Data Analysis and Performance Evaluation of Japanese Dual-sensor Systems Tested in Croatia

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Data Analysis and Performance Evaluation of Japanese Dual-sensor Systems Tested in Croatia

Two years ago, the Croatian Mine Action Center—Center for Testing Development and Training Ltd. tested two Japanese dual-sensor systems for humanitarian demining in Croatia. The test’s results show that these detection systems can potentially increase the accuracy of mine-detecting operations, but several improvements to the sensors may be required before the systems are fully effective.


In October 2007, the Croatian Mine Action Center—Center for Testing Development and Training Ltd. (HCR-CTRO), with assistance from the German Federal Institute for Materials Research and Testing (BAM), tested two sensor systems: the Advanced Landmine Imaging System, developed by Tohoku University, Japan, and the Gryphon, developed by Tokyo Institute for Technology, Japan. Both systems employ commercial metal detectors (the ALIS with CEIA MIL-D1 and the Gryphon with Minelab F3) and ground-penetrating radar. The metal detector only indicates the presence of metal; it cannot determine if the metal is a mine. The GPR indicates objects with a shape that could resemble a mine. The operator of the system decides whether to reject the metal clutter. Together, the systems improve the productivity of demining operations.1,2,3 This article discusses the test’s results, the systems’ performances and the data analysis.

Test Conditions

The complete report, detailing the conditions, procedures and results of the two dual-sensor systems is available online. 4 The test was carried out at the Benkovac test site in Croatia where previous metal-detector trials have taken place, such as the Systematic Test and Evaluation of Metal Detector (STEMD) trial.5 Three soils are available at this site: red bauxite (Lane 1), neutral clay (Lane 3), and red bauxite with neutral stones (Lane 5, local soil), as shown in the figures on the next page.6,7

Blind tests were conducted in these lanes with real, rendered-safe mines (11 were PMA-2 and nine were PMA-3 mines) and metal clutter. The target layout was the same as that in the International Test and Evaluation Program for Humanitarian Demining STEMD trial with additional small pieces of various metals (nine per lane) placed on the ground surface. Thus, each lane comprised a total of 38 buried targets.

Table 1: Differences in categorization of sources of alarms for stand-alone metal detectors and dual sensors.

<table>
<thead>
<tr>
<th>Metal detector scan</th>
<th>Place a red marker</th>
<th>GPR scan</th>
<th>Place a yellow marker</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>1</em> The metal-detector scan in ALIS is performed in the conventional manner (i.e., manual scan with sound alert), while the metal detector on Gryphon is scanned by the robot arm and the detection is according to visual interpretations of the metal-detector image.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>2</em> Scans of the GPR in ALIS are performed for each metal-detector alarm. Gryphon scans both sensors for an area approx. 1 x 2m at once and interpretations are done for each scanned area, i.e., Gryphon scans all the area with both sensors.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 1: Operation procedure of the dual-sensor systems.

Lane 1: red bauxite.
Lane 3: neutral clay.
Lane 5: red bauxite with neutral stones.
Three deminers from the Croatian Mine Action Center served as operators of the ALIS; the developer had trained them together 10 weeks prior to the test. In the test, each deminer went through each of the three lanes once. The developer’s team of five to six persons operated the Gryphon.

Both dual-sensor systems employ a metal detector as a primary sensor and a GPR as a secondary sensor; the metal detector first detects all the metal objects, and then the GPR identifies objects suspected to be landmines. In the test, red markers indicated positions of objects detected by the metal detector and yellow markers indicated positions of objects confirmed as landmines by the GPR, so that those detections could be classified later. The operation procedure is schematically illustrated in Figure 1 on the previous page.

After each run, all the markers’ positions were measured and compared to the real positions of mines measured when they were planted. A circular area around a target, called a halo, is defined according to CWA 14747-1:2003. A marker is considered a hit (true positive) if it falls into the area, and a marker is counted as a false alarm (false positive) if it is placed outside the area. A target with no markers in its halo is counted as a miss (false negative).

Data Analysis

Probability of detection has been commonly used to evaluate performance of metal detectors. Since the dual sensors employ two kinds of detection, two kinds of POD can be defined. The POD for a metal detector is defined as:

\[
\text{POD}_{\text{MD}} = \frac{\text{X}_{\text{GPR}} + \text{X}_{\text{MD}}}{} \]

where \(\text{X}_{\text{MD}}\) and \(\text{X}_{\text{GPR}}\) are alarm numbers caused by metal and soil, reported by the metal detector and the GPR, respectively.

The POD for a GPR is defined as:

\[
\text{POD}_{\text{GPR}} = \frac{\text{X}_{\text{GPR}}}{\text{X}_{\text{GPR}} + \text{X}_{\text{MD}}} \]

where \(\text{X}_{\text{GPR}}\) is number of mines correctly confirmed after the use of the metal detector and the GPR. Metal-detector alarms not caused by mines and GPR alarms incorrectly confirmed as mines are considered.

Results

Although performance of metal detectors and GPRs can be quite different in various types of soil, the results in the three lanes are analyzed together in this article to show the overview. An analysis of each soil can be found in the trial report. The ALIS operator whose results differed greatly from the others had his results excluded as an outlier.

Figure 2 (see page 68) shows the receiver-operating-characteristic diagram in which probability of detections are plotted against false-alarm ratios and the 95% confidence limits. Each device has two plots, one from using only the metal detector (primary sensor) and one from using both sensors (metal detector and GPR). It can be observed that the FARs by metal detectors (squares) are shifted toward the left by using GPRs (circles), meaning that FARs are reduced significantly. However, at the same time, reductions of PODs also occur for both devices, which should not happen for safety reasons.

Although levels of POD and FAR are basically given by the metal detectors, which are commercial ones in both systems. The reductions of PODs also occur for both devices, which should not happen for safety reasons.

The ALIS dual-sensor system evaluated in the test.


so significant considering the 95% confidence limit, but devices for demining must avoid the POD reduction as much as possible. The results suggest that the Gryphon can reduce FAR more than the ALSs. However, the absolute level of FARs is almost the same as shown in Figure 2 (see page 68) and the larger FAR reduction is due to a large number of false alarms given by the metal detector implemented in the Gryphon. Therefore, performances of the whole system need to be considered. The FAR of Fk can be characterized as almost the same.

Figure 4 (see page 69) shows probability of detections given by the metal detector and by both sensors, along with the discrimination rate with respect to depth for each device. As the theory in the Das and McFee article12 states and former tests verified, the PODs given by the metal detectors are decreasing with depth. Since the GPRs are always used after the metal detectors, the PODs used by the dual sensors cannot exceed those by the metal detectors. It can be observed that the PODs by both sensors positively correlate with the PODs by the metal detectors. Furthermore, discrimination rates tend to increase with depth in these results. This fact cannot be determined conclusively because the number of mines belonging to each depth class is small and other factors are not included. The PODs and the theory cannot clearly be confirmed. This fact may be because both sensors measured data of GPR as images in terms of horizontal slice reflections from the ground surface mask the ground surface since the sensors measured the whole ground surface. It is not clear whether both sensors yielded the same result because the PODs with the metal detectors were positive for metal detectors.

Conclusions and Discussion

The results of the test campaign for the dual-sensor systems tell us that these systems reduced false-alarm rates significantly more than one-half. However, the systems also reduced probability of detections, which must be avoided in real clearance operations. Usefulness of the dual sensors may strongly depend on improvements with POD. The full report3 stated that the three deminers who worked on the ALSs achieved different results in terms of POD, FAR and working hours. The variation may be caused by the way the deminers interpret the output of the sensor and make decisions when operating the ALS. The visual interpretation of images and decision-making process are easily subject to the operators themselves. In order to avoid unstable and/or unexpected results, further developments/improvements, such as an automatic-recognition algorithm, are recommended.

Unfortunately, it was not possible to use stand-alone metal detectors at the same time as a benchmark, making a direct comparison of dual-sensor systems to stand-alone metal detectors unanswerable. However, one can roughly compare the detectors to those from the STEAD trial, taking into account additional metals. The ALS and the Gryphon needed approximately five and nine minutes, respectively, to survey one square meter. It can be roughly estimated that the ALS may be too three times slower and the Gryphon may be four to five times slower than stand-alone metal detectors.24 Even if the search speed in this test is slower than for a stand-alone metal detector, it is possible that these dual sensors would accelerate the clearance operation in total, because rejected alarms from metals would reduce the need for excavation or could be rapidly excavated. Increased search speed would also multiply these benefits. Another dual-standalone sensor trial in Germany was carried out in September 2009 by the International Test and Evaluation Program for Humanitarian Demining and led by the German Federal Office of Defense Technology and Procurement.25 The results are being analysed and we hope that a more detailed evaluation of dual-sensor performance will be available soon.

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Figure 1: Testing platform and positioning rig. (i) BLUSPRING Source of EOD Company

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The authors acknowledge Mr. N. Penković and Mr. T. V. R. Vendrusc, from HCR-CTRA, for managing the test. We also thank the developers and demonstrers that participated.

See Endnotes. Page 79

13.1 fall 2009 | the journal of ERW and mine action | research and development

Blast Testing of Visors Used for Humanitarian Demining

This article discusses experimental results from blast testing of Security Devices Ltd., polycarbonate visors used by humanitarian deminers. Visors used in the blast testing fell into one of three categories: new visors, manually scratched visors, and scratched and heat-gun-repaired visors. Results show that the visors in all three categories failed to meet the draft international standard for blast testing relevant at the time, that further research is required to establish pressure profiles for the standard charge size being tested, and that the proposed heat treatment method does appear to decrease the blast resistance of the visor used in the test.2

In 2007, the Director of the Canadian Centre for Mine Action Technologies received a request to investigate a potentially promising heat-treatment process to extend the operational life of humanitarian-deminer visors through removal of scratches from the field of view. The heat-treatment procedure was developed by undergraduate students as part of a product-design course and was published in The Journal of Mine Action.1 The author of that article noted that further testing would be required to determine whether the visor properties were adversely affected by the scratch-epoxy procedure. In order to allow for an independent assessment of the technique, the authors provided a detailed outline of the procedures in the article that readers could follow independently.

Trial Objectives and Methodology

The objective of this research was to assess the blast and ballistic performance of a visor visors before and after heat treatment. To ensure compatibility with the original student project, the same type of visors were obtained from Security Derries Ltd.