ALIS : GPR System for Humanitarian Demining and its deployment in Cambodia

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Abstract

We are currently testing a dual sensor ALIS which is a real-time sensor tracking system based on a CCD camera and image processing. In this paper we introduce the GPR system for detection of buried antipersonnel mines and small size explosives. ALIS has been deployed in Cambodia since 2009 and detected many mines in real mine fields.

Keywords : GPR Humanitarian Demining Sensor Tracking Migration

1. Introduction

More than 10 years has passed since the Ottawa Treaty or the Anti-personnel Mine Ban Treaty became effective in 1997, humanitarian demining is still important and unsolved problems in may mine affected courtiers. Antipersonnel mines have been left buried in many of regions where conflicts have occurred, and after many years, the land has to be returned to the local people. DMZ in Korea is also known as a remaining huge mine field. “Metal detector”, which is equivalent to the Electromagnetic Induction (EMI) sensor, is widely used for humanitarian demining. Even a “plastic mine” contains small amount of metal part, and it can be detected by a metal detector developed for humanitarian demining. However, large amount of metal fragments left in the battle field makes the discrimination of anti-personnel mines very difficult. Ground Penetrating Radar (GPR) is very useful for discrimination of targets, because it can visualize the shape of the body of buried plastic mines. However, GPR is very sensitive to inhomogeneous soil moisture. Therefore the combination of EMI sensor and GPR is more practical and it is called “Dual Sensor” in humanitarian demining. Many attempts have been done for deploying the dual sensors, but it is still under development. Tohoku University, Japan has developed ALIS, which is a dual sensor, since 2002 and it is only one dual sensor which can visualize the buried mine. 2 sets of ALIS have been used in Cambodia since 2009 and more than 70 mines were successfully detected. In this paper, we introduce the ALIS stem and its signal processing, then introduce its activities in Cambodia.

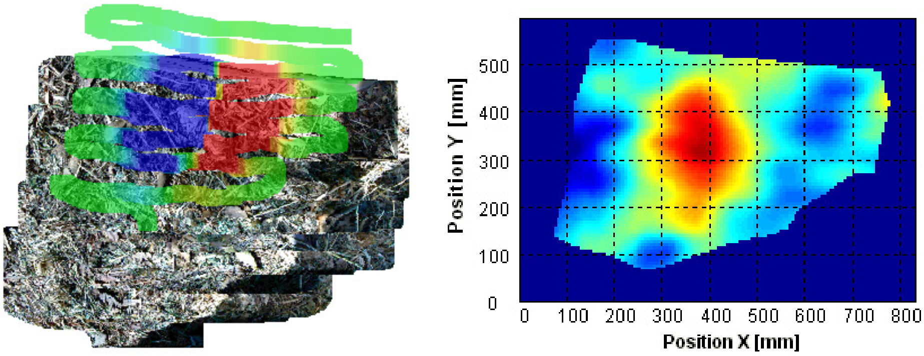
Figure 1: ALIS in operation in one of Cambodia mine fields.

2. Dual Sensor ALIS

ALIS is a dual sensor, which is a combination of EMI sensor and GPR. It is a hand held sensor, i.e., the sensor antenna is scanned by a hand of an operator (deminer). In order to reconstruct the buried land mine image, we need a synthetic aperture radar (SAR) processing or migration processing. In order to achieve this signal processing, we need the information of the sensor position. ALIS is quite unique among some dual sensors, because it is only one duals sensor which has a visualization function of GPR image.

2.1 **GPR**

Anti-personnel mines are initially buried at very shallow depth, i.e., typically 5-10cm from the ground surface. However, after many years, landmines can move and many of them moved deeper, mainly due to heavy rain. Deep mines are not dangerous, because it may not explode, and by UN regulation, we normally have to detect land mines buried up to 20cm. This is relative shallow, and the anti-personnel mines have a diameter of less than 10cm, we need high resolution. Considering the depth and the required resolution, we employed an impulse radar, which operates in the frequency range of 1-3GHz, with cavity-back spiral antennas for ALIS. This antenna is used, because high isolation between the transmitting and receiving antenna can be achieved.



(a) EMI signal (b) GPR

Figure 2: Visualized image of ALIS signals.

2.2 **Sensor positioning system and signal processing**

Sensor position information is essential for the image reconstruction. We use a CCD camera attached close to the antenna, which captures the images of the ground surface continuously. The relative position movement of the sensor is estimated from the differences of the captured images. This is very simple system, but we found it works effectively. The positioning accuracy is about 10%, and it is quite enough for this purpose. While the sensor head containing of a coil for EMI sensor and antennas for GPR is scanned by a hand, and the EMI sensor signal and GPR signal are acquired simultaneously with the sensor position information. Fig.2 shows an example of ALIS signal visualization. Fig. (a) is a EMI sensor signal and we can see the locus of the sensor head movement. Red and Blue colours indicate the sense of the signal. Fig.2(b) is the reconstructed image of GPR, which was obtained by signal processing after the data acquisition. We use Synthetic Aperture Radar processing (SAR), or migration processing. In ALIS, we reconstruct a 3-D GPR image by Kirchhoff migration algorithm[3]. The Kirchhoff migration gives the output wave field $P_{out}\left(x_{out}, y_{out}, z, t\right)$ at a subsurface scattering point $\left(x_{out}, y_{out}, z\right)$ from the input wave field $P_{in}\left(x_{in}, y_{in}, z=0, t\right)$, which is measured at the surface (z=0). The integral solution used in migration is given by:

$$P_{out}\left(x_{out}, y_{out}, z, t\right)=\frac{1}{2\pi}\iint\left[\frac{\cos\theta}{r^2}P_{in}\left(x_{in}, y_{in}, z=0, t+\frac{r}{v}\right)+\frac{\cos\theta}{vr}\frac{\partial}{\partial t}P_{in}\left(x_{in}, y_{in}, z=0, t+\frac{r}{v}\right)\right]dxdy \quad (1)$$

where v is the RMS velocity at the scatter point (x_{out}, y_{out}, z) and $r = 2\sqrt{(x_{in} - x_{out})^2 + (y_{in} - y_{out})^2 + z^2}$, which is the distance between the input point $(x_{in}, y_{in}, z = 0)$ and scatter point (x_{out}, y_{out}, z).

We found that the migration processing is effective not only for image reconstruction, but also clutter reduction. ALIS GPR does not have very high resolution, however, the migration process has an effect of spatial averaging, and we found that the clutter caused by inhomogeneous soil moisture or small grains can be reduced by this processing. At the same time, this is very robust processing, and the error of the velocity of electromagnetic wave in migration processing does not affect to the image.

3. Field Evaluation of ALIS in Cambodia

We have tested ALIS in mine effected courtiers including Afghanistan (2004), Egypt (2005), Croatia (2006-) and Cambodia (2006-). We need the experience of the operation by professional deminers in real mine fields to improve the sensor performance. However, governmental organizations do not allow sensors which are not proven well. After many trials in test lanes in these mine affected courtiers, in 2009, we could obtain the permission of the use of ALIS in real mine field in Cambodia by Cambodian Mine Action Center (CMAC). We rented two sets of ALIS systems to CMAC, and CMAC organized a ALIS team with 6 deminers. We instructed the operation of ALIS to them and after several months, they are very well trained and started operation of ALIS in real mine fields.

For example during one month in July 2009, ALIS cleared 4,192 m2 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. Fig. 4 shows the probability of the correct judgment for all the objects detected by metal detector. We should note that since March 2009, there is no misjudgment of mine.UXO as metal fragment. All the wrong judgment is metal fragment to mine/UXO. We can find that the ratio of the correct judgment is around 70-80%.

Figure 3: One of the detected mines by ALIS in Cambodia.

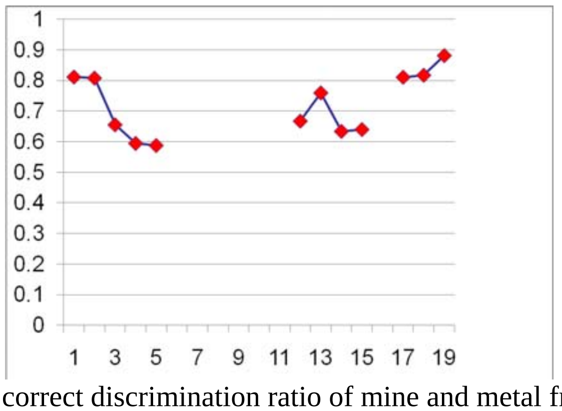


Figure 4: Monthly correct discrimination ratio of mine and metal fragments by ALIS (March 2009-October 2010).

4. Conclusion

ALIS, a dual sensor for humanitarian demining has been developed at Tohoku University, Japan since 2002. It is quite unique sensor, with a string visualization function by a sensor tracking system combined with GPR and EMI sensor. GPR is working at the frequency range of 500mHz-3GHz, and can detect mined buried up to 20cm in real mine fields. The performance of ALIS has been tested in Cambodia since 2009. More than 80 anti-personnel mines have been detected and removed from local agricultural area. ALIS has cleared more than 70,000 m^2 area and returned it to local farmers. We are still working for deployment of ALIS in more mine affected courtiers.

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