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The SIMCA algorithm for processing Ground Penetrating Radar data and its use in landmine detection.

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Introduction

• Landmines and improvised explosive devices (IEDs) pose a serious threat to civilians in many countries.
• Ottawa Treaty stipulates countries have to clear the landmine stockpiles.
• Unfortunate death of UK military personnel in Afghanistan and Iraq. Most of the casualties have been caused by IEDs.

Landmine statistics:

• 85 to 90 million landmines currently scattered in 62 countries [1].
• In 2009, there were 7,288 attacks in 62 countries [1].
• 94% of the landmines were caused by IEDs [2].

This volumetric potential can then be used to determine the location and size of the target.

Results 2D

• The Pearson’s correlation coefficient between two variables is used which is defined as the covariance of the two variables divided by the product of their standard deviations:

\[ r_{XY} = \frac{\sum(x-x\bar{X})(y-y\bar{Y})}{\sqrt{\sum(x-x\bar{X})^2 \sum(y-y\bar{Y})^2}} \]

• As a contrast enhancing phase the correlation matrix or convolution (4) is used to demonstrate this technique for differences in gain and black level. The image is the result of the convolution between the ground and the antenna. The threshold is the area of the image being matched.

Method of study

• Ground Penetrating Radar (GPR) is non-destructive geophysical technique that uses radio waves to probe the “ground.”
• Transmitter and receiver is a fixed geometry are moved over the surface to detect the reflections from landmines.
• Computer image processing techniques on GPR data can be used to detect the location of landmines.
• GPR images are typically hard to interpret being full of artifacts produced by the imaging modality. GPR images contain artifacts because of the interference caused by interactions between the ground and the antenna, soil reflections, maps antenna effects from the GPR signal and clutter.
• As a result the images contain a lot of curved lines and are difficult to interpret.
• Current techniques do not successfully remove the artifacts and this calls for a technique which is able to help the deminer to predict the location of the landmine more accurately.

SIMCA continued

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Results 2D continued

• The optimum threshold level for each method was calculated by firstly selecting one of the landmines in each case to be the training set. For this training set the threshold was varied using a binary search approach and the volumetric error calculated using:

\[ \text{Volumetric Error} = \left( \frac{1}{n} \sum_{i=1}^{n} \left( v_i - t_i \right)^2 \right)^{1/2} \]

where \( v \) is the volume of the landmine found at that threshold using the PARAVIA software and \( t \) is the true volume of the actual landmine.

• Using the optimised threshold for each case the reconstruction of the volumes of real targets after scanning by a GPR was carried out.

Novelty of SIMCA algorithm

• Use of Correlation, use of the systems aspects of the radar and the soil properties and raising the brightness to an odd power >2.
• In imaging processing, area correlation can give sub-pixel accuracy in locating the source of target [3].
• Faster than existing techniques and better results in terms of locating landmines.

SIMCA algorithm

• SIMCA (SIMulated Correlation Algorithm) is a technique based on an area correlation between the trace that would be returned by an ideal point reflector in the soil conditions at the site and the actual trace.

• Trace that would be generated by the ideal point reflector is generated using GPRMAX2D v1.5, an electromagnetic simulator for GPR which is used to simulate the GPR reflection from landmines.

Conclusion

• SIMCA algorithm is therefore a novel method of helping the demining personnel in predicting the location of landmines with acceptable degrees of accuracy.
• SIMCA outperforms correlation for the landmine data.
• SIMCA algorithm will help reduce the number of deaths and also enable more of the land to be put to good use.

Table 1. Graph for conventional Convolution

<table>
<thead>
<tr>
<th>Method</th>
<th>Volume of Plastic (cm³)</th>
<th>Volume of Plastic (cm³)</th>
<th>Volume of Metallic (cm³)</th>
<th>Processing time (s)</th>
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<td>Ground truth</td>
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<td>500</td>
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<td>-</td>
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<td>491</td>
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<td>24.0%</td>
<td>17.0%</td>
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References