.

## 3. Feature Extraction from Measured Data

As mentioned Introduction, since the ground surface reflection is very strong compared to the response from the buried landmine and both the reflections are overlap in time, a data preprocessing of ground clutter removal from the raw GPR data is needed. In our approach, we first introduce a procedure for subtracting ground clutter using a least squares method [6] combined with

iterative extraction proposed in reference [7], and next enhance the target signature by ensemble averaging of the data measured at the multiple observation points. After this data preprocessing, we extract features from the resultant waveform. In references [5], we have proposed some features for landmine discrimination and have evaluated the performances through Monte Carlo simulations. According to the simulation results, the correlation  $\bar{C}^{\max}$  and time interval  $T_{12}$  defined below are good features for discriminating the AP landmine.

- (a) Normalized correlation  $\bar{C}^{\max}$  between the extracted target signal  $\bar{x}(t)$  and reference template  $\bar{s}(t)$  defined by the following equation. (This corresponds to a matched filter.)

$$\bar{C}^{\max} = \max_t \frac{1}{\|\bar{x}\| \|\bar{s}\|} \int \bar{s}(\tau-t) \bar{x}(\tau) d\tau \quad (1)$$

- (b) Time intervals  $T_{12}$  between two peaks defined by (see Fig. 6):

$$T_{12} = t_2 - t_1 \quad (2)$$

where  $t_1$  and  $t_2$  represent the times when two peaks appear.

Thus, we here concentrate on these two features.

Figure 7 shows the GPR signal that includes the target response together with the ground surface reflection. The target is located about 4 cm below the ground surface. In order to reduce the coupling effects between the Tx and Rx antennas, the response measured in free space with no targets is subtracted from the raw GPR signal. We can clearly observe from the result that the strong ground clutter and the target response overlap in time. By applying the signal preprocessing technique mentioned before, a desired target response can be extracted. Figures 8 and 9 show the target responses after once and three times extraction of the ground clutter, respectively. For comparison, the target template that is the response of the same target located under *flat* ground surface is also plotted in broken line. We can confirm that the preprocessed GPR signal agrees well with the target template after three times clutter extraction. In this experiment, the extracted features are  $\bar{C}^{\max} = 0.83$  and  $T_{12} = 0.186[\text{ns}]$  ( $0.217[\text{ns}]$  for the template), respectively. The value 0.83 seems to be a little worse than the mean value of  $\bar{C}^{\max}$  estimated by our numerical simulation. It is considered that this degradingness is due to the fact that the waveform of the incident pulse is not an ideal monocycle pulse as we used in the numerical simulation. This indicates that the waveform of the incident pulse is important for feature extraction.

## 4. Conclusions

We have extracted two features for landmine discrimination from measured GPR data and have discussed the result. By applying the data pre-processing, the effect of ground clutter has been successfully reduced, however, the extracted feature seems to be a little worse than that estimated by the numerical simulation due to the deformation of the pulse waveform. Since, however, the experimental data is still insufficient and the investigation is still in progress, the present report should be regarded as only preliminary. Further investigation using various kinds of experimental data samples should be required.

## Acknowledgments

This work was supported in part by a Grant-In-Aid for Scientific Research ((C)18560340, 2006) from the Japan Society for the Promotion of Science.

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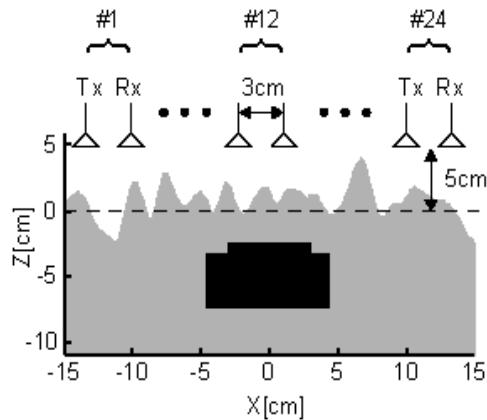


Figure1: GPR system for landmine discrimination.



Figure2: Transmitting and receiving antennas (Vivaldi type).



(a) Dummy of Type-72



(b) Component parts

Figure3: Plastic dummy of Type-72 AP landmine with rubber cap used for experiments.

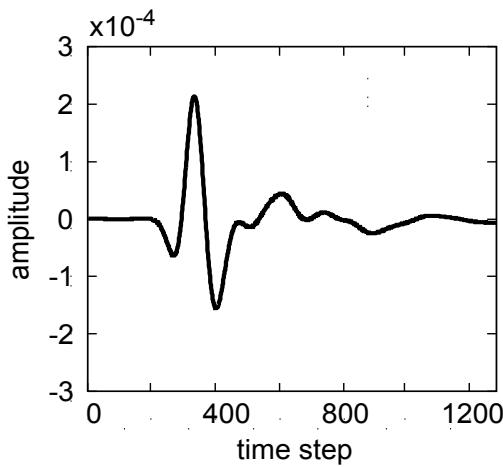


Figure 4: Incident pulse used for experiments.



Figure 5: Surface of the bed.

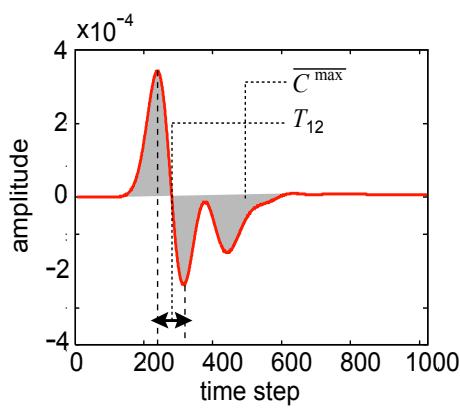


Figure 6: Schematic of the features.

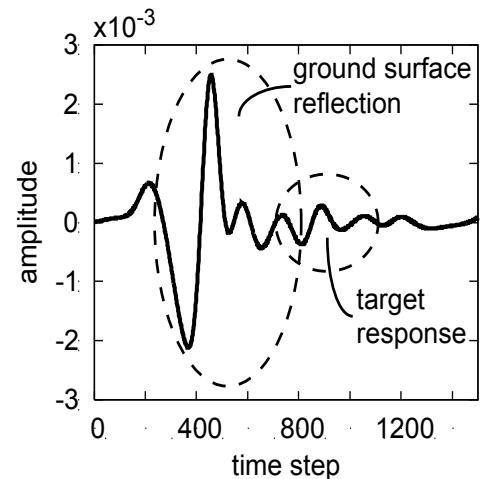


Figure 7: Measured GPR data sample.

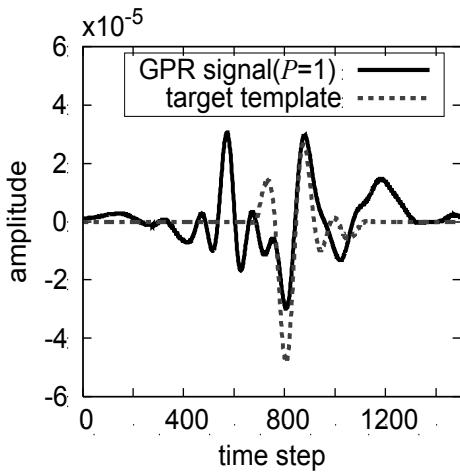


Figure 8: Target response after only once ground clutter extraction.

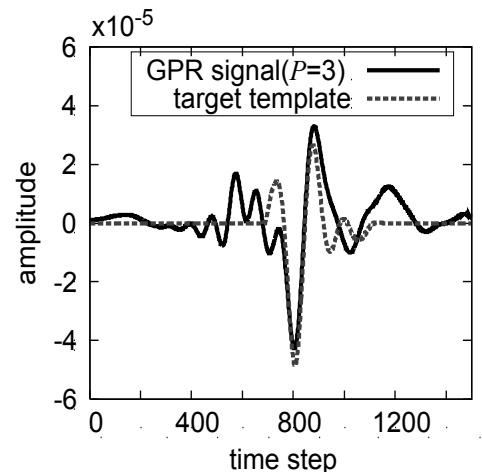


Figure 9: Target response after three times ground clutter extraction.