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ALIS Evaluation Tests in Croatia and Cambodia

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Abstract *- Tohoku University, Japan is developing a new hand-held land mine detection dual-sensor (ALIS) which is equipped with a metal detector and a GPR. ALIS is equipped with a sensor tracking system, which can record the GPR and Metal detector signal with its location. The Migration processing drastically increases the quality of the imaging of the buried objects. Evaluation tests of ALIS have been conducted in several mine affected courtiers. Tests in real mine fields in Croatia has been conducted between December 2007 and April 2008 in collaboration with CROMAC. Under different soil and environment conditions, ALIS worked well in QC (Quality Control) stage of mine clearance operations. Then ALIS evaluation test started in Cambodia in February 2009 with CMAC. We could find discrimination capability of ALIS by using GPR in test lanes, and we are planning to start evaluation test in real mine fields in Cambodia in April 2009. Through these evaluation tests in real mine fields, we will gain more experience for improvement of the system, and plan to optimize the SOP for ALIS. In 2009, ALIS will be tested in two international evaluation tests, namely Defuse to be held in Denmark and ITEP test to be held in Germany in 2009.*

Keywords *– GPR, Humanitarian Demining, Dual Sensor, ALIS, Sensor Tracking System, Croatia.*

I. INTRODUCTION

It is expected that more than 100,000,000 landmines are still remaining buried in over 60 countries. Humanitarian demining is a very important and urgent issue not only in mine affected courtiers, but all over the world. Metal detectors, which is a Electro Motive Induction sensor, has been widely used for humanitarian demining, However, in order to improve the efficiency of the demining operation, identification of buried landmines and discrimination fro metal fragments by Ground Penetration Radar (GPR) is believed to be useful. Although there has been some approached to use unmanned vehicles for sensor scanning in mine fields, most of the mine fields are very small and hand-held sensors are more effective.

Due to very strong clutter from the ground surface and inhomogeneous soil to GPR, combined use of GPR with metal detector is more common approach, and this kind of sensor is called "Dual sensor" for humanitarian demining. A few dual sensor systems are now available for humanitarian demining in commercial basis. We have been developing a dual sensor system, namely, Advanced Landmine Imaging System (ALIS) since 2002. The unique feature of ALIS is in its novel technique of tracking the sensor position, even though it is scanned by hand by deminers. Then, ALIS can provide 3-D GPR image and it will help to understand the subsurface conditions much better than the conventional audio signal. It leads to the higher efficiency of detection of buried landmines.

Figure 1. ALIS in operation in Croatia.

The performance and characteristics of dual sensors are quite different from conventional metal detectors. Therefore, new procedures for dual sensors must be established. CEN working group is now working for a document of soil evaluation for dual sensor, and ITEP is now planning evaluation tests of dual sensors. In this paper, we introduce the latest status of ALIS development and its evaluation in Croatia.

II. ALIS SYSTEM

Since 2002, ALIS has been developed and the current system has a few variations dependent on its applications. ALIS can select one from two different GPR systems, namely a stepped-frequency radar by using a VNA (Vector Network Analyzer) and an impulse GPR. The two systems use the same sensor tracking system and a sensor head.

2.1 GPR System

A compact hand-held VNA was developed by Tohoku University under the support from Japanese Science and Technology Agency (JST). The developed VNA is small, approximately 30×20×8 cm, and light weight, less than 1.7 kg, but it has almost the same performance as the conventional commercial VNA

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especially for the sweep speed and the measurement accuracy. VNA is a combination of a synthesizer and the synchronized receiver. It is controlled by a CPU and can store the measured data in its memory. The operation frequency of the GPR system can be adjusted depending on the soil condition by using a VNA, which is not easy for an impulse radar system. The calibration data can be stored in the memory of the VNA, and the output data can be calibrated by using this stored data. This calibration function is useful for better antenna impedance matching, and can improve the radar data quality, because it suppresses the reflection from the antenna.

On the other hand, an alternative type of ALIS, namely ALIS-PG is operated by using an impulse GPR system. This impulse GPR system was also developed in the JST project, and can generate a short pulse having approximately 200ps which covers the frequency ranging from DC to a few GHz. Compared to the VNA system, the impulse duration is fixed, and we cannot change the operation frequency dependent on the soil condition. The important advantages of using an impulse GPR system are its light weight and fast data acquisition rate.

We think, if we operate ALIS-PG in normal conditions, since the impulse GPR system is easier to operate, but if we need to use ALIS in very wet soil condition, ALIS with a VNA GPR is strongly recommended.

ALIS uses cavity back spiral antennas for transmitter and receiver. The antennas are combined with a coil sensor for a metal detector. The location of the coil and antennas were optimized to avoid the interferences. The metal detector is a differential type sensor, therefore it is insensitive to metal objects which are symmetrically placed near the metal detector coil. Electromagnetic wave is transmitted through the coil, and it has some influences, but we founds that the reflection from fixed objects can be suppressed by signal processing.

2.2 Sensor Tracking System

The most unique feature of ALIS is its sensor tracking function. During the operation, the sensor operator can observe the metal detector response image together with a picture of the ground surface displayed on the palmtop PC in real-time as shown in Fig.1. Thus, the area, which shows a high metal detector response, can be scanned thoroughly.

Signal processing and imaging of GPR data is quite common in GPR survey, however, it was not possible in conventional hand-held GPR and dual sensors for humanitarian demining, because the position of the sensor could not be obtained by a hand-held sensor. For imaging of GPR data, the sensor position information is necessary. Since the trajectory of the sensor is unpredictable in a handheld system, therefore images cannot be constructed without sensor tracking.

ALIS uses a CCD camera fixed on the handle of the sensor head for the sensor tracking. The CCD camera captures images of the ground surface, and the relative movement on the ground surface is calculated by cross-correlation algorithm, and the sensor position can be tracked. Fig.2 shows an example of the tracked sensor position. The dots indicate the positions, where ALIS acquired the data of GPR, metal detector and the sensor position.

This sensor tracking function has significant advantages as follows:

(1) The handheld scanning operation can be visualized, which improves the reliability of detection by a deminer.
(2) A deminer can monitor the locus of scanning, and can avoid the scanning blank area.
(3) The record of the locus of the scanning by the deminer can be recorded and it can be monitored in real time, and can also be checked afterward. This record can be used for quality control of the demining. In addition, it can be used for training of deminers, and can be used also for the determination of the cause of mistake, in the case of accident.

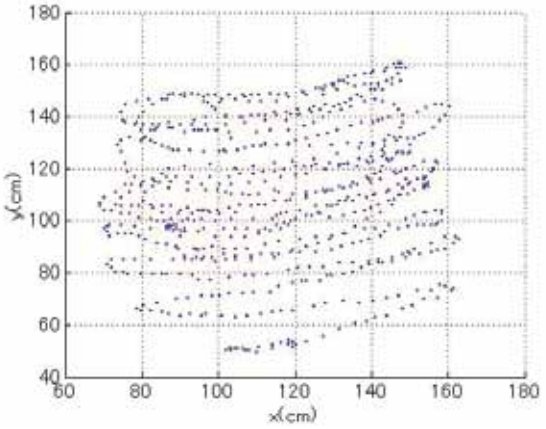


Figure 2. The locus of the sensor trace and the data sampling points.

2.3 Image Reconstruction

The GPR data acquired with the sensor position information is processed after the scanning the ALIS sensor over the area of about 1m by 1m. At first, all the acquired data set was relocated on a regular grid points. Interpolation algorithm is used for this process. After the relocation of the data sets, metal detector signal can directly be displayed in a horizontal image as shown in Fig.3.

3-D GPR image is reconstructed by the diffraction stack migration algorithm. In this signal processing, the vertical inhomogeneity of the soil is considered.

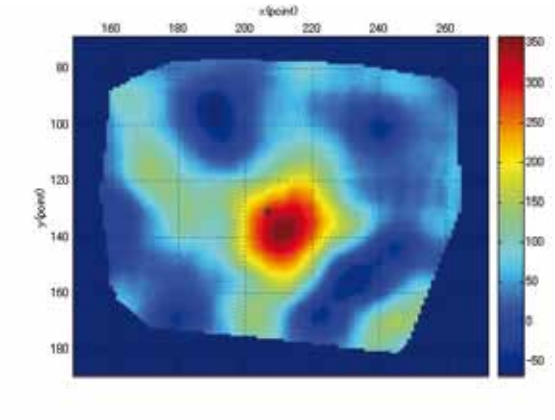


Figure 3. ALIS GPR image acquired at CDS test site (Afghanistan, 2004).

The migrated GPR data gives 3-D reconstructed subsurface image. However, we normally use only horizontal slice image (C-scan) as shown in Fig.3 for data interpretation. However, we think 3D image gives too much information to deminers for judgment, and we normally use a horizontal slice for detection of buried landmine.

III. EVALUATION TEST IN CROATIA

3.1 Evaluation Test in Test Lanes

ALIS has been evaluated in some mine affected courtiers including Afghanistan (2004), Egypt (2005) and Cambodia (2006). Then, systematic evaluation test of ALIS was conducted in September-October 2007 in Croatia. This test was originally planned as ITEP dual sensor test, but due to cancellation of other sensors, only ALIS was evaluated in this test. Therefore, it is not ITEP test, but ITEP sent observers in this test. The test was sponsored by JST (Japan Science and Technology Agency) , and conducted by CROMAC-CTDT, and the test lanes were designed by BAM. In this test, we used ALIS-PG. We trained the operation of ALIS-PG to Croatian deminers for two weeks. It included tutorial of fundamental principle of sensors, and signal acquisition, processing and interpretation. Then, we conducted training operations in calibration lanes. We think two-week training is sufficient, however, longer experience of operation of ALIS improves the skill of the operators.

3.2 QC Test in Mine Fields

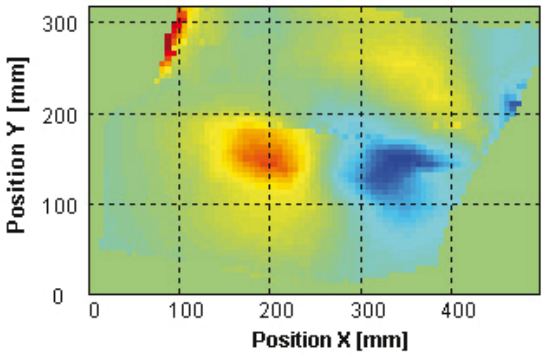
After the evaluation test carried out in the test site of CROMAC-CTDT, we agreed with CROMAC-CTDT to start evaluation tests of ALIS-PG in mine fields in Croatia. In this test, ALIS-PG has been tested in QC(Quality Control) operation. ALIS will not be used as a primary sensor, but has been used for a confirmation sensor. The first trial was conducted in December 2007. In the first test, ALIS was operated in the sites which were manually demined and machined demined. The soil in the manually mined are is normal, except the positions where anomaly was dug out, but in the machine demined area, soil was excavated and then it is very soft as shown in Fig. 4. In this area, many gravels were dug out and distributed in the soil. However, we found that the imaging capability of ALIS is not much affected by the soil conditions.

Figure 5 shows one of the buried objects which was detected by ALIS in this site. It is a stone, and a piece of metal located close to the stone. Figure 6 shows the ALIS image for this object. We can see clear response to the metal detector shown in Fig.6(a) and also can see round shape in GPR image shown in Fig.6(b). Therefore, the deminer has judged it as a possible landmine.

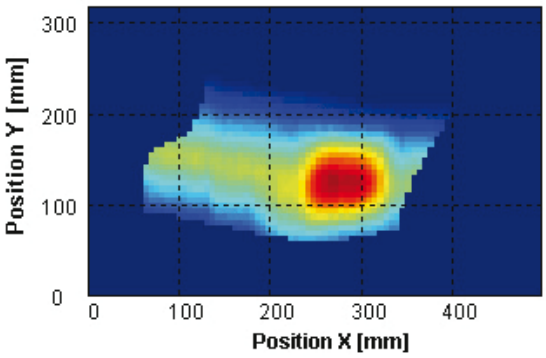
Since this is QC test, we have low possibility to detect real buried mines in operations, we will accumulate much experience of operation of ALIS in different soil conditions, The test is planned to continue for a half year.

Figure 4. ALIS operated in machined demined area. The soil is very soft, because it was excavated, but we found the capability of GPR imaging by ALIS is not much affected.

Figure 5. A stone with a metal pieces detected by ALIS in QC test. (2008, December 19-PG-2-No.11)



(a) Metal detector image



(b) GPR image

Figure 6. ALIS images of the stone with a metal pieces detected by ALIS in QC test. (2008, December 19-PG-2-No.11)

IV. CONCLUSION

We developed ALIS, which has high efficiency with better reliability for landmine detection by MD-GPR sensor fusion. The developed ALIS can visualize the signal, even if it is a hand-held sensor.

In the Eleventh International meeting of Mine Action Programme Directors and United Nations Advisors was held in April 2008, In Sibenik, Croataia. ALIS was demonstrated in the field demonstration with the results of QC test held in Croatia for about a half year. We are now planning the commercialization of the ALIS systems, and it will be available by the end of 2009. After evaluation test in QC in Croatia, we will plan deployment of ALIS.

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