MINE DETECTOR WITH DISCRIMINATION ABILITY

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Metal detectors are widely used to detect Explosive Remnants of War such as landmines and Unexploded Ordnance. Almost all professional detectors are based on the eddy current principle. Currently count of false alarms rises up to 99.9% of total alarms count. Discrimination ability added to professional mine detector is therefore highly required by demining community. We show two complementary methods: using vertical signal profile and horizontal spatial maps. This is achieved by adding vertical distance sensor and inertial positioning unit to the search head. Image processing methods can be used to differentiate between metal ballast and dangerous objects. In this paper we show first steps in the development of the fully autonomous 3-D positioning unit for eddy current imaging.

Keywords: metal detection, mine detector, discrimination, signal height profile, eddy-current

1 INTRODUCTION

Detection and clearance of Explosive Remnants of War (ERW) such as landmines and Unexploded Ordnance from former military areas and after war conflicts is still made by human operators using eddy current metal detectors. All methods of remote sensing turned to be unpractical and the only real alternatives are two: 1. using trained animals such as dogs of rats to sniff explosives 2. handheld ground penetrating radar (GPR). GPR is able to detect plastic mines, but fails in wet soil. Currently it is becoming very hard to differentiate between the ERW with low metal content and ordinary scrap metal such as cans or metal foils.

Increasing the sensitivity of metal detectors to detect low metal content mines also increases false alarms count [1]. Therefore the main objective of this paper is to introduce method to differentiate ordinary ballast and expected objects during demining procedures by adding discrimination ability to professional mine detector.

Several methods how to discriminate mine types were recently described in [2]. However the ultrasound tracking system used in that paper requires a minimum of three ultrasound receivers with precisely known locations being installed in the close vicinity. This is a configuration which can be used in the laboratory conditions but which is unsuitable for the field work such as routine demining of large areas.

Kellermann proposed method which registers the detector signal for several heights of the sensing head [3]. This technique helps to distinguish between shallow and deeply buried objects of different size. Measured signal intensity for small objects ideally decreases with $1/d^3$, where d is the distance.

In this paper we describe an effort to combine Kellerman's approach with x-y mapping. The proposed method of discrimination uses signal from the metal detector together with information of height above the ground and relative x-y position. Based on this information height profiles of metal detector signal can be constructed and estimation of detected object can be made by comparison with known signal profiles for different objects.

The signal profile depends on the size, shape, material and depth of the measured object, making the inverse problem very complex. A priori information about the possible buried objects should therefore be used. While the complete mine catalogue is very extensive, for practical applications the number of types of landmines in a given area is limited. Even an ability to discriminate between the deeply buried anti-tank mine and shallow anti-personnel mine can save lives of deminers.

2 EXPERIMENTAL EQUIPMENT

All Terrain Mine Detector (ATMID) [4,5] manufactured by Schiebel Austria was used in this study. This metal detector is based on eddy current principle and works with continuous wave. The ATMID was equipped with optical triangulation distance sensor [6] which enables measurement of the height above the ground and relative angle between the ground and the search head. The used setup is shown in Fig. 1. The distance sensor is installed above the search head to minimize the influence of its metal parts and also to avoid threshold limit for short distances.

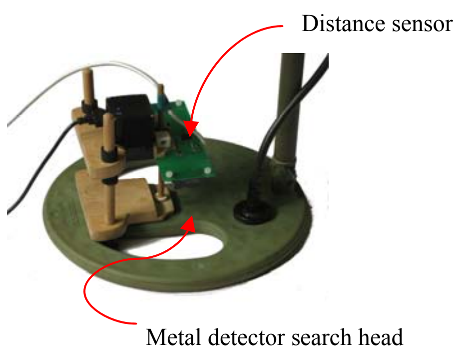

Fig. 1. Mine detector with optical ground distance sensor.

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The non-metallic height adjustment stand, shown in Fig. 2, was developed for the testing. The stand allows fast change of the testing distance while keeping the search head parallel to the testing plane.

We have made experiments with the processing of the audio output of the metal detector. This is the only available standard output of professional metal detectors [6]. Unfortunately the signal processing used to generate the audible output limits the detector signal and thus highly reduces its information content. This effect is shown in Fig. 3.

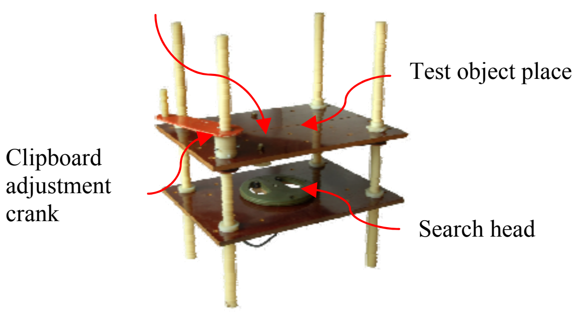

Fig. 2. Non-metallic height adjustment stand.

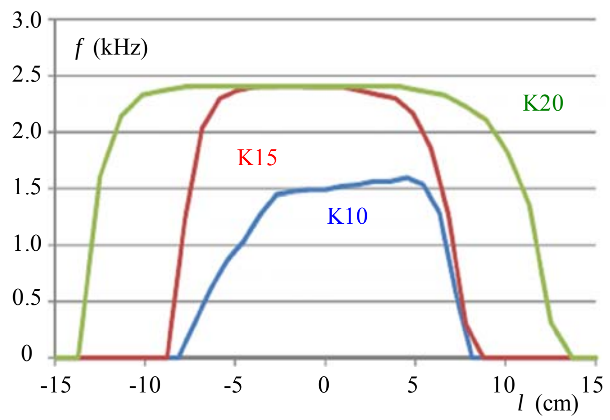

Fig. 3. Dependence of the acoustic signal frequency on horizontal position of the search head, for 3 sizes of metal balls [6,7].

We therefore decided to use the internal signal of the detector, namely the output of the logarithmic amplifier after the phase-sensitive detector.

For the field measurement of the relative position of the search head in the x-y plane we currently develop the aided inertial navigation system with 1 cm position accuracy. Large drifts of the used accelerometers and angular rate sensors are corrected by periodical nulling of the speed (using optical flow video sensor mounted on the detector head) and position (using magnetic, reflective optical or conductive markers). First steps in this effort have been reported in [7]. Here we report of using metal markers on both sides of the scanned area. This is in conformity with the commonly adopted procedures for the mine clearance: during the fast scan the location of the suspicious object is marked by two flags in a 1 distance with the "hot spot" between them. If the poles of the flags are made of the conductive material, the position of the detection head above these markers is sensed by the metal detector itself. The simplest situation is for the pendulum-like line pinpointing. In this case the marker position is reached every one or two seconds, which allows very frequent nulling of the navigation drift. Area scanning (typically in 1x1 m square) brings more demanding situation – the marker is reached only every 10 to 30 s. The integrated drift in position caused by the offset of inertial grade accelerometers is only in the order of 1 mm for the first second. Ideally the well-trained operator should keep the detector head always in the horizontal position. However in the real field scanning the tilt of the detector head is slightly changing. This changes the projection of g into the sensing axes of the accelerometers and brings much larger error. Our present effort is to use angular rate sensors to compensate for this effect. Standard adaptive filters used for inertial navigation should be modified to accommodate specific repetitive pattern of this motion.

For the calibration and testing purposes we use a digital laboratory USB camera with complementary metal oxide semiconductor (CMOS) image sensor of resolution 752 x 480 pixel and pixel size of 6μm. Camera was mounted 3 m above the testing area. The search head was equipped with an active marker (Light Emitting Diode) and center of image gravity algorithm [8] was used for marker position detection. Position of the search head was measured with resolution of 0.5 cm.

It should be noted that the described camera tracking system is not intended for the field work – in the final stage it will only be used for the calibration and testing of the portable inertial navigation system and for training of the operators.

3 RESULTS

Signal intensities were measured in the laboratory conditions in heights range from *50* to *300* mm for the simple testing objects of various size made of different metals. One example of the results is vertical signal intensity profile for the INOX AISI 420 steel balls shown in Fig. 4. The measurement was made using metal balls with diameters of 9.4 mm and 15 mm, shown in Fig. 5

Measured intensity function shows clear dependency on the object size. However the information content of such profile is not rich enough for practical applications.

In the following section we demonstrate the stability of the present laboratory tracking system: the detector head was marked by LED diode and its *x-y* position was tracked by video camera. Figure 6 shows time evolution of the repetitive pendulum-like scan over the clean area equipped with two large metallic markers. Figure 7 shows the signal of a metal ball positioned between the same markers.

The signal variations caused by interference can be averaged off the periodic signal record.

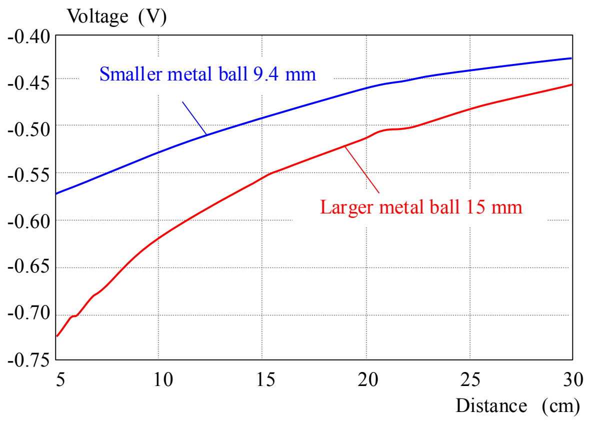

Fig. 4. Measured signal intensity as a function of the object distance.

Fig. 5. Tested metal balls, INOX AISI 420.

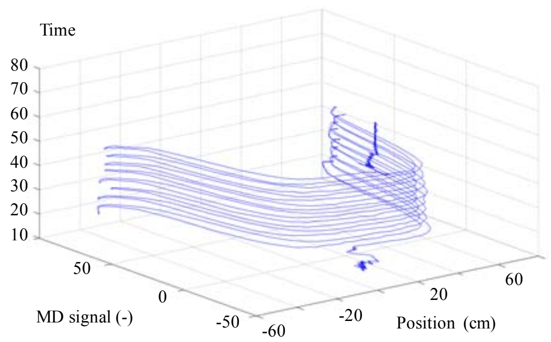

Fig. 6. Time evolution of the repetitive line scan. No detected object, only signal of two metal markers is visible

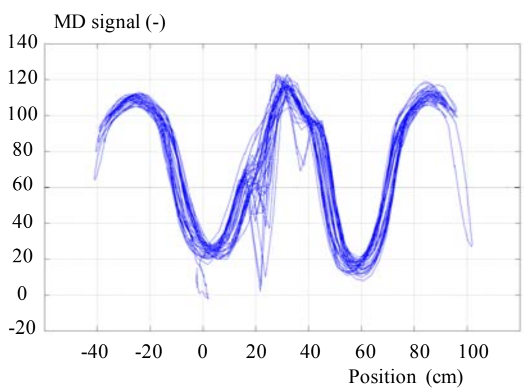

Fig. 7. Repetitive line-scan of metal ball (with two markers still present). Rough signal before averaging shows interference. object, only signal of two metal markers is visible

4 CONCLUSION

The described results present gradual achievements towards the fully portable 3-D imager for eddy-current metal detector. Metal detector with position tracker allows constructing eddy-current signal map, which is characteristic for specific objects. Mine signatures can be automatically recognized from these maps. Position sensing also allows detecting very weak signals buried in the environmental noise by repetitive scanning of the suspicious area. The developed system is also useful for the training of deminers.

Independent approach for increasing of the discrimination ability of metal detectors is using multiple excitation frequencies and processing both amplitude and phase information. This path is fully compatible with the path described in this paper.

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