Lessons learned from the Deployment of Dual sensor ALIS for Humanitarian Demining in Cambodia

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Abstract:
ALIS is a hand-held dual sensor developed by Tohoku University, Japan since 2002. Dual sensor is a general name of sensor for humanitarian demining, which are equipped with metal detector and GPR. ALIS is only one hand-held dual sensor, which can record the sensor position with sensor signals. Therefore, the data can be processed after data acquisition, and can increase the imaging capability. ALIS has been tested in some mine affected courtiers including Afghanistan (2004), Egypt(2005), Croatia(2006-) and Cambodia(2007-). Mine fields at each country has different conditions and soil types. Therefore testes at the real mine fields are very important. ALIS has detected more than 70 AP-Mines in operation in mine fields in Cambodia since 2009.

1. Introduction

Conventional landmine detection depends on highly trained and focused human operators manually sweeping $1m^2$ plots with a metal detector and listening for characteristic audio signals indicating the presence of AP landmines. We are in the process of developing a high-resolution landmine scanning system which produces horizontal slices of the shallow subsurface for visualization of buried explosives and inert clutter. As many AP mines contain minimum amounts of metal, metal detectors need to be combined with a complimentary subsurface imaging sensor. Ground Penetrating Radar (GPR) is widely accepted for subsurface sensing in the fields of geology, archaeology and utility detection. The demining application requires real-time imaging results with centimetre resolution in a highly portable package. The key requirement for sharp images of the subsurface is the precise tracking of the geophysical sensor(s) during data collection. We should also notice that GPR system is a very wide band radar system, and equivalent to UWB radar, which has recently been developed for short-range high-accuracy radar. We are testing simplified but effective signal processing for imaging mines. We are currently testing a dual sensor ALIS which is a real-time sensor tracking system based on a CCD camera and image processing.

Figure 1. ALIS in operation in Cambodia

In this paper we introduce the GPR systems which we have developed for detection of buried antipersonnel mines and small size explosives. ALIS has been deployed in Cambodia since 2009 and detected more than 70 mines in mine fields, and returned more than 13ha cleaned fields to local farmers. We also report the current status of ALIS in Cambodia.

Center for Northeast Asian Studies (CNEAS), Tohoku University jointed the TIRAMISU in 2013. Based on our rich experience in the mine fields, we think we can provide a good chance to use ALIS along with other partners.

2. ALIS development

Metal detectors, which is an 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 for 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 normally referred as “Dual sensor” in humanitarian demining. A few dual sensor systems are now available for humanitarian demining in commercial

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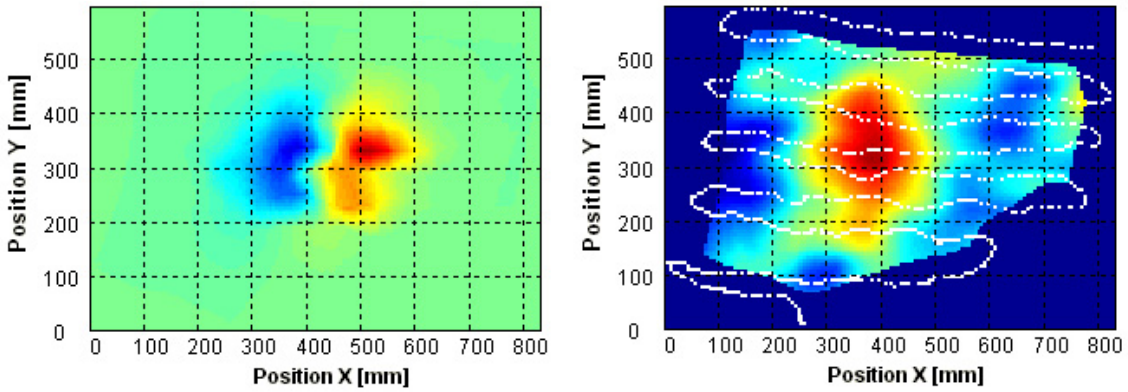
basis[1,2]. Tohoku University, Japan has been developing one of the dual sensor systems, namely, Advanced Landmine Imaging System (ALIS) since 2002. ALIS is unique in its novel technique of tracking the sensor position, even though it is scanned by hand by deminers. Then, ALIS can provide 3-D GPR image 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. Therefore, we will also demonstrate GPR data acquisition and its processing in realistic situation in mine fields.

The raw GPR signal is strongly contaminated by clutter which is caused by soil inhomogeneity, and ALIS apply synthetic aperture radar (SAR) processing, or which is equivalent to migration, to the law GPR signal to reconstruct the subsurface image. Figure 2 shows an example of ALIS signal display. It can visualize both the metal detector signal with GPR signal in the same horizontal plane. GPR signal is 3-dimentional, and the depth slice can be changed on the display.



(a) Metal Detectro sugnal after interpolation. (b) GPR Image with the locus of the sensor head.
Figure 2. ALIS visaulized images

3. Deployment in Croatia

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 send 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.

(a) CROMAC test site (b) QC operation in a mine field in Croatia, October 2007.
Figure 3. ALIS operated in Croatia in 2007-2008

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 will be tested in QC(Quality Control) operation. Therefore, ALIS will not be used as a primary sensor, but will be 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. 3. 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. 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.

4. Deployment in Cambodia

After a half-year test in Croatia, where ALIS has been used in real mine fields for Quality Control, 2 sets of ALIS were introduced to Cambodia in spring 2009. The first trial of ALIS in real mine fields has started in May 2009 near Siem Reap, Cambodia.

Operation tests at real mine fields has been conducted in Cambodia with a collaboration with CMAC (Cambodian Mine Action Center) since April 2009. 2 sets of ALIS were operated by ALIS-team of CMAC and more than 80 mines were detected as of April 2013.

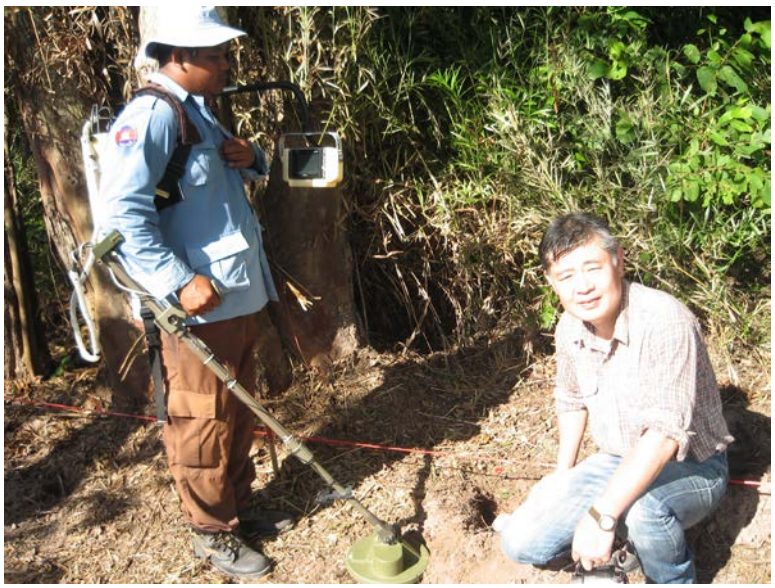


Figure 4. ALIS in Cambodia with detected mine.

For example during one month in July 2009, ALIS cleared 4,192 m^2 area, and detected 9 mines, which are all PMN-2 type. Metal detector detected 1,193 objects, and deminers judged 484 of them as possible mines, and 709 as metal fragments. This means, 709 points out of 1193 points (app. 60%), did not have to be prodded, and it can reduce the time of demining operation drastically. This is the most important capability of ALIS.

5. ALIS mounted on a unmanned vehicle

ALIS was also equipped on a robot of a buggy system Gryphon developed by the research group of Prof. Hirose at Tokyo institute of technology. All the same hardware and software of ALIS was used, and the data acquisition rate can be improved by the scanning by a robot arm. The ALIS mounted on a buggy uses an VNA based GPR with a Vivaldi antenna, which gives the best GPR performance. An unmanned buggy system can survey over a larger area, and improves the working efficiency compared to manual operation. The scanning of ALIS sensor by a robot hand is more stable than manual scanning, therefore we found that the quality of the GPR images acquired by this system is better than that obtained by manual scanning.

Figure 5. ALIS mounted on a buggy Gryphon (developed by Tokyo Institute Technology). A Vivaldi antenna is attached with a metal detector sensor on the robot arm. The buggy mounted ALIS uses a VNA based GPR for the best performance.

6. Conclusion

In this paper, we introduced a case study of GPR applied to humanitarian demining. A small target buried in inhomogeneous soil is a target difficult to detect by GPR, but we showed it can be achieved by combination of an advanced hardware and signal processing.

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