ITEP dual sensor test in Germany

Kazunori Takahashi[1] **and Dieter Guelle**[2]

Abstract

An ITEP test campaign of landmine detection sensors has taken place in September-October 2009 in Germany, led by the Federal Office of Defence Technology and Procurement (BWB), Germany. The main objective of the test is the performance evaluation of dual sensors (DS) which combine metal detector (MD) and ground-penetrating radar (GPR) for identifying detected objects. In addition stand-alone metal detectors, stand-alone metal detectors with discrimination capability and stand-alone GPR have also been tested for comparison. The result clearly shows that the tested dual sensors is capable of discriminating metal clutter and landmines, which is expected to contribute to the efficiency improvement of clearance operations. However, at the same time, some issues that may need to be overcome for the use in humanitarian demining have been arisen.

1. Introduction

A dual sensor test has taken place in September-October 2009 in Oberjettenberg, Germany. The test campaign is a part of an ITEP project [1][2] and has been led by the Federal Office of Defence Technology and Procurement (BWB), Germany. In the test as well as in this paper dual sensor refers to a device which integrates metal detector and ground-penetrating radar (GPR) for detection of metal-containing objects and identification of landmines, respectively. The Advanced Landmine Imaging System (ALIS) developed by Tohoku University, Japan participated in the test. The details of the detector can be found in [3], as well as at manufacturer's website [4]. For the comparison the base metal detector of the dual sensor (CEIA MIL-D1) and stand-alone GPR (ERA SPR-scan 2 GHz) have also been tested. The paper shows the overview of the test results and discusses the performance of the detectors. The detailed description of the test, results and interpretation will be found in the test report [5].

2. Test conditions

There are lanes with three types of soil prepared in the test site. These test soils can be categorised into: laterite, sand mixed with magnetite and humus soil. The detailed descriptions of the soils as well as the properties can be found in the report "Physical characterisation of the test lanes in the ITEP dual sensor test Oberjettenberg/Germany 2009" [6]. Three types of mine-like targets including rendered safe mines were planted in these soils: ERA Calibration Target, Gyata-64 and PPM-2. In addition various sizes of metal pieces such as bullets and cartridges were buried as metal clutter. The test objects are shown in Fig. 1. The burial depths are ranging from 2 to 15 cm.

The test was a blind test; the operators of detectors did not know the locations and types of objects. The dual sensor operators first used the metal detector part of a dual sensor for detecting a mine suspected objects, and then switched over to GPR for discriminating mines from metals. To indicate the locations of a metal detection and types of object (mine or mine-like) after the search with dual sensors two colours of markers were used. After each test run positions of markers were measured.

[1] Leibniz Institute for Applied Geophysics, Stilleweg 2, 30655 Hannover, Germany, kazunori.takahashi@liag-hannover.de
[2] Consultant, Federal Office of Defence Technology and Procurement, Germany, dieter.guelle@xyz.de

Fig. 1. Objects used in the test. ©BWB

3. Data analysis

Positions of detections as well as discrimination results whether a detected object is mine or metal are compared to the test plan, applying the halo radius defined in CWA 14747-1:2003 [7]. For evaluation of detection performance alarms from metals and soil should be treated as false alarms in case of dual sensor test, whereas only soil is used to be considered source of false alarms in formally conducted stand-alone metal detector tests. The difference is listed in Table I.

Detection performance can be evaluated probability of detection (POD) and false alarm rate (FAR), which indicate how much targets are found and how much false alarms are produced in one square metre, respectively. These values are obtained as follows.

$$POD = \frac{Number\ of\ detected\ targets}{Number\ of\ buried\ targets} \quad (1)$$

$$FAR = \frac{Number\ of\ false\ alarms}{Area\ searched} \quad (2)$$

For the evaluation of discrimination performance two more values are introduced. One is FAR reduction which indicates how much false alarms reported by the metal detector part of a dual sensor are correctly identified and reduced by using the GPR part of a dual sensor, and the other is POD loss which tells how much mines are falsely identified and rejected. They are defined as [8]

$$FAR\ reduction = \frac{Number\ of\ rejected\ false\ alarms\ by\ GPR}{Number\ of\ false\ alarms\ by\ MD} \quad (3)$$

$$POD\ loss = \frac{Number\ of\ rejected\ targets\ by\ GPR}{Number\ of\ detected\ targets\ by\ MD} \quad (4)$$

By the definitions the higher FAR reduction and the lower POD loss indicate the better discrimination performance.

TABLE I. Difference of categorising sources of alarms for stand-alone MDs and dual sensors.

	Stand-alone MDs	Dual sensors
Sources of true positives	Mine-like targets, metals	Mine-like targets
Sources of false positives	Soil	Metals, soil

4. Test results

Fig. 2 shows POD plotted as a function of FAR for ALIS in total. The result of one dual sensor has two plots. The dot indicates *detection* result after using the metal detector part and before using the GPR part of the dual sensors, while the circle shows result after the *discrimination* using the GPR part of the dual sensor. It can clearly be seen that the plot moves towards left after using GPR, meaning that FAR is reduced. However, at the same time, the plot moves slightly downwards, meaning that some mines are falsely rejected as clutter, which is supposed not to happen for safety. How much false alarms are successfully reduced and how much mines are falsely rejected are depicted in Fig. 3 in which FAR reduction is plotted as a function of POD loss. In this figure the stand-alone GPR achieved behind the marking of different metal detectors a much higher FAR reduction than ALIS; however the stand-alone GPR has a higher POD loss, about 10% of the found mines from the different metal detectors. Thus, there is a trade-off that a higher FAR reduction can be obtained with a higher POD loss and a lower POD loss causes a lower FAR reduction. It can also be observed that when a straight line is drawn from the origin of the figure, all points are more or less on the line. The fact indicates that the discrimination capabilities of these detectors are almost equal, but the results look different because operators may be applying decision-making criteria differently. For example, a deminer who wants to maximise FAR reduction may achieve a higher POD loss, and another deminer who wants to keep POD loss low may obtain a low level of FAR reduction even using the same detector. Results of the manufacturer showed a very low POD loss but also a low FAR reduction (the result is not shown in the figure), despite the fact that the manufacturer achieved already a lower level (about 1.8 m^{-2}) of FAR with the metal detector. The reason may be that the experts operated minimising POD loss because they know it has to be avoided and they know how to do so. The fact tells us that the longer working experience and more knowledge on a dual sensor use improve the performance.

Fig. 4 shows discrimination performances as a function of depth. In the figures FAR reduction is increasing and POD loss is decreasing with depth, though the tendency is weak. The results indicate that the discrimination performance by GPR is worse at shallow depth and is better in depth. It can be explained as follows: rough ground surface may create additional response on GPR which is falsely recognised as target, resulting in less FAR reduction and GPR signals reflected from the ground surface disturbs reflection from targets which makes difficult to correctly recognise mines, resulting in high POD loss. The performance of ALIS depending on depth seems to be more robust than that of the stand-alone GPR. One of the reasons may be its sophisticated signal processing and way of interpretation.

The tested dual sensor, which combines metal detector and GPR is supposed to be used as follows: detection of metal-containing object with metal detector part of dual sensor and then discrimination of this object with GPR part of the detector. The detection performance entirely depends on the performance of the metal detector part and it has to be as good as the stand-alone metal detector. In order to ensure that GPR does not negatively influence on the metal detector part, the detection performance of a dual sensor is compared to that of a stand-alone metal detector which is the base model of the dual sensor. The results are shown in Fig. 5. The detection performances of the base metal detector (CEIA MIL-D1, cross) and ALIS (dot) are very close and no obvious difference can be observed. It indicates that there is no obvious deterioration of metal detector performance due to combining GPR antennas and the metal detector part of the dual sensor is as good as the stand-alone metal detector.

It is not possible to discuss on efficiency improvements of the entire clearance operation based on the test, where only detection (as well as discrimination) was performed but excavation and conformation of detected objects were not included. However, to have an idea, search speeds of detectors are evaluated. In Fig. 6 search speeds are plotted in minutes per one square metre. As one can see, ALIS needed almost doubled time of stand-alone metal detectors needed to search, in other words, ALIS is two times slower than stand-alone metal detectors. The results allow us to roughly estimate that, assuming that ALIS can reduce one-half of false alarms as shown in Fig. 3, the clearance operation in total is expected to be accelerated when the excavation process for an object needs more than twice the time necessary for finding an object, which is not unrealistic.

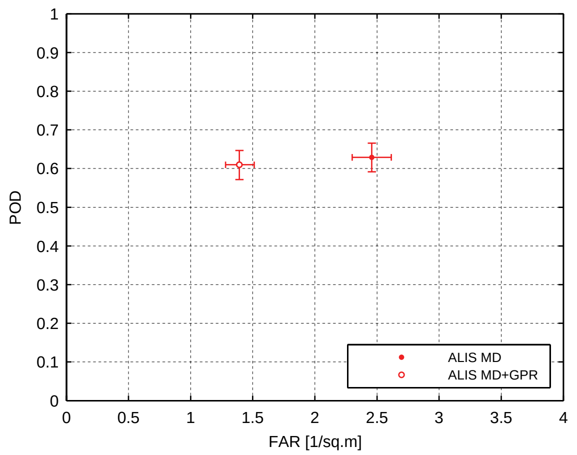


Fig. 2. POD versus FAR of ALIS in total of all runs. The dot and circle indicate before and after the discrimination, respectively, and the error bars show 95 % confidence bounds.

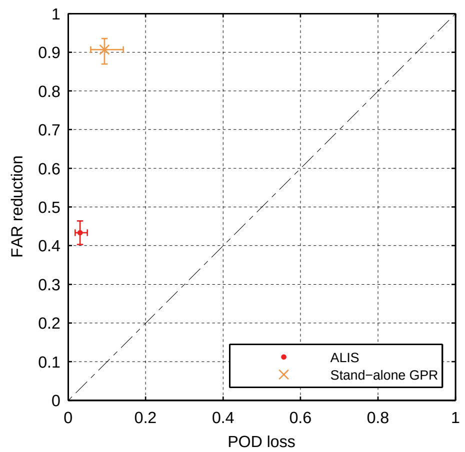
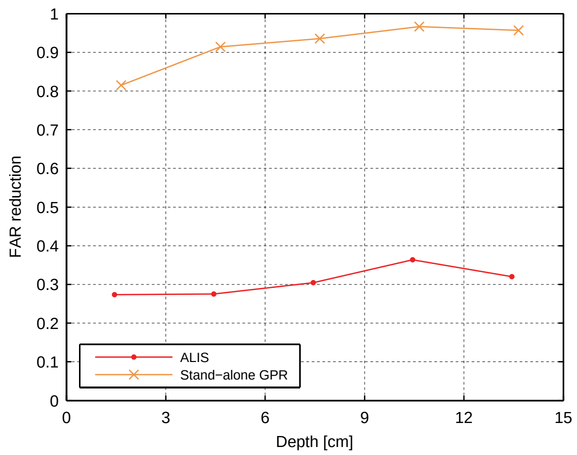
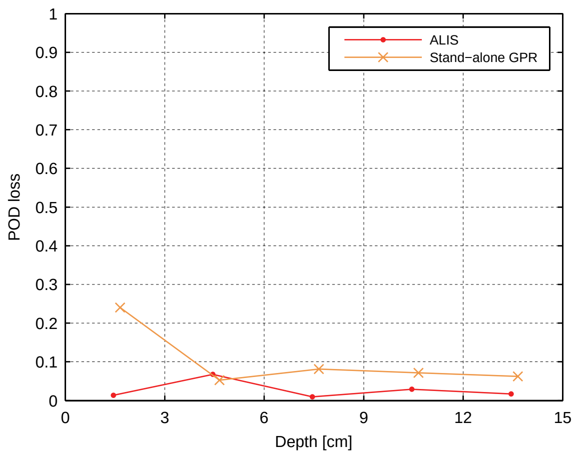


Fig. 3. FAR reduction versus POD loss due to the discrimination process in total of all runs. The error bars show 95 % confidence bounds.



(a)



(b)

Fig. 4. Discrimination performance depending on depth. (a) FAR reduction and (b) POD loss.

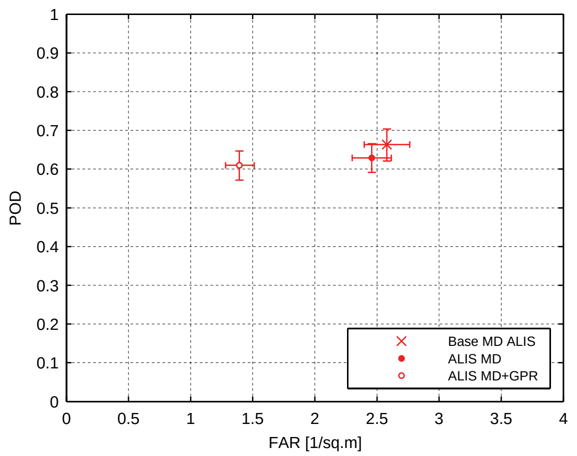


Fig. 5. POD versus FAR of ALIS in comparison to the base metal detector (CEIA MIL-D1).

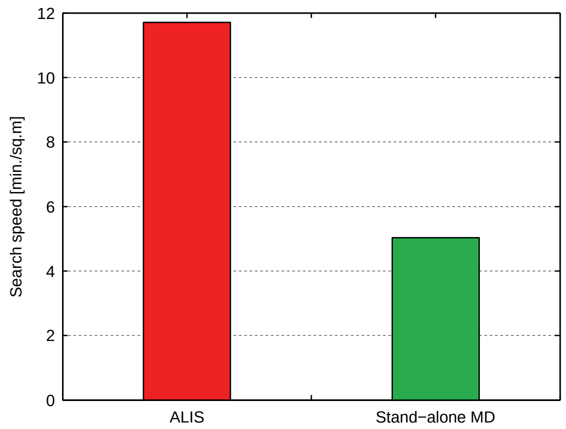


Fig. 6. Search speeds of ALIS and stand-alone metal detectors.

5. Conclusions and discussions

By analysing the results of the dual sensor test, it is clearly confirmed that dual sensor can reduce false alarms compared to stand-alone metal detector, which potentially indicates the efficiency improvements of clearance operations in total. However, there are a few issues that need to be considered, such as POD loss, search speed and training, for maximising benefits and minimising shortcomings of dual sensors. It can be observed that dual sensors can correctly reject false alarms but also it sometimes falsely rejects mines. It seems to be happening especially at shallow depth and it is also related to soil type [9]. The false rejection of mines (POD loss) can be avoided by selecting favourable soil types for dual sensors by investigating soil properties, for example. The search speed is directly related to the efficiency improvements of clearance operations and the higher search speed the more improvements can be expected. The test results show a dual sensor is twice slower than stand-alone metal detectors. However, operators for a dual sensor who have longer experience and more knowledge on the detector needed as much as time for the stand-alone metal detectors and in this case the improvements are more likely achieved. As mentioned, experienced operators of dual sensors obtained much better results in discrimination performance as well as in search speed. The fact indicates more training and/or practice is necessary for the use of dual sensors, compared to metal detectors. In the test operators trained for a short period could not act as same as experienced operators.

The dual sensor test allows us to evaluate detection as well as discrimination performances of dual sensors in a blind test. For investigation of the efficiency improvements of clearance operations in total, there are other factors need to be taken into account, such as the time for excavation, cost of detectors and cost for training and practice.

6. References

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