ITEP Test Trials for Detection Reliability Assessment of Metal Detectors

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ITEP Test Trials for Detection Reliability Assessment of Metal Detectors

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Abstract

The test detection reliability of a mine-searching system is governed by the following three elements:

- Intrinsic capability, which describes the basic physical-technical capability of the method.
- Application factors, which include: those due to environment.
- Human factor, which is the effect of human operators on the detection reliability.

Some of these can be determined in simple laboratory measurements in which the effect on detection capability of individual parameters is measured. However, the human factor and some aspects of the effects of environmental conditions on the system need to be treated statistically.

For the most common "mine-searching system" in use is a metal detector. The test and evaluation procedures for metal detectors described in European Committee for Standardization (CEN) Workshop Agreement (CWA) 14747:2004 (Pod) include the above ideas. This is why, in addition to parameter tests, they include detection reliability or blind field tests under local conditions with local personnel.

A series of these field trials was performed in the International Test and Evaluation Program for Humanitarian Demining (ITEP) project 2.1.1.2, "Reliability Model for Test and Evaluation of Metal Detectors," in order to specify the optimal conditions to obtain reliable trial results with affordable effort. Each set of specific working conditions is characterized in terms of a combination of mine type, mine depth, and its detection feasibility determined by local personnel. For each set of conditions, the testing system will deliver a workable model of metal detectors' characteristics using the parameters of detection rate as a function of mine depth, and a census overall false alarm rate. During the ITEP trials in Workshop and Obergeleen, the authors learned to determine this function separately for each mine type in each soil. This is especially important for low-mined mines in soil that can influence metal detectors, as will be illustrated for the case of the PMA-2. Two discussion points still remain: how to represent the trials are of field conditions, and what statistical setup is required if we are to distinguish between the capabilities of individual detectors.

Introduction and Background

The CEN Working Group 07 began the process of standardizing test and evaluation methods for metal detectors in humanitarian demining, including both laboratory measurements of detection capability and blind field trials (reliability tests). In reliability tests, the probability of detection (POD) and receiver operating characteristics (ROC) help to evaluate the performance results. Under the umbrella of ITEP, a number of test trials with metal detectors have been conducted. The aim was to specify the trial setup and the statistical rules necessary to achieve true, repeatable, and reproducible results.

Figure 1: Exploration for ROC and POD diagrams (FA, false alarms per m2).

Figure 2: Typical POD curves.

Figure 3: Test parameters.

Devices

- Type of soil:
  - Cooperative (neutral)
  - Uncooperative

- Temperature dependence:
  - Thermotaxis

- Metal contamination:
  - Iron contamination
  - Stainless steel

- Depth of mines

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When land is cleared of mines where minimum-metal mines are the main threat, the "metal-free" procedure is sometimes used. This means that detectors are used on minimum sensitivity and all metallic pieces found are removed from the ground. In trials for metal detectors to be used in this way, any metal piece found should be considered a true detection, not a false alarm.

In some cases, 70/50 cleaner operations, relatively large metal objects are sought. In this scenario, it is often possible to reduce false alarm sensitivity so that avoiding all of the possible metallic clusters that may be present, while still having the detection capability is the main task.

In trials designed for this type of operating procedure, it is possible to consider detection of only small pieces of metal as a false call. However, the validity of this approach depends upon the size of the metal pieces in the test setup. If metal pieces are present that have an equivalent response to the targets, then the test becomes rather meaningless because reporting these detections as false calls does not indicate that the detector is not performing as required.

For a fixed amount of false alarms, the ROC plot or operating point of the system for a fixed sensitivity can be taken and further analyzed for its dependence on the main influencing factors such as the mine depth or the metal content of the mine.
Overview of the Parameter Matrix of the Trials

The main aim of the trials was to investigate how the device performance matches itself in different application circumstances. The authors reviewed three sets of trials for which the main parameter setup can be seen in Figure 3. The first and third took place in Obersteinberg, WTD 52 on the testing ground of the German army.

The conditions for the first trial in May 2003 were representative of four circumstances likely to yield poor performance: inexperienced operators with a short training period and not lines with significant metal contamination. Three neutral trails were used and a fourth lane was artificially made "uncooperative" by adding a layer of magnetic glass-burning slag. (With the benefit of hindsight, we would now recommend this technique because the slag was found to contain metallic particles, creating additional metal contamination.) The burial mines were characterized by a medium to large metal content, some Geometric International Ten Operations Procedure (ITOP) targets were also used, irregularly distributed over a predefined depth range.

The second trial set was organized in Benkovac, Croatia, with eight experienced Croatian operators, three of whom were active deminers at the time of the trials. A brief training period (half a day for each deminer) was given. These were three types of soil on eight lanes, neutral soil, homogeneous non-cooperative soil and homogenous cooperative soil. The last two had frequency-dependent susceptibility. The mines had large, medium or small metal content and were symmetrically distributed over a depth ranging between zero and 20 cm to allow statistical analysis. For training metal detectors, the normal target depth should be to the limits of the physical detection capability in the soil. The depth of 20 cm was chosen because it is the required depth for mine clearance under Croatian law. The lanes were "almost ideal" in terms of metal pieces.

The lessons learned from the first two trials were applied to the third trial set in Obersteinberg in November 2003, with the intention of creating conditions likely to yield better performance. Three new lanes were set up (in addition to the ones available from the previous trials in May) and carefully cleaned of any metal fragmentation. Mines with large to medium and small metal content were selected and distributed symmetrically to a depth ranging from ten to 20 cm. The operators, who were inexperienced, were trained carefully in open and blind exercises until they were confident in operating the reaction of each detector to each mine at different depths. To avoid confusion among the different detector operating procedures, the operators were assigned detectors belonging to one class both during the training and during the first week of the trial only (double-D coil, static mode or single coil, dynamic mode). In the second week, they changed to the second class of detectors.

Results of the Trials

Figure 4 shows the overall results of each trial set in ROC diagrams. These diagrams illustrate the influence of factors (application factor and human factor) degrading the performance of all the detectors, without distinguishing among individual detectors. The results of inexperienced operators with a short training on metal-contaminated ground shows a mean detection rate of 70 percent and 0.3 false alarms per square meter. The artificial uncontaminations reduce the performance in a 60-percent detection rate and almost one false alarm per square meter, which is surprisingly poor.

Even more surprising are the total overall results for Benkovac in June 2003, where the operators consisted of eight experienced Croatian deminers. The detection rate of about 65 percent in neutral soil decreases to almost 50 percent in a real, local, cooperative soil with frequency-dependent susceptibility. The false alarms rate grows from 0.5 false alarms per square meter to almost 0.6. Possible reasons for this extremely poor result are as follows:

1. Many of the targets were deeply buried and in some cases beyond the physical capability of some of the detectors. Minimum metal mines, which are inherently difficult to detect, were buried according to a systematic depth distribution, ranging from zero to 20 cm in order to evaluate the detection rate as a function of depth. The maximum depth of 20 cm was chosen because it is the requirement of the Croatian clearance law. A more realistic mean value of detection rate for the region could be determined if the real depth distribution of mines is known by using the PDD as a function of depth measured in the trial. Usually, anti-personnel mines are mainly buried at a depth ranging from zero to 20 cm, which is much shallower than the range used in the trial and would be detected with a higher average PDD than measured in the trial.

2. Only three of the detectors are currently active.

3. It has been suggested that experienced deminers may need a longer training phase because they are generally accustomed to using a particular detector model and cannot handle too many different device types at the same time.

4. In the trial, the deminers are not in
danger and are less motivated to be careful than they would be in a real minefield.

5. The sea schedule required the detect-
ions to work more quickly and for longer
hours than they would normally.

6. The test laces were constructed
with metal.

Heterogeneous soil with strong fre-
quency-dependent magnetic susceptibility is a challenge for all detectors, especially in
combination with minimum metal mines,
since the soil signals often mask the mine
signal.

The performance in the third trial is
much better than in the first two, as
expected from the conditions of the test
with respect to the human factors and
application factors. In Figure 4c, the up-
per left corner of the ROC points is 90-
percent detection rate and false alarms below 0.1
per square meter. The "score" is care-
fully considered and longer training,
reduced workload, and very clean soil,
and targets that are easier to detect. If
we were to estimate a realistic POD, it is
necessary to ask. "Was is the appro-
priate scenario of application and
human factors for the situation we want
to investigate?"

Full Process Simulation

In Oberjenseberg in November, another
additional test was conducted, on the
advice of Dieter Gaisler. The test simul-
ated the full manual detection process,
including panning and excavation. Since
the statistical basis was too small to be
represents, results of this test must be
considered indicative only and any
conclusions provisional. The detection rate of
the manual detection process appeared to be
higher than that of the detection process
without excavation, probably due to con-
misconceptions where a minimum metal mine
was hidden by a larger false-alarm area.

Indications that could be assigned to iden-
tifiable metal fragments were excluded
(according to a "truth-free" approach), so
the false alarm rate is lower. The latter is,
of course, a advantageous situation, rather
than performance. A more detailed investi-
gation is planned within the GCHG pro-
grram for improvement of the manual detec-
tion methods mentioned above.

Figure 7: The soil sample is heterogeneous and loose, uncooperative. Being that it has
real basaltic with neutral stromatolite has frequency-dependent susceptibility, its detection
rate as function of mine depth (PMKE 2) only has four different devices with 95-percent con-
fi
Figure 5 gives an overview of all the
soils in the three trials.

In Figures 6 and 7, the individual
detector results are illustrated for the
PMK 2 minimum metal mine under ideal
conditions (i.e., neutral soil without metal
concentration, well-trained operators and
optimized working hours). Figure 6a-d
show the detection rates as functions of the
burial depth for each device separately and
Figure 6e shows the ROC points of all
detectors together.

Figure 7a-d and Figure 7f present the
same results for the most difficult soil. The
anomalous results for detector X is due to
a high FDR in the uncooperative soil, up to
one false alarm per square meter and the
sparsely higher detection rate at large
depth. The latter phenomenon can be
explained by the fact that some of the
"true" positive indications appear to be sig-
nals from the soil that happened to fall
within the halo of a coper, so that the
apparent POD does not approach zero at
large depth. To avoid this type of anomaly,
the soil compensation and sensitivity of
the detector should be adjusted to produce
an acceptable low FAR prior to starting
the blind trial. CWA 14747. 2003 section
8.1.5 specifies a procedure for checking the
adjustment of a metal detector to the soil
under test. The test is only to be consid-
ered valid if the detector can be adjusted in
a representative one-meter by one-meter
sandbox so that no false alarms are given
when it is placed on the soil surface and
then raised 30 cm above it. It seems like-
ly that detector Y was not adjusted (or not
adjustable) according to this procedure.

Why Data Fusion?

Within humanitarian mine action,
progress in integrating information is
manifested chiefly by the way the traditional
array of survey activities have been
refined. Following the 1997 Ottawa
Treaty to ban ant-personnel mines, sever-
ne mine action non-governmental organi-
zations (NGOs) and the United Nations
Mine Action Service (UNMAS) launched
the Global Landmine Survey, a multi-
country survey project. This initiative has
helped to institutionalize the collection of
social and economic data, along with con-
taminated and socio-economic impacts. The classification relies on an internationally standardized survey
system that combines types of munitions
and cleared areas as well as recent vic-
tims, using weights that national stake-
holders may adjust within limits. Technical
information at the contaminant-ed area level
and demographic data on incident survivors are also generated and
available to national mine action coordi-
nators through the Information Mar-

Data Fusion for Mine Action Decision Support:
An Example From Lebanon

by Xiilo Benini and Charles Conley, PEGE
Working Towards a “Mine-Free” Hemisphere

The government of Ecuador served as the host of the Americas Regional Mine Action Conference “One More Step Toward a Mine-Free Hemisphere” held in Quito, Ecuador, on August 12-13, 2004. The government of Canada and the Organization of American States Mine Action Program (AICMA, for its initials in Spanish) co-sponsored the conference, the fourth in a series of annual meetings convened in the region since 2001.

The regional gatherings have promoted the exchange of information among members of the mine action community in the hemisphere and fostered a sense of common purpose as the countries strive to reach the goal of a hemisphere free of the negative effects of anti-personnel landmines. This year’s conference, like the one in Lima, Peru, in 2003, also served as a regional preparatory meeting for the Ottawa Convention Review Conference to take place in Nairobi, Kenya, from November 29–December 3, 2004. Over 100 participants from both within the Americas and beyond attended the Quito event.

The meeting’s agenda included an opportunity for each country delegation to report on the status of its mine action program, as well as regional updates on the mine action pillars of mine clearance, mine risk education, victim assistance and mine-impact destruction. Mr. Kenny Bandel of the Geneva International Center for Humanitarian Demining (GICHED) provided an overview of the implementation of the Ottawa Convention in the Americas and other participants reported on preparations for the upcoming Nairobi Review Conference. A panel was included in this year’s conference that reported on the newly drafted (November 2003) Protocol V of the Convention on Certain Conventional Weapons (CCW) pertaining to Explosive Remnants of War (ERW) Conference proceedings are posted on the AICMA-Ecuador website at http://www.aicma-cu.org/conferencia_regional.htm.

Among the noteworthy announcements that emerged from the gathering was that all of the States Parties in the hemisphere should have met the requirement to destroy their stockpiled mines by the time they report to Nairobi. Furthermore, all of them will have launched a clearance program by that time, considering Chile’s commencement of demining operations this past August, with Costa Rica and El Salvador already having completed clearance and Honduras finishing in 2004, Colombia continues to work on developing its mine action program, and as an internal conflict remains unresolved, it announced plans to clear its first minefield in October. One remaining issue that arose on several occasions during the conference was the number of landmines that the countries were retreating for development and training purposes under Article 3 of the Ottawa Convention. The countries agreed that transparency on this matter was essential.

The countries of the Americas aspire to serve in Nairobi as an example of regional success with lessons learned to share with others. Conference participants announced progress in furthering South- South Cooperation, including plans for Honduran mine clearance operators to assist in Suriname and the aid provided by Argentina as well as Canada to Colombia in its stockpile destruction activities. These developments continue the pattern in the Americas of employing expertise from within the region to support mine action programs, as with the use of International Supervisors drawn from a number of Central and South American countries to assist with clearance operations as part of the Mission of Assistance for the Removal of Mines in Central America (MARMENA) program.

Ecuador and Peru took advantage of the regional conference to hold discussions concerning joint efforts to clear their common border, an initiative supported by the OAS Mine Action Program with technical assistance from the Inter-American Defense Board (IADB). Such joint efforts were cited as examples of how coordinated mine action projects between friendly neighbors can serve as important confidence-building measures. Guatemala presented an excellent case of the value of mine action programs that incorporates former combatants from different sides in an internal conflict.

Several United States government agencies sent representatives to the regional meeting, including the Department of State (DOS), the Defense Security Cooperation Agency (DSCA) and the Humanitarian Demining Training Center (HDTCC). Mr. Ed Trimble of the U.S. DOS, Office of Weapons Removal and Abatement (PM/WRA), in a reference to the participants, reviewed the changes that had occurred in his DOS office in the past year, the U.S. government’s humanitarian mine action goals and priorities, and its continued commitment to addressing the mine/USO problem.

* Photo credit: N. Nelson Castillo, OAS/MCHA- Ecuador

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