International Symposium "Humanitarian Demining 2010"
27 to 30 April 2010, Šibenik, Croatia

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CONTENTS

Quality Assurance During Use of Demining Machines

Tomislav Ban[1]

Abstract

Quality assurance during the use of demining machines represents a number of measures and activities conducted with the purpose of ensuring the quality of mechanical treatment of mine suspected areas and, at the same time, reduction of danger for the conduct of activities upon mechanical treatment.

The precondition for the conduct of quality assurance procedure is, prior to all, quality laws and by-laws that stipulate the framework for the conduct of the activities required and well-trained expert staff. When speaking of regulations that provide framework for the conduct of QA activities, this primarily refers to the International Mine Action Standards (IMAS), national standards (laws, rules and regulations and HRN 1142) and Standard Operating Procedures (SOPs). Each of the above-mentioned regulations has an important effect on realization of complete and high quality assurance of quality during the use of demining machines.

Quality assurance is conducted through the following phases:

1.   testing and annual verification,
2.   accreditation
3.   awarding the operations,
4.   internal inspection and maintenance and
5.   external inspection, quality assurance.

Testing and annual verification are performed by accredited laboratories and centers. During the accreditation procedure, information on the machine are being verified and recorded and SOPs certified. When all conditions have been met, the committee issues the competence assessment that is a precondition for the authorized legal entity for participation in public tender procedure.

Internal inspection and maintenance are conducted by authorized legal entity according to manufacturer's instructions and SOP.

Quality assurance during the use of demining machines is performed by the authorized staff of the Croatian Mine Action Centre, in line with the positive regulations and SOPs:

http://www.hcr.hr/pdf/SOP%2004.01.%20QUALITY%20ASSURANCE%20AND%20QUALITY%20CONTROL.pdf
http://www.hcr.hr/pdf/SOP%2004.02._Eng.pdf,

The above-stated phases of quality assurance together with application of safety and occupational health measures are the basis for the reliable and safe use of demining machines and quality mechanical treatment of the area.

Key words: quality assurance, humanitarian demining

1.   Introduction

Demining in the Republic of Croatia (hereinafter: RC) started during the Homeland War partially for the needs of military and police actions and partially for the reconstruction purposes and population return. Demining operations were conducted by the Croatian Army troops (hereinafter: CAT), Ministry of Interior (hereinafter: MI) and Civil Protection. Humanitarian demining started in 1996 with the establishment of the state owned commercial company AKD Mungos d.o.o. Besides the AKD Mungos, demining operations in the period until 1998 were also conducted by the Croatian Army and Ministry of Interior.

With the establishment of the Croatian Mine Action Centre in 1998 ended the, so called, first phase characterized as the classic quality control phase. This meant that upon the completion of demining operations, the area was either accepted or rejected. The foundation of CROMAC and constitution of demining companies created the preconditions for market establishment and beginning of conduct of quality control operations in humanitarian demining. This was also the beginning of permanent upgrade and improvement of humanitarian demining system. Rules and regulations, necessary preconditions for the establishment of quality ''Total Quality Management'' (TQM) system, have been continuously upgraded until today. The TQM system is also possible to establish by implementing the Deming's Circle (PDCA – Plan-Do-Check-Act).

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Such development process is followed by the development of demining capacities – deminers, demining machines and mine and ERW detection dogs. The most important progress was made with demining machines[2] so that currently, there are 54 accredited demining machines in the RC out of which: 19 light, 21 medium and 8 heavy machines and 6 machines for the vegetation and waste removal.

2. Quality Assurance

Quality assurance in humanitarian demining represents a group of measures undertaken with the purpose of ensuring safe and quality demining. In order to achieve Total Quality Management (TQM), it is necessary to meet certain preconditions such as legal framework that includes international standards as guidelines for passing the national standards. When we speak of the international standards, we primarily think of the series of standards IMAS[3] which provide guidelines for drafting the national humanitarian demining standards. Based on IMAS, the Republic of Croatia built its own national standards, the Law and by-laws (Rules and Regulations). Such foundations are preconditions for passing the working procedures and instructions, Standard Operating Procedures (hereinafter: SOPs) that elaborate the work methods, use of tools and equipment and S&OH measures.

Quality assurance has to provide answers to the following questions: who conducts the operations, using what, how he does that, who supervises the conduct of operations and how, what records should be kept in order to meet the requirements etc.

3. Quality Assurance Implementation Phases

Quality assurance during the use of demining machines is implemented through the following phases:
•   testing and annual verification;
•   accreditation;
•   supervision over the work of demining machines
     -   internal inspection (company)
     -   quality assurance (CROMAC)

Testing and annual verification of demining machines prior to putting them in use is conducted by an authorised centre accredited by the Croatian Accreditation Agency.

Accreditation i.e. competence assessment of an authorised legal entity is conducted by CROMAC, in the Quality Assurance and Quality Control

Department. Assessment of competence is performed by the committee appointed by CROMAC director on the basis of the Rules and Regulations[4] and CROMAC SOP[5]. In the process of establishing the capacity of demining machines (see Photo 1), there should be the following documents submitted: relevant information on prescribed forms from the Rules and Regulations, original documents upon request and SOP that stipulates the work of demining machines in detail. When all the requests have been fulfilled and SOP certified, the conditions required for the committee to assess the competence of the authorised legal entity for the work with demining machines are considered to be met. 54 demining machines are currently accredited in the Republic of Croatia, see Table 1.

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[2] Book of Rules and Regulations on Technical Requirements and Conformity Assessment of Machines Used in Humanitarian Demining Operations, NG 53/07
[3] IMAS, International Mine Action Standards
[4] Rules and Regulation on Competence Assessment of Authorised Legal Entities and Tradesmen for the Conduct of Demining Operations, NG 53/07
[5] SOP CROMAC 03.02, Competence Assessment of Authorised Legal Entities for the Conduct of Humanitarian Demining

DEMINING MACHINES	54
HEAVY	8
MEDIUM	21
LIGHT	19
EXCAVATORS	6

Photo 1: Demining machine, MV-20   Table 1: Accredited demining machines

Supervision over the work of demining machines at the worksite is conducted by company's staff (worksite leader, team leader and machine operator). Inspection and quality assurance are conducted by the authorised CROMAC representatives (QA monitors and QC officers).

Internal inspection includes regular servicing and maintenance of demining machines, determination of working conditions, work according to instructions and control of mechanically treated area. Regular maintenance of the machine at the worksite includes machine checkups prior to the beginning of work and after as well as observation during the machine work. Machine checkups are performed according to instructions stated in company's SOP. Servicing is performed by accredited service centres according to planned intervals. Determination of conditions for the work with demining machine is done by the worksite leader on the basis of criteria stipulated by the Rules and Regulations and SOP. The aim is to establish weather the conditions for the quality machine work have been met or not. If the conditions are met, starts the worksite organization in accordance with company's SOP i.e. work method is chosen based on machine type and method of operation, see Photo 2.
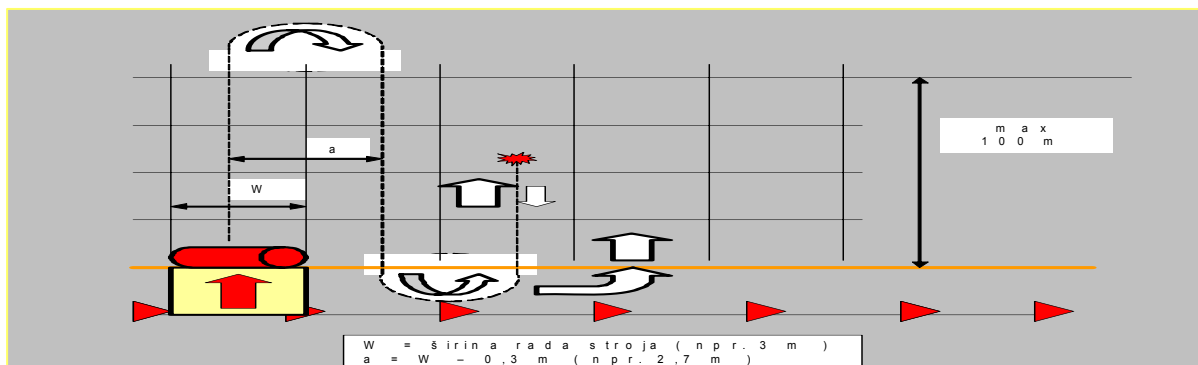
Photo 2: The scheme of demining machine work

Worksite leader and team leader perform a continuous supervision through all the phases at the worksite. They are responsible for the quality of mechanically treated area and if they observe any deviations in the quality, they warn the machine operator to correct them i.e. to repeat the mechanical treatment of the area in order to be able to implement the planned methods after demining machine use. Worksite safety is something that should be worried about, primarily the safety of machine operator either he operates the machine remotely (safe distance – 100 m min.) or directly from the protected cabin. If operated from the cabin, special attention should be paid to potential evacuation of the machine operator in case of machine damage (malfunction or uncontrolled detonation of a mine).

Quality assurance is performed by the authorised CROMAC representatives, QA monitors (at the worksite, every day) and QC officers (at the worksite, once a week). They implement the QA procedures in accordance with SOP 04-01[6] and 04.02[7]. QA monitor checks the technical machine booklet and conformity of the machine/working tool with the technical booklet, and type of working tool prior to the beginning of demining machine work at the worksite.

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[6] SOP, CROMAC 04.01. Quality Assurance and Quality Control of Mine Search and/or Demining
[7] SOP, CROMAC 04.02. SAMPLING – Sampling for Inspection and Control of Soil Treatment Depth during the Use of Demining Machines

Photo 3: Flail and/or tiller

Photo 3: Demining machine working tool

Photo 4: Flail completeness control

Besides comparing the tool type, the completeness of tools that is extremely important for the proper machine work should be checked as well (see Photo 4).

When all the conditions have been met, the QA monitor allows the work of a demining machine. During the work, QA monitor controls the safety measures and performs visual observation over the work of demining machine i.e. establishes if the machine moves without interruptions, if the areas overlap and other elements affecting the quality of mechanically treated area. If QA monitor observes any irregularities, he informs the worksite leader about them and orders their correction. He also informs the QC officer about the irregularities and enters the information about them in the worksite records.

After mechanical treatment with the demining machine, the QA monitor performs sampling in accordance with the SOP 04.02. The SOP is made based on HRN ISO 2859-1[8]. The sampling procedure is described in detail in the SOP and it primarily comes down to establishing trust with regard to the demining machine type. Heavy demining machines are assigned the biggest confidence level due to their characteristics. Light machines are assigned the smallest confidence level.

In accordance with the SOP, QA monitor determines the lot size[9] and reads the sample size, number of measurements in the sample and code letter (with regard to the confidence level and inspection level, see Table 2) off from the table.

No.	Lot size (m^2)	Sample size (m^2)	No. of depth measurements in the sample	Special inspection levels				General inspection levels		
				S-1	S-2	S-3	S-4	I	II	III
1	200 - 500	1	1	A	A	A	A	A	B	C
2	501 - 1 200	1	1	A	A	B	B	B	C	D
3	1 201 - 3 200	6	3	B	B	C	C	C	D	E
4	3 201 - 5 000	10	3	B	C	C	D	D	D	E
5	5 001 - 8 000	20	5	C	C	D	D	D	E	F
6	8 001 - 15 000	20	5	C	D	D	E	E	F	F
7	15 001 - 35 000	20	5	D	E	E	E	E	F	G
8	35 001 - 150 000	50	7	D	E	E	F	F	G	H
9	150 001 and more	50	7	E	E	F	F	G	H	J

Table 2: Enclosure to the SOP 04.02. Determination of numbers of samples and measurements in the sample

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[8] HRN ISO 2859-1, Sampling Procedures per Attributes
[9] Lot, area treated with the same machine type and working tool type

After the above-given values are read off, QA monitors enters them into the form and from the Enclosure C to the SOP reads off the number of samples with regard to the AQL[10]. This represents the fulfilment of conditions for worksite sampling. The QA monitor performs sampling according to sampling plan and enters the measured values into the form. After sampling, QA monitor processes the results and, in respect to defined acceptance terms, accepts or rejects the mechanically treated area, see Table 3.

ACCEPTANCE TERMS	I cat	II and III cat	ACCEPTABILITY LEVEL	
			ACCEPT (Ac)	REJECT (Re)
	depth 20 cm	depth 10 cm	Xsr>20 cm Xsr>10 cm	
INCORRECTNESS	Deviation from the characteristic of quality-does not meet the requirements			
INCORRECTNESS A	< 12	< 6	0	1
INCORRECTNESS B	< 17 >12	< 8 > 6	2	3
INCORRECTNESS C	< 20 > 17	< 10 > 8	3	4

The table defines incorrectness and non-conformity. Incorrectness is a deviation from the characteristic of quality that results in a fact that mechanically treated area cannot be accepted. Non-conformity is a deviation that, under specific circumstances, allows the acceptance of mechanically treated area. There are three types of non-conformity – A, B and C. They define the following: under specific circumstances, mechanically treated area can be accepted under the condition that it meets the medium value (projected depth) i.e. that the specified number of measurements can be even smaller than the medium value but the treated area accepted anyway.
The QA monitor enters the sampling results into the worksite record and if the area is rejected, he informs the QC officer about it. Then, the QA officer orders the repetition of mechanical area treatment or change of work method.

4. Conclusion

Quality assurance procedures during the use of demining machines established at all levels, as presented in this paper, ensure good quality, safe, cost-effective and efficient performance of humanitarian demining operations in the Republic of Croatia and represent the basis for further system upgrade.

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(1) Croatian Mine Action Centre, http://www.hcr.hr, 25 April 2010

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   - Rules and Regulations on the Technical Requirements and Establishment of Conformity of the Machines Used in Humanitarian Demining Operations, NG no. 53/07

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[10] AQL, Acceptable Quality Level

ITEP Dual Sensor Test in Germany

Kazunori Takahashi[11] and Dieter Gülle[12]

Abstract

An ITEP test campaign of landmine detection sensors has been taken place in September-October 2009 in Germany, led by the Federal Office of Defence Technology and Procurement (BWB), Germany. The main objective of the test is the performance evaluation of dual sensors which combine metal detector and ground-penetrating radar (GPR) for identifying detected objects. In addition stand-alone metal detectors, stand-alone metal detectors with discrimination capability and stand-alone GPR have also been tested for comparison. The result clearly shows that the tested dual sensors are potentially capable of discriminating metal clutter and landmines, which is expected to contribute to the efficiency improvement of the clearance operation. However, at the same time, some issues that may need to be overcome for the use in humanitarian demining have been arisen.

1. Introduction

A dual sensor test has taken place in September-October 2009 in Oberjettenberg, Germany. The test campaign is a part of an ITEP project [1][2] and has been led by the Federal Office of Defence Technology and Procurement (BWB), Germany. In the test as well as in this paper dual sensor refers to a device which integrates metal detector and ground-penetrating radar (GPR) for detection of metal-containing objects and identification of landmines, respectively. The Advanced Landmine Imaging System (ALIS) developed by Tohoku University, Japan participated in the test. The details of the detector can be found in [3], as well as at manufacturer's website [4]. For the comparison the base metal detector of the dual sensor (CEIA MIL-D1) and stand-alone GPR (ERA SPR-scan 2 GHz) have also been tested. The paper shows the overview of the test results and discusses the performance of the detectors. The detailed description of the test, results and interpretation will be found in the test report [5].

2. Test conditions

There are lanes with three types of soil prepared in the test site. These test soils can be categorised into: laterite, sand mixed with magnetite and humus soil. The detailed descriptions of the soils as well as the properties can be found in the report "Physical characterisation of the test lanes in the ITEP dual sensor test Oberjettenberg/Germany 2009" [6]. Three types of mine-like targets including rendered safe mines were planted in these soils: ERA Calibration Target, Gyata-64 and PPM-2. In addition various sizes of metal pieces such as bullets and cartridges were buried as metal clutter. The test objects are shown in Fig. 1. The burial depths are ranging from 2 to 15 cm.

The test was a blind test; the operators of detectors did not know the locations and types of objects. The dual sensor operators first used the metal detector part of a dual sensor for detecting a mine suspected objects, and then switched over to GPR for discriminating mines from metals. To indicate the locations of a metal detection and types of object (mine or mine-like) after the search with dual sensors two colours of markers were used. After each test run positions of markers were measured.

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Fig. 1. Objects used in the test. ©BWB

3. Data analysis

Positions of detections as well as discrimination results whether a detected object is mine or metal are compared to the test plan, applying the halo radius defined in CWA 14747-1:2003 [7]. For evaluation of detection performance alarms from metals and soil should be treated as false alarms in case of dual sensor test, whereas only soil is used to be considered source of false alarms in formally conducted stand-alone metal detector tests. The difference is listed in Table I.

Detection performance can be evaluated probability of detection (POD) and false alarm rate (FAR), which indicate how much targets are found and how much false alarms are produced in one square metre, respectively. These values are obtained as follows.

$$POD = \frac{Number\ of\ detected\ targets}{Number\ of\ buried\ targets} \tag{1}$$

$$FAR = \frac{Number\ of\ false\ alarms}{Area\ searched} \tag{2}$$

For the evaluation of discrimination performance two more values are introduced. One is FAR reduction which indicates how much false alarms reported by the metal detector part of a dual sensor are correctly identified and reduced by using the GPR part of a dual sensor, and the other is POD loss which tells how much mines are falsely identified and rejected. They are defined as [8]

$$FAR\ reduction = \frac{Number\ of\ rejected\ false\ alarms\ by\ GPR}{Number\ of\ false\ alarms\ by\ MD} \tag{3}$$

$$POD\ loss = \frac{Number\ of\ rejected\ targets\ by\ GPR}{Number\ of\ detected\ targets\ by\ MD} \tag{4}$$

By the definitions the higher FAR reduction and the lower POD loss indicate the better discrimination performance.

TABLE I. Difference of categorising sources of alarms for stand-alone MDs and dual sensors.

	Stand-alone MDs	Dual sensors
Sources of true positives	Mine-like targets, metals	Mine-like targets
Sources of false positives	Soil	Metals, soil

4. Test results

Fig. 2 shows POD plotted as a function of FAR for ALIS in total. The result of one dual sensor has two plots. The dot indicates *detection* result after using the metal detector part and before using the GPR part of the dual sensors, while the circle shows result after the *discrimination* using the GPR part of the dual sensor. It can clearly be seen that the plot moves towards left after using GPR, meaning that FAR is reduced. However, at the same time, the plot moves slightly downwards, meaning that some mines are falsely rejected as clutter, which is supposed not to happen for safety. How much false alarms are successfully reduced and how much mines are falsely rejected are depicted in Fig. 3 in which FAR reduction is plotted as a function of POD loss. In this figure the stand-alone GPR achieved behind the marking of different metal detectors a much higher FAR reduction than ALIS; however the stand-alone GPR has a higher POD loss, about 10% of the found mines from the different metal detectors. Thus, there is a trade-off that a higher FAR reduction can be obtained with a higher POD loss and a lower POD loss causes a lower FAR reduction. It can also be observed that when a straight line

is drawn from the origin of the figure, all points are more or less on the line. The fact indicates that the discrimination capabilities of these detectors are almost equal, but the results look different because operators may be applying decision-making criteria differently. For example, a deminer who wants to maximise FAR reduction may achieve a higher POD loss, and another deminer who wants to keep POD loss low may obtain a low level of FAR reduction even using the same detector. Results of the manufacturer showed a very low POD loss but also a low FAR reduction (the result is not shown in the figure), despite the fact that the manufacturer achieved already a lower level (about 1.8 m^{-2}) of FAR with the metal detector. The reason may be that the experts operated minimising POD loss because they know it has to be avoided and they know how to do so. The fact tells us that the longer working experience and more knowledge on a dual sensor use improve the performance.

Fig. 4 shows discrimination performances as a function of depth. In the figures FAR reduction is increasing and POD loss is decreasing with depth, though the tendency is weak. The results indicate that the discrimination performance by GPR is worse at shallow depth and is better in depth. It can be explained as follows: rough ground surface may create additional response on GPR which is falsely recognised as target, resulting in less FAR reduction and GPR signals reflected from the ground surface disturbs reflection from targets which makes difficult to correctly recognise mines, resulting in high POD loss. The performance of ALIS depending on depth seems to be more robust than that of the stand-alone GPR. One of the reasons may be its sophisticated signal processing and way of interpretation.

The tested dual sensor, which combines metal detector and GPR is supposed to be used as follows: detection of metal-containing object with metal detector part of dual sensor and then discrimination of this object with GPR part of the detector. The detection performance entirely depends on the performance of the metal detector part and it has to be as good as the stand-alone metal detector. In order to ensure that GPR does not negatively influence on the metal detector part, the detection performance of a dual sensor is compared to that of a stand-alone metal detector which is the base model of the dual sensor. The results are shown in Fig. 5. The detection performances of the base metal detector (CEIA MIL-D1, cross) and ALIS (dot) are very close and no obvious difference can be observed. It indicates that there is no obvious deterioration of metal detector performance due to combining GPR antennas and the metal detector part of the dual sensor is as good as the stand-alone metal detector.

It is not possible to discuss on efficiency improvements of the entire clearance operation based on the test, where only detection (as well as discrimination) was performed but excavation and conformation of detected objects were not included. However, to have an idea, search speeds of detectors are evaluated. In Fig. 6 search speeds are plotted in minutes per one square metre. As one can see, ALIS needed almost doubled time of stand-alone metal detectors needed to search, in other words, ALIS is two times slower than stand-alone metal detectors. The results allow us to roughly estimate that, assuming that ALIS can reduce one-half of false alarms as shown in Fig. 3, the clearance operation in total is expected to be accelerated when the excavation process for an object needs more than twice the time necessary for finding an object, which is not unrealistic.
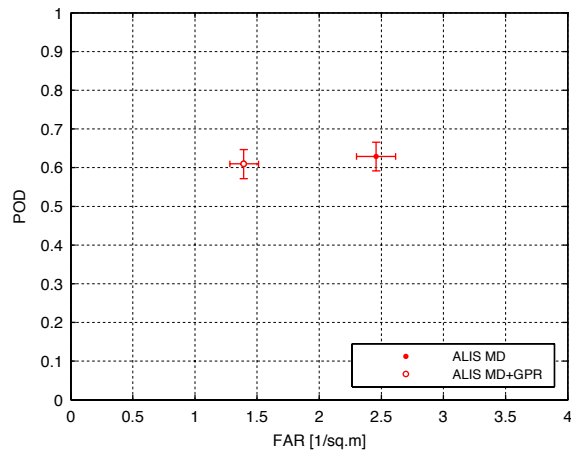
Fig. 2. POD versus FAR of ALIS in total of all runs. The dot and circle indicate before and after the discrimination, respectively, and the error bars show 95 % confidence bounds.
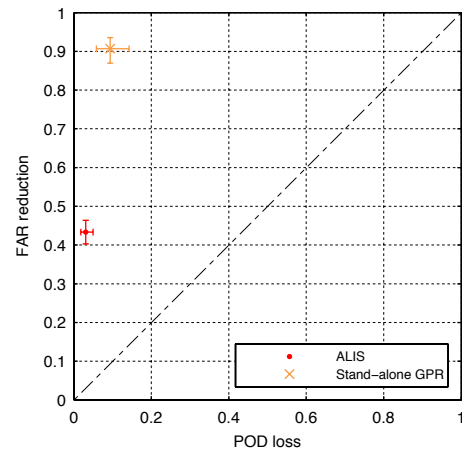
Fig. 3. FAR reduction versus POD loss due to the discrimination process in total of all runs. The error bars show 95 % confidence bounds.

(a)

(b)
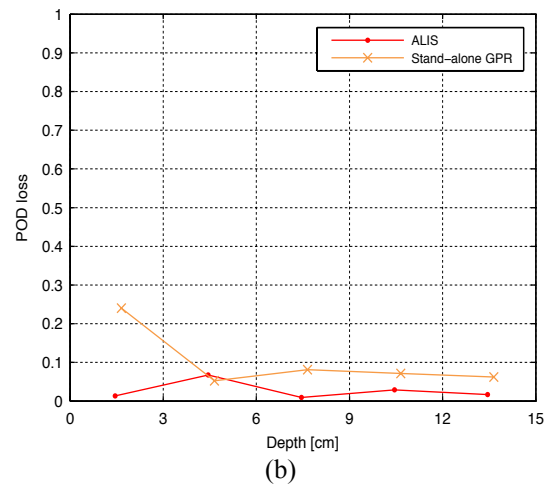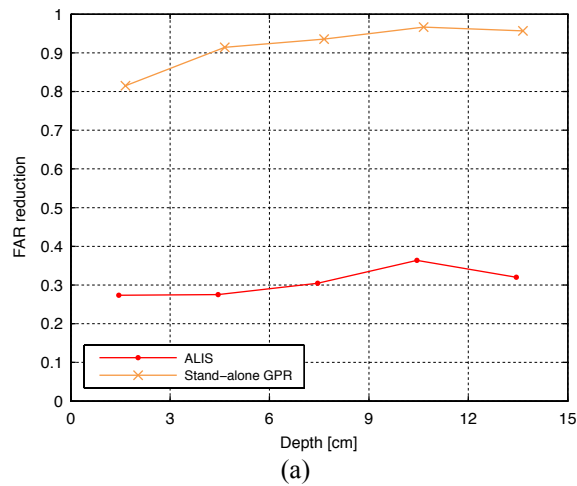
Fig. 4. Discrimination performance depending on depth. (a) FAR reduction and (b) POD loss.
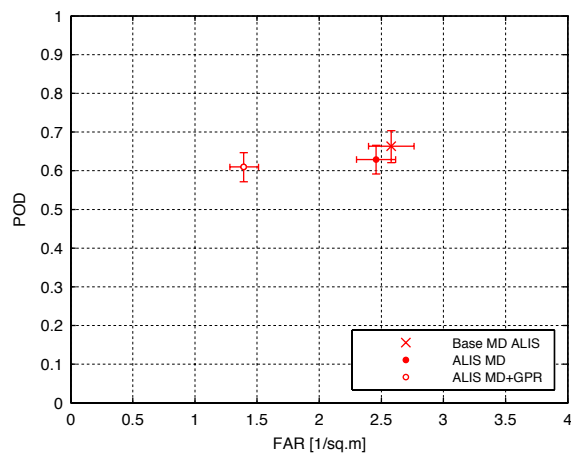
Fig. 5. POD versus FAR of ALIS in comparison to the base metal detector (CEIA MIL-D1).
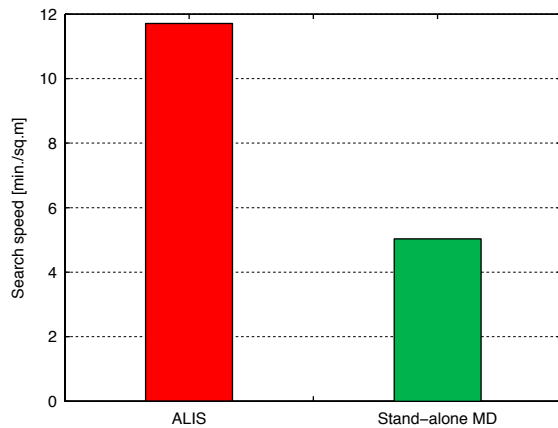
Fig. 6. Search speeds of ALIS and stand-alone metal detectors.

5.   Conclusions and discussions

By analysing the results of the dual sensor test, it is clearly confirmed that dual sensor can reduce false alarms compared to stand-alone metal detector, which potentially indicates the efficiency improvements of clearance operations in total. However, there are a few issues that need to be considered, such as POD loss, search speed and training, for maximising benefits and minimising shortcomings of dual sensors. It can be observed that dual sensors can correctly reject false alarms but also it sometimes falsely rejects mines. It seems to be happening especially at shallow depth and it is also related to soil type [9]. The false rejection of mines (POD loss) can be avoided by selecting favourable soil types for dual sensors by investigating soil properties, for example. The search speed is directly related to the efficiency improvements of clearance operations and the higher search speed the more improvements can be expected. The test results show a dual sensor is twice slower than stand-alone metal detectors. However, operators for a dual sensor who have longer experience and more knowledge on the detector needed as much as time for the stand-alone metal detectors and in this case the improvements are more likely achieved. As mentioned, experienced operators of dual sensors obtained much better results in discrimination performance as well as in search speed. The fact indicates more training and/or practice is necessary for the use of dual sensors, compared to metal detectors. In the test operators trained for a short period could not act as same as experienced operators.

The dual sensor test allows us to evaluate detection as well as discrimination performances of dual sensors in a blind test. For investigation of the efficiency improvements of clearance operations in total, there are other factors need to be taken into account, such as the time for excavation, cost of detectors and cost for training and practice.

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A Study on Prodding Detection of Antipersonnel Landmine Using Active Sensing Prodder

Jun Ishikawa[13] and Atsushi Iino[14]

Abstract

This paper proposes an active sensing method using a prodder that emits white Gaussian noise vibration, the amplitude of which is about less than 10 micro meters, to identify what kind of object is in front of the pointed tip of the prodder. Anti-personnel landmines have their own natural frequencies around from 3 to 5 kHz, and the resonant frequencies are different from those of stones, metals or other hard objects. The prodder is driven by a piezoelectric actuator and senses the tip acceleration, the measurement time of which is expected to be less than 1 seconds per object.

Preliminary experiments were conducted to compare the prodder acceleration induced by white Gaussian noises for landmine-like targets with those of other harder targets (aluminum and brass cylinders). The experimental result showed that the acceleration wave forms from landmine-like targets were different from those of aluminum and brass targets. Signal processing techniques to discriminate landmine-like targets from other objects are also discussed based on the preliminary experimental results. It was found that there could be a possibility to discriminate landmine-like targets by analyzing response signals in frequency domain after digital Fourier transform (DFT).

1.   Introduction

It has been more than decades since advanced mechanical demining have started, and demining machine technology has made remarkable progress. Furthermore, advanced sensing technologies such a ground penetrating radar (GPR) have recently become to be practically used in the minefields as well as metal detectors. In the close-in detection phase, however, prodding still plays an important role. Actually, the use of prodders in manual demining and post clearance inspection after mechanical demining is still essential as a method of final confirmation whether it is a landmine or not. It is also well known that the prodding is one of the most difficult works in manual demining. Thus, it is desired that easy-to-use prodders will be developed to improve working efficiency and safety.

Many researches have been conducted on improving prodders. It is well known that many landmines have their own natural frequencies [1], which allow us to discriminate them from other objects such a stone. One way to utilize this feature is seismic/acoustic methods [2]. On the other hand, there are also researches on adding a kind of sensing function to prodders. In [3]-[7], prodders that use narrow-band ultrasonic waves have been proposed and evaluated on a large scale. There is another kind of prodders that use laser to sense plastic materials of landmines [8][9].

In this paper, an active sensing method for prodders is proposed. In the proposed method, white Gaussian noises, which have a broad bandwidth, are used as a source of ping vibration of a prodder. By sensing and analyzing acceleration of the prodder during the vibration, a kind of hardness of target objects is expected to be estimated. In Section 2, modeling of a prodder touching an object is derived, and Section 3 gives evaluation results for the derived model. In Section 4, signal processing techniques for discriminating landmine-like targets from other harder objects are discussed, and Section 5 gives some experimental results to see validity of the proposed method.

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2. Anti-personnel(AP) landmine and prodder model

Figure 1 shows a structure of a prototype of the proposed prodder, which is vibrated by a piezoelectric actuator and has an accelerometer to measure the vibration. The piezoelectric actuator used here has a displacement gain of 9.1×10^{-6} [m] when the maximum input of 150 V is applied.

In this section, a model of a prodder where the prodder is touching an object is derived. Figure 2 shows a simplified structure of a prodder-object model, and definitions of the parameters are listed in Table I. Note that though an output of the model is a displacement of the prodder formally, an actual measurement is its acceleration. In Figure 2, the yellow-framed part corresponds to the prodder model, and the green one is the object model. The spring in Figure 1 is modeled as a spring of k_0 in Figure 2. The equation of motion of the model in Figure 2 is given by

$$m_1 \ddot{y}_1 = -k_0 y_1 + k_1(u - y_1) + d_1(\dot{u} - \dot{y}_1) + k_2(y_2 - y_1) + d_2(\dot{y}_2 - \dot{y}_1)$$
$$m_2 \ddot{y}_2 = k_2(y_1 - y_2) + d_2(\dot{y}_1 - \dot{y}_2) - k_3 y_2 - d_3 \dot{y}_2 \qquad (1)$$

Thus, the transfer function from u to $\ddot{y}_1$ can be derived as

$$G(s) = \frac{b_5 s^5 + b_4 s^4 + b_3 s^3 + b_2 s^2}{a_4 s^4 + a_3 s^3 + a_2 s^2 + a_1 s + a_0} . \qquad (2)$$

Those parameters in Figure 2 are to be a basis of landmine-like target discrimination, and Section 3 discusses a way to identify the parameters.
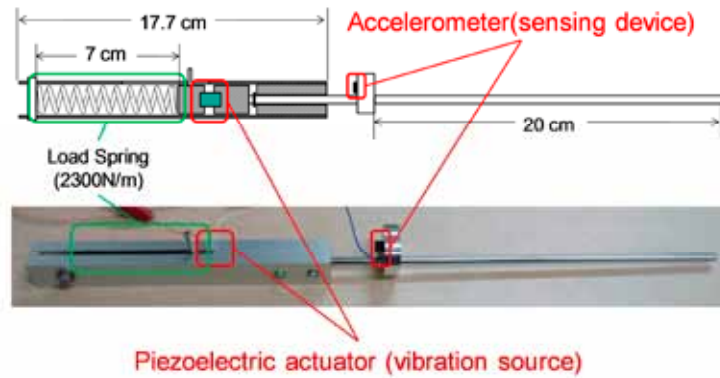
Figure 1. Structure of a prototype of prodder.
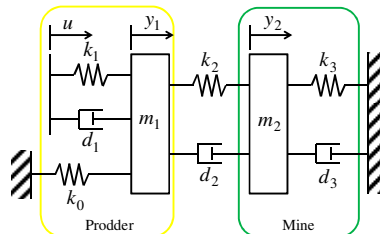
Figure 2. Modeling of anti-personnel landmine and prodder (no-soil model).

Table I. Parameters of anti-personnel landmine and prodder models.

Symbol	Definition
m_1[kg]	Mass of prodder
m_2[kg]	Mass of object
k_0[N/m]	Stiffness of adjuster spring
k_1[N/m]	Stiffness of prodder
d_1[Ns/m]	Damping of prodder
k_2[N/m]	Stiffness between prodder and object
d_2[Ns/m]	Damping between prodder and object
k_3[N/m]	Stiffness of object
d_3[Ns/m]	Damping of object
u[m]	Vibration input
y_1[m]	Displacement of prodder during vibration
y_2[m]	Displacement of object

3. Preliminary experiment

3.1. Experimental system and procedures

For the purpose to check if the parameters in Table I have some features of target objects, a preliminary experiment was conducted to identify the parameters for typical kinds of targets, *i.e*., an aluminum cylinder, a brass cylinder, a landmine surrogate and no object.

Figure 3 shows an experimental setup for parameter identification. In the experiment, one end of a target object was clamped against an anchorage by pushing the other side by the pointed tip of the prodder. The clamping force was kept to be 11.5 N by retracting a spring by 5mm, the stiffness of which is 2300 N/m. To measure frequency responses from the input u to the output $\ddot{y}_1$, swept-up sinusoidal inputs from 100 Hz to 10 kHz were applied to the piezoelectric actuator.
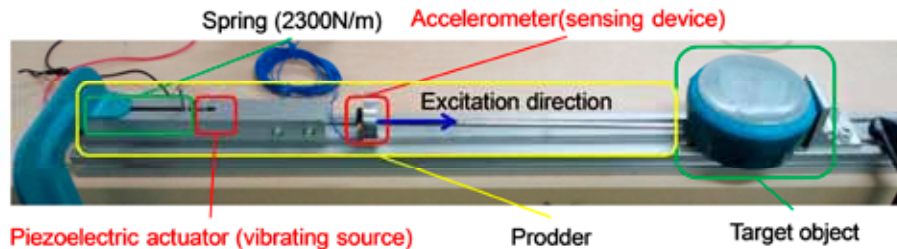
Figure 3. Experimental system.

3.2. Parameter identification result

Figure 4 shows measured frequency responses from 100 Hz to 10 kHz for three objects and no object. From these results, it is found that feature of each object emerges in the frequency range from 1 to 10 kHz. Thus, the model parameters in Table I were determined by fitting frequency responses calculated by using model parameters to the measured ones in the frequency range. Figure 5 shows the fitting results and the identified parameters are listed in Table II. By focusing attention on resonances and anti-resonances in the frequency range, hardness of objects is expected to be detected.
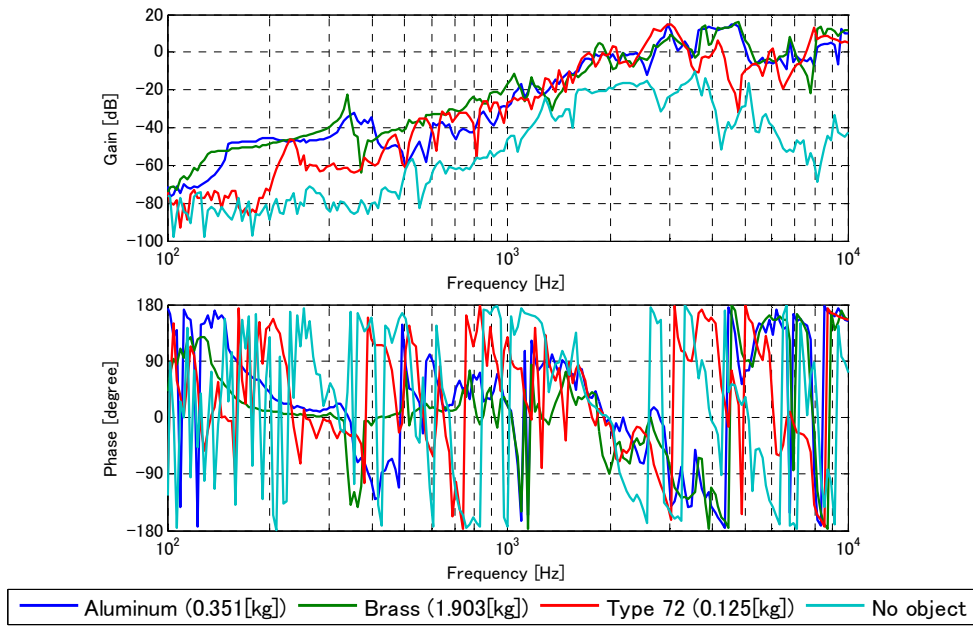
Figure 4. Frequency response of the transfer function from u to $\ddot{y}_1$ derived by using swept-up sinusoidal inputs.
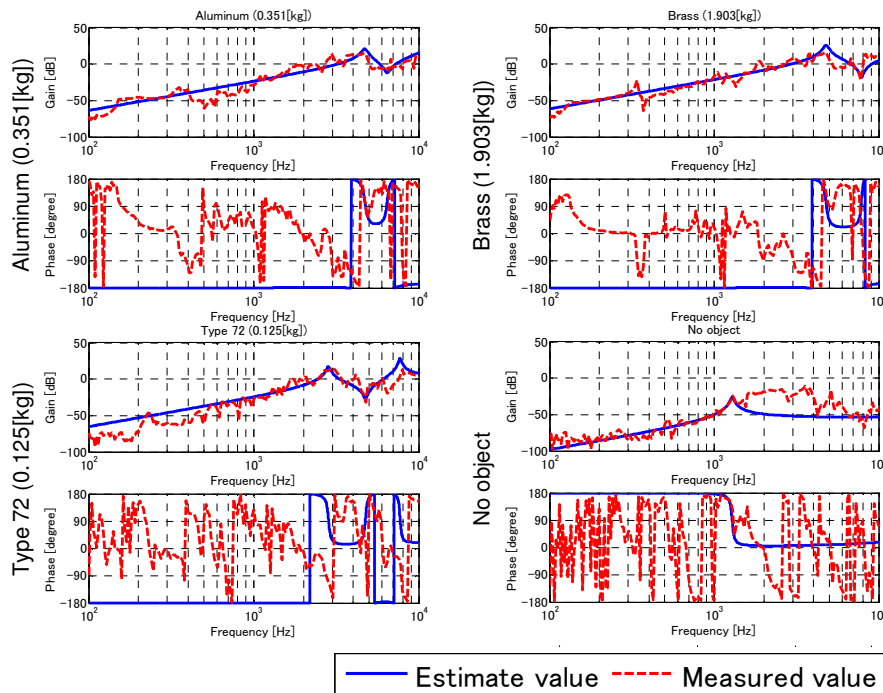
Figure 5. Curve fitting result of numerical model based on estimated parameters.

Table II. Identified parameters by curve fitting.

Symbol	Aluminum	Brass	Type 72	No object
m_1[kg]	0.036	0.036	0.036	0.036
m_2[kg]	0.351	1.903	0.125	0.0001
k_0[N/m]	2300	2300	2300	0
k_1[N/m]	2.34×10^6	2.34×10^6	2.34×10^6	2.34×10^6
d_1[Ns/m]	12	12	12	12
k_2[N/m]	2.34×10^8	2.8594×10^9	6.12×10^7	0
d_2[Ns/m]	60	5.8	30	0
k_3[N/m]	3.42×10^8	1.7493×10^9	5.04×10^7	0
d_3[Ns/m]	780	3480	120	0

4. Signal processing

4.1. Frequency response analysis

From the preliminary experimental results, it is considered that the transfer function from u to $\ddot{y}_1$ can be structured by two resonances and one anti-resonance. Therefore, Equation (2) is rewritten as

$$G(s) = \frac{\beta_1 s^2 (s + \beta_2)(s_2 + 2\zeta_c \omega_c s + \omega_c^2)}{(s_2 + 2\zeta_a \omega_a s + \omega_a^2)(s_2 + 2\zeta_b \omega_b s + \omega_b^2)} \ . \tag{3}$$

As described in the previous section, hardness of target objects can be estimated from those resonances and anti-resonance of the transfer function. However, it takes long time to measure a frequency response by using swept-up sinusoidal inputs. Instead of this kind of inputs, a white Gaussian noise can be used as an input to measure a frequency response for shorter duration. In this subsection, frequency responses of the transfer function calculated by the spectrum analysis method using a white Gaussian noise input, the duration of which is 0.64 s, are compared with those derived by using the swept-up sinusoidal input method. In the spectrum analysis method, a frequency response is derived as a ratio of the cross power spectrum density between u and $\ddot{y}_1$ to the power spectral density of u. As shown in Figure 6, both results agree with each other. Thus, in the following experiments, the spectrum analysis method using a white Gaussian noise input is used.
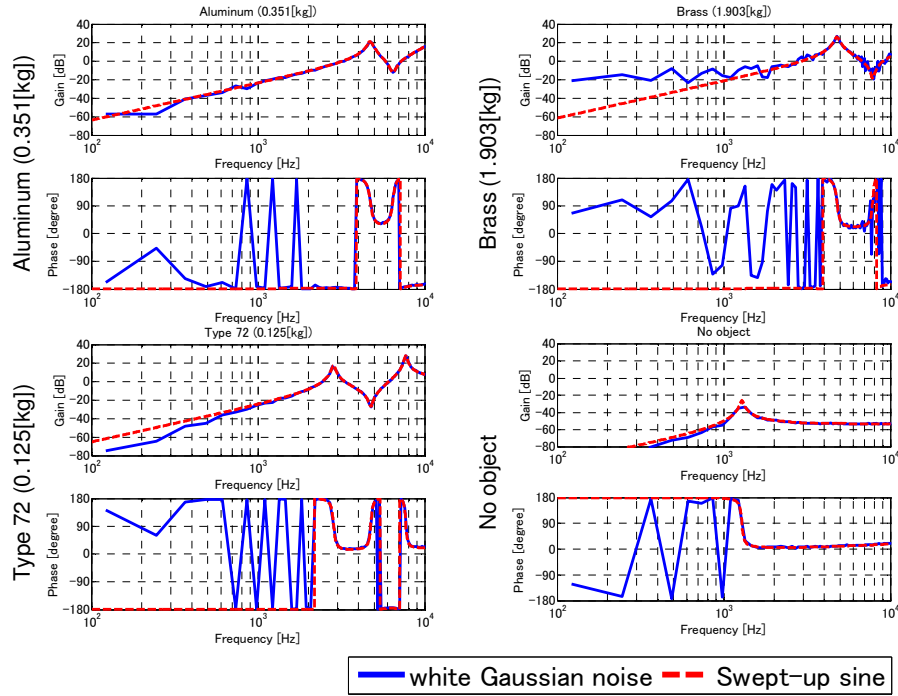
Figure 6. Comparison of frequency responses derived by both methods (simulation).

4.2. Time response analysis

Consider processing the acquired data in another way. In this subsection, time traces of the output (the acceleration of the prodder $\ddot{y}_1$) are analyzed by digital Fourier transform (DFT) analysis. Figure 7 shows DFT results for the same simulation data as used in Subsection 4.1. As shown in this figure, frequencies of resonances are observed in different ranges for different target objects. This means that DTF results can be also used to discriminate landmine-like targets from other objects.
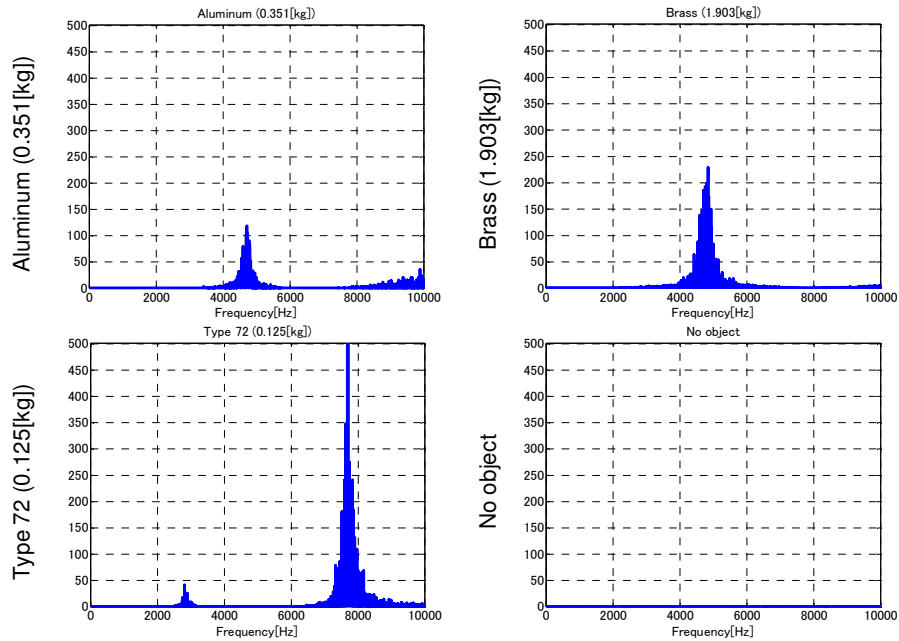
Figure 7. Digital Fourier transform (DFT) of output signal (simulation).

5. Experiment

Experiments were conducted to measure the prodder acceleration $\ddot{y}_1$ during the prodder was vibrated, and data for 6 objects and a no object case shown in Figure 8 were acquired. The data were processed in the way explained in Section 4. Although an appropriate measurement time, *i.e.*, an input signal duration, should be carefully chosen taking into account environmental conditions, in the experiment, a white Gaussian noise input of 0.64 s was added to the piezoelectric actuator for every measurement.
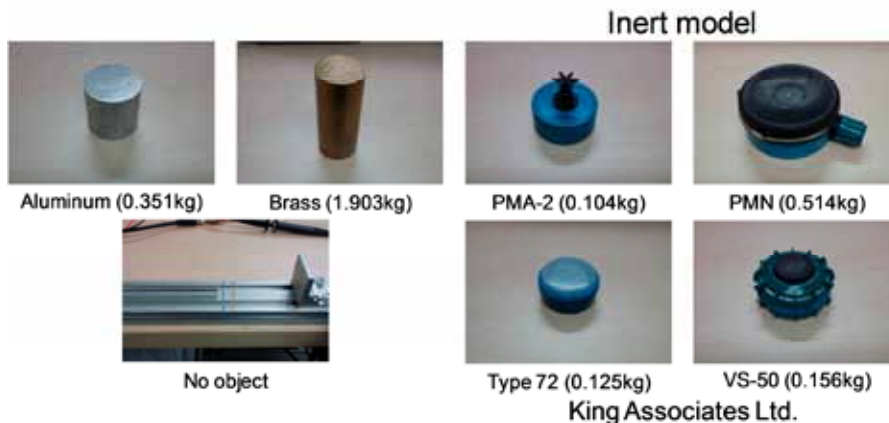
Figure 8. Target objects used in experiment.

5.1. Experimental setup

Figure 9 shows the experimental setup. A signal generator generates swept-up sinusoidal inputs or white Gaussian noises, and the generated signals are input to a piezoelectric driver so that a piezoelectric actuator can vibrate the prodder system. An accelerometer is equipped at the base of the prodder needle, and the sensing signal is acquired by a frequency analyzer through a signal amplifier. The white Gaussian noise input used here is biased so that the generated input is kept within the range from 0 to 120 V. As explained in Section 3, a target object is clamped by the force of 11.5 N using the load spring.
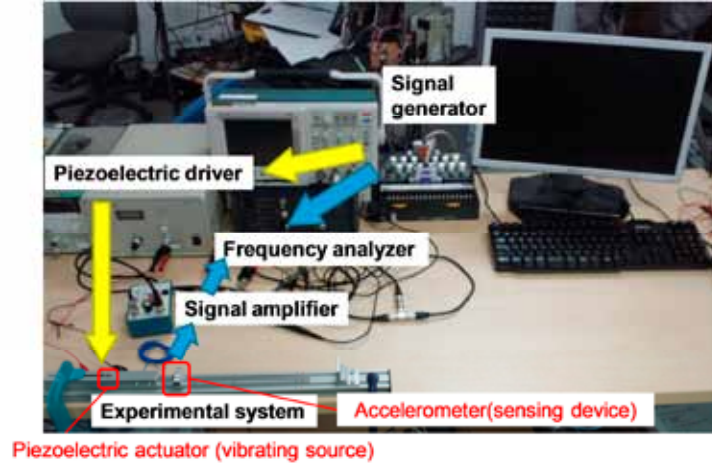
Figure 9. Experimental setup.

5.2. Experimental results

Figure 10 shows raw time traces of both input and output signals for 4 ms, *i.e.*, 1/160 of the whole duration of 0.64 s. Note that the input voltage were measured before the amplifier and that the range were different from the said range from 0 to 120 V. In the following subsections, results of frequency response analysis and time response analysis are explained.
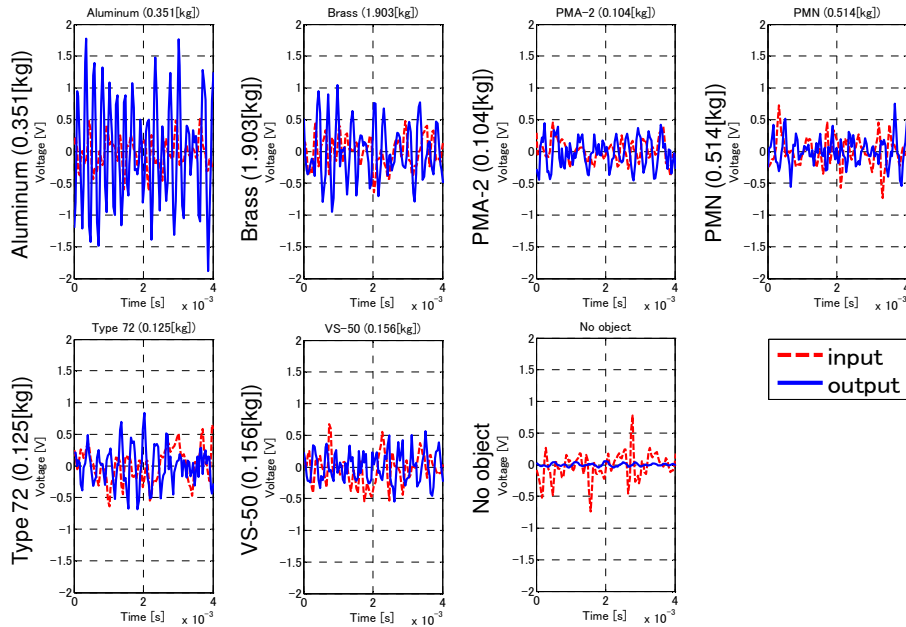
Figure 10. Time traces of u and $\ddot{y}_1$ for white Gaussian noise.

5.2.1. Frequency response analysis

Figure 11 shows frequency responses calculated by the spectrum analysis method (blue solid lines). Frequency responses derived by using swept-up sinusoidal signals (red dashed lines) are also plotted in Figure 11 to compare those with each other. As agreed with simulation results in Subsection 4.1, both responses were similar to each other. This means that frequency responses calculated by the spectrum analysis method for short duration can be an alternative to those derived by the swept-up sinusoidal signal method that takes longer time than the spectrum analysis method. In this experiment, it was found that landmine-like target could be discriminated from other harder objects to pay attention to the response around 3 to 5 kHz.
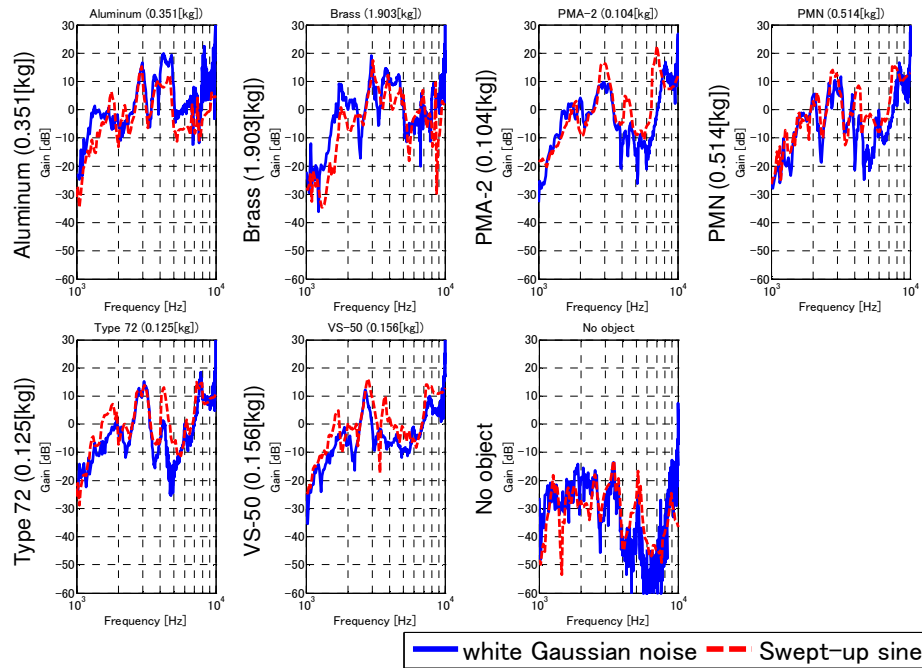
Figure 11. Frequency responses: white Gaussian noise case and swept-up sinusoidal input case.

5.2.2. Time response analysis

Figure 12 shows DFT results for the same data acquired by using the white Gaussian noise inputs as in the previous subsection. Difference between DFT features of landmine-like targets and the other objects becomes clearer than those between frequency responses. From these results, it can be said that there is a possibility to discriminate landmine-like targets from other objects by focusing attention on the frequency range from 3 to 5 kHz and the amplitude of DFT results.
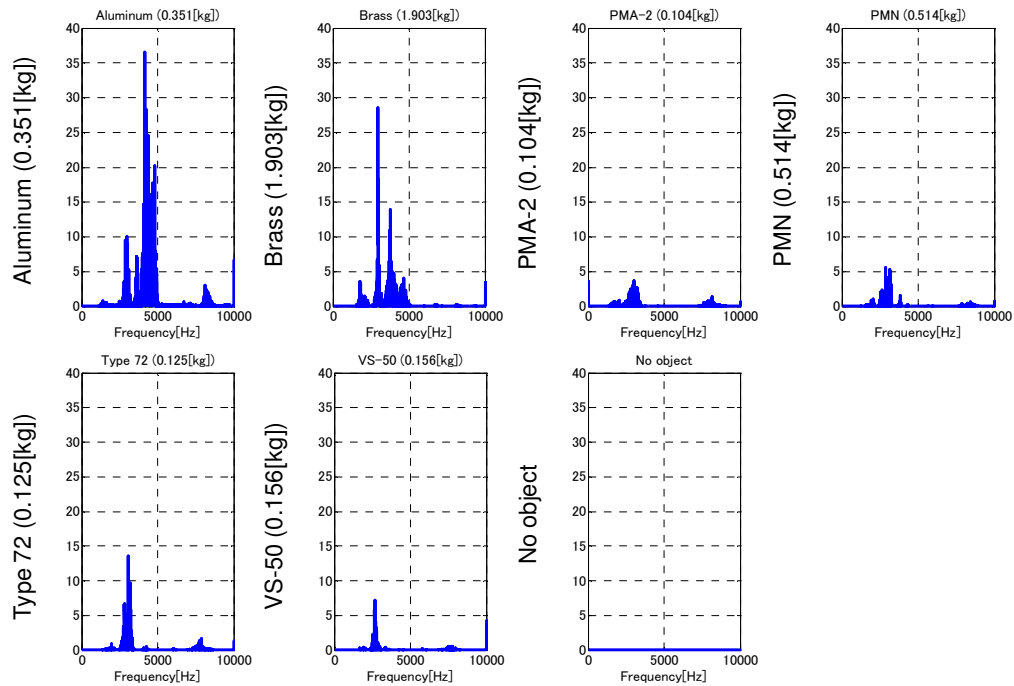
Figure 12. Discrete Fourier transform (DFT) result of output signal.

6. Conclusion

This paper proposed a new prodder concept using an active sensing function using a piezoelectric actuator and an accelerometer. Experimental results showed that landmine-like targets could be discriminated from other harder objects by focusing attention on the DFT signals in the frequency range from 3 to 5 kHz.

Future work will be making the system more easy-to-use especially for decision making using data in other frequency ranges less than 1 kHz and conducting experiments for buried targets in soil.

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The Anomalies, Perceptions and Contradictions that Exist in the Use of Dogs in Demining

Ashley Williams[15]

Abstract

Whilst dogs and other animals have been used to serve man for many years, we know very little about the psychology of these animals. Dogs in particular have been used to serve man due to their intelligence, excellent olfactory capacity, stamina and loyalty. Despite much study that has gone into the behaviour of dogs over the past century, there still remain many anomalies, perceptions and contradictions concerning their behaviour and how it can best be manipulated to the advantage of man. One only has to get a number of canine experts into a conference such as this to see how drastically the opinions differ on subjects such as breeding, training, history and utilization.

The role of dogs in modern warfare and especially in mine warfare and later demining can probably be traced back to World War One where dogs were initially starved for a few days, then given food under own forces' battle tanks. Later explosive charges were attached to the dogs that then ran to the enemy tanks in expectation of food just to be used as involuntary suicide bombers. Once again this is my interpretation of the history which can be disputed by other subject experts.

This paper will in no way serve to answer the anomalies, perceptions and contradictions that exist, but it is only an introduction to the papers that will be delivered by subject experts and will hopefully answer some of these anomalies, perceptions and contradictions.

The following anomalies that today still exist within the canine fraternity and on which the subject experts cannot agree will be discussed:

- *Is dog handling an art or a science?*
- *What constitutes a good working/detection dog?*
- *Which breeds are best suited?*
- *Exactly what is the dog detecting/smelling?*
- *The dog handler and his/her role.*
- *Accreditation.*
- *Perceptions surrounding the use of MDDs and other working dogs.*

INTRODUCTION

Whilst dogs and other animals have been used to serve man for many years, we know very little about the psychology of these animals. Dogs in particular have been used to serve man due to their intelligence, excellent olfactory capacity, stamina and loyalty. Despite much study that has gone into the behaviour of dogs over the past century, there still remain many anomalies, perceptions and contradictions concerning their behaviour and how it can best be manipulated to the advantage of man. One only has to get a number of canine experts into a conference such as this to see how drastically the opinions differ on subjects such as breeding, training, history and utilization.

The role of dogs in modern warfare and especially in mine warfare and later demining can probably be traced back to World War One where dogs were initially starved for a few days, then given food under own forces' battle tanks. Later explosive charges were attached to the dogs that then ran to the enemy tanks in expectation of food just to be used as involuntary suicide bombers. The use of dogs for mine detection goes back as far as World War 2. Once again this is my interpretation of the history which can be disputed by other subject experts.

This paper will in no way serve to answer the anomalies, perceptions and contradictions that exist, but is only an introduction to the papers that will be delivered by subject experts and who will hopefully answer some of these anomalies, perceptions and contradictions.

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SCOPE

The following anomalies that today still exist within the canine fraternity and on which the subject experts cannot agree will be discussed:

- Is dog handling an art or a science?
- What constitutes a good working/detection dog?
- Which breeds are best suited?
- Exactly what is the dog detecting/smelling?
- The dog handler and his/her role.
- Accreditation.
- Perceptions surrounding the use of MDDs and other working dogs.

ART OR SCIENCE?

The question whether dog handling is an art or a science often comes up. On the art side it is argued that many people just have the gift of working with dogs, why this is so no-one can really explain. One finds people with no or very limited educational qualifications who can teach a dog to do virtually anything. Most of the time such individuals use skills and techniques carried over to them from family or mentors who themselves had the gift of training dogs. When one observes different dog handlers working their dogs there is often one individual who stands out from the rest and whose handling can best be described as poetry in motion; to my mind this is an art.

On the other side of the coin it is argued that one has to know more about the physiology and psychology of the dog to know why it is reacting in a certain manner and how to manipulate its behaviour. This scientific knowledge has led to the development of systems such as REST/MEDDS as well as to the research into the early detection of cancer using dogs. There is no doubt in my mind that science will assist us in future to discover even many more capabilities dogs possess and are presently still unknown to man.

What is the answer to this question then? I would propose that it is both an art and a science and only by combining the two will we really be able to maximize the unique capabilities that canines have to offer.

WHAT CONSTITUTES A GOOD WORKING/DETECTION DOG?

This is one of the questions I believe most subject experts do not differ too strongly on. Attributes such as good health, high energy and drive (enthusiasm), possessiveness, endurance and intelligence will feature high on the list of most canine experts. With the exception of health which can be determined by any veterinarian, the importance of these attributes will and can be fiercely contested. Differences of opinion also exist on whether these attributes are in- born/bred or whether they can be acquired or strengthened through training. However it is accepted that the attributes required for a guide dog for the blind are not necessarily the same as those required for a mine detection dog. This has led the breeding of task specific dogs over the centuries, such as Retrievers, Rhodesian Ridgebacks, Border collies, etc. Unfortunately there is until today no consensus on what really constitutes a good mine detection dog and thus there has been no specific breeding for this role. Furthermore it is a fact that most demining takes place in harsh environments with climatic extremes which often results in a breed with excellent olfactory abilities not being rugged enough to survive the physical conditions. The best results will be obtained by compromising the different attributes against one another.

With all this said, it remains a fact that within a litter one will find dogs excellently suited to become working dogs as well as others that can only be used as pets. Certain experts will however argue that planned pairing of dogs and early manipulation of the pup litter can ensure a drastic reduction in the "attrition" rate.

WHICH BREEDS ARE BEST SUITED?

Quite a number of studies have been done on this subject by the GICHD and other organizations and although there tends to be a broad consensus, there will inevitably still be differences of opinion and personal preferences amongst the experts. General working dogs such as German shepherds and Malinois still tend to be preferred, mainly due to their extraordinary nose and stamina. However other breeds such as Labradors, Border collies, Retrievers and Springer spaniels have also been used to good effect. At MECHEM we have also had good results with Australian cattle dogs as well as Collie/Labrador crosses. Then there is also the case of Snowy, a Fox terrier/Jack Russell, cross that gained almost celebrity status in Croatia, Sudan and South Africa and was affectionately known as "the Minekiller" and proved that any dog with the necessary drive and enthusiasm can become a mine detection dog.

In my experience at MECHEM we have found that although intelligence and a good nose are very important characteristics for a successful MDD, the environmental and climatic conditions under which the dogs have to live and work are the deciding factor on which breeds to use. Only dogs that are rugged and physically strong can survive in the typical demining environment. The short contractual nature of demining contracts also results

in a fairly high turnover of dog handlers in most demining companies and one finds certain breeds that prefer a single handler and do not perform   well with multiple handlers. The Border collies are a case in point. These dogs are arguably the most intelligent and trainable breed with an excellent nose. However in our experience they have not performed well in the field as MDDs, mainly due to being fairly "soft" dogs and not taking well to multiple handlers. On the other hand they are excellent REST/MEDDS dogs as well as explosives and narcotics detection dogs due to the general circumstances in which such work is done being much more moderate than those in the field.

Until such time as a specifically bred dog for mine detection has been produced I believe there will not be any consensus on which breed is best suited for this role. However I do believe that the harsh circumstance under which demining is executed will result in the general working dogs remaining the preferred breeds in the interim.

EXACTLY WHAT IS THE DOG DETECTING/SMELLING?

This is probably one of the most difficult questions that presently exist in the detection world. Whilst canine experts may have specific opinions on this aspect, it is a question that even the best chemists have not reached consensus on. To illustrate this point I want to take you back a number of years to when Dr. Vernon Joynt made the distinction between so-called bouquet and TNT specific dogs; meaning that the bouquet dog was trained on a range of explosives, whilst the pure TNT dog was only imprinted on TNT and was deemed to have a more acute sense of detection. This theory was however challenged when it was found that TNT specific REST/MEDDS dogs were indicating Tetryl filled mines as well as weapons and ammunition. Furthermore it is now an accepted fact that 100% pure TNT does not exist in practice. Studies have shown that whilst the solid state of TNT consists mainly of 2,4,6-TNT, the vapour state also has high concentrations of 2,4-DNT and 1,3-DNB present. This begs the question whether the dogs are smelling TNT, DNT, DNB or a combination thereof?

The amount of explosive leeching, or flux, that occurs from a landmine or UXO will enhance the dog's chances of identifying the object. Leeching/flux varies depending on the following:

- Permeability of the casing material used (metal, hard plastic, Bakelite, soft plastic, etc).
- Presence of holes, fuse wells, cracks or other openings.
- Temperature (flux is greater at high temperatures).
- Amount of soil moisture, and standing or flowing water (flux is greater into water than into air or soil).
- Painting on mines limits permeability.

From the above it is clear that there is still no clear cut answer to this question and that further research is still necessary. Whilst most people have their own opinions, they remain opinions with no scientific foundation or validity.

THE ROLE OF THE DOG HANDLER

There is a theory that a dog is only as good as its handler, although in practice it has also been found that some dogs respond so well to their training that they can actually make the handler look proficient even if he/she is not! The fact of the matter is that in demining operations the handler and dog always form a team and as we all know a team is as strong as its weakest link. Although many people may have different opinions on the role of the dog handler, I believe there is a broad consensus that the handler plays a major role in the success of MDD operations.

Unfortunately there is not much literature available on the characteristics a good handler should possess. In my opinion the person needs to have a love for dogs, must not be afraid of dogs, have a high self-esteem, be literate and of above average intelligence. I believe most experts will agree with the first two characteristics, but possibly not with the latter three.

I can expand on the last three characteristics from my own military experience. Many years ago as a young soldier I recall the troops that were not fit for advanced training being made dog handlers. These chaps usually had no self esteem and before long their dogs also looked lack lustre and uncared for. Furthermore they were also usually not very intelligent and had no real ambition in life. However today the picture has changed drastically and demining companies cannot afford to entrust valuable assets to illiterate and unintelligent handlers. Today dog handlers need to understand the psychology and physiology of their dogs, be able to draw up reports and returns and accurately survey areas using GPS. In MECHEM we now only employ handlers who have completed their high school/secondary education. Furthermore all permanent handlers and senior handlers on contract have completed the Basic Dog Behaviour Course whilst some have even completed the advanced course. All MECHEM handlers are also sent on the Basic Demining and EOD Level 1 course so as to present them with a carrier path within the company and mine action fraternity.

I truly believe that if we uplift our dog handlers we will be able to enhance the ability and production of our MDDs. To this end it is necessary that a psychometric test should be drawn up to assist in the selection of candidates for dog handlers.

ACCREDITATION

Whilst everyone will agree that it is necessary to accredit MDD teams before operational deployment, the question of who and how is debatable. Many people believe that anyone with an approved checklist can do accreditation. In my opinion and experience this is not true. Companies that worked in Sudan in 2004 will be able to attest to the fact that it was impossible to get accredited and that in early 2005 it was even considered by UNOPS to declare Sudan a non-MDD mission. Up until that stage the UN in Sudan had no canine experts on their staff, however with the appointment of a canine expert this changed. With a canine expert doing the accreditations MECHEM even had up to 31 dogs accredited in Sudan at one time. Excellent results were also achieved by the MDD teams and without these teams the demining process in Sudan would not have been as far advanced as what it is today.

I want to propose that the accreditation of MDD teams should only be executed by canine experts with a proven track record.

PERCEPTIONS SURROUNDING THE USE OF MDDS

Many well meaning animal lovers believe that it is cruel and inhumane to use dogs in mine action. These people are often of the opinion that dogs are indiscriminately sent into minefields whilst we know that dogs are used in suspected hazardous areas to indicate the location of the minefield from where manual deminers and other tools take over. There is also the perception that the dog will sit on the mine; the leaching of explosives from landmines is however such that dogs almost never indicate right on top of the mine. I believe if the animal lovers see the excitement and enthusiasm with which MDDs work, they will change their perceptions. The reality unfortunately is that many try and ascribe human attributes to their dogs/pets.

The other criticism that is often levelled at demining companies is the treatment of dogs once their working life has passed. The problem is that most of the countries in which demining operations are executed do not have any animal rights legislation meaning that redundant and pensioned dogs have no protection. However from experience I know that most companies usually find good homes for their redundant/pensioned dogs and often go to great lengths and expense to get the dogs back home. In 2003 after the invasion in Iraq MECHEM chartered an aircraft to take 60 dogs back to South Africa that were to be put down by the institution which took over our UN contract.

I am of the opinion that most companies are responsible dog owners and treat their dogs as valued members of their organizations. However I feel we can do more to create awareness amongst the general public.

CONCLUSION

In conclusion I believe that although our knowledge of dogs has increased tremendously in the last number of years there are still a number of anomalies, perceptions and contradictions regarding the few aspects I have touched on. There are still more aspects of partial or total disagreement within the dog fraternity such as training methodology, reward systems, breeding and operational deployment, over and above the few I have discussed here. I trust I have given some food for thought and further scientific research. Hopefully the speakers to follow will even answer some of the questions raised.

Use of Dog-Handler Teams in Humanitarian Demining in the Republic of Croatia

Mirko Ivanušić[16]

Abstract

The paper presents a development of dog-handler team capacities since the beginning of their more intensive use in 2000 until the end of 2009. There is also the structure of mine and ERW contaminated areas in the Republic of Croatia presented as well as examples and descriptions of terrains suitable for undisturbed work of mine detection dogs. In the part of the paper relating to legal regulations, there are most relevant factors and rules referring to the work with mine detection dogs and worksite organization presented as well as limiting factors relating to terrain conditions. In addition, there shall be the methods and terms of testing elaborated but also the results achieved in relation to the number of tests per year and validity period of accreditation issued. Special part of the paper presents the results of dog work and their safety during detection i.e. possibility of a mine detection dog to detect locations after the mines and ERW have been removed from the test site in Rakovo polje. The results undoubtedly confirm the creation of an atmosphere of bigger trust in dog use that has been visibly undermined in the past few years and finally resulted in a reduction of a number of quality dogs. At the end, the paper brings a brief overview and proposes the solutions that should result in bigger and more efficient use of dogs in humanitarian demining in the Republic of Croatia, especially in the sphere of training, conditioning and measures of regular daily dog treatment.

INTRODUCTION

Today, around thirty countries use dogs in different humanitarian demining operations. The dogs are used in different methods stipulated by Standard Operating Procedures (SOP) of each company. Over 1 000 dogs are trained to search mine suspected areas (MSA) by different methods. In the Republic of Croatia, most frequently used dog breeds are: German Shepherd, Belgian Shepherd and Labrador. Most frequently used breeds in the rest of the world, besides the ones mentioned above, are: Springer Spaniel, Golden Retriever, Cocker Spaniel, Australian Cattle Dog and many other local breeds. It is possible to achieve better results in gaining most desirable mine detection dog characteristics by hybridization and selection procedures.

We have training and selection centres supported by science already working on that matter.

In the Republic of Croatia and the world, dog-handler team is used:
- in reduction of mine suspected area (MSA) by defining the minefield boundaries; primarily in detection of first mines on the areas of small density of ERW,
- as first method in mine search combined with other manual detection methods,
- in searching mine suspected areas (MSA) from the safe lanes on the area with fields defined and marked in a different manner,
- as second method in demining projects, mostly on areas treated by demining machines after a certain period of time and soil stabilization,
- in mine search of ruined buildings with considerable amounts of metal and removal of parts of construction waste in layers,
- in mine search of railway infrastructure as well as other firm surfaces along asphalt, macadam, stone and concrete systems and infrastructure facilities with considerable quantities of metal such as water supply systems, gas pipelines etc.
- in sample search during quality control over demining operations,
- during inspection of a lane to be used for quick access to the victim in case of mine incident.

These are the possible forms of MDD from which the liberalization of dog use in many countries on different levels is clearly visible as well as acceptable risk boundaries in relation to mine action and accepted methods.

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At the beginning of 2010, there were 887 km² of mine suspected area (MSA) defined in the Republic of Croatia. The MSA extends through 12 counties and covers the territory of 104 towns and municipalities. Around 93 000 different mines and ERW are scattered all around the MSA.
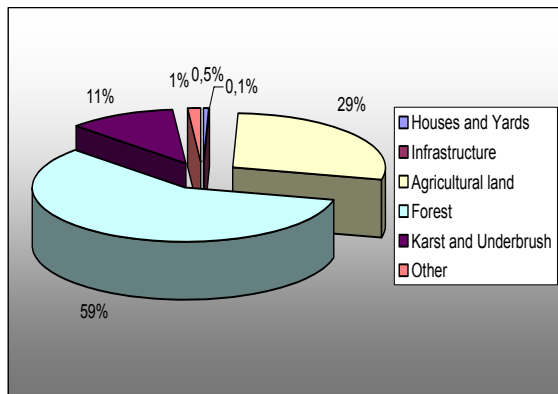
Graph 1: MSA Structure in the Republic of Croatia

Photo 1: Mine suspected area (MSA) of the Republic of Croatia

It is important to mention that forest areas with 59% and agricultural areas with 29% are the most dominant in the MSA structure. Most part of the MSA is categorized for mine search what actually means that there is no clear or accurate information on mine contamination. The area must be searched in order to remove any doubt in mine danger. Extensive use of MDDs on such areas is desirable, especially in the continental parts of Croatia such as Lika-Senj County, Osijek-Baranja County and Sisak-Moslavina County. These are the areas of rare forests where the visibility is very good and it is relatively easy to establish the communication with the dog. Agricultural areas treated by demining machines as first method provide excellent preconditions for the use of MDDs as a second method.

Photo 2: Forest area marked for the work with MDDs by using the method of mine search from the safe lanes with

Photo 3: Agricultural area treated by the machine for the work MDDs

Legal Framework

Law on Humanitarian Demining is the basic legal act that regulates and defines the mine action in the Republic of Croatia. Until today, it has suffered several changes and modifications. The one still effective was passed in December 2005 and entered into force on January 1, 2006.

Second important legal act that regulates this matter is the Rules and Regulations on Methods of Demining which has so far also suffered several changes. Document from October 2005 is currently effective.

Besides defining the procedures related to dog-handler use, the Enclosure 1 contains the Program of Training and Evaluation of Dog-Handler Teams in humanitarian demining operations.

I would like to select several articles from the Rules and Regulations relating to the use of dogs in humanitarian demining:

- When mine search operations are conducted by using mine detection dogs (MDD), prior to the beginning of works, demining team leader is obliged to:
    - hold the meeting with handlers and define the individual tasks;
    - temporarily send the handler who declared himself to be incapable of performing his daily task or the same was established by the demining team leader off the site;

- directly assign the handlers to the work site
- determine the conditions for the work with MDDs by using technical instruments.

Mine search and/or demining operations can be performed by:
- combining demining machine capable of reaching the depth specified by the project and manual mine detection along with the use of mine detection dogs;
- combining demining machine incapable of reaching the depth specified by the project and mine detection dogs after the machine or a combination of mine detection dogs and manual detection.

If mine search operations are carried out using mine detection dogs, it is necessary to search the working lanes 1 m wide each 10 m horizontally and vertically, i.e. using the grid system and manual mine detection. Fields formed should be searched by mine detection dogs. If the dog detects the explosive ordinance or its fragment, manual detection method must be used to inspect the area in the radius of 20 m from the place of detection.

Daily internal inspection can be performed using mine detection dogs on at least 5% of searched area.

Safety distance between the dog handler and the nearest deminer should be 25 m at least. If fragmentation mines are found, the distance between the deminers should be increased to 50 m.

Each area inside the worksite must be searched by at least 2 dogs.
Rules and Regulations also define possible team performance per day:
- during internal inspection -1 500 m²/day
- as a second method upon demining machine use - 1 500 m²/day
- for searching ruins and/or buildings and removal of construction waste in layers – 500 m²/day
- mine search in fields in combination with manual method – 1 000 m²/day
- during quality control of demining – 500 m²/day.

It is important to point out that the Law on Humanitarian Demining and the Rules and Regulations on the Method of Conducting Demining passed in 2005 enabled the use of dogs and handlers as an independent method in mine search projects (low risk areas or areas where mine and ERW existence or non-existence should be established up to the depth specified by the project).

Rules and Regulations also define the conditions when dog use is unallowable:
- when the air temperature is lower than 0 i.e. higher than 30 degrees Celsius,
- when the wind speed is bigger than 25 km/h, i.e. 7m/sec,
- when the soil is extremely moist,
- when the vegetation disturbs normal search by MDDs and the terrain is not properly marked,
- on the frozen ground or the ground covered in snow,
- in case of a rain or a fog,
- when unplanned circumstances would make the dog work more difficult (smoke, unknown odours, noise, dust, food etc.),
- in case of dog illness or handler's decision.

Photo 4: NPA's team performing mine search in Zadar County

The Enclosure 1 - Assessment of trainability and evaluation[17] - of the Rules and Regulations on Methods of Demining in 12 chapters defines:

- the holder of training verification and evaluation of dogs and handlers – accredited institute or institution. The holder in the Republic of Croatia is CROMAC-CTDT,
- the term «dog-handler team» consists of one handler and two dogs the most, trained to properly detect all mines and ERW on specially prepared sites during mine search process in order to make an objective assessment of individual team capacity,
- general information about the dog and the handler,
- test application procedure,
- documentation in the test process,
- testing committee,
- basic elements of dog-handler trainability verification,
- test methods and quality control,
- criteria for the establishment of quality of dog-handler team in demining projects,
- dog and handler assessment,
- other regulations among which – giving up testing or its interruption, possibility for repeating the test, decision on accreditation validity suspension, test site appearance and supporting forms.

During the test process, all actions required as part of obedience exercises are checked on an adequately prepared test sites. According to results achieved i.e. scores, dog and handler are issued an accreditation for the work in the period of 6, 9 or 12 months. If QA Officers establish any irregularities in the dog work, the team can be asked to take an additional test despite of valid accreditation.

Two test sites have so far been built on the territory of the Republic of Croatia for the needs of dog testing. One test site has been built in the southern part of the Republic of Croatia, in Škabrnja with typical characteristics of Mediterranean and one in the continental part of Croatia, in the test complex in Cerovac. Test sites provide good conditions for undisturbed testing of many dog-handler teams and they are built based on recommendations of IMAS and field experiences in the region.

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Demining companies with MDD teams	**10**	**23**	**23**	**15**	**17**	**18**	**18**	**15**	**10**	**8**
Deminers in all demining companies	292	420	408	586	601	599	609	571	617	623
Demining machines in all demining companies	10	27	30	41	43	62	54	46	50	56
MDD	15	40	52	111	127	129	130	74	44	34

Table 1: Development of dog-handler capacities in the period 200-2009

The table above shows the capacity development i.e. number of companies, owners of MDD teams and number of teams owned. Since 2000, the number of teams has been increasing until 2006. After that, in the past three years, the number of demining companies and teams has been decreasing. The reasons for such a dramatic fall are multiple. Prior to all, the quality of teams has constantly been decreasing from year to year. Therefore, demining companies started using MDDs as less as possible and took a lot less care of the dog conditioning and overall dog treatment. There were periods when a dog handler that is also a deminer worked solely on demining operations by manual method and the dog used to stay at home without any expert to look after it. Generally speaking, all these things led to a general distrust in the work of mine detection dogs, even though there was no exceeding in the percentage of repetitions of demining operations, after mines and ERW have been detected during quality control or during the execution of operations, in relation to other demining methods. Instability in running business of certain companies resulted in getting rid of mine detection dogs and use of dogs as a demining method. Most owners of demining companies and part of the QA and QC staff have been showing certain animosity and insufficient understanding for the total dog care and their use. Some dogs have been excluded from the list of active ones due to being too old and some of them due to being ill.

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[17] Book of Rules and Regulations – Assessment of trainability and evaluation is available in English language on CROMAC website www.hcr.hr
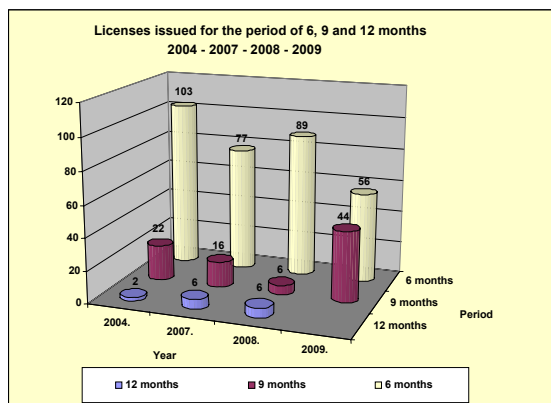
Graph 2: Test results of dog-handler teams 2004-20
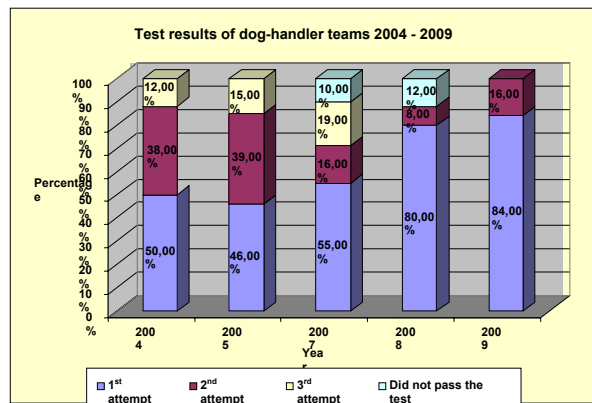
Graph 3: Licenses issued for the period of 6,9 and 12 months / 2004-2007-2008-2009

World experience show that even in cases of training related to the scent units i.e. explosives (TNT, DNT etc.) there are situations when dogs do not detect ERW containing the explosive TNT which is most frequently used. Our experiences show that this is actually the ERW which is more or less hermetically sealed, and in case of quality dogs, that was not a limiting factor. Another important factor is definitely a terrain. Experiences and researches undoubtedly showed different evaporisations and infiltration to the soil in relation to the soil consisting of clay, silt and sand as well as the impact of moistness and temperature on spreading of explosive particles to the surrounding soil. Those couple of facts was fundamental when building the test sites. During the organization of testing, we had in mind all the necessary prerequisites. Weather and technical conditions were controlled by technical instruments. Generally speaking, during testing we tried to maximally respect the favorable conditions for the work of MDDs.

Photo 5: Testing of dog-handler team on Cerovac test site

It is clear from the above-given graphic displays that the results during the stated years were pretty average. The same results were obtained during the period of licenses issued presented in the graph. In 2007, 10% of dogs did not pass the test from the 3rd attempt. In 2008, 13% of dogs did not take the test for the 3rd time. Part of the reasons for that has already been mentioned in this paper. The ʹʹConclusionsʹʹ will elaborate what I think would contribute to a better quality and bigger trust in dog-handler team use in humanitarian demining operations.

The Results of Rakovo Polje Test Site Experiment

The results of the experiment presented in this paper speak in favor of proved quality of work of dog-handler teams in special conditions and they should contribute to creation of a climate of trust in dog-handler team use in the Republic of Croatia.
Before Rakovo Polje test site near Sisak was officially closed, all mines and ERW had been removed from the ground and the terrain leveled.
The experiment started month and a half later, on November 30, 2006, after the period of ground settling and heavy rains. The aim was to establish if the dogs, Aska (8) and Tyna (10) and their handlers were capable of detecting the positions where mines used to be buried. Weather conditions on that day were far from favorable but the testing was performed anyway. In spite of unfavorable circumstance, first results were very surprising. The dogs detected over 70% of former positions of mines and in less then 30%, indications were a bit less strong.

Photo 7: Mines taken out from the ground on Rakovo polje test site, Sisak-Moslavina County site,

Photo 8: Mines taken out from the ground on test Rakovo polje test Sisak-Moslavina County

New experimental testing was held on July 5, 2007 – after 8 months of test site being at rest. This time, weather conditions were favorable, test site boundaries marked with old stripes and the positions could have been precisely defined in accordance with the test site sketch. In 9 tested fields, the dogs Asja and Rocky[18] succeeded in detecting the positions where different types of AP and AT mines used to be buried with 100% certainty.

Conclusions

The conclusions cannot comprise all aspects and factors that should contribute to the quality and safety of team use in humanitarian demining. Therefore, I am going to list all relevant facts and guidelines that are partially covered by conclusions from the 7th International Symposium ''Humanitarian Demining''.

- The results of trial testing show that it is possible with quality dog-handler team to detect the scent of explosive from the ground even after 8 months or more since the removal of mines and ERW from the ground after being buried for 5 years. There are clear indicators that it is possible to detect the positions of different types of mines, regardless of their smaller or bigger hermeticity and specific characteristics. Vegetation was no obstacle to the mine search or bad weather conditions during the first test. There is a possibility for the dogs, in the actual conditions of mine search and demining, to detect the positions of mines removed from the ground by different subjects without informing CROAMC about it. This might put the handler into a delusion and make him/her doubt into the reliability of dog work on specific worksites.
- Use scientific methods in selection, hybridization and breeding programme in order to gain most favorable characteristics required for MDDs; general opinion is that puppies should not be separated from their mother very soon after being born in order to have enough time to learn lessons taught by the mother.
- Training centers need to be accredited and approved, own the stipulated accommodation capacities as well as properly maintained test sites for their own needs. It is necessary to introduce and standardize explosives, numbers and types of targets buried in the test site. The same should be made for test sites owned by accredited centers and laboratories.
- Only the dogs from the recognized training centers with approved training programme should be licensed.

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18 Dog teams of two Croatian companies that look after the dogs and reach the best results at testing

- Dog handlers should be the persons with finished course of 300-500 teaching hours of theoretical and practical teaching material minimum.
- The companies dog owners should have an an accredited instructor for permanent education that supervises and looks after the dogs in the period when deminers are at work using some other demining methods.
- Need for permanent CROMAC's control and possibility of an insight into the daily or weekly conditioning along with the corresponding documentation.
- It is necessary to perform an additional training of QA officers and QC Monitors that includes all aspects of limitations in the work with mine detection dogs.
- By changing the legislation and liberalization of use, the companies should be provided opportunity for cost-effectiveness and trust in work with MDD method.

Effects of Inadequate Care for Mine Detection Dogs on MDD Performance Quality in Mine Action Activities

Nermin Hadžimujagić[19]

Abstract

Since humanitarian demining is a relatively new activity, the use of mine detection dogs is known for approximately 20 years. Techniques of using mine detection dogs in humanitarian demining are constantly being improved and nowadays it is almost impossible to comprehend mine action without the use of MDDs. Experts in area of mine detection dog training and use of MDDs in the field are recognized as creators of MDDs credibility and reliability in mine action. The use of MDDs in humanitarian demining is regulated by international and national standards which are constantly being developed and improved with new experiences and information.

Basic goal of this topic is to contribute to further use of mine detection dogs as a demining method. Following are frequent questions on mine detection dogs:
Why MDDs?
When and where MDD should be used in demining?
What breeds should be used?

SHORTAGES NOTICED
Derived from our experience, there are a number of irregularities and problems related to proper care and utilization of mine detection dogs on the ground. The most common are:

Transportation of dogs
Inadequate care
Accommodation of dogs on the ground
Low-quality training

However it may seem that use of mine detection dogs can only bring benefit to mine action; incompetent training of mine detection dogs and handlers or superficial and merely routine MDD testing procedure could extensively undermine the credibility of this demining method. While there is an enormous growth rate in the use of

anti-terrorism and drug detection dogs in the world, on the other side the use of mine detection dogs in the region have been questioned, all due to the constant commercialization of demining. This urges us to repeatedly make effort to confirm the role and importance of mine detection dogs in humanitarian demining.

Users of mine detection dogs need to treat this good quality "product" with due respect and attention. The dogs are not merely the demining tool as demining machines are, and they are certainly not cheap. Their relatively high price, which include purchasing dog with high quality genes and other preconditions necessary for conducting long-term training, maintenance costs and handler's deployment, can be observed as an advantage, because it motivates their users to properly treat and care MDDs. High level of trainability accomplished during the extensive and demanding training can be maintained only by regular working and conditioning the dog and by taking proper care over MDD. Mine detection dogs need to be maintained at highest standards, and neglecting their values and needs directly lead to reducing their operational level and efficiency on the ground.

INTRODUCTION

Humanitarian demining is relatively new discipline, while the use of the dogs in the humanitarian demining operations is known for approximately 20 years. The technique of use of the dogs in the humanitarian demining operations is constantly developing. Nowdays it is difficult to comprehend the mine action without involvement of the dogs. The credit for trust and role given to the dogs in the mine action primarily goes to the good experts in the field of abilities of the dogs. The use of the dogs in the humanitarian demining is regulated both by the international and national standards that are being improved daily with the new experiences and knowledge.

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DOG IN THE MINE ACTION

The mine detection dogs are in use for more then 40 years, but as for the humanitarian demining, the dogs are used since 1989. They were first used in Afghanistan, and later their use spread to other countries facing the mine contamination problem. Today, several hundreds of mine detection dogs are involved in the mine action in almost each country facing the problem of unremoved minefields.

When it comes to the dogs in the humanitarian demining, the most common questions asked are the following:

Why dogs? The basic advantage of the dogs in the mine action is that they are able to search the suspected area much faster then using the manual method, and they are able to work in the surfaces with large presence of metal. The dogs themselves are not the tool for clearing the mines, they detect the odor of the explosive contained in the mine or UXO with their nose, while some of the dogs can be trained to detect the trip wires as well.

Where are the mine detection dogs used? It is pointed out in the BH Standard for removal of mines and UXOs that the use of MDDs gives good results especially in the following situations: reduction of suspected areas during the technical survey; detection of first mines in the areas of low density, where there are no reliable records on mine locations; clearing the hard surface areas and areas contaminated with the metal (buildings, gravel roads, rocky, concrete or tarmac surfaces, railroads, waterlines); clearing the area after the mechanical preparation of land; sampling in the demining quality control and clearing the lane for faster approach to the mine victim.

What breeds of dogs to use? The most commonly used breeds in the humanitarian demining operations are German and Belgian shepherd (malinois), while Labrador can be found in the field as well.

The reasons for the selection of those breeds of dogs are the following: German shepherds are working dogs that show certain amount of courage and they are used for various purposes. They attach to the humans – handlers easily, creating the strong bond between them, which gives good results in the field. The dog attached to his handler is willing to obey his commands and once the dog understands what he is asked to do, then he will do it without doubt. They are suitable for the training and show strong endurance and persistence. The Malinois dogs show certain amount of nervousness, but once they are controlled, they are very efficient. This breed of dogs show high level of intelligence, since the training requires learning of complex and uncharacteristic actions with high reliability demanded from them.

OBSERVED SHORTAGES

Working in the demining tasks in the countries of Southeast Europe, the Mine (Explosive) Detection Dog Center for Southeast Europe noticed a number of irregularities related to the care of dogs and the work with the mine detection dogs in the field. The most common shortages are the following:

4.1 <u>Transport of dogs.</u> Transport of dogs is conducted in inappropriate vehicles, without the canvas top cover or in the vehicle without the transport box;

4.2 <u>Inadequate care.</u> During the summer period with the high temperature, the dog is not being offered water after the work, the temperature of the dog is not being measured, and the nose is not being cleaned;

4.3 <u>Accommodation of the dogs in the field.</u> The dogs are often accommodated in the locations with big noise; the access of the unknown persons to the dogs is not prevented; the dogs are often fed by the deminers or local population, instead of the dog handlers; the dogs are tied to the building, being that way disturbed by other dogs and people passing by and causing the dogs look exhausted when going for work.

4.4 <u>Law-quality training</u> is noticed in the work of large number of MDD teams. It reflects in handler giving the command to the dog to continue with the search even in the moment when the dog is standing and "decoding the odor", inexpertness in giving the commands, and inappropriate punishing and unjustified rewarding of the dog.

4.5 <u>One handler working with two dogs or more.</u> It is noticed that the quality of the work is much bigger in the tasks where the team is consisted of one dog handler and one dog then in cases where one dog handler works with two dogs.

4.6 <u>Essential rest time.</u> The dogs are most often entered in the task and they start with the work immediately after arriving to the field without allowing them necessary period of rest after the long travel.

PRECONDITIONS FOR ACHIEVING THE QUALITY IN THE WORK OF MDD TEAM

Selection of the dogs: Only the dog that gives 100 % in the field is reliable dog. Any method that improves the dogs' training process and their operational potential significantly affects their operation quality and profitability. It is the experience of the Mine Detection Dog Center for the Southeast Europe (MDDC) that prior to the training itself, the particular significance should be given to the good selection of the dogs. In order to have a working dog of good quality, the selection of the dogs is the first and elementary step. During the selection process, the attention is given more to the motivation of the dog to work, and less to the sex of the dog. Primary selection and criteria depend on the purpose of the dog. That way, initial motivation of the dog to sniff, physical endurance and appearance of the dog, health condition of the dog, desire for the ball and focus are, among other, requirements for the training of the mine detection dogs at MDDC. The desire for the ball is important because of the rewarding system. The ball is connected to playing, which is the operational contest of the training. The dogs age 1 to 2 are coming from the best breeding facilities and they must be focused. After the dog has been evaluated as suitable for the training, the next step is the detailed physical examination that includes the x-ray of the hips and vaccination.

Training: The next step after the selection of the dogs is completed is the training. The training of the dogs and dog handlers must be precise, consistent, thorough and adequate. The training of the dogs and dog handlers is under constant supervision during all phases of the training in order to achieve adequate results in appropriate time. The training can be conducted solely by the training schools registered for that purpose, all in accordance with the positive regulations of the country in question, and according to the program verified by the MAC or some other authorized institution. The training of the mine detection dogs is conducted for six months. During the first three months of the training, the work is focused on connecting the odor of the explosive to the ball, while the following three months are focused on the integration of the dog and dog handler. Together with the dog, the dog handler also goes through all the phases of the training and in the future, they will make the inseparable professional unity.

Hygiene and control of the dog's health: The guarantee of the good health of the dog is strict maintaining of the hygiene and periodical control over the dog's health condition. Besides that, constant or daily care offers the moment of closeness that strengthens the trust of the dog in his master/handler. The dogs are living in the conditions in the kennels that must meet minimum requirements set by the National Mine Action Center. The handler is the person who takes care of his dog on daily basis. The issue of daily care of the dogs that also includes the daily work with the dog to maintain his condition is regulated by the SOP of the organization. Every dog will be more lively and endurable if he has been constantly taken care of and if he is in good physical condition. The veterinarian protection is regular and their nutrition is carefully selected. The strength and vitality of the dog is crucial in the quality performance of their duty.

MEASURES TO IMPROVE THE WORK OF MDD TEAM

National body in charge of the mine action should determine the rules and regulations specifying the minimum of the conditions aimed to the improving of this method of the work in the mine action operations, such as:

To conduct the training of the staff conducting the testing of MDDs :   The body that will conduct the testing must be comprised of the staff that is trained to monitor and evaluate the work of MDD teams. The experience must be measured through the possibility to make a quality evaluation of the work of each MDD team, taking into consideration all the aspects that show the quality of the work of MDD team, such as the team work of the dog and dog handler, motivation of the dog to work, movement of the dog, the way of rewarding the dog etc. The test must assure the body conducting the testing that the dog is truly capable to indicate the mine. The attitude towards the dog must as well have the influence on final evaluation of the MDD team quality. The body in charge of testing must make the inspection of the accommodation, have information on periodical training and the measures aimed to the health protection of the dogs.

The conditions for becoming the dog handler: The specific school and training course is required for the profession of the dog handler. When selecting the future dog handlers in the mine action operations, the affection and love towards the dogs is crucial, which should be evaluated by the expert commission formed by the national organization in charge of mine action or MAC, followed by the psychophysical examination, and then the training of the dog and dog handler. Our experiences show that the real results in the mine action operations are given by the team consisted of one dog and one dog handler, even though, it is common in the field that one dog handler works with two dogs. Even though MDD team significantly reduces the price of the demining, it must not be reduced to the total commercialization, the consequence of which can be "skipped mines".

 Care for dog: It is pointed out in the International standard that the handler is responsible for all the aspects of his dog. The handler takes care that his dogs is well treated. The handler must have the training skills, regular practicing skills and satisfying skills to manage the dog during the demining operations. He also needs to have

skills related to the common care for dogs, medical evaluation and basic procedures with the dog. In short, the handler must be fully dedicated to one dog and he can not perform other work, such as the demining work. Special attention must be given to the dog during the work in the field. The national body that controls the work of the demining organizations must have information on the accommodation of the dogs in the field, the necessary rest of the dogs after the transport, as well as on the dedication of the handler to his dog. All above mentioned factors directly or indirectly affect the performance quality itself during the demining process.

CONCLUSION

However it may seem that use of mine detection dogs can only bring benefit to mine action; incompetent training of mine detection dogs and handlers or superficial and merely routine MDD testing procedure could extensively undermine the credibility of this demining method. While there is an enormous growth rate in the use of dogs in the mine action operations in the world, on the other side the significance and role of the dogs in the demining operations in the region of Southeast Europe must be constantly confirmed, all due to the commercialization of demining.

Users of mine detection dogs need to treat the good quality "product" such as the mine detection dog with due respect and attention. There is also the human aspect of the training of the dogs as living creatures, which should not be neglected. The dogs are not merely the demining tool as demining machines are, and they are certainly not cheap. Their relatively high price, which include purchasing dog with high quality genes and other preconditions necessary for conducting long-term training, maintenance costs and handler's deployment, can be observed as an advantage, because it motivates their users to properly treat and care for MDDs. High level of trainability accomplished during the training can be maintained only by regular working and conditioning the dog and by taking proper care over MDD. The dog with certain amount of experience in the work in the minefield is of invaluable use for the organization-user. That can be confirmed by all the organizations that reduced millions of square meters using the mine detection dogs over 8, 9 or 10 years of their active work. Mine detection dogs need to be maintained at highest standards and neglecting their values directly lead to reducing their operational level and efficiency on the ground.

From the Concept to Operational Airborne Remote Sensing System and the Suspected Hazardous Area Assessment

Milan Bajić[20]

Abstract

*The main mission of the mine action system is to return the land contaminated by land mines to its previous use, by any available and approved technology. The airborne and space borne remote sensing technologies were first and very promissing candidates for this mission, due to their wide area coverage. The first European civilian R&D airborne remote sensing project was lounched in 1998; it had the ill-posed objective to detect anti-personnel land mines. Later R&D projects were focused on the support to the decision makers in the process of the suspected hazardous area eduction. Although very valuable experience was acquired with several projects, only in 2009 the first operational project was realised; this Croatian project was based on the generic methodology of EC SMART. Original advancements in the airborne acquisition system were implemented as was the fusion of the indicators of mine presence and mine absence, contextual data and the formalised experts' knowledge. Key was the introduction of the quantitative terrain analysis as a new source of the indicators of mine absence, procedures for the definition of the needs for information completition; reconstruction of the warring parties separation zones, detection of the war remnants. The ultimate goal of the project was achieved and large area was prepared for the process of the reduction while the improved assessment of the suspected hazardous area is the added value. The similar operational project is under way in Bosnia and Herzegovina. The coopetition („**coo**peration & com**petition**) between the brute force mashine-based demining, and a „soft"suspected hazardous area reduction started in 2009. The new (although expected) experience of this first operational remote sensing project is very significant contribution of the information extracted from satellite imagery; this shall be ordinary practice in the future projects on the assessment of the suspected hazardous area. The proces that started with the ill-posed objective in 1998 (detect anti-personnel landmines) is now in a new cycle, and new airborne technology of ground penetrating synthetic antenna radar (GP SAR) could enable detecting the landmine. The testing of Mirage GP SAR at test ranges Benkovac is expected in*

summer 2010. The story of the remote sensing technology aimed to support humanitarian mine action passed one significant cycle and a new one is in front of us.

Key words: suspected hazardous area, land mines, airborne remote sensing, multisensor imaging, expert knowledge, contextual information, mine information system, GIS, cost-benefit, CROMAC

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Mine Detection by Air Photography

Avi Buzaglo Yoresh[21]

Finding remnants and traces of mines and UXO broken down to the ground, by air photo taken with hyper spectral band.

GOAL:
To provide this breakthrough solution for detecting mine fields in the most fast, accurate, safe and in unexplored areas.

ABSTRACT:

HyMap imagery was acquired from several sites in Angola during June 2009. One of these sites (MAP1), is situated in the vicinity of the town of Malange, and had been processed to access the potential of locating Mines in the area of "ALDEA NOVA" Neo agricultural program.
The processing of the imagery was applied into a mosaic of the geometrically rectified 125 channels HyMap data which was atmospheric corrected by Tel Aviv University's remote sensing laboratories.

GEOMINE developed a unique technology for identification of minefields by spectral analysis of air and satellite photographs. As far as we know no other company offers this kind of analysis. It allows identifying suspected minefields in size of 30x30 meters from satellite photo, and of smaller size of 1x1 meter from aerial photos.
Conflicts all around the world leave millions of unexploded mines. Today, mapping the contaminated areas is limited to the specific location of the known combat areas. The system is based on chemical reaction which takes place between the materials of the mine (nitrogen) and the soil and vegetations at its vicinity. This chemical reaction affects the color of the soil and the vegetations. Our unique spectral analysis discovers where the color has been changed. There lies the mine.

The following sample, carried out in Angola, provides an evidence to the efficiency of the system.

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MAP 1: Thematic map HyMap image of suspected mines accompanying with results of VERSOL group: blue polygons are areas of interest, blue points are detected materials in field, bright green polygons are spectral classes with highest probability, and dark green polygons are spectral classes with mid to low probability
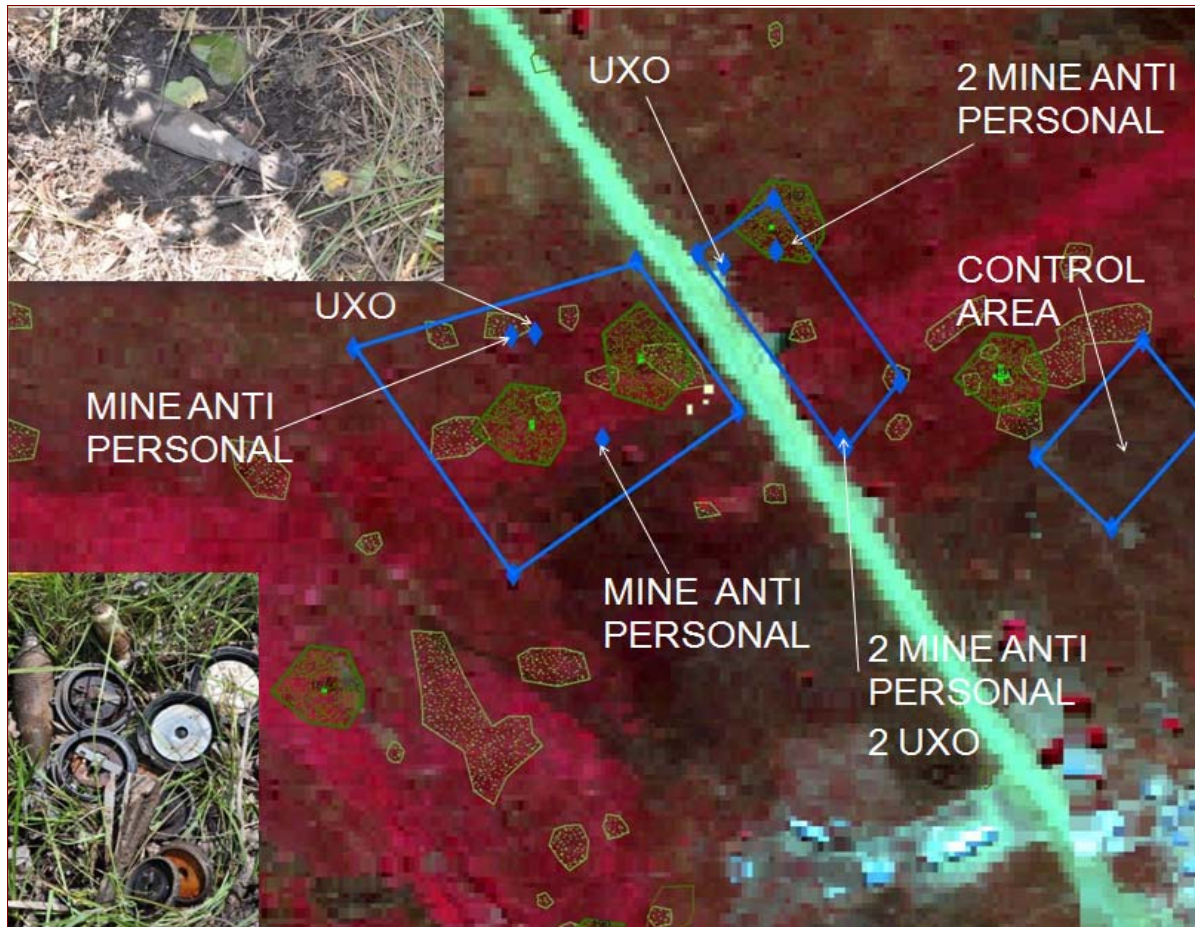
Conclusion

The new procedure, based on airborne and space-borne platforms and the optimized set of hyper-, multi-, and digital high resolution sensors including Digital Terrain Model (DTM) allow a repetitive and fast survey for area reduction, increase the flexibility and adaptation to several scenarios, and above to all reduce the risk. An enhanced GIS, resulting in a 4-Level information and decision system based on satellite and airborne data, aerial photography, ground investigation, GPS measurements and Level-1 survey gathered information, was developed. The System developed based on the existing GIS program provide additional information from external sources and the results of the suggested system presented as a complete project. The multiplicity of experimental areas all over the globe clearly demonstrates the robustness of developed methodology. The method has a full potential to provide a useful addition to existing procedures and technology to solve the mine problem as currently exists in many mine infected countries. The use of airborne sensors allows flexible approach in flight altitude and patterns. The presented experiments of different campaigns, sensors and locations are undertaken to proof and optimize the method to true suspected mined areas. The results of the System were validated based on conventional field mines detection provided by Norway group in Angola and Israeli government for Golan Heights regions. The total accuracy of presented method is very high (up to 90%) that provides a robust, generic and fast tool for possible minefields detection using remote sensing technique.

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MineFree: Space Assets for Demining Assistance

T. Bouvet[22], M. Kruijff[23],

Abstract

By providing timely updated and critical information, anywhere it is needed, space assets could potentially further increase the efficiency of land release, thereby minimizing the socio-economic impact of landmine and explosive remnants of war. Space borne observations could provide valuable information to feed impact maps, for educated decisions on priority setting. They are also instrumental to characterize the environmental setting of hazardous areas, to best select the most appropriate detection tool and period. Space assets could offer more than a planning aid. In fact space is also a valuable vantage point to identify indicators of mine absence or mine presence, in turn fostering discrimination between mine free and mine contaminated fields. All along the land release process, global satellite navigation systems, when combined with updated terrain maps, can facilitate access to and operation within the target zone of interest. They also enable geo-referencing of all collected data, for readily integration into a Geographical Information System (GIS). At last satellite telecommunication is instrumental to real time bi-directional links between "data collectors" in the field and such a centralised center for data storage and processing. Therefore operators could be catered with updated information anywhere they need it. The Integrated Application Promotion programme of the European Space Agency is launching a 400k€ feasibility study on demining assistance services enabled by space assets. The Invitation to Tenders closes on 12 July 2010. It should be followed by a demonstration project, and ultimately pave the way to operational services.

Most of the land plots searched for landmines proves mine free in hindsight. Is a meticulous close-in search for landmine the appropriate approach to investigate the vast stretches of land alleged (with low confidence levels) contaminated? Spending one euro to perform demining activities on mine free land is not acceptable, as this euro is not available to save the lives of people actually affected by landmines. Financial resources are limited. They shall be used wisely and smartly. The idea is to progressively focus the land release efforts, from the less technical, quicker and cheaper surveys, through technical surveys, to costly clearance, only where it is critically needed.

The space enabled services considered in the study have the ambition to further enhance the efficiency and effectiveness of land release, towards minimizing the socio-economic impact of landmine and Explosive Remnants of War (ERW) on affected populations. In a nutshell, Earth Observation data, Satellite Communication and Satellite Navigation could contribute to provide the right information at the right time, thereby improving the quality and the efficiency of decision making (i.e. mine action priority setting), improving the planning and improving the implementation of land release operations. The schematic provided at the end of the document captures a recommended process of land release, where each step is addressed with the appropriate tool, for optimal resource efficiency. It shows the tools currently in use. In parallel examples of space enabled assistance services are provided where relevant. The figure will be repeatedly referred to for illustration of the services described below. The numbers in brackets are tags directing to the space enable services presented on the figure.

1 – Priority setting and action assessment.

The objective of mine action is not removing all mines on Earth, but rather eliminating the socio-economic impact they have on people. In practical words, a mine buried in a secluded and arid area does not have the same impact on populations than a mine laid by a busy road or within valuable arable land. Space-borne imagery can feed into maps showing the demography and the economic value (e.g. infrastructure, land fertility, water bodies, etc…) of an area of interest. This is particularly valuable in countries where records of population and assets are not available or reliable. Decision makers can set priority where mines are most detrimental to people's lives, based on factual and quantified information (1a). Such knowledge can also be used by donors: impact maps

overlaid with land release data (see later) enable donors to quantitatively evaluate the outputs generated by their donation, and the efficiency of it (1b).

2 – Planning of detection campaigns.

There is no one single silver bullet technology appropriate to detect all mines / ERW on this planet. Each possible sensor has a limited range of operation and cannot satisfactorily cover all possible detection scenarios. For example SAR sensors are not much skilled in wet soils, metal detectors are not sensitive enough to detect plastic-cased personnal landmines, etc… Over the past years, researchers have developed multi-sensor detectors, to combine the capabilities of several sensing technologies into a single detector. For example, ESA was involved in the early 2000 in the HOPE project, aimed at developing a hand-held close-in detector combining a GPR (Ground Penetrating Radar), a passive microwave sensor and metal detector. This approach undeniably enhances detection capabilities. Yet developing a universal and reliable detector is still not a realistic short term objective. Today many detection technologies are available. The challenge is to have the capability to pick the most suitable tool from the toolbox. Space-borne Earth observation can help characterize the detection scene (humidity, vegetation cover, soil mineralogy, etc…), and the time dynamics of it. In turn the most adapted tool can be chosen and run over the most appropriate time of the year, for optimal detection reliability on a specific scenario. This service is applicable for close-in (i.e. on the field; 2a) and stand-off (i.e. remotely; 2b) detection.

3 – Discriminating between mine contaminated and mine free land

Beyond planning, space assets can be instrumental to implement land release actions. They can be particularly useful to facilitate the discrimination between contaminated and clean lands. Obviously, space borne observation is not capable enough to detect individual burried personal landmines. However it may enable the identification indirect indicators of mine presence (e.g. trenches, damaged infrastructure, cross roads, hilltops, etc…) or mine absence (e.g cultivated field). Together with other sources of information, like local interviews or military records, space information can reinforce the confidence of land hazard assessment.

On a side note, interesting developments on identifying the (direct) signature of a mine field from space are carried out. In fact, the nitrogen chemicals out-leaked from explosive ordnance are taken up by plants growing in the vicinity, and change the natural plant N_{14} /N_{15} isotropic ratio. This signature can be identified from space-borne hyperspectral imagery (3). [1]

Remote sensing from aerial platform has also been experimented in the past few years for identification of mine contaminated / free fields. SAR sensing is the most common technology used. An interesting project also attempts to enhance the visibility of trace explosives with a biomarker, i.e genetically engineered micro-organisms producing a fluorescent protein when in contact of the Nitrogen released by ordnance. The scene is investigated from an airborne platform with a laser scanner exciting and detecting the fluorescent signals. In such airborne stand-off detection methodologies, space assets can provide a valuable assistance [2].

4 – Assisting navigation of field data-collectors and geo-referencing of data colleted.

Satellite navigation could enable the optimization of aircraft routing over the zones of investigation, to reducing overlap and time to achieve full coverage, thereby saving costs on fuel, manpower and maintenance. Precise navigation is also required to geo-reference remote sensing data to the observed position on the ground (4b). GNSS (Global Navigation Satellite Systems) for navigation and geo-referencing of collected data (or work achieved) could also support other stages of land release: from interviews of local people (4a) to demarcation of hazardous zones (4c), and subsequently to clearance of geo-referenced mines (4d). In this latter scenario differential GNSS is required for centimetric accuracy. It enables navigation to mines along safe or minimal effort trajectories.

Updated terrain and elevation maps are the necessary companions of GNSS enabled applications, to navigate to and within target zones. Demand for free (or cheap) and readily accessible updated maps are actually the need most voiced up to us.

5 – Real time communication between field data collectors and IMSMA, for quality management and educated action.

Finally satellite communication services could valuably assist land release. In fact the geo-referenced data collected along the process (e.g. interviews, visual inspections, updates on hazardous zone delineation, location of cleared mines, reduced land perimeter, etc…) could be transferred to a remote processing center for integration into the centralized system called IMSMA (International Management System for Mine Action). In this manner global deployment of land release campaigns can be achieved while traceability and quality management of actions can be improved. Satellites could also enable communication in the other direction, from servers connected to the terrestrial network to local demining groups operating in secluded areas, to deliver updates on the current situation they tackle. This two way communication could assist all operational stages, from non technical surveys (5a) to technical surveys (5b), demarcation (5c), and ultimately clearance (5d).

6 - "Space assets for demining assistance": an activity run under the IAP programme of ESA.

The Integrated Application Promotion (IAP) programme was established in 2008 to meet increasing demand for end-to-end services. It aims at the development of operational services for a wide range of users through the integration of both space and non space elements. It is designed to avoid pitfalls of the past, i.e. it bridges the cultural gap and lack of dialogue between potential users and the space sector. It also overcomes the traditional compartmentalisation between space technologies. In practice it fosters the incubation of those new services by funding and managing feasibilities studies and pre-operational demonstration projects. The programme has no topical restriction, and welcomes any space enabled services tackling global challenges such as health, development, transportation, energy, safety, etc. The services should build upon mature technologies and / or existing system elements, so they can be brought to market over a short period. IAP activities are implemented through partnerships of users and relevant stakeholders across the value chain. Because it is a key element toward sustainability, IAP strives to keep its endeavours user-driven.

The "Space Assets for Demining Assistance" feasibility study was initiated by an innovative proposal by the International Astronautical Federation. The Invitation To Tenders is now open and will close on 12th July 2010. The study will run over 15 month on a 400 k€ budget. Conditional to a positive outcome, it will be followed by a demonstration project, last step paving the way to operational services aimed at enhancing the socio-economic impact of demining services.

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[2] Meurer. Heinrich: Personnal communication, February 2010

Possible space enabled services along the land release process.

Land Status	Loosely defined suspect Area	Priority zones	Zone with undetermined hazard	Low hazard zone	High hazard zone	Mine decontaminated zone	Released zone
Action steps	Landmine Impact Survey	Non technical Survey	Technical Survey	Fencing off	Clearance	(Test) & Release	
Current Tools	Reports of accident Conflict data Collection of demographic and economic data	Interviews Stand-off visual inspection	Close-in visual inspection Airborne stand-off detection (experimental)		Manual deminers with prodders, electronic sensors or dogs; Possible mechanical assistance		
Possible space assistance	1a	4a / 5a	2a / 4b / 5b / 3	4c / 5c	2b / 4d / 5d	1b	

Legend

Service enabled by satellite Earth Obs.	xx
Service enabled by satellite Navigation.	xx
Service enabled by satellite telecommunication.	xx

Soil Characterisation and Performance of Demining Sensors

Kazunori Takahashi[24], Holger Preetz and Jan Igel[24]

Abstract

A field trial for the evaluation of detection performances of demining sensors including metal detectors and dual sensors were carried out in September 2009. During the trial, geophysical measurements were also conducted for characterising soils in the test lanes. The measured and estimated soil properties include: soil texture, humus content, magnetic susceptibility, electric conductivity, permittivity and water content. Considering these measurements and the impact of the properties on sensors, a comprehensive qualitative characterisation of the test soils with regard to detection performance was provided for both metal detector and dual sensor. The trial results in terms of detection performance agree with our prediction of soil impact. It indicates that performance of landmine detectors can qualitatively be predicted by some geophysical and pedological analysis which can be performed not only inside a mined area but also at an adjacent representative area with the same soil type. Further, the applicability of the guideline "CWA 14747-2: Humanitarian Mine Action – Test and Evaluation – Part2: Soil Characterization for Metal Detector and Ground Penetrating Radar Performance" has been demonstrated.

1. Introduction

Soil properties play an important role for performance of demining sensors such as metal detectors and dual sensors. Electrical engineers, geophysicists and soil scientists have been working on this issue in order to assess the performance of sensors and, further, the effectiveness of the techniques in various soil types. A guideline has been made for characterising soil properties for metal detector as well as for ground-penetrating radar (GPR) which is a part of dual sensor being used in humanitarian demining [1]. In order to demonstrate the characterisation and influence of soil properties on demining sensors, Leibniz Institute for Applied Geophysics (LIAG) has carried out geophysical and pedological investigations during the ITEP dual sensor test in Germany in 2009 [2][3]. This paper briefly reviews the influence of soil properties on metal detector and GPR in general, and then the measurements of these properties in the trial are reported. An estimation of soil influence on the detection methods is made based on the measurements, and relationships between the estimation and test results in terms of the detection and discrimination performance of detectors are also discussed.

2. Influence of soil properties on demining sensors

A. Magnetic susceptibility

Magnetic susceptibility is considered to be the most influential property on metal detectors, whereas it has no influence on GPR. In general, the absolute level affects frequency-domain (CW; continuous wave) metal detectors and its frequency dependence has more influence on time-domain (impulse) detectors [4]. Soil with a high magnetic susceptibility and frequency dependence creates additional response to metal detectors. This response from soil can be misinterpreted as a metal detection or can disturb response from landmines. As a result, it can be a cause of false alarms or even missing mine detections. Most of modern metal detectors have a ground compensation function which aims to reduce soil influence. The measurement of magnetic susceptibility at a location and at one or two frequencies can be made in the field quickly and easily. Measurements at two frequency is often enough to observe the frequency dependence because it is usually linear. The measurement of the complete frequency dependence at numbers of frequencies needs to be carried out at a laboratory with a fragile instrument.

B. Electric conductivity

Electric conductivity is considered to be an influential property on metal detectors only if it is extremely high [1]. Such a high conductivity is related to salt water and can be found in some coastal areas but is very

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uncommon in other areas. However, it has influence on GPR even if it is not extremely high. The property is mainly related to the attenuation of electromagnetic energy, meaning that a radar signal cannot propagate a long distance in a high conductive medium. The measurement of electric conductivity at a location can easily be carried out in the field.

C. Permittivity (dielectric constant) and water content

Permittivity, also called dielectric constant, is the most influential property on GPR [5] and it is directly related to the water content of soil. It mainly defines the propagation velocity of radar signals. Since the reflectivity of radar signals is controlled by the contrast of permittivities, the property can cause both positive and negative influence. The measurement of permittivity at a location can easily be carried out in the field.

D. Inhomogeneity

Soil properties always vary with location. The changes can be quantified by geostatistical analysis and the parameters correlation length and variability. The former quantity indicates the spatial length of the change and the latter represents the amount of changes. If the correlation length is significantly smaller or larger than the target dimension and the variability is relatively small, the soil can be considered homogeneous. If not, the soil is inhomogeneous and can have additional influence on detectors. For example, a metal detector is compensated at a location and has no response of the soil at this position. However, it is not valid any more at other locations and gets false alarms from the soil if the soil is very inhomogeneous. For GPR, the spatial changes of permittivity generate reflections which can disturb mine signatures and/or create additional responses to the radar. The measurement of the spatial variation of a property can be done by repeating a single point measurements at various locations and some analyses. The measurement can only be performed in the field, because it is impossible to take soil samples back to laboratory keeping the natural spatial pattern of variation.

3. Investigation of test soils in ITEP DS trial 2009

Measurements of the soil magnetic/electric properties mentioned above as well as pedological investigations have been carried out during the ITEP dual sensor trial in 2009 for characterising soils in the test lanes. The details of the measurements and results can be found in [2] and [3]. There were four types of soil prepared in 12 lanes. These soils can be categorised and described as follows:

i) "Laterite" (Lanes 1.1-1.4)
   The soil material is a tropical soil formation from the Tertiary period. It stems from a former bauxite pit that is located in medium range mountains of Vogelsberg area, Germany. Its parent rock is basalt. The texture is clay loam with a small stone content (basalt) of approximately 2-5 %.

ii) "Magnetite" (Lanes 2.1-2.4)
   The soil material in these lanes is a synthetic mixture of calcareous sand with engineered magnetite. The texture is coarse sand with a low content (2-5 %) of fine gravel.

iii) "Humus" (Lane 3.1)
   The parent material of this top soil material is loess and the texture is loam with a low content of fine gravel. Its provenance is in the region of the foothills of the Alps in Bavaria. Its humus content is 2.7%.

iv) "Humus with high stone content" (Lane 3.2-3.4)
   High humus content and high stone content which is about 30-40%.

From the grain size analyses, the textures of test soils are determined as shown in Fig. 1 and Table I.
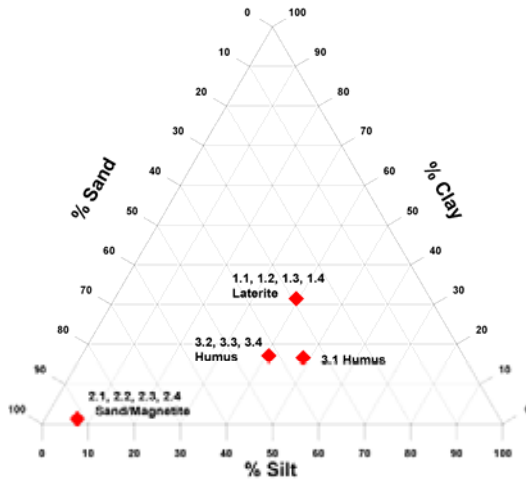
Fig. 1. Texture triangle of test soils.

TABLE I. Soil texture and humus contents of test soils.

	Laterite	Magnetite	Humus	Humus with high stone content
Clay [%]	31.5	1.3	16.6	17.1
Silt [%]	39.4	7.0	48.4	40.7
Sand [%]	29.1	91.7	35.0	42.2
Humus [% of total soil]	0.8	< 0.5	2.7	12.4

Fig. 2 shows the frequency dependence of magnetic susceptibility of the test soils measured in laboratory. Both Laterite and Magnetite have very high absolute levels of magnetic susceptibility and only Laterite shows frequency dependence. Both Humus lanes have very low susceptibility; however Humus in Lane 3.1 has remarkable frequency dependence. Fig. 3 shows the magnetic susceptibility normalised by the mean of each soil as a function of position. It can be observed that the relative spatial variation is very large in Humus with high stone content whereas it is relatively small in Laterite and Magnetite. The measurements are summarised in Table II.

Fig. 4 shows the spatial distribution of electric conductivity measured in field. Electric conductivity is ranging from 0.2 to 15 mS/m in all soils together, which is not high. Humus with high stone content (rightmost figure) seems to have higher relative inhomogeneity than others, however the influence is not serious since the absolute level is fairly low. The frequency dependence of electric conductivity is also measured in laboratory as shown in Fig. 5. Certain amounts of frequency dependency can be observed, but the absolute levels are low and no significant influence on metal detector as well as on GPR is expected.

Fig. 6 shows the spatial variation of permittivity (dielectric constant) and the converted water content measured with a TDR (time-domain reflectometry) probe in field. Laterite and Humus have higher permittivities (higher water content) than Magnetite and the higher permittivity is expected to cause higher reflectivity of landmines. However, the spatial variations in these soils are also very large and the variation is supposed to create radar response which can falsely be interpreted as mines. On the other hand, Magnetite has a very small spatial variation of permittivity and very "*clean*" mine response is expected in this soil. Table III shows the summary of the permittivity measurements.

Considering measured soil properties, the impact of soil on the performance of detector is estimated as shown in Table IV. For the classification, thresholds of magnetic susceptibility as well as its frequency dependence for metal detector performance as defined in [1] and [6] are taken into account. However, such thresholds are not established for GPR and the estimation is made according to our interpretation of the analyses.
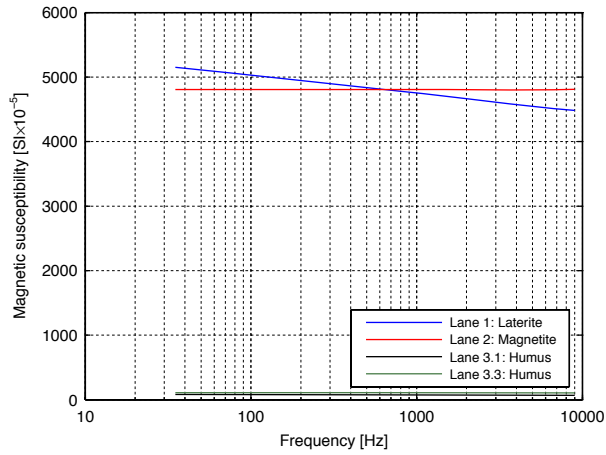
Fig. 2. Frequency dependence of magnetic susceptibility.
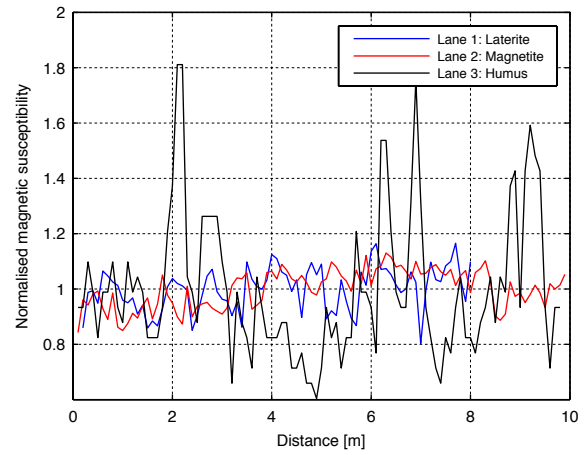
Fig. 3. Spatial variation of normalised magnetic susceptibility.

TABLE II. Summary of magnetic susceptibility measurements.

	Laterite	Magnetite	Humus	Humus with high stone content
Absolute value	Very high	Very high	Very low	Very low
Frequency dependence	High (6 %)	Very low (0.1 %)	High (7 %)	Very low (1 %)
Spatial variation	Small (8.4 %)	Small (7.4 %)	-	Large (38.9 %)

Fig. 4. Spatial distribution of electric conductivity in mS/m at a depth of 5 cm. Left to right: Lane 1 (Laterite), Lane 2 (Magnetite), Lane 3.1 (Humus) and Lane 3.2 (Humus with high stone content).

Fig. 5. Frequency dependence of electric conductivity.

Fig. 6. Spatial variation of permittivity (dielectric constant) and water content.

TABLE III. Summary of permittivity measurements.

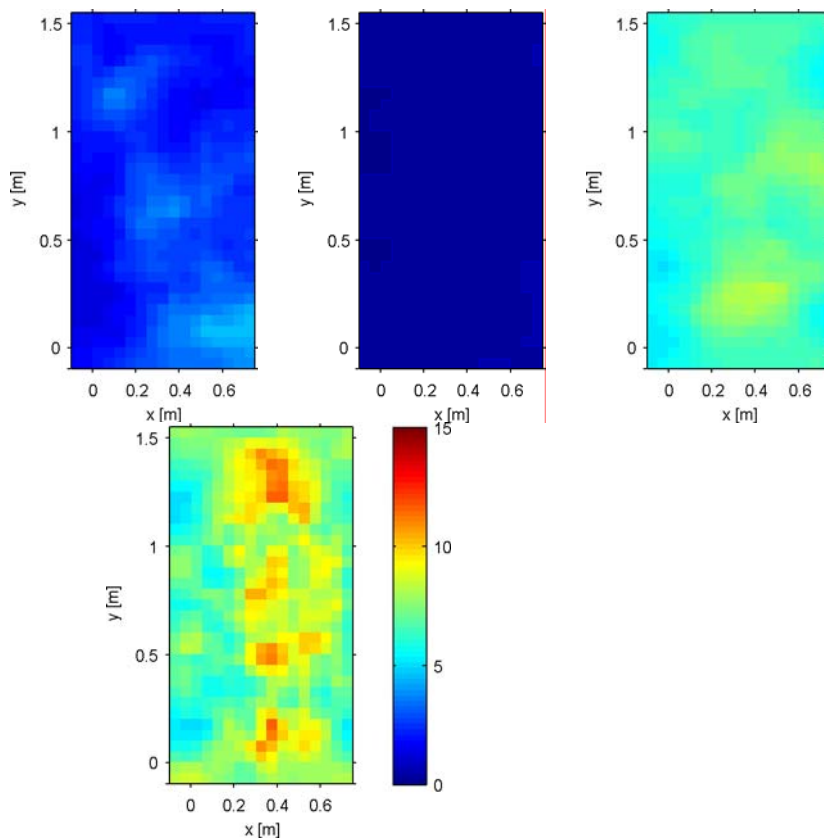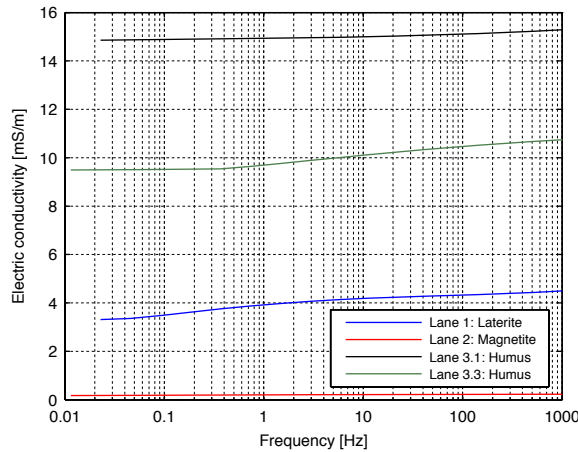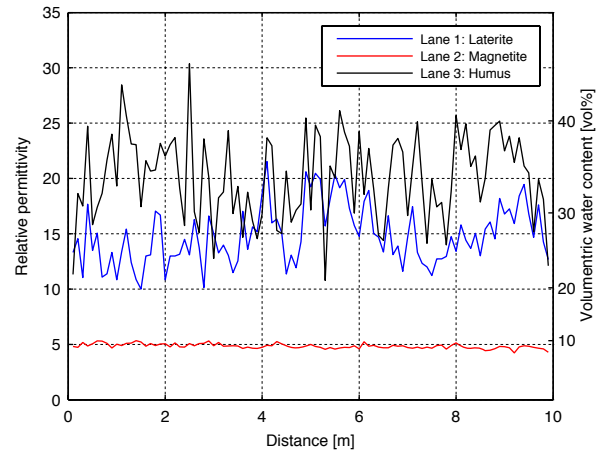|	Laterite	Magnetite	Humus
Mean	High (14.9)	Low (4.8)	High (20.1)
Correlation length	1.35 m	-	0.63 m
Coefficient of variation	Large (18 %)	Very small (4 %)	Large (19 %)

TABLE IV. Estimated impact of soil on the performance of detectors.

	Laterite (Lane 1.1-1.4)	Magnetite (Lane 2.1-2.4)	Humus (Lane 3.1)	Humus with high stone content (Lane 3.2-3.4)
Metal detector	Very severe	Moderate	Neutral-Moderate	Neutral
GPR	Moderate-severe	Neutral	Moderate	Very severe

4. Soil characterisation and sensor performance

The estimation of soil influence on detector performances are compared to the test results. Fig. 7 shows the probability of detection (POD) and false alarm rate (FAR) of stand-alone metal detectors in total in each test soil. The horizontal axis shows soil types used in the test and the order is sorted from influential soil (or "*difficult*" soil) to less influential soil (or "*easy*" soil) according to the rating for metal detectors in Table IV. The blue bars showing POD are increasing and the red bars showing FAR are decreasing from left to right. It indicates that POD is low and FAR is high in difficult soil, and POD is high and FAR is low in easy soil. The similar representation is made for dual sensors in Fig. 8. In the figure FAR reduction and POD loss which indicate the performance in discrimination are plotted in the order of the difficulty of soil for GPR (the definitions as well as the meaning of FAR reduction and POD loss can be found in [3] and [7]). While the FAR reduction by GPR (blue bars) does not vary so much in different soil types, POD loss (red bars) is decreasing. It means that POD loss is high in "*difficult*" soil and it is low in "*easy*" soil when FAR reduction is kept constant. Therefore, our estimation of soil influence on detector performance shown in Table IV agrees with the test results and validates the geophysical investigation methods used.
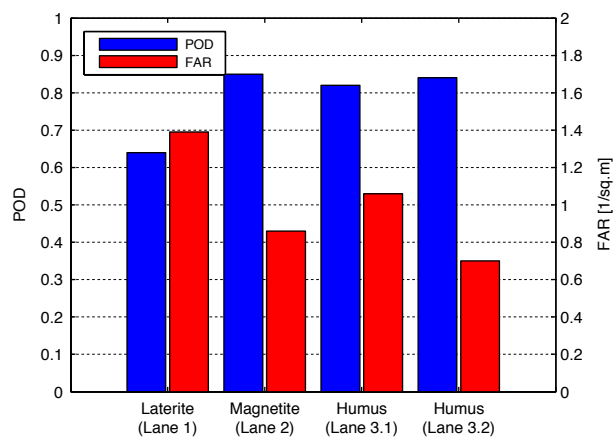
Fig. 7. POD and FAR of stand-alone metal detectors in total in each soil. Soil on left-hand side is difficult and right-hand side is easy soil for metal detector.
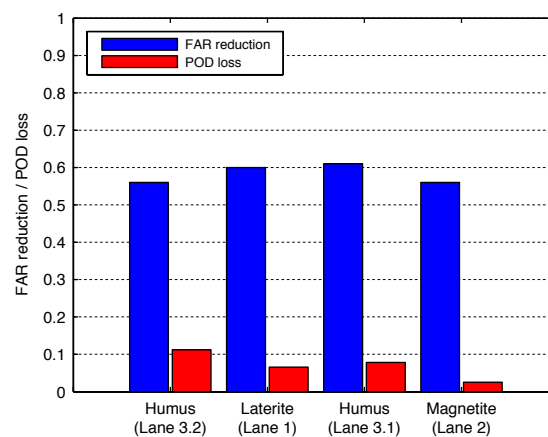
Fig. 8. FAR reduction and POD loss of a dual sensor in each soil. Soil on left-hand side is difficult and right-hand side is easy soil for GPR.

5. Conclusions

The relationships between soil properties and test results of demining detectors have been demonstrated in this paper. The soil characterisation based on the influence on metal detector and dual sensor estimated from pedological and geophysical measurements agrees with the test results; low POD and high FAR in difficult soil and high POD and low FAR in easy soil for metal detector; high POD loss in difficult soil and low POD loss in easy soil for dual sensor whilst FAR reduction is kept constant.

The fact that our estimation of soil influence agrees with the test results indicates that the performance of landmine detectors can qualitatively be predicted by some geophysical and pedological analyses which can be performed not only inside a mined area but also at an adjacent representative area with the same soil type. The influence of the soil properties on metal detector and GPR and the characterisation of soil according to the properties are described in the guideline "CWA 14747-2: Humanitarian Mine Action – Test and Evaluation – Part 2: Soil Characterization for Metal Detector and Ground Penetrating Radar Performance [1]", therefore the results also demonstrate the applicability of the guideline.

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ALIS Evaluation Test by CROMAC and CMAC in 2009

Motoyuki Sato[25]

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. In 2009, ALIS was evaluated in DeFuse and ITEP. These tests were conducted by ALIS operators of CROMAC and CMAC. ALIS has detected more than 30 AP-Mines in evaluation test in Cambodia since June 2009.

Keywords- Humanitarina Demining; Dual sensor, ALIS, GPR, Croatia, Cambodia, CROMAC, CMAC

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. A metal detector, which is an Electro Motive Induction (EMI) sensor, operating at around 10-50 kHz has been widely used for humanitarian demining. The current metal detectors for humanitarian demining can detect metal pieces which weight less than 10 mg contained in plastic anti-personnel mines buried at shallower than 20 cm. Therefore, these metal detectors can detect almost 100% of buried miens, which can explode by the pressure on the ground surface. However, even in a former battle fields, statistically, only one out of 1000 metal objects detected by a metal detector is a buried landmine, and this large number of metal fragments increase the cost of humanitarian demining operations.

Figure 1. ALIS in operation in mine fields in Croatia

In order to improve the efficiency of the demining operations, discrimination of landmines and metal fragments by Ground Penetration Radar (GPR) is believed to be one of the most promising sensors. It can decrease the False Alarm Rate (FAR) in detection of landmines, and can directly reduce the cost of humanitarian demining.

For a hand-held system, a sensor has to be compact. However, 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. This kind of sensor is named "Dual sensor" for humanitarian demining. Only a few dual sensor systems including Mine Hounds (UK and Germany)[1], HSTAMIDS (USA)[2] and ALIS (Japan)[3]-[9] (Figure 1, http://www.alis.jp/,Sato, 2005, http://www.jst.go.jp/kisoken/jirai/EN/index-e.html) are now available for humanitarian demining in commercial basis as of 2009. Our research group at Tohoku University, Japan has been developing this dual sensor system, namely, Advanced Landmine Imaging System (ALIS) since 2002 and deployment in real mine fields started in 2009.

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Hand-Held GPR ALIS

GPR and Metal Detector Hardware
There is several different radar hardware architectures used for GPR. ALIS has two different types of GPR hardware, namely Stepped-frequency Continuous Wave (SFCW) radar and impulse radar[7].
ALIS-PG is operated by using an impulse GPR system. This impulse GPR system generates a short pulse having approximately 200ps which covers the frequency ranging from DC to a few GHz, and down sample the RF (Radio Frequency) signal to audio signal for further signal processing and recording..
The metal detector used for ALIS is the same system used for MIL-D1 (CEIA). The sensitivity and performance of the metal detector is almost equivalent to the original Mil-D1.

Figure 2. Sensor Head of ALIS

Fig.2 shows the sensor head of ALIS. ALIS uses cavity back spiral antennas for transmitter and receiver of GPR. This type of antenna is selected due to a good performance in wide frequency range, and high isolation between transmitter and receiver antennas, when they are set close to each other. In addition, circular polarization is suitable for detection of targets, whose orientation is unknown. The antennas are combined with a coil sensor for the metal detector. The location of the coil and antennas were optimized to avoid their mutual interferences. The metal detector which we used for ALIS has a differential type receiving coils. Therefore it is insensitive to metal objects which are placed symmetrically to the metal detector coils. Therefore, metal detector is not affected by cavity-slot antennas for GPR. Electromagnetic wave from GPR is transmitted through the coils of metal detector, and it has some influences, but we founds that the reflection from fixed objects can be suppressed by signal processing.

Imaging System of ALIS
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 on a display. 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, because the trajectory of the sensor is unpredictable in a handheld system. The sensor position tracking system was achieved by using a CCD camera attached to the sensor handle.
One of the advantages of GPR is its easiness in understanding and interpretation of the acquired data sets. In many occasions, the location of the buried objects can directly be observed in GPR profiles. However, detection

of buried anti-personnel mines by GPR is unfortunately, very difficult by interpretation of raw GPR profiles, mainly due to strong clutter. Fig.3 shows an example of raw GPR horizontal profile, which is acquired in a mine field in Cambodia. We know that an AP-mine is buried in this area, however, strong clutter shade the image of a buried mine. In this particular location, soil did not contain any other materials such as gravel, therefore this GPR image is principally caused by moisture inhomogeneity. We can define "clutter" as radar reflected signal from objects, which are not our interests. Clutter is caused mostly by strong inhomogeneity in soil. Small buries material such as grains grass root, difference of geological materials and inhomogeneous soil moisture is the

principle reasons of this electrical inhomogeneity in soil. The size of targets, i.e., AP-mines is close to these scale of inhomogeneity, while most of other GPR targets such as buries pipes have different scales. We cannot find very strong inhomogeneity in a sand pit in controlled laboratory conditions, therefore, the importance of signal processing in GPR for landmine detection has been overlooked.

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. In ALIS, we reconstruct a 3-D GPR image by Kirchhoff migration algorithm[3].
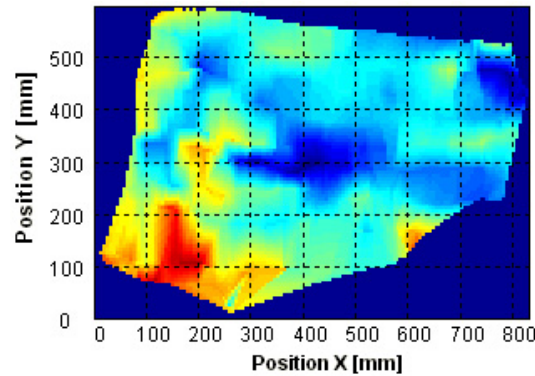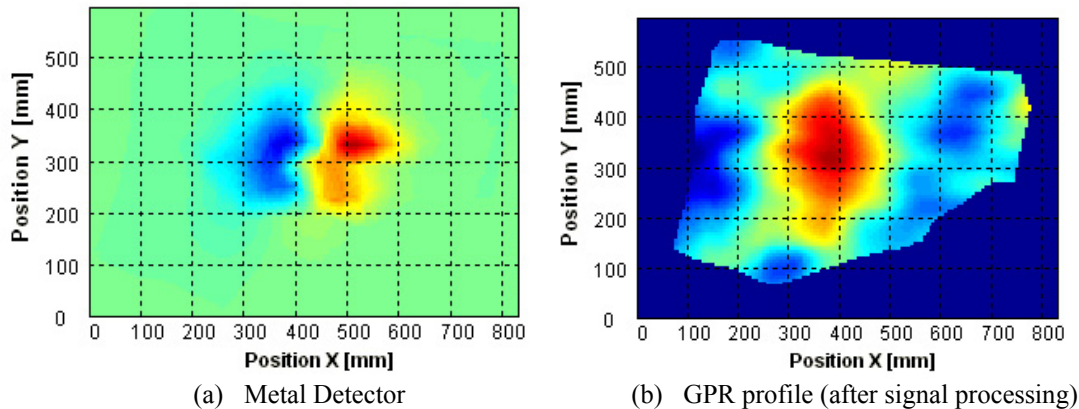

Figure 3. GPR horizontal profile (Raw data)

(a) Metal Detector   (b) GPR profile (after signal processing)

Figure 4.Visaliaze image of a buried PMN-2 by ALIS (02 July 2009 by PG-2 data No.28, Cambodia)

A migrated GPR data gives 3-D reconstructed subsurface image. However, we found that the horizontal slice image (C-scan) as shown in Fig.4(b) is very useful for data interpretation in real situations. It should be noticed that ALIS does not use signal processing to reduce the reflection from the ground surface. The ground surface in real mine fields is quite rough, and the signal processing normally used for GPR acquired on a even ground surface, such as mean average subtraction does not work in our case. However, we found the migration drastically improves the quality of the reconstructed image, and the image of miens can clearly be shown. Fig.4 (b) is one example of GPR horizontal profile (c-scan) after migration processing applied to the raw data shown in Fig.4. PMN-2 (produced in former USSR) anti-personnel landmine is the target in these GPR profiles.

Fig.4(a) is the visualized metal detector signal, which is acquired simultaneously with the GPR data shown in Fig.4(b). The operator will interpret both the metal detector and GPR images on the PC display as we can see in Fig.1 and judge the types of buried objects.

Evaluation Tests in Mine Affected Courtiers

Evaluation test until 2006
ALIS has been tested in some mine affected courtiers including Afghanistan[12], Egypt, Croatia[13] and Cambodia. Mine fields at each country has different conditions and soil types. Therefore testes at the real mine fields are very important.

Evaluation test in Croatia in 2008

During December 2007 and April 2008, in more than 15 locations in Croatia, ALIS has been used and evaluated in QC

Figure 5. Hirvoje Stipetic and Nikola Gambiroza (CROMAC technical manager) QC after machine demining. The soil is plowed and many small rocks appear on the surface.

Evaluation test in DEFUSE and ITEP in 2009

For the future deployment of dual sensors including ALIS, now we are planning a test in Denmark with colleagues from Nordic Demining Research Forum (www.ndrf.dk). The project "DeFuse" has been planned by the Nordic Demining Research Forum, which is consists of members in Nordic countries. The objective of the project is acquiring a lot of record of mine detection by using various mine detection systems in one test site, in order to understand the statistical properties of demining operations. The systems to be tested will include Mine Dogs, Metal detectors, machine frails and ALIS. They plan to bury more than 500 mines in 28 lanes, each has 10m by 100m area. The results of this test will be analyzed, the reports will be published. What we expect from the project is a proposal of an useful use of multiple mine detection systems. For example, we want to demonstrate that the machine demining and ALIS will improve the probability of detection from 90% to 99.9%. The final results of the project will not show the advantages of ALIS only, however, the data which will be corrected can be used for analysis of ALIS operation, and thus can be used for advertisement of the ALIS in the future.

Actual evaluation test of DeFuse project was conducted by 2 ALIS operators dispatched from CROMAC in June 2009. The test lane was prepared at Karp air field in Denmark.

Figure 6. Deminers of CROMAC operating ALIS in DeFuse test site in Karp Air field in Denmark.

At the same time, International organizations such as ITEP(International Test and Evaluation Program for Humanitarian Demining : http://www.itep.ws/) are conducting evaluation testes of sensors for humanitarian demining at control conditions, and provides technical information of sensors to the end users.

Evaluation tests in 2009

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. In the operation in July 2009, ALIS detected 1193 buried objects, and found 8 ante-personnel mine PMN-2. Examples of GPR profiles in Fig.3 is one of the data acquired in this campaign.

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 for two months, and more than 30 mines were detected.

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.

Figure 7. ALIS in Cambodia with detected mine.

Conclusion

In this section, 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.

Acknowledgment

ALIS evaluation test in mine fields has been conducted by the collaboration with CMAC.

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Gradual Dispersal of Explosives by Ants and its Possible Implication for Smart-Landmine Production

Stephen B. Achal[26], John E. McFee[27] and Jason Howse[15]

Abstract

In April 2008, during IED detection trials at Kandahar Airfield, Afghanistan, two of the authors unexpectedly discovered the gradual dispersal of explosives by indigenous ants. The authors then investigated whether similar behavior had been by observed by humanitarian deminers in and around minefields, with a focus on very old minefields. Anecdotal evidence from a humanitarian group operating in Angola support similar processes, such as ants removing TNT blocks from old Russian wooden PMD-6s, cracked casings with explosives 'cleaned-out' and insect-ravaged detonation cords.

Self-destruct/passivate mechanisms in smart landmines are not 100% reliable. Currently, the Landmine Protocol of CCW allows for production of smart landmines with a self-passivation failure rate of up to 10%. The observed biological processes, though preliminary, hint to the possibility of improving this self-passivation rate by allowing indigenous insects access to the explosives via extremely simple, low-tech and low-cost mine-casing modifications. Such modifications may further reduce the civilian and environmental impact of long-term situated smart landmines.

Introduction

In spring 2008, the authors, while performing hyperspectral imaging experiments on landmines and IEDs in the Pashtunistan region, noticed that ants were attracted to exposed panels of loose TNT and RDX explosive[1]. In fact, the ants were observed carrying away clumps of TNT and RDX to their nests.

After the experimental trials, this surprising and curious behavior led the authors to conduct an open literature search to see if a similar phenomenon had been previously observed. Unfortunately, there were no published accounts of ants dispersing explosives. Instead, existing publications focused on the use of biological systems such as insects, mammals, and single-celled organisms for the <u>detection</u> of explosives.

The authors then sought to see if a similar phenomenon had been observed by humanitarian deminers working in old minefields. Several of the demining groups that were approached reported seeing such phenomena in diverse regions ranging from Bosnia to Eritrea to Angola. For example, deminers recounted seeing ants removing pieces of TNT blocks from old Russian PMD-6 mines while other workers reported discovering that the explosives in cracked and weathered PPM-2s had been mysteriously 'cleaned-out'.

Based on the authors' observations and the deminers' anecdotal evidence, it seems that ants may have an affinity to collecting TNT and RDX. The reasons why ants collect these explosives are, as yet, unknown.

Further examination of this intriguing phenomenon has allowed the authors to speculate and formulate the following hypothetical question: If ants were allowed access to the explosives contained in landmines (via small prefabricated holes in the landmine's casing), then how long would it take a colony of ants to neutralize an appropriately modified landmine and/or a minefield containing such mines?

Analysis of the ant-borne dispersal rate of explosives and ant phenomenology tantalizingly indicates that indigenous ants may be used as an effective long-term neutralizing solution for appropriately modified landmines. However, more research is needed to determine if this approach is truly viable. If so, then an amendment to the Landmine Protocol of the 1980 CCW (Convention on Certain Conventional Weapons) accord should be requested to constrain the manufacture of future landmines to include the appropriate casing modifications.

This paper describes the discovery of ants dispersing explosives, the search for similar phenomena, why ants are attracted to explosives, the rate of explosive dispersal by ants, and possible implications for the future production of landmines.

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Discovery of Ants Dispersing Explosives

In the spring of 2008, while in the Persia-Pashtun region, scientists from DRDC Suffield and ITRES conducted systematic diurnal experiments on detecting surface-laid and buried landmines, improvised explosive devices (IEDs) and their components using shortwave and longwave hyperspectral imagers mounted on a personnel lift. As part of one of the experiments, explosives were spread in a thin, uniform layer over each of two plywood panels (one square meter each) placed on the native soil. One panel was covered with a layer of TNT (2,4,6 trinitrotoluene) on top of a layer of indigenous soil, while the other was covered with a layer of RDX (cyclotrimethylenetrinitramine), also on top of indigenous soil (Figure 1).

Day Zero   Day Two

Figure 1. Experiment area showing panels of RDX (white-dotted square, lower left) and TNT (orange-dotted, lower right).

In the morning two days later, just after sunrise, personnel from the night shift were completing a set of measurements. From high atop the personnel lift they noticed a thin, linear trail of white explosive exiting from one corner of the RDX-covered panel. The trail was noticeable as it seemed out of place given the recent weather. A moderate, round-the-clock rainfall had occurred the day after the explosives had been spread on the panels. Light to moderate winds had also been seen over this period. Aside from this anomalous panel corner there was no suggestion of explosives having left the panels, nor would the weather have been likely to disperse the explosives in the thin, linear pattern that was observed. As soon as the hyperspectral measurements were completed, the RDX panel was closely examined and found to be teeming with ants, later identified to be ordinary Harvester ants (*Pogonomyrmex* sp.) as seen in Figure 2[2]. At close range, the wispy trail initially appeared to extend a short distance from the corner of the RDX panel (Figure 3). Upon closer examination, however, it was observed that the trail was composed of ants carrying individual clumps of the RDX from the panel to their ant hill, a distance of almost 20 m from the panel's corner (Figures 4, 5, 6, and 7).

The next evening, further examination of the site revealed a short section of a trail that led from the corner of the TNT-covered panel. It was seen that ants from a second hill (Figure 8), located about 30-40 m away from the first ant hill and 10 m from the explosives-covered panels, had found the TNT and were carrying it away one clump/flake at a time.

Figure 2. Harvester ants (*Pogonomyrmex* sp., dropped by ants. seen as black specs) teeming on the RDX panel

Figure 3. Faint white trail of RDX (outlined in red) The trail extends from the upper right corner of the RDX panel towards the top right corner of the image

Figure 4. Trail of ants carrying RDX lumps to their nest, located ~10 meters to the right of the image.

Figure 5. Close-up of Harvester ants carrying clumps of RDX.

Figure 6. Close-up of the entrance to the ant nest. Ants are black with some seen carrying white RDX clumps.
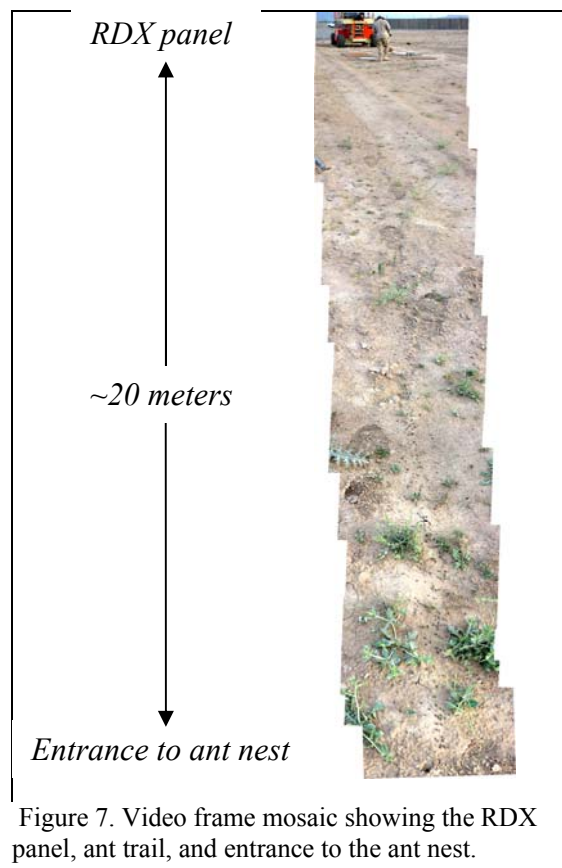

RDX panel

~20 meters

Entrance to ant nest

Figure 7. Video frame mosaic showing the RDX panel, ant trail, and entrance to the ant nest.

Figure 8. TNT panel (top) and ant nest with TNT flakes surrounding the entrance (bottom middle).
Figure 9. Close-up of TNT flakes at the ant nest's entrance

The ants carried away both types of explosives. They carried the RDX down the holes of their ant hill, but the flakes of TNT were piled around the entrances, apparently being too big to take down (Figure 9). Ants were observed swarming in large numbers on the explosives-covered boards. At times, the ants seemed to be writhing on the explosives, but it was not clear that they were in distress. This is supported by the fact that the explosives did not seem to be killing them immediately (very few dead ants were seen on the explosives) and that they continued to carry the explosives away to their nests. This behavior was seen until observations were stopped at the conclusion of the imaging experiments and removal of the explosives during the afternoon of the fourth day after the imaging experiment had begun.

Search for Similar Phenomenon

The authors performed an in-depth open literature search and did not find any descriptions of similar explosive-dispersing behavior by ants or other insects. The authors then asked experts in the field of humanitarian mine clearance if they or their co-workers had any anecdotal information or observations on the behavior of insects in old minefields. For example, the experts were asked if, when digging out mines, they had noticed an unusual number of ant hills or nests nearby. They were also asked, in the case of weathered or eroded mines, if there had been any evidence of current or former insect activity inside the mines.

The following are condensed anecdotal testimonials from three veteran humanitarian deminers:

Hendrik Ehlers, CEO of the well-respected humanitarian demining organization Menschen gegen Minen (MgM) and a person with many years of experience in humanitarian demining, was aware of such behavior. He recounted that, in southern Angola, ants seemed to love Russian TNT blocks such as those used in their wooden PMD-6 mines (the loose wooden boards of their cases possibly providing easy access to the explosives). He noted that he and his associates had found many landmine cases that had been cleaned out by ants. He also cited an experience in Angola where ants had eaten through the outer edge points of the kinks and sharp angles of the detonation cord in an IED. The cord, typically filled with Pentaerythritol tetranitrate (PETN), connected a BM-21 122 mm rocket to a South African R2M2 antipersonnel mine used as a trigger.

Magnus Boström, Head of Marketing & Operations at MDR Complete Demining AB Sweden, said that his peers at DDG (Danish Demining Group) had spotted the phenomena in antipersonnel minefields in Eritrea. He noted that DDG have observed that anthills were built over at least 50 antitank mines in South Africa.

Hrvoje Stipetić, Chairman of the Committee for Demining Osijek-Branja County in Croatia, said that during his group's many years of mine clearance he routinely came across minefields in Bosnia and Croatia where anthills were formed over landmines. They commonly came across anthills that were formed over bounding mines as well.

Why do Ants Find Explosives Appealing?

It is not yet known why ants are attracted to explosives such as TNT, RDX, and PETN. Ant experts suggest that three possibilities are likely [3,4]. The first is that the explosives may possess the smell and appearance that mimic plant seeds. The second is that explosives are nitrogen-rich and may help stabilize the chemistry and/or fertilize the soil that the ant colony is found in. The third possibility is that the ants may use the explosives as a construction material (bedding, insulation, structural, etc.) in their nests.

Calculation of Ant-Borne Loose Explosive Dispersal Rate

The following is a back-of-the-envelope calculation showing the daily ant-borne dispersal rate for loose explosives (D_{loose}) based on the authors' in-situ observations:

The average density of TNT and RDX ($\rho_{TNT/RDX}$) is 1.70 g/cm^3.
The average TNT/RDX 'clump' radius (r_{clump}) is 0.5 mm (based on the authors' observations).
If the clumps of explosives carried away by the ants are roughly spherical, then the mass per clump of explosives (m_{clump}) is equal to $4/3 \times \pi \times \rho_{TNT/RDX} \times (r_{clump})^3$. Thus, the mass of each clump of explosive (m_{clump}) is approximately one milligram (0.001g).
The average ant walking speed (v_{ant}) is 20.0 mm/s (based on the authors' observations).
The distance to the observed ant nest (d_{nest}) is 20.0 m.
The bi-directional linear ant density (υ) is 50.0 ants/m (this is a conservative estimate!).

The average foraging time (τ) of the ant colony is 10,000 s/day, ~2.8 hours/day. This, again, is a conservative estimate to facilitate a quick and easy calculation! The authors observed that ants were actively foraging explosives from a few hours after sunset to half-an-hour after sunrise (> 4.0 hours).

The average dispersal rate (loose) can be described by the following expression:

$$D_{loose} = m_{clump} \times v_{ant} \times \upsilon \times \tau$$

Thus, using all of the above numbers, the average dispersal rate of explosives (loose) of an ant colony is $_{loose} \approx$ **10.0 g/day**.

The dispersal rate of ten grams per day is gradual. Nevertheless, the significance of this gradual rate becomes apparent when one considers that an ant colony can effectively harvest a 'source' for hundreds of days. For example, one ant colony has the potential of removing one kilogram of loose explosives in 100 days.

Possible Application to Minefields Containing 'Ant-Accessible' Landmines:

Once an ant colony has found an ant-accessible landmine, the colony's ants may require extra time to break off clumps of explosives from the landmine's solid explosives block. This, however, may be offset by the authors' observations that the ants spent a significant amount time 'randomly' wandering around the panels' loose TNT and RDX before deciding which clump to carry-off to their colony. Thus, the dispersal rates for both loose and solid explosives may be similar.

In fact, the authors, based on similar problems in physics, assume that the ant-borne dispersal rate for solid explosives (D_{solid}) will be related to the root-mean-square of the dispersal rate for loose explosives:

$$D_{solid} = D_{loose} \div 2^{1/2} \approx 7 \text{ g/day}$$

The following is another back-of-the-envelope calculation showing the yearly ant-borne explosives dispersal rate per hectare (100 m $\times$ 100 m) for ant-accessible landmines containing solid explosives:

The estimated average foraging period for an ant colony (P) is 180 days/year.

The estimated average number of ant colonies per hectare (N) is 15 colonies/ha. This is a conservative estimate since the authors observed more than 45 colonies/ha in the experiment site.

The average area dispersal rate for solid explosives (A) inside ant-accessible landmines can be described by the following expression:

$$A = P \times N \times D_{solid}$$

Thus, using all of the above numbers, the average ant-borne dispersal rate for solid explosives per hectare is:

A $\approx$ 19 kg/year/ha

There is, on average, 200 grams of explosives in each anti-personnel (AP) landmine and five kilograms of explosives in each anti-tank (AT) landmine. The above rate then translates to:

A $\approx$ 95 AP/year/ha (0.2kg/mine)
A $\approx$ 4 AT/year/ha (5.0kg/mine)

The rough and conservative calculation shows that indigenous ants may have the ability to gradually neutralize a minefield containing ant-accessible landmines at a rate of ~**95 AP**, or ~**4 AT** landmines per year per hectare.

Implication for the Future Production of Landmines

Countries such as the US, China, Russia, India and Pakistan have not signed the International Mine Ban Treaty because its terms would require them to give up a seemingly much-needed military capability. However, the US and China have agreed to the terms outlined in the Landmine Protocol of the CCW accord which call for the elimination of persistent landmines in favor of 'smart' landmines[5]. In fact, the US has approved the elimination of all persistent landmines from its arsenal by 2010. Unfortunately, the self-passivate/destruct mechanisms in the smart landmines are not 100% reliable. The Protocol allows for this and permits a failure rate of up to 10%!

Based on the authors' observations, one method to improve the self-passivation/destruction abilities of 'smart' landmines would be to provide some degree of biodegradability by allowing indigenous ants access to the explosives. This may help neutralize, over time, appropriately modified landmines, especially those that failed to self-passivate/destruct. After all, ants are found in almost every terrestrial environment, from the desert to the tundra to the rain forest. They are on every continent except Antarctica. Their total collective mass on Earth rivals that of humans!

The landmine modifications to permit ant-based biodegradability may be accomplished through the use of something as simple, low-tech, and extremely low-cost as strategically incorporating a few small holes in the

landmine's casing (Figure 10). The holes would also facilitate the slow environmental 'erosion' (mainly through action of moisture and local microbes) of the explosives and ancillary mechanisms. In addition, the explosives and/or other components within the landmine could incorporate trace amounts of chemicals (such as milk powder… described in US patents 5618565 and 6274368!) that would further attract ants, yet not impede the landmine's short-term functionality. The holes would also allow for vapors/volatiles to escape the landmine… facilitating future removal via dogs and/or chemical sniffers.

The proposed methodology would be 'green' since it would solicit only the local 'bio-talent' to biodegrade landmines and would not introduce any potentially harmful invasive species (microbe, or animal) into the local arena as would be the case with genetically-modified microbes, 'trained' honey bees, etc..

The inclusion of insect access holes into the landmine casing would add next to no extra cost to the manufacture of both smart and persistent ('dumb') landmines. This, in principle, should not be a deterrent to the landmine manufacturers.

Initial modeling, though very preliminary, shows that minefields with ant-accessible landmines may be biologically-neutralizable within a few years (in most cases, well after their initial strategic military importance). Further research (in-situ and anecdotal… more stories required from de-miners working old minefields) is required to ascertain the true viability of the ant-based bio-degradation. However, if viable, then lobbying for an additional amendment to the Landmine Protocol of the CCW accord for the 'greening' of landmines via the slight modification of landmine production to permit ant-based biodegradation should be pushed forward.
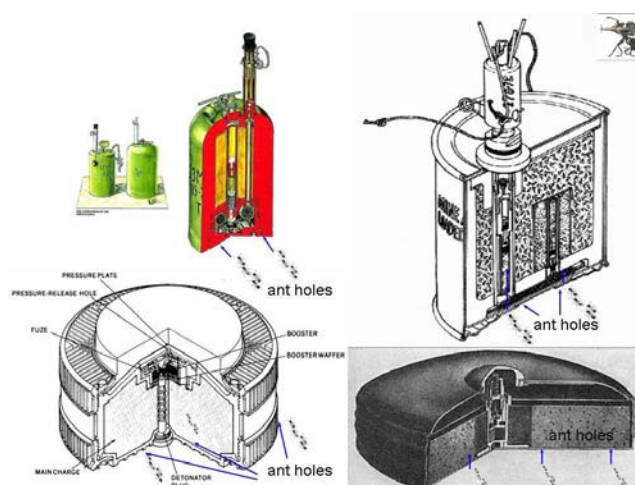

Figure 10. Basic schematic examples of ant-access ports.

Concluding Remarks

The discovery and possible application of the gradual dispersal of explosives by ants does not address the current, enormous, and tragic humanitarian demining problem. It does, however, have potential application to the production of future landmines via the incorporation small ant-access holes to permit gradual ant-based neutralization. The landmines with ant-access holes will not only lose their bulk charge over time, but will also emit vapors that dogs and future advanced chemical sniffers can easily detect, both which will facilitate future humanitarian demining. This will hopefully eliminate the scenario where old and forgotten landmines in future minefields remain civilian and environmental threats.

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An Emerging Remote Sensing Technology and its Potential Impact on Mine Action

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Abstract

In order to clear land from landmines and explosive remnants of war one first has to detect these devices as safely and economically as possible. Established and long proven detection methods are the use of metal detectors and mine detection dogs. Both technologies are close in technologies requiring a man on the ground in the minefield. Many other technologies - close in as well as stand off - have been proposed, tried or are still under development. This paper reports on the concept and initial results of an emerging remote sensing technology proposed for the detection of trace explosives leaking from landmines. It uses live soil bacteria as fluorescent biosensors to detect and signal trace explosives. Biosensors are spread using conventional crop duster planes equipped with precision flight management systems. Airborne scanning laser technology (LIDAR) is then used to detect in flight fluorescent biosensors on the ground. The technology is GIS-enabled and its spatial resolution expected to be high enough to georeference the halos of trace explosives leaking from individual landmines. The capability to detect landmines over large areas and from a safe distance could increase the safety of demining operations and facilitate a multitude of task in humanitarian demining, among them the cancellation of land previously recorded as hazardous areas, the detection and delineating of defined hazardous areas requiring full clearance and the marking and clearance of individual mines.

Introduction

The current consensus of the international humanitarian demining community appears to be that - beyond the detection of the single landmine - further improvements in identifying hazardous areas and appropriate technologies for land release are most urgently needed *[1]*. The GICHD publication "Guidebook on Detection Technologies and Systems for Humanitarian Demining" *[2]* lists nineteen different systems and associated technologies for the close in detection of single landmines. Among them are metal detectors, ground penetrating Radar (GPR), passive radiometer systems, various trace and bulk explosive detection and acoustic systems. In addition five remote sensing systems are described. They use high resolution aerial cameras and/or on hyper-spectral and infrared sensors mounted in airborne platforms. All remote sensing systems are aimed at either the direct visual identification of surface laid mines or at the detection of changes/disturbances on the surface as a clue for the presence of landmines or a minefield. Not mentioned in the publication is another noteworthy approach which employs Ground Penetrating Synthetic Aperture Radar (GPSAR) mounted in an airship to detect buried landmines *[3]*.

So fare no remote sensing technology has been proposed or developed which is capable to search for traces of explosives leaking from landmines. Such a technology could utilize a chemical signal which can be considered to be rather stable and persistent in the environment for a long time. As a remote sensing technology it would in fact copy for the first time the approach of the successful and trusted mine detection dog. However a much higher productivity and safety could be reasonably expected. We hope to approach this goal by combining for the first time ever a whole cell fluorescent live biosensor for the detection of trace explosives and an airborne scanning laser system (LIDAR) which is modified to detect in full flight fluorescent biosensors on the ground activated by the presence of landmines.

Technology

Burlage et al *[4]* published in 1998 that the soil bacterium Pseudomonas putida could be successfully employed as a biosensor to detect trace explosives leaking from landmines.. Pseudomonas putida is a begnin soil bacterium which can utilize TNT as a carbon source. It was demonstrated that this bacterium could be genetically

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engineered to produce green fluorescent proteins (GFP) inside its cell envelope if it gets in contact with traces of TNT. The production of fluorescent proteins would start when the bacterium produced enzymes for the necessary break down and consumption of TNT. Fluorescent proteins could be made visible by exciting them with UV light to receive green fluorescent light in return. To be able to observe and record green fluorescent light of fluorescent proteins inside Pseudomonas putida it was necessary to operate at night against a sufficiently low background of ambient light *[5]*. For unknown reasons no further development of this technology was reported and no further results published. One can perhaps speculate that this was the case because the procedure to detect landmines required the presence of personnel at total darkness in the middle of a minefield.

Our project is based on Bourlage's initial work. But we needed to improve significantly on the biosensor performance in order to develop a technology which allows the detection of fluorescent biosensors from the air in flight and therefore from a safe distance and over wide areas.

To improve the response of a biosensor for trace explosives we choose the begnin soil bacterium *Pseudomonia. putida* pMGCK. In this strain a regulative gene sequence was identified which is stimulated by trace amounts of TNT. The gene sequence was used as a promoter gene and fused with a genetically introduced reporter gene. The reporter gene encoded the production of the protein tdTomato which yields a bright red fluorescence if excited with green light. The fusion of both genes in the bacterium forced it to start the production of red fluorescent proteins as soon as it came in contact with TNT explosives. In a subsequent effort the biosensor was modified in order to become also inducible by trace amounts of DNT. This appeared to be advantageous as DNT molecules are degradation compounds of TNT. They are found at generally higher concentrations on the surface of landmines and in the soil next to landmines than TNT molecules themselves *[6]*. It can be expected, that the ability of the biosensor to sense DNT molecules will result in improved sensitivities and consequently stronger fluorescent signals.

The capability to produce large amounts of bright fluorescent proteins under the control of the promoter gene establishes the bacterium's function as a whole cell live biosensor for TNT and DNT molecules. The fact, that bright fluorescent proteins inside the tiny cells of live soil bacteria are detectable from a distance establishes the principal possibility for a remote detection of these biosensors.
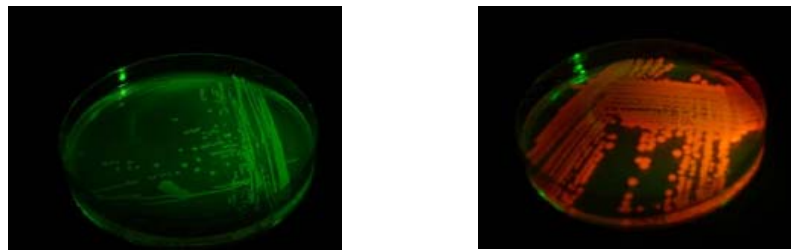

Fig.1 Biosensors excited with green laser light showing no fluorescent response (left) and bright red fluorescent response from the fluorescent protein tdTomato after the biosensor was exposed to TNT traces (right)

The selection of the red fluorescent protein tdTomato as the signalling protein for our biosensor was made for several reasons. Among them were brightness, a quick maturation time of the protein to obtain full fluorescent response and sufficient stability of the protein in the cell envelope of the biosensor *[7]*. Most important however was a possible excitation of the fluorescent protein by a commercially available airborne LIDAR system to allow the in flight detection of fluorescent biosensors over wide areas.

Airborne LIDAR systems integrate a laser scanner, a Global Positioning System and an Inertial Measurement Unit. They were initially developed in military applications for target acquisition and precision navigation of cruise missiles. In civilian applications they are today employed to acquire Digital Elevation Models (DEM) of the terrain using a multitude of single high precision distance measurements *[8]*. Distances are obtained measuring the total travel time of single laser pulses send from the airplane to the ground and back as a reflection into the receiver unit of the LIDAR. State of the art airborne LIDAR systems are capable to take more than 200.000 distance measurements per second and map areas of more than 100 square kilometres per day. The resulting spatial resolution of a Digital Elevation Model (DEM) is usually chosen to be 1 m in the horizontal plane. About 8 – 10 distance measurements per square meter are taken. Most of these measurements are redundant and used for quality control only but are available if need arises for a more detailed description of the surface over flown.
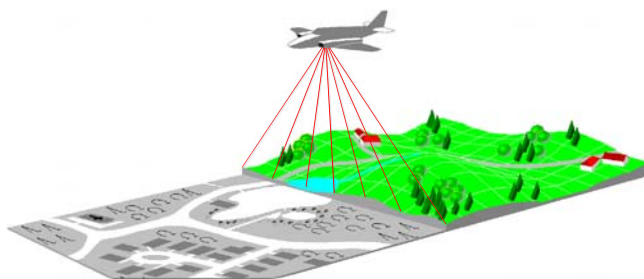
Fig. 2   airborne LIDAR

Fig. 3   airborne LIDAR in operation generating a DEM

LIDARs and the resulting Digital Elevation Models are used for various applications, among them corridor planning, flood plane mapping, open pit mining and the mapping of urban areas and forest. All LIDAR systems used are equipped with Nd:YAG laser sources operating in the infrared spectrum near 1000 nm or 1500 nm. Unfortunately fluorescent proteins which could be excited within this spectral range are not yet known *[9]*, but might become available in the future pending further research. However some commercially available airborne LIDAR systems use a frequency doubled Nd:YAG laser emitting green light at 532 nm. Green laser light is capable to penetrate water and these LIDAR systems were initially developed for submarine hunting *[10]*. In civilian applications they are nowadays used to map the bottom of rivers and shallow coastal waters.
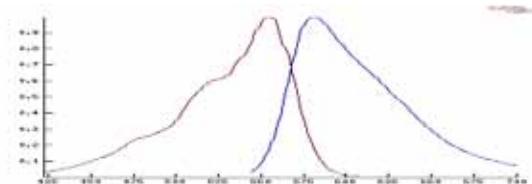

Fig. 4   excitation (red) and emission (blue) spectrum of the red fluorescent protein tdTomato

Since we selected for our biosensor the red fluorescent protein tdTomato - which is excitable by green light - we can use an airborne LIDAR systems operating with a green laser at 532 nm to excite tdTomato for red fluorescent light. Maximum stokes shifted red fluorescent light intensities can be expected between 575nm and 625nm (Fig.4). Using appropriate filters any green light from the excitation pulse reflected from the ground back to the LIDAR can get blocked and only red fluorescent light emitted from fluorescent biosensors on the ground allowed to enter the receiver.

Initial results

We were able to develop TNT and DNT sensitive live biosensors based on the soil bacterium Pseudomonas putida. When exposed to TNT and DNT and excited with green laser light at 532 nm they emitted red fluorescent light. A strong fluorescent response from biosensors was generally reached 24 hours after the exposure to traces of TNT and DNT. Fluorescent responses were observed at various concentrations of TNT and DNT. Concentrations ranged between 1-10 mg/litre of TNT and DNT dissolved in a nutritional solution and 10 mg TNT dissolved in 1kg of soil. Fluorescence was induced and recorded using a fluorescence macroscope and later a scanning laser with receiver optics rigged on an optical bench in a S1 bio-safety lab. When using the scanning laser with a somewhat restricted amplification system a detection of fluorescent biosensors at a distance of 12 meters was possible.

Fig.5 Biosensors activated by TNT (left), excited with green laser light (middle), showing bright red fluorescent response from fluorescent protein tdTomato inside the biosensors (right)

We had the chance to test our biosensor concept in one trial with an airborne fluorescence LIDAR used by the German government in patrol flights over costal waters to detect auto fluorescence from oil spills. This LIDAR was equipped with a green laser emitting at 532 nm. For our test it was set up in a stationary mode for usual horizontal calibration measurements. Under night light conditions we positioned various small targets of a mock up biosensors containing the original fluorescent protein from the biosensor. Targets with a volume as small as 1 cm³ were detected at a distance of 300 meters with no problems. We considered this as a major break through in our project and proof of principle for the intended airborne detection of fluorescent biosensors in full flight.
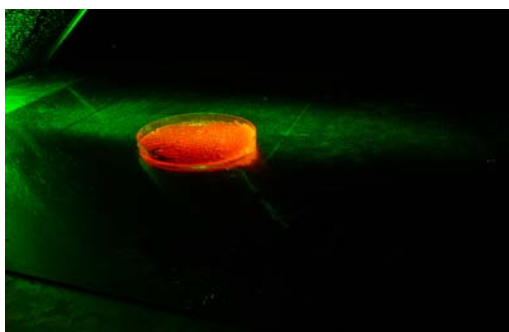

Fig.6 Biosensor target exhibiting strong red fluorescence

Fig.7 test area at Bremerhaven airport, Germany Successful detection of targets at 300 m

Discussion

Using a genetically engineered strain of the soil bacterium Pseudomonas putida we were able to develop a live biosensor for traces of TNT and DNT leaking from landmines or other explosive devices. Detection thresholds of the biosensor were found to vary between 1-10 mg for TNT and DNT dissolved in 1 litre of a nutritional solution and 10 mg for TNT dissolved in 1 kg of soil. This brings the sensitivity of our biosensor close to observed levels of trace explosives reported from landmine surfaces and soils next to landmines *[6]*.

Upon contact with TNT or DNT the biosensor would produce enough fluorescent proteins inside the cell envelope to yield a bright red fluorescence signal if excited with green laser light. This signal was detectable over a maximum distance of 12 meters using a laboratory set up of a scanning green laser with a receiver unit. This distance could already be considered to be a safe stand off distance. In an outdoor set up we were able to detect the red fluorescent protein from biosensors over a distance of 300 meters using an airborne fluorescence LIDAR in a stationary set up. We consider this detection distance to be a safe flight altitude for airborne LIDAR operations and as proof of concept for our ongoing research project.

Using conventional crop duster planes with precision flight management to spread the biosensors in low level flight we expect the biosensors to delineate and signal with their fluorescent proteins halos of trace explosives originating from landmines. This would allow the pinpointing of landmines as well as the delineation of entire minefields. The dense footprint of LIDAR measurements on the ground (8-10 measurements per square meter) compliments this task. If need arises the horizontal resolution of a LIDAR could be increased by lowering its flight altitude.

The concept of using an airborne LIDAR system to detect fluorescent biosensors on the ground appears to be feasible. It opens for the first time the chance to detect, record and georeference in flight trace explosives on the ground. As the entire process is airborne the operational safety and productivity is expected to be high. If developed into an operational system the technology could be useful to delineate the extend of minefields, to detect the positions of individual mines or to release vast stretches of land previously recorded as hazardous areas.
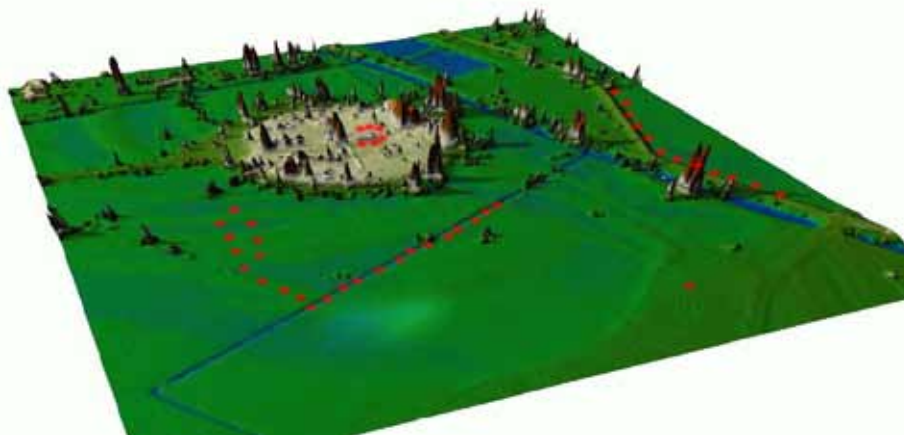
Fig. 8   concept of a Digital Elevation Model flown by an airborne LIDAR showing red fluorescence on the ground emitted from biosensors activated by trace explosives

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Aircraft Mounted Ground Penetrating Synthetic Aperture Radar

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Abstract

Mineseeker Operations is proposing a forward thinking solution which could rapidly detect landmines with great accuracy and more precision when defining minefield boundaries. Now is the time to aggregate and merge available wide area assessment technologies to give safe land back to communities and local people.
State Parties to the Ottawa Treaty have a ten-year deadline to clear mines which has passed for the countries that joined the treaty at its entering into force in 1999. According to the Landmine Monitor, technical surveys hold great promise for finding areas of hazard and reducing quarantined areas by segregating areas that actually contain landlines and other munitions from productive land.
The five critical parts of the Mineseeker solution are
1. *A comprehensive analysis of the terrain and conflict history*
2. *Assimilation of the right set of sensors appropriate to the terrain and the targets of interest*
3. *Development of a mock test site to pretest the survey to ascertain frequency response and to set a base line for imaging by bombarding the area of interest with a wide variety frequency bands and sensor arrays*
4. *Collection o f airborne video and data using a variety of flight patterns geared to accuracy for a specific terrain and munitions set*
5. *Coalescent of the data collected into a multilayer terrain / land hazard map.*

Introduction

State Parties to the Ottawa Treaty have a ten-year deadline to clear mines. 2009 was the deadline for countries that joined the treaty at its entering into force in 1999. According to the Landmine Monitor, technical surveys hold great promise for finding areas of hazards and reducing quarantined areas to areas that actually contain landlines and other monition from productive land.

Have acceptable solutions been defined in 2010? According to the Landmine Monitor, "*Acceptable techniques for technical survey, and the definition of what constitutes technical survey and how that is distinguished from area reduction, remain a matter of debate within the demining communityi [i]*

Mineseeker Operations is an innovator and an aggregator of the latest airborne survey and sensing technologies and data collection practices. Mineseeker Operations has embarked on a multi-phase testing and validation process in partnerhip with the Centre for Testing, Development and Training and the Faculty of Geodesy, University of Zagreb.

The increased accuracy of the Mineseeker Operations solution over prior applications of airborne survey techniques is accomplished through:

1. Comprehensive analysis of the terrain and conflict history
2. Assimilation of the right set of sensors appropriate to the terrain and the targets of interest
3. A pre-survey of a mock test site to ascertain the best data collection frequencies and to set a base line for imaging and sensor array settings
4. Airborne video and data collection using a variety of flight patterns
5. Coalescing all data collected into a multilayer terrain / land hazard map for analysis.
6.

Terrain and Historical Analysis

Soil and terrain composition have a tremendous influence on the success rate of airborne wide area surveys. The density and composition of the soil alter the probabilities of detection of targets. According to Geophysical Survey Systems, Inc. (GSSI), the amount of success using GPR varies due to the composition of soil, the type of material being surveyed and the frequencies used during the survey. GPR signals have the capacity to penetrate ice, rock, and soil and asphalt though each varies due to that material's electrical properties *[ii]*. Ž

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Conflict Analysis

The other key portion of pre-survey information to gather is the status and the history of the contamination by landmines in the particular region. *[iii]* A comprehensive analysis of the conflict and the historical strategies of engagement and encampment protection enhance the way data is collected and images delivered after processing the data. This analysis begins with collection and review of archive maps and surveys. Plastic explosives, for example, reflect electrical and magnetic impulses differently than metal explosives. The goal of this exercise is to create a data set of all munitions used in the conflict to better understand which signal frequencies to use to gain the best signal response from a buried hazard.

Assimilation of the right set of sensors

At the core of the solution is to mount some combination of Ground Penetrating Radar, Electro Optical Sensors and high definition video systems on a fixed wing or rotary aircraft appropriate to the terrain and the type of munitions used at the locale.

For example, heavy-based clay or humus soil doesn't allow a great deal of frequency contrast while using Ground-Penetrating Radar (GPR). A medium density soil yields reasonable probability of detection relative to depth, size, shape, and conductivity contrast. Rocky / limestone / sandy based environments are good environments for GPR sensing as is fresh or brackish water. For detection on beaches and in shallow sea water, infrared sensors combined with high resolution video are a powerful combination for data collection.

For example, soils at Los Alamos National Laboratory have been studied for explosive and munitions chemical contamination. This area has been used in the past for explosive testing and explosive research. The high explosives most commonly found included hexahydro-1,3,5-trinitro-triazine (RDX), octahydro-1,3,5,7-tetranitro-1,3,5, 7-tetrazine (HMX), 2,4,6-trinitrotoluene (TNT), 4-amino- dinitrotoluene, 2-amino-4,6-dinitrotoluene, and 1,3,5-trinitrobenzene *[iv]*

Foliage can offer clues about potential explosive and war remnant contamination when photographed using infrared sensors and high resolution video. Plants have been found to absorb explosive compounds after being exposed to TNT and RDX for as few as 50 days. *[v]* This change in chemical composition may not be seen by the human eye but will be readily detected by an infrared camera. Infrared lights and sensors see energy emitted by objects versus color and shape as with the human eye. The current infrared sensors see objects at a photon level and can identify changes in chemical composition in soils and in plants. *[vi]*

The mock test site

Previous airborne sensor attempts faced frustrating results due to the high number of false positives. The hope of flying over square kilometers of land and receiving a detailed and complete dig map were largely a miscalculation of technology capabilities.This was especially true since most airborne solutions were first tested in a controlled test site where the results were found to be unpredictable. Regardless of those staged results, the gap between a test site and a real mine field remained large.

To reduce the amount of false positives, the best solution involves ways of adding human intellect to the data collection process in an organized and regimented way. The creation of a mock test site at the place of a field survey will add much intelligence to the airborne survey results.

The first outcome of a landmine field mock up is to ascertain the best frequencies for data collection of this particular munitions set in this locales' soil. Secondly the landmine field mock up can be used to set a base line for imaging. This is done by bombarding the targets of interest with signals from a wide variety frequency bands and sensor arrays on munitions planted at a variety of depths. The outcome of the mock test survey is a "cheat sheet" of results to which the results of the real landmine field survey can be compared. The mock site results are further tested by breaking off a small portion of the quarantined landmine field to survey then compare to the mock test site. Once the success rate is determined from this pre-test, the survey team can make good decisions about how to approach the large areas of quarantined land.

Video and data collection

There are several aircraft platforms and flight patterns that have proven successful in data collection and video efforts. A large stretch of land with few land features such as mountains and rivers can successfully be surveyed with a fixed wing aircraft. An example of a good utilization of this aircraft platform is surveying levees, rail road tracks and roadways. Areas with mountains, rivers and a variety of tree lines will be better surveyed by a rotary aircraft.

The first flight over the land is to create a 2-dimensional map of the surface that identifies the areas of interest and hazards. For stretches of land with few land features, flight patterns are simply straight lines up and down the area of land or perhaps a checkerboard flight path. The outcome of which is the identification of "areas of interest" or a minefield "footprint".

Once areas of interest are identified, the next set of flights will focus on characterizing the areas of interest. The aircraft, typically the rotary aircraft, flies in a 360 degree pattern around the areas of interest bombarding the areas with signals along the appropriate frequency range established during the mock test. With this set of data, the number and pattern of anomalies, the burial depth and the dimensions of the unknown objects should be exposed.

All of these outputs are synthesized in the creation of three-dimensional (3D) maps of the landmine field. The detail of the depth and size of munitions overlaid with any munitions layout patterns noted overlaid with land features combined with video and/or other optics will provide more clues about the landmine field than ever before. The field manager consolidates this information to guide the decision to quarantine areas identified or to send a team to the location for further exploration or clearance.

The multilayer terrain / land hazard map

The data collected from these systems will be geo-referenced within centimeters' accuracy. The goal is a multilayered visual representation of the terrain to provide more accurate intelligence about the safety of the location. The GPSAR will show surface and subsurface landmines and ordinance with a geo-referenced visual mosaic layer showing a detailed view of the ground. The thermal imaging layer will show both munitions versus other ground anomalies and also soil and foliage contamination.

Now is the time to join forces to eradicate land mines once and for all…

Now is the time to aggregate and merge available wide area assessment technologies to give safe land back to communities and local people. Airborne multi-sensor technologies have evolved to now provide an effective means to differentiate lands without munitions and release them. The mistakes of the past have been typically been expecting the technology to do more than is reasonable and not having a process that synthesizes the best of the outcomes of the technology with the human interpretation of military strategies and land features. This more accurate solution maximizes the effectiveness technology with the intellects of the analysis team so land free of hazards can be quickly ascertained and freed for productive use. The best additional outcome is to maximize the precious funds designated for demining and land restoration to only those lands that have been proven to contain landlines and munitions

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Decision Support to Experts for Better Defining and Reduction of Mine Suspected Areas

Andrija Krtalić[34], Čedo Matić[35], Milan Bajić[36]

Abstract

Survey and definition of mine suspected area (MSA) of all territory of Republic of Croatia was conducted the by employees of Croatian mine action centre (CROMAC). However, due to the lack of information and in order to reduce the risk for the local population MSA was defined in larger dimension. In the following years, when after MSA was defined, CROMAC was updating it's mined information system (MIS) with new information and did permanently reduction/extension of MSA in accordance with the mentioned information. The multi-sensor system for reconnaissance and surveillance, and decision support system in conditions of uncertainty provide help in collecting and process new information for purposes of humanitarian demining community in Croatia.
Requirements for new information on objects that are present on the scene are defined in collaboration with experts from CROMAC. Collecting and processing information are carried out according to those requirements. Collecting information with multi-sensor system is performed in order to find and position an object which was assumed by the experts that can be defended/protected with mines (indicators of mine presence - IMP) or an object for which experts assumed that can be free of mines (indicators of mine absence - IMA). In the conditions of uncertainty, the data fusion of all available data (MIS, GIS, ortho-photo, (war/military) maps, aero-photo images, multi-spectral images, satellite images, contextual data, common and expert knowledge) is used within decision support system.
Result of the fusion is a thematic map which displays impacts of all indicators onto their environment and their mutual impacts onto each other. Such map is called a danger map, and it displays degree of danger around indicators within some specific MSA. This thematic image (danger map) is used as help to experts in humanitarian demining for better definition and reduction of MSA. Above mentioned systems were used in three locations in Croatia, and this article will present some results of this processing.

Keywords: *multisensor data, contextual data, formalisation of expert knowledge, data fusion*

1. Introduction

Survey and definition of MSA in Croatia was conducted by CROMAC. Because of lack of information and in order to reduce risk for the local population MSA was defined with safe margins. In the former years, CROMAC was updating mined information system (MIS) with new information and did permanently reduction or extension of MSA in accordance with the mentioned information.

2. The multisensor system

The main problem is collecting information about situation deep inside of MSA, because that areas are unreachable for CROMAC scauts. But, in Croatia exist AMAS for reconnaissance and surveillance and it is in operate use. This system collect imagery of unreachable areas in variety of wavelenght. Requirements for new information of object that are present on the scene are defined in collaboration with experts from CROMAC. Collecting and processing information are carried out according to those requirements. Collecting information with airborne multisensor system is performed in order to find and position objects which were assumed by experts that can be defended/protected with mines (indicator of mine presence - IMP, figure 1a, 1b), or objects for which experts assumed that can be free of mines (indicator of mine absence - IMA, figure 1b).

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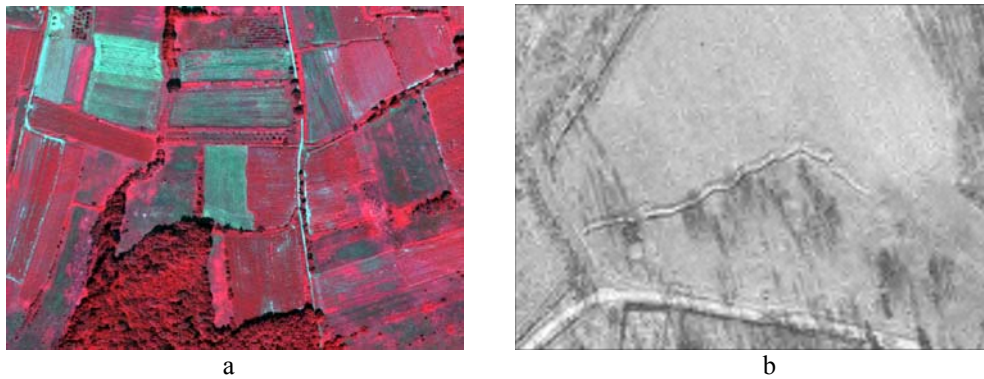
a   b

Figure 1. Examples of indicators: a) cultivated (IMA) and area no longer in use (IMP) on CIR image, b) trench (IMP) on DOF 1:2000.

This AMAS consist of several different type of cameras: matrix color infrared (CIR) camera, digital matrix foto camera (RGB), hyperspectral push broom camera, thermal matrix camera. These cameras are collecting diferent type of information about the same scene. Requirements for new information on objects thet are present on the scene (IMP and IMA) are defined in collaboration with experts from CROMAC. Collecting and processing information are carried out according to those requirements. So, after airborne aquisition multisensor and multispectral images was provided for preprocessing and processing in DSS.

3. Decision suport system

The DSS (**figure 2**) was designed for analyzing, preprocessing and processing all accesible compatible data, information and expert knowledge about some particular scene and specific phenomenon on it, in this case, about mined scene. Better presentation of existing CROMAC data can be done by using DSS methodology.
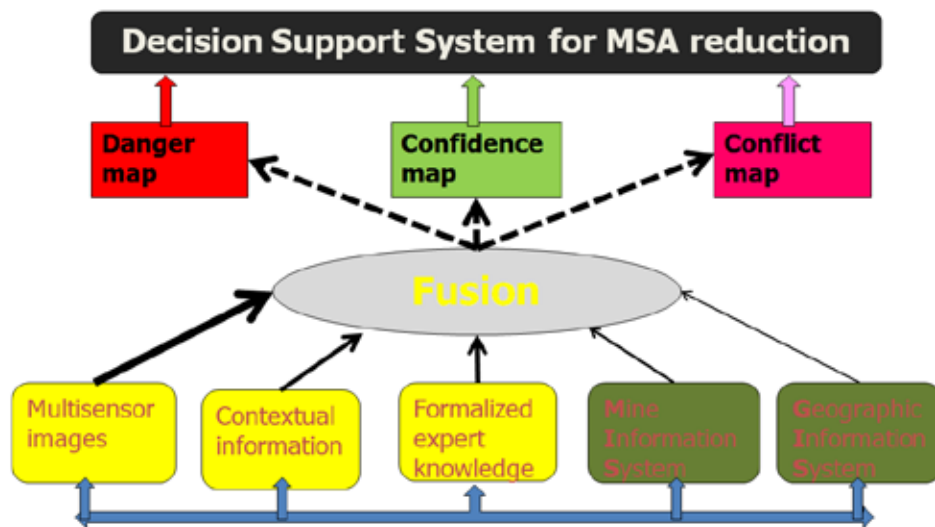

Figure 2. Concept of DSS

Input information and data for DSS are: mined information system (MIS), geoinformation system (GIS), ortophoto images, (war/military) maps, aerophoto images, multispectral images, satelite images, contextual data, comon and expert knowledge. The DSS was also designed to provide end user with methodological tool for processing multispectral images, hyperspectral images, contextual data and expert knowledge. Further more, mine scene interpretators are people which interactively search and extracts indicators from collected images [3]. After that actions mine scene experts estimates areas of impacts located indicators on they environment for each indicator. This is formalisation of expert knowledge which used for estimation of membership function (**figure 3**). This function are used in production of thematic maps (danger maps).
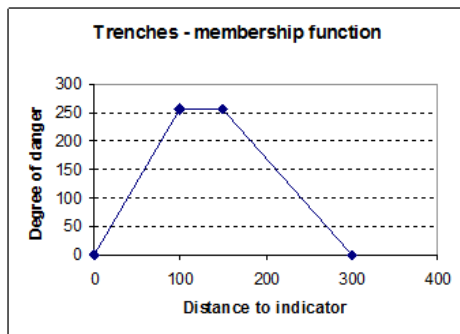
Risk start from: 0 m

High risk from : 100 − 150 m

No risk beyond: 300 m

Figure 3. Example for formalisation of expert knowledge throu membership function [2].

3.1. Data fusion

After collecting and processing of all data and information, data fusion can be done. The different quantities, relative to the same scene, measured by the different sensors, can be reconstructed inverting the data collected by each sensor ignoring the other available data or can be reconstructed inverting the data collected by the different sensors all together. This last approach is a fusion approach and attempts to improve the quality of the information obtained about the scene from the data set available when compared to the information obtained by the inversion of the data of the individual sensors taken one by one.

3.2. Thematic maps

The final results of data fusion are thematic maps. That maps show impacts of all indicators onto their environment and their mutual impacts onto each other. Such maps are called a danger maps **(figure 4)**, and they display degree of danger around indicators within MSA. Anyone can easily reed degree of estimate value of danger from those maps. Because of that fact, those danger maps are used for help to experts in humanitarian demining for better definition and reduction of MSA.
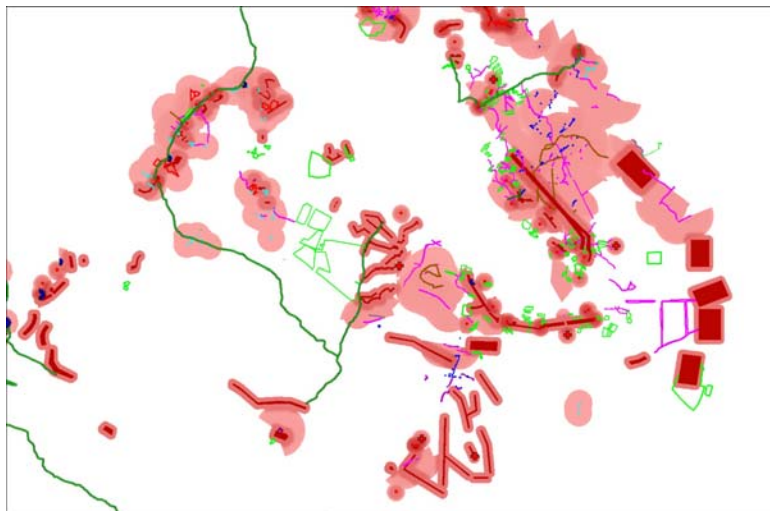

Figure 4. Part of denger map of Gospić region with delineation of found indicators [2].

Conflict between IMP and IMA also exist. For example, as you can see on **figure 5**, reconstructed mine field lies across cultivated land. Cultivated land was delineated on basis of DOF 1:2000 produced 11 year after war was over. The DSS produced conflict map as well as danger maps, and experts need to solve out this conflicts.
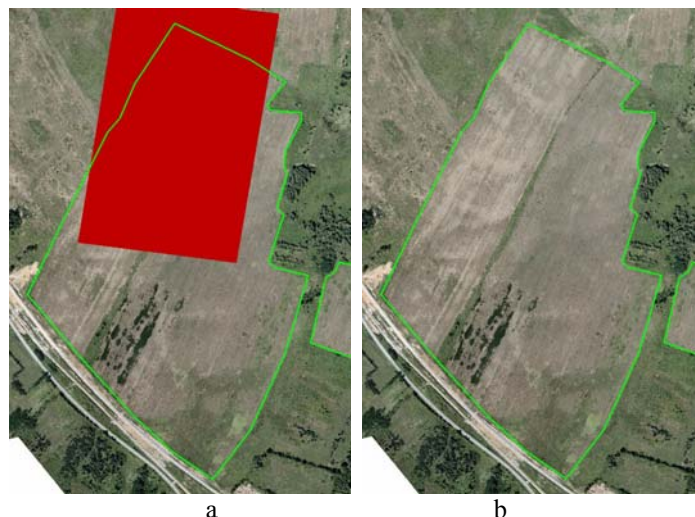
Figure 5. Conflict between information in MIS and from the field - a) red poligon is reconstructed minefield (MIS), b) area within green line sems to be in use (DOF2).

4. Conclusion

The main fact is that data from CROMAC and AMAS are compatible and only together gives the best results. The DSS methodology according the images from AMAS, CROMAC data (MIS, GIS, maps, images), contextual and expert data derived proposal for better definition and reduction of MSA. The DSS is methodological system developed, applied and proved on humanitarian demining problem on three communities in Croatia with large suspected area [2]. The presented DSS is the symbiosis of a specific "archeology" (due to temporal scale of 18 years) and military reconnaissance and surveillance (postponed many years after the battle activies). The danger map and conflict map are big help for mine scene experts in decisions making in humanitarion demining.

5. Acknowledgements

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Statistical Processing of Minefield Records

Andrija Krtalić[38], Čedo Matić[39]

Abstract

Minefield records on placing mines are the best source of information about presence, position, shape and contents of minefields. Experience showed that those information are not perfect, so, there is need for critical assessment of their value and applicability. In other words, type of imperfection has to be defined, and if possible, expressed quantitatively. This article will show some results of the statistical analysis of information quality in one set of minefield records within specific mined suspected area (MSA). Quality of information obtained from minefield record is important for production of danger map, since minefield records are the stronger indicator of mine presence on the scene with the highest level of danger. Because of the mentioned, it is very important to position a mine-field, and this can be done only based on good quality information from the minefield records.

Keywords: *minefield records, type of information, assessment, quality of information*

1. Motivation

The team of researchers (Scientific council of CTDT) and experts of CROMAC invited by ITF, supported by USA State Department donation, realised the project: *Deployment of the Decision Support System for Mine Suspected Area Reduction*. CROMAC asked by CTDT defined mined suspected areas (MSA) for deployment of mentioned project and provided MIS data, GIS data (HOK, TK25, DOF5, DOF2). Some of MIS data (minefield records of one MSA) were used in this work.

2. Introduction

Minefield records (MR) on placing mines are the best source of information about presence, position, shape and contents of minefields, because they generate one of the stronger indicator of mine presence (IMP). However, experience showed that those information are not perfect, so, there is need for critical assessment of their value and applicability. In other words, type of imperfection has to be defined, and if possible, expressed quantitatively. Quality of MR data is important for production of danger map and confidence assessment of data on it. Because of the mentioned, good positioning of a minefield (according the information from MR) is very important.

3. General characteristics of information

Information consists of direct observations (raw data), of processing results on these observations, of more or less generic pieces of knowledge, of experts opinions (estimation), etc. The level of information is also an important aspect. Depending if the information is considered at low level (typically the original data) or at higher level, which often calls for preliminary processing, constraints and difficulties that arise are not the same [1].

One important characteristic of information is its imperfection. It is always present like [1]:
  - **uncertainty**: is related to the truth of some information, characterizing its adequation to reality,
  - **imprecision**: concerns the content of information and describes a quantitative defect of knowledge or measure,
  - **incompleteness**: information provided by a source is generally partial, and gives only one point of view or one aspect of the observed phenomenon,
  - **ambiguity**: of information extracted from each source,
  - **conflict:** conflicting situations occur often, and are usually difficult to solve because detecting conflicts is not easy, they can be confused with other types of imperfection.

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4. Reconstruction of minefield positions

Experts analyzed 122 MR from one community in Croatia and tried to locate their positions in space according to the information from them. They found 39 different information in MRs, and sorted them in 5 categories:

- – A – cartographycal data (name and scale of the map,...),
- – B – data for orientation and positioning of minefield (coordinatee os referent point,...),
- – C – type and number of mines in minefield,
- – D – characteristics of minefield (type and dimension of minefield),
- – E – information about placing mines (date, unit, person,...).

They are create binary table with value 1 were information exist and value 0 were information is absent (**figure 1a**). After that analyze they give the assessment (in percents) of this statements **(figure 1b)**. Average accuracy of positioning of all 122 MR is 43%.

52	1	1	1		1	1
53	1	1	1		1	1
54	1	1	1			1
55	1	1	1	1	1	1
56	1	1	1	1	1	1
57	1	1	1	1	1	1

a

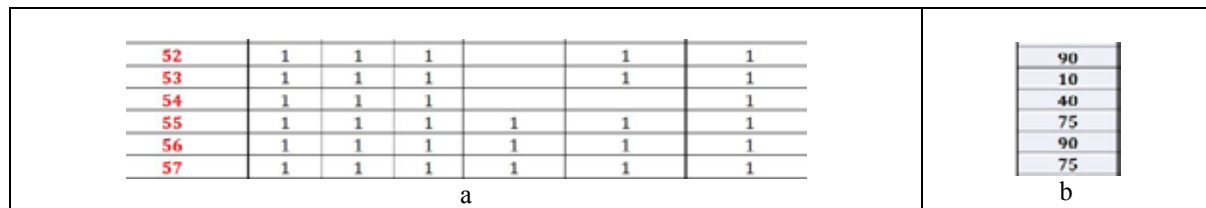| |
|---|
| 90 |
| 10 |
| 40 |
| 75 |
| 90 |
| 75 |

b

Figure 1. Part of binary table with: a) existing or don't existing information in some MR (red numbers marks MR), b) experts estimation of value of information from MR.

5. Statistical processing

Frequency (average quantity) of categories for mentioned group of information are show in **table 1**. So, the difference between quantity and quality of the same data is obvious. Quantity values (totality of information) are bigger then quality value (expert assessment).

Table 1. Frequency of group of information from 122 MR.

A	B	C	D	E	Totally
%					
92	42	11	29	93	54

This is difference between statistical value (frequency) and experts estimation of value of information from MR. This relationship displayed on diagram on **figure 2**. Because of the mentioned, it is very important to position a minefield, and this can be done only based on good quality information from the minefield records. So, some need to know the value of confidence for statements in MR.
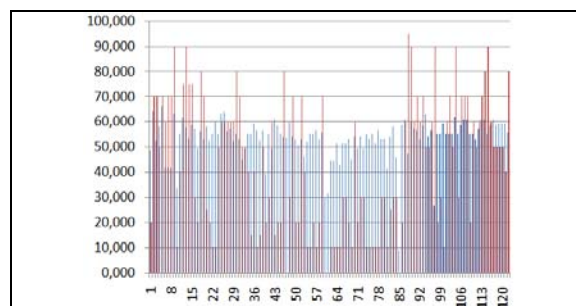

Figure 2. Blue histogram indicate quantity of information and red histogram indicate expert estimation of minefield positioning accuracy.

For further statistical processing is necessary changeover from binary to numerically (decimal) expression, and to express (quantitatively) level of imperfection of information from MR if that possible. For that reason the expert's estimation of minefield positioning was used. The general idea is to define the ratio between totally of information (in %, by each MR) and expert's estimation of mine-field positioning accuracy **(figure 3)**.

totality of information	Experts estimation of mine-field positioning	ratio
60,893	20,000	0,328
64,110	70,000	1,092
52,396	70,000	1,336
58,110	50,000	0,860
66,110	70,000	1,059
51,964	60,000	1,155
51,964	70,000	1,347
51,964	70,000	1,347
63,253	90,000	1,423
56,190	10,000	0,178
55,253	40,000	0,724
61,648	75,000	1,217
57,868	90,000	1,555
53,330	75,000	1,406
58,791	75,000	1,276

Figure 3. Part of table with totality of information in particular MR, expert's estimation of minefield positioning and ratios between them.

$$\frac{\exp ert'sestimation}{totalyof\inf ormation} \equiv ratio$$

This ratios gives following relations:
- ratio < 1 - information from this MR are less imperfect,
- ratio = 1 - information from this MR are 100% match with expert's estimation,
- ratio > 1 - information from this MR are more imperfect.

Smaller ratio means better quality of data, and vice versa.

5. Conclusion

Statistical processing of MR can gives some kind of quantitatively measure of the imperfection of information of MRs. This terms can be used in production of danger maps. MR with different ratio need to be displayed with different level of confidence on danger map. Further research maybe can give information which parameter (information) has biggest impact in positioning of MR.

6. Acknowledgements

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Appropriate Technologies in Humanitarian Demining: Potential Impact of Participatory Re-designed Agricultural Machines and Tools

Emanuela Elisa Cepolina[40]

Abstract

The presentation suggests introducing agricultural derived technologies in humanitarian demining activities as an answer to the pressing need of reducing cost and time of land release processes and, in parallel, increasing investments in research and development in agriculture to reduce hunger and poverty and help poor and the planet to cope better with the effects of climate change.

The similarities between demining and agricultural operations are underlined before presenting research fields that could benefit the development of mine action technologies around commercial off the shelf agricultural machines. After considering the benefits such technology can bring to a more sustainable future of mine affected countries the presentation introduces briefly the project the author is working on, called Locostra (Low Cost Tractors for humanitarian demining).

Introduction

Land release is achieved through one of these, increasingly more costly and more technical, actions: general survey, technical survey or full clearance. While general survey does not involve the use of clearance or verification assets but only collecting and analysing new and extant information on specific Suspected Hazardous Areas (SHA) through interviews with local stakeholders and by visual field inspections, technical survey is a detailed technical intervention with clearance or verification assets into a SHA. It aims to confirm the presence or absence of mines and Explosive Remnants of War (ERW) following the implementation of a general survey. Technical survey may not be required if general survey suggests that full clearance should be applied and can involve the use of technologies not accredited for proper clearance (UNMAS, 2008).

Toward the fulfillment of the Ottawa treaty obligations and the pressing needs of handover of clear land to local population, the wise approach recently adopted is to use current resources more efficiently by managing information better: re-defining the actual size of minefields and spend expensive resources and dedicated equipment only on those areas that have good probability to really contain mines. The remaining areas that are released through general and technical survey are not physically cleared, or at least not completely, as they are believed not to contain mines. Clearance of a small percentage of land and ground processing of the whole area can occur in a way that gives confidence that there is no reason to believe there are mines in that part of SHA. If assumptions were wrong and explosive hazards are found, the entire area is fully cleared. Decisions whether to release land by general survey or technical survey are taken in accordance with the rules written in the organization Standard Operational Procedures (SOPs).

Guidelines on SOPs for land release through means other than full clearance have already been written by the mine action specialist Andy Vian Smith (Smith, 2009).

While in the past full clearance was considered as the only possible method to handover land to local communities, it is now widely understood that other quicker and inherently less reliable methods can be used instead. Anyhow, also manual de-mining, the most expensive and accurate de-mining process, cannot guarantee to clear all mines. Therefore, it makes more sense to approach the problem in terms of risk management, in other words finding a compromise between available clearance funds, technical feasibility and the intended use of the land: achieving a risk that is tolerable to the end users, but which represents the best use of the resources available. In Western Europe the residual risk in areas contaminated by mines and UXO and subsequently released for public use after the 1914-1918 and 1939-1945 wars persist today. The reality is that mine-affected countries will always remain mine-affected to some degree and they must continue to take measures to deal with that threat (GICHD, 2005).

As full clearance is inherently a slower process than technical survey, more land can be released by technical survey than by full clearance over the same time. This means that the area that waits to be processed and therefore contains an unacceptable risk, can be approached and released before. An increase in the mine clearance rate, even when that increase is associated with a reduction in reliability, results in accelerated socio-economic benefits (GICHD, 2005).

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Therefore, although already pointed out by the Mine Action Equipment: Study of Global Operational Needs carried out by the GICHD in 2002 (GICHD, 2002), the need of developing new very simple technologies for what was formerly called area reduction and it's now addressed as land release through means other than full clearance is now more evident than ever. Current expensive technologies and work intensive manual demining practices can be used to clear land not released otherwise and the largest possible quantity of new simple and less reliable technologies converted from mature technologies available locally can be used for area reduction.

As long as no machine is expected to conduct clearance without manual or Mine Detection Dogs (MDD) follow-up, a wide range of machines can be used in any way that does not increase risk to staff (Smith, 2009). A quick solution to the landmine problem could already be there available in mine affected countries.

Local agricultural technologies for land release

While machines specifically designed for demining, generally expensive and high resistant, could be employed where full clearance is needed, other less expensive and more widely available machines need to be conceived for gathering the information required to release land through technical survey. These machines mainly need to verify the absence of mines in the given area. If they encounter an explosion the area needs to be re-categorized and needs to be fully processed by proper clearance. This means that machines need to process the ground and to resist, or not to be severely damaged, by only one explosion at time, while keeping the operator safe.

As their job is to process the ground, agricultural machines originally conceived to work the soil could be efficiently employed. Agricultural technologies are largely available everywhere and in different sizes. Where they are not already available their presence might be desirable to increase the capability to produce food by farm mechanization. Investments in research and development in agriculture is seen as key need to deal with a changing climate, as well as with rapidly increasing water scarcity.

Following up the multidisciplinary world crisis, raging from economic to food and energy crisis, we are assisting at a general re-localization of trades, also occurring in mine action as many operations are being handed over to local commercial companies or NGO's (Filippino & Paterson, 2008). In this context, it assumes particular importance not to introduce newer technologies dedicated to de-mining, but to use local ones. Machines developed or re-adapted locally have initial lower cost, shorter downtime and lower repairing cost. They would not be underutilized as much as proper de-mining machines, that are often left aside minefield unused due to the lack of spare parts or the experience needed to fix them that has to come from abroad. They would be much more sustainable than technologies imported from western countries, not designed taking local conditions in mind.

Moreover, involving local technicians into the re-design of new or improved technology helps reducing dependency of local communities from donor's help as well as facilitating local human development (Cepolina, 2006).

Human development requires three broad areas of need and capability to be satisfied. First, adequate provisioning for basic human needs - food, shelter, clothing, health and other necessary services – through both public and private effort. Second, development of basic human capabilities; these are, in Amartya Sen 's conception, the substantive freedoms a person needs to lead "the kind of life he or she enjoys". They include health, education, knowledge and skills. Third, space for people to apply their innate and acquired assets, individually and communally, to achieve higher welfare outcomes. The defining features of such space include an environment of stability (political, social and economic), of democracy, a human rights culture, and freedom for all to operate as political and economic agents (UNDP, 2005).

The word technology comes from the fusion of two old Greek words: τέχνη (transliterated as techne), art or craft or every kind of knowledge that finds a practical application and λόγος (transliterated as logos), word. At light of etymology, the close relationship between technology and human development becomes clear. Advances in science and technology in terms of progresses in knowledge on how to do practical things, have been driving the development of human beings from the Stone Age. The desire to innovate and find ways to do labor-intensive activities using less man power is innate in the mankind. The ability to do it, by dealing with problems and finding practical solutions, can be defined as technology, and also the outputs of the process, the practical solutions achieved, can be defined technologies. When developed by the same people who need it and is not driven by a consumerist market but on basis of real needs, technology is not only sustainable and suitable to the environment where it is designed to work but can also promote end-users human development. It does so incrementally, according to a circular path (fig. 1).
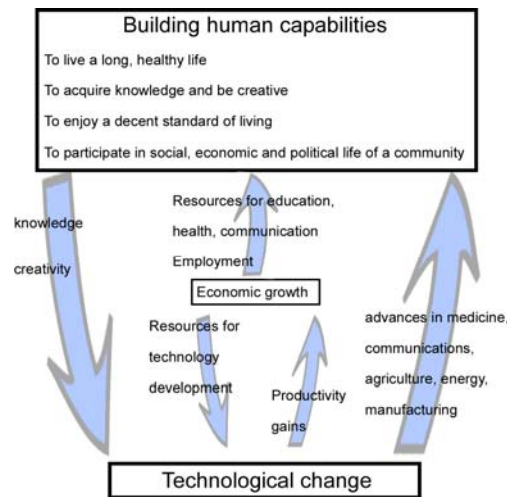
Fig. 1. Links between technology and development (source: human development report 2001, UNDP)

Unfortunately, the innovation process leading to the development of new technologies and the enhancement of human development, described by the circle in fig. 1, in many developing countries cannot start. Poor people, living in un-secure, conflict environments, are seldom innovators. They lack the basic resources they need to develop new technologies that could help them solving their own problems and start the innovation incremental process.

An external, possibly only one in time, input is needed to start the process. This could be in the form of a participatory design process, bringing together researcher of western countries and local people, through all stages of the technical design.

Empowerment is an integral part of many poverty reduction programmes. It is seen as essential to promote human development and human freedom to help individuals and communities to function as agents for the improvement of their own wellbeing. Empowerment is not only about the state providing resources and opportunities, is about the citizens taking responsibility for self-improvement (UNDP, 2005).

Technology developed on the basis of real needs, in a participatory way together with people who expressed these needs, contributes significantly to their human development, by enhancing their knowledge and creativity and hopefully by solving a real problem and improving their lives. And such technology, because developed with end-users who live and know the environment in which it will operate, using local available materials and resources, is appropriate and sustainable. Not only, but it can be upgraded further, when and if it is needed, without anymore the help of outsiders. This technology and the knowledge behind are actually owned by the users.

Moreover, if this technology is derived from agricultural technology, research and development efforts that lead to its production can be later exploited to innovate agricultural techniques and help the country to cope with the wide spread food crisis and with climate change negative effects.

Locostra (LOw COST TRA ctor) project

The LOCOSTRA project has its roots in the Participatory Agricultural Technology (PAT) project. The PAT project led to the development of a single machine prototype built around a commercially available powertiller, a small, two-wheeled tractor, largely available to small farmers in South East Asia, and widely used both for agriculture and transportation. The machine was designed and developed with end-users, with the specific aim of creating local capacity to enhance development. While the final prototype costs less than 5000€ and is designed to be manufactured in basic workshops, its application is limited to loose soils.

Most of the partners in the PAT project joined together again for the development of LOCOSTRA machine. Agricultural and mechanical engineers combined with experienced deminers are working to produce a low-cost, remotely controlled, machine for use in land release process.

Using a commercially available drive unit combined with converted off-the-shelf agricultural tools, the machine will be able to cut and clear undergrowth before preparing the ground with specialized rakes or harrows in advance of deminers entering the minefield. The only entirely innovative parts are blast resistant wheels designed to withstand the forces associated with an anti-personnel detonation, so allowing the machine to continue to work if it inadvertently detonates a mine. LOCOSTRA is built around the P796V tractor produced by Pierre Trattori, a small, lightweight, four wheel drive, agricultural mini-tractor with 79hp. A standard, category one three point linkage attachment at the rear allows hydraulic lifting and positioning of many off-the-

shelf agricultural tools. The machine is designed to be easily transported over unimproved terrain without the need for a dedicated transporter. The innovative blast resistant wheels, designed to withstand the detonation of 240g of TNT without damage that would halt operations, and the relatively high travel speed (30km/h) allow self movement, easy also on uneven terrain, while the overall vehicle weight and dimensions allow it to load into a trailer easily pulled by any vehicle, when long distances will have to be covered. The radio control allows the tractor to be driven from a safe distance of 100m. Only essential commands are actuated remotely, reducing complexity and increasing system robustness.

The cost and complexity of the machine are such that it can be afforded and maintained in post-conflict economies. It is intended that the final purchase price will be kept below € 50,000 per unit, with operating costs comparable to that of a road vehicle. As a result, the finished machine with its tools will be no more expensive that the cost of the truck used to transport it. The use of the machine will reduce deminer accidents (which occur during undergrowth removal and ground excavation) and increase the speed of clearance in a cost effective manner.

Fig. 2. Locostra: tractor with team on board, tractor during blast resistant wheels test and ballistic pendulum for pre test of blast resistant wheels.

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Future Development Trends in Mechanical Demining Systems

Heinz Rath[41], Dieter Schroeder[42]

Abstract

Many mine affected countries are also suffering by the world food crisis. Procedures for Land Release with Non-Technical Survey and /or Technical Survey will be used in the near future to speed up the land use for agriculture and grazing. There is also an urgent need to change to cheaper and more efficient mechanical demining, to react to financial restrictions and to strengthen national ownership in demining activities. This report will lead to an optimized mechanical demining machine, to meet new requirements for cost effectiveness.

In 2005, Richard G. Kidd, then Director of the Office of Weapons Removal and Abatement in the U.S. Department of State's Bureau of Political-Military Affairs, reported in his speech "Perspectives on Global Policies to End the Landmine Crisis": "The most significant factor limiting the future impact of the Ottawa Convention is not one of policy but one of economics. And while the money will not be there to make the world 'mine free,' the funds, commitment and insight already exist to make it 'mine safe.' We can remove the most pressing impacts of landmines within years, and then redirect those funds to other areas and other causes where they will do more to save lives and promote reconstruction.

The United Nations, the Geneva International Centre for Humanitarian Demining and various international ministries report that the landmine problem has been considerably reduced, and this success can be attributed directly to the Ottawa Convention. The Ottawa Convention has increased inhibition in using anti-personnel mines; the global trade of AP mines has come to a halt; and the United States and China, currently not members of the Convention, have agreed to an export moratorium. Furthermore, the number of victims has steadily decreased while the number of demining machines available for clearance has progressively increased throughout the years; and quality assurance to release cleared land has been considerably simplified.

Unfortunately, it is likely that other humanitarian catastrophes, such as combating hunger, HIV, malaria and environmental pollution, will take priority in the minds of donors, which could reduce funding for mine action. National ownership in demining activities has to be strengthened with a need for simplified and robust demining technologies.

Changes Required in Demining Technology

We believe a number of changes need to be made to the current spectrum of demining technologies. In particular, with regard to demining machinery, the following topics should be considered.

Variety of mechanical demining machines.

There are too many different types of mechanical demining machines currently on the market, with sizes ranging from five to 55 tons. They can be the wheel or crawler type and function with or without an operator. In addition, machines are available with multi-tool applications as shown in the GICHD *Mechanical Demining Equipment Catalogue 2010*. Neither a specific system nor a specific configuration is dominating the market. Rather, despite enormous international, technical and commercial efforts, many machines have never left the prototype status or have not proven to be successful in the market. Testing more than 50 different types of machines, with variations in size, weight, demining technology and operation types (i.e., onboard-driver or remote-control operated), will lead to excessive purchasing and operation costs. This scenario is typical for the research phase if insufficient basic knowledge about the machines and the demining context is available, because there is no standard data set, and funds have to be set aside to test the machines every time, which is a waste of resources.

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**Optimizing cost-effectiveness of mechanical-demining machines.**

The international symposium "Humanitarian Demining – Mechanical Demining" in Šibenik, Republic of Croatia (24–27 April 2007), included the demonstration of different types of machines. The program committee summarized the results as follows:

- Tillers are preferable for some conditions and threats, but flails are preferable for other conditions.
- Machine operators exhibit a large influence on the performance of machines.
- Change in management thinking and planning is required in order to avoid the purchase of machines that are not necessary.
- The management and costs required to transport big machines nationally and internationally contrast with the efficient and cheap transport of smaller machines, which require a separate guiding vehicle.

Size of demining machine with operator

Analytical examination of global activities with different types of mechanical demining machines and results from the test centers at the Croatian Mine Action Centre, International Test and Evaluation Program for Humanitarian Demining, Swedish Explosive Ordnance Disposal and Demining Centre, and the Swiss, British and German Armies have resulted in an optimum specification for demining machines.

Tests with and without dummies, with and without flail and tiller equipment and a very detailed measurement of actual loads on the human body lead to a machine with a total weight of 15 to 20 tons (13,607 to 18,143 kilograms). Experience gained by deminers in field deployment with flail and tiller operation in different soil and vegetation conditions leads to an engine power of 250 to 400 horsepower. In addition, tests with anti-tank mines demonstrated that a distance between the AT detonation and the driver cabin has to be at least four meters (13 feet).
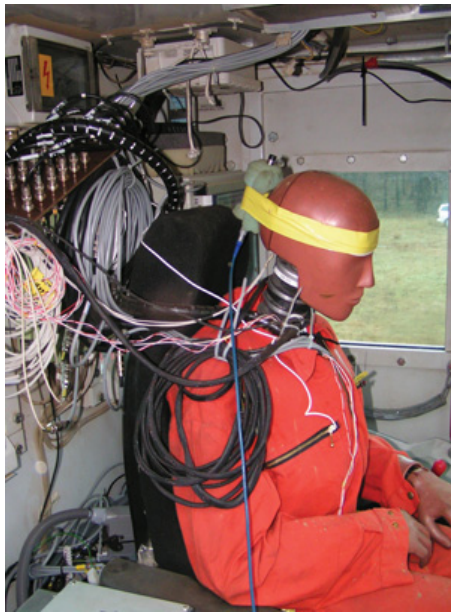
Machines should not only meet optimum specifications but be fitted with a range of mine-clearing tools as well. The "toolbox concept" outlines the idea that machines could be fitted with a number of different attachments so they are able to deal with a wider variety of mine threats. The benefit of this type of machine is that it would be equipped to perform development and/or livelihood operations after demining ceases. These operations include farming, forestry, the building industry and a number of other possibilities.

In summarizing the different key requirements, we came to the following specifications that will lead to dramatic cost reductions for the machine's operation, maintenance, repair and transport. Proposed specifications for both tracked and wheeled vehicles using the toolbox system include:

- Total weight of vehicle with tiller or flail: 15–20 tons
- Engine power: 200–300 kilowatts (250–400 HP)
- Safety distance between detonation (flail/tiller) and cabin: four meters (4.4 yards)
- Direct-driver operated
- Includes both flail and tiller options
- Open tiller design
- Container Transport

Tracked or a wheeled-type vehicle?

Our knowledge base of 10 years in demining technology informs the summary found in Table 1, and takes into account 10 key points including safety, cost and comparisons of the medium crawler, medium tractor, and the light crawler with remote control, as found in the GICHD catalogue.

	Medium Crawler max. 20 to Operator Control	Medium Tractor max. 20 to Operator Control	Light Crawler max. 10 to Remote Control
1. Safety	10	10	-
2. Mine Clearing Effectiveness	10	9	5
3. Ground/Vegetation/Topography	10	7	7
4. Vulnerability/Damage	10	8	6
5. Demining Performance	10	8	5
6. Application/Handling	6	10	5
7. Serviceability	7	10	7
8. Mobility/Transport	4	10	7
9. Multiple Use Toolbox	4	10	0
10. Cost Operation, estimated	5	10	3*
11. Estimated Cost Manufacturing	Up to 350.000 €	Up to 180.000 €	Up to 180.000 €
	* Cost of separate guiding vehicle not included best in class		

As demonstrated, the crawler type machine is the best in terms of demining performance and effectiveness, but the tractor-based demining machine with flail and tiller unit is by far the most cost-effective arrangement. Tractors with operators do not require a logistical support vehicle and/or a system for remote-control operation.

Powerful tractors up to 400 HP (e.g., John Deere, New Holland, Claas, Valtra, Case, Fendt, Belarus), are available globally. Such tractors could be modified into demining tractors locally, wherever expert support is available. Modifications of off-the-shelf tractors have already been demonstrated by Pearson, Armtrac and the U.S. Department of Defense's Humanitarian Demining Research and Development Night Vision and Electronic Sensors Directorate's Rapid Area Preparation Tool. Protected tractors are currently the standard equipment for most nongovernmental demining organizations such as the HALO Trust and MAG (Mines Advisory Group).

All modifications in line with our proposed specifications have been used during extensive test programs on existing machines as noted above and in other test situations, including the open tiller technology, protected cabin and protection of the basic machine. The proposed changes are modifications to existing machines and do not require additional costly tests.

Multi-function system

A multi-function tractor-based system is more cost-effective, less complicated, and easier to handle and maintain than a special machine. In addition international tractor companies offer a globally available supply of spare parts with fast shipping. This system can be used for:

- Mine clearance
- Survey, reconnaissance
- Quality assurance
- Transportation
- Cultivation, farming, vegetation cutting
- Reconstruction and development
- Obstacle removal
- Airfield clearance, bomblets
- Pioneer vehicle for military use
- Vehicle for multi-sensor technology

Conclusion

In summarizing the different key requirements we came to the following optimum specifications for both the tracked and wheeled vehicles for demining of AT- and AP-mines.

- **Total weight of vehicle with tiller or flail: 15-20 tons**
- **Engine power: 200-300 kilowatts (250-400 HP)**
- **Safety distance between detonation (flail/tiller) and cabin: four meters (4.4 yards)**
- **Direct-driver operated**
- **Includes both flail and tiller options**
- **Open tiller design**
- **Container Transport**
- **Tool box concept for demining, cultivation, building industry etc.**

Demining machines with a total weight above 15-20 tons are over engineered, to big in size, to heavy and to expensive.

There are far to many different type of machines and manufacturers in the market leading to high cost for investment and operational cost.

As demonstrated, the crawler machine is the best in terms of demining performance and effectiveness, but the tractor based machine with flail and tiller is by far the most profitable arrangement. Powerful tractors with operator do not require a logistical support vehicles and/or a system for remote control operation.

Reduced cost level will allow demining efforts to continue without diverting funding from other important issues.

Biographies

Heinz Rath is the owner of STS Safety Technology Systems, inventor of the MineWolf Toolbox concept and founder of MineWolf Systems GmbH. In 1997, Rath retired as International Director for Research and Quality at Lucas Automotive. He is the former Chairman of the supervisory board of MineWolf Systems and now serves as Engineering and Consultant Manager.

Rath is also the recipient of the *Bundesverdienstkreuz*, the highest award from the Federal Republic of Germany.

Dieter Schröder, Chief Engineer at STS Safety Technology Systems, was formerly Engineering Manager at TRW Automotive Holding Corporation, having supported Heinz Rath in all aspects of engineering and quality. Schröder retired from TRW in 1995.

Raymond Alain Twiesselmann studied political science at the University of Cologne, graduating in 2007 with an emphasis in the influence of Islam on the politics of Islamic countries. Later, he worked for a newspaper and in the *Staatskanzlei* of Rhineland-Palatine. He is responsible for public relations at STS Safety Technology Systems, an engineering and consulting firm.

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Measurement of Impulse Imparted by the Detonation of Anti-tank Mines by Using the VLIP Technique

P.M. de Koker[43], N. Pavkovic[44], J. T. van Dyk[44], I. Steker[45]

Abstract

The impulse imparted by the detonation of anti-tank mines is an important characteristic of the mine used to design and develop protective countermeasures. CSIR, in collaboration with CTRO, conducted explosive testing during 2008/2009 to determine an empiric formula to predict the impulse values resulting from the detonation of anti-tank mines [1][2]. This formula predicts the impulse values at a height of 500 mm. above ground level. Whilst acceptable correlations were obtained between predicted and measured impulse values for a number of mines, the results are academically of nature- these values can only be used to compare the resulting impulse values on a quantitative basis for the different mine types.
In real life mines are buried underneath the soil. The additional contribution to the resulting impulse due to the depth of burial in the soil needs to be established and added to the theoretical impulse values obtained for mines buried flush with ground level. Further collaborative explosive testing was conducted by the CSIR in conjunction with CTRO in the RSA during October 2009. During these tests the VLIP method was used to determine the total impulse imparted in the 500 mm region above ground level for TM-46 a/t mines buried at various depths. The data recorded during testing was used to develop an empirical formula that can be used to predict the impulse in the 500 mm region above ground level imparted by buried a/t mines.

Introduction

The empirical formula that resulted from collaborative testing conducted by CSIR Landwards Sciences[45] and HCR-CTRO during 2008/2009 is represented as follows:

$$I \quad = \quad \alpha \, M \, A \tag{i}$$

Where   I is the impulse (kNs) in the area 500 mm above the ground.
                         α is the mine type factor (3.1 for blast type mines and 3.3 for self forming
fragmentation   (SFF) mine types (TMRP-6 and UKA63).
                         M is the netto explosives content (NEC) based on TNT in kg.
                         A is the TNT equivalent when explosives other than TNT is   concerned.

Values for TNT equivalents are summarised in Table 1.

Table 1: TNT equivalent values.

Explosive type	TNT equivalent for impulse (A)
TNT	1.00
RDX/5% wax	1.16
Comp B	1.06
Torpex	1.28
Pentolite (TNT/PETN: 50/50)	1.15
Minol ii	1.22

This formula was used to predict impulse values for the detonation of a variety of mines as shown in Table 2. Additional testing was done in order to verify the validity of the calculated impulse values by comparing them with measured values obtained during testing as shown in Table 2.

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[45] Landwards Sciences is a competency research area within the Defence Peace Safety and Security Research Unit within the CSIR

Table 2: Comparison between calculated and measured impulse values.

Mine Type	Impulse (kNs)	
	Calculated	Measured
TM-46	16.43	14.6
TM-62M	23.10	22.1
TM-62B	21.73	21.2

The VLIP method

The vertical launched impulse plate (VLIP) method for measuring impulse uses a thick steel plate with a steel mast that is accelerated as a unit vertically by the detonation of an anti-tank mine underneath the plate. (Figure 1). The velocity of the plate during its vertical displacement and the mass of the plate are required to determine the impulse that is imparted to the plate.
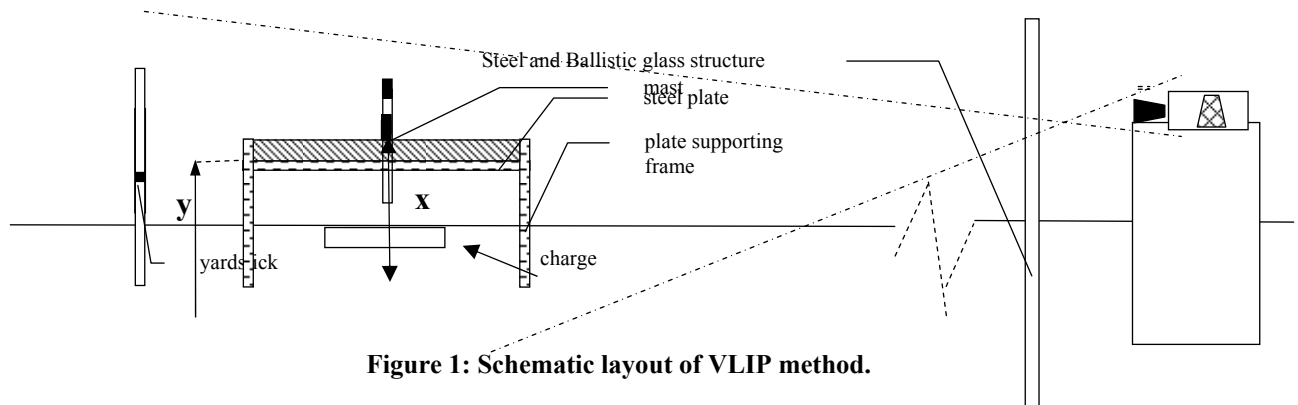

Figure 1: Schematic layout of VLIP method.

Impulse equals a change in momentum and the initial momentum is zero, therefore the following formula is valid:

$$I = mv \qquad \text{(ii)}$$

Where m is the mass of the plate [kg] and v, the velocity [m/s] of the plate at any given position. The mass of the plate is known as it is weighed for each of the experiments prior to the tests in the workshop. The velocity of the plate is determined using video footage from a medium speed camera (5000 frames per second). The tip of the mast is used to track the upward distance traveled in order to create a distance (x) vs time (s) curve. Velocity is obtained by differentiation of this curve.

Determination of the effect of burial depth on imparted impulse

LS and HCR-CTRO conducted further testing during October 2009 in the RSA to investigate the effect of burial depth on imparted impulse. The VLIP method was used in conjunction with TM-46 a/t mines buried at various depths underneath the soil surface. Depth of burial (DOB) is defined as the distance between the top of the mine and the soil surface. Testing was conducted in dry shale.

Seven shots were fired and recorded at high speed using a frame rate of 5000 frames per second. Figure 2 summarises the vertical displacement (x) –time curves for the different shots.
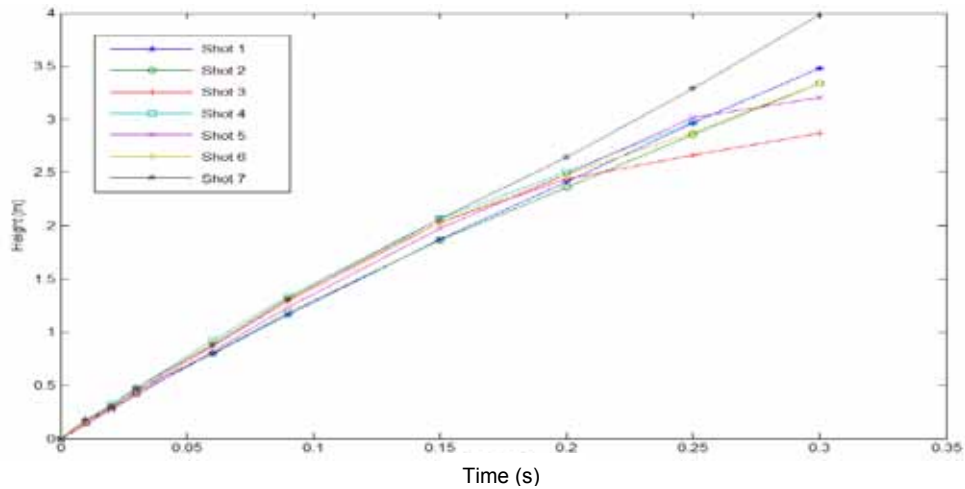
Figure 2: Summary of test results.

Velocities were calculated by calculating the gradient of each of these displacement- time curves as shown in Table 2. The impulse was determined by multiplying the calculated velocity with the mass of the plate.

Table 3: Calculated velocity and impulse for each shot.

Shot	Depth of burial (mm)	Velocity (m/s)	Impulse (kNs)
1	0	12.70	16.03
2	50	13.06	16.49
3	100	14.36	18.12
4	200	14.87	18.76
5	330	13.77	17.38
6	160	14.64	18.48
7	175	14.38	18.11

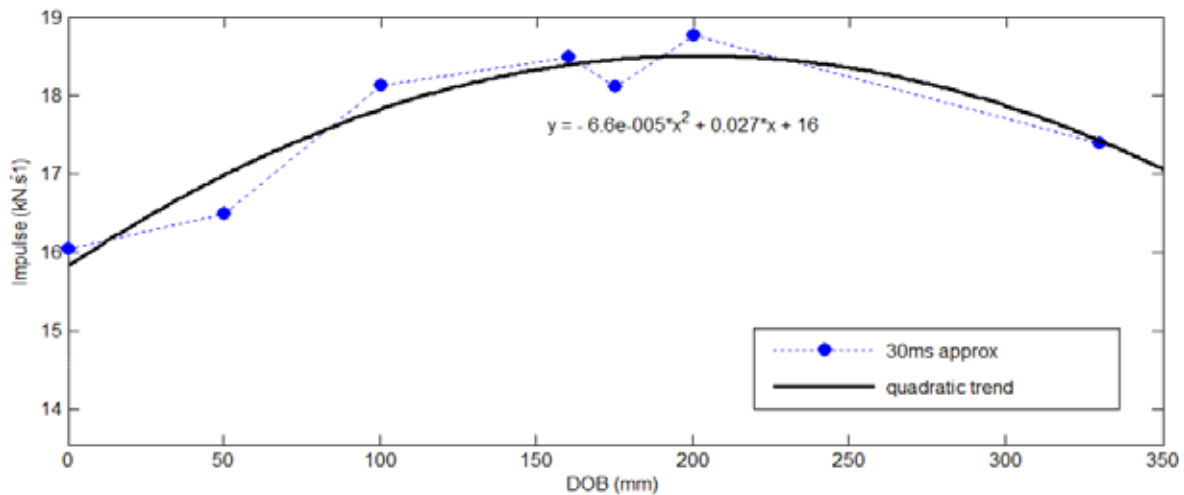Figure 3 shows the relationship between impulse and depth of burial.

Figure 3: Relationship between impulse and depth of burial.

A quadratic fit of the data points in Figure 3 results in the following quadratic equation:

$$I = -6.6 \times 10^{-5} x^2 + 0.027 x + 16.03 \quad \text{(iii)}$$

Where   I is the impulse (kNs).
             x is the depth of burial (mm).

For a TM-46 mine detonated in a position level with the soil surface ($x = 0$) the corresponding impulse is 16.03 kNs according to Equation (iii). This corresponds with the calculated value of 16.43 as shown in Table 2.

Thus, if it is assumed that the netto imparted impulse is the accumulated impulse of the mine alone (DOB of 0 mm) and the impulse due to the soil effect, Equations (i) and (iii) can be combined to render an equation that takes soil effect into consideration as well.

The result is the following equation:

$$I = -6.6 \times 10^{-5} x^2 + 0.027 x + \alpha M A \quad (iv)$$

Where I is the impulse (kNs) in the area 500 mm above the ground.

        x is the depth of burial (mm).

α is the mine type factor (3.1 for blast type mines and 3.3 for self forming fragmentation (SFF) mine types (TMRP-6 and UKA63).

M is the netto explosives content (NEC) based on TNT in kg.

A is the TNT equivalent when explosives other than TNT is concerned.

This empirical formula can be used to obtain a first order value for the impulse impaired onto a target 500 mm above a buried a/t mine.

It should be noted that soil effect is minimal where the TMRP-6 is concerned. The booster charge in the fuse removes the soil from the top of the mine prior to the detonation of the main charge.

Equation (iv) was used to predict the imparted impulse generated in the area 500 mm above the ground by the detonation of the TM-62M and TM-62B anti tank mines buried at various depths as shown in Table 4.

Table 4: Predicted impulse values for TM-62M and TM-62B mines at various depths of burial.

DOB (mm)	Impulse TM-62M (kNs)	Impulse TM-62B (kNs)
0	23.10	21.73
50	24.29	22.92
100	26.33	24.96
150	28.89	27.52
200	31.65	30.28
250	34.28	32.91

These predicted values should be verified by further blast tests.

It is known that soil type and moisture contents also affect the impulse impaired onto targets above the soil. Further testing needs to be conducted in order to determine these effects quantitatively.

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The Selection, Training and Deployment of Mine Detection Dogs (MDD's), and Measures to Keep this Important Asset in Optimal Working Condition through Proper Care and Welfare Programs

J. M. Slabbert[46]

Abstract

According to the GICHD mine detection dogs (MDD's) have rapidly become the second most common mine clearance approach, after manual demining. In the year 2007, it was estimated that, worldwide, there were more than 25 organizations using MDD's. Dog detection can be faster and more cost–effective than manual demining if implemented correctly. Depending on environmental conditions, type of task and operational concept of each organization, improvement in mine action has been reported to be between 200 to 700 percent.
Good quality dogs, however, are hard to find, they cost a lot of money, require long training periods and it takes time before an effective and efficient MDD capacity is established in a mine or ERW – affected area.
The aim of this paper is to discuss the selection, training, deployment and care for the animals before, during and after deployment.

Key words: *Mine detection dogs, dog training, selection, care, breeding.*

1.   Introduction

Along with manual and mechanical clearance, dogs have become an indispensable part of the mine action toolkit approach to mine - and ERW clearance, due to the fact that they can be trained to detect odors from specific sources, such as landmines. They are particularly useful in detecting landmines with a low metal content and also mines buried in areas with a high metal contamination or background, where most metal detectors would be deemed as insufficient. The average clearance rate by manual deminers, appear to be in the region of 15 to 20 square meters (m²) per deminer, per day [1]. Whereas, a Mine Detection Dog (MDD) team can, easily clear 300 m² to 400 m² per day. Other reasons why MDD's play such an important role in demining is that machines have not been fully accepted as being as reliable as manual deminers and trained canines [1] and using machines is harsh on the environment (ecosystems) [2], [3].

According to the GICHD (MDD's) have rapidly become the second most common mine clearance approach, after manual demining. In the year 2007, it was estimated that, worldwide, there were more than 25 organizations using MDD's. Dog detection can be faster and more cost –effective than manual demining if implemented correctly. Depending on environmental conditions, type of task and operational concept of each organization, improvement in mine action, by using dogs, has been reported to be between 200 to 700 percent [1]. Good quality working dogs, however, are hard to find [4], they cost a lot of money, require long training periods and it takes time before an effective and efficient MDD capacity is established in a mine or ERW – affected area [1]. The aim of every company using dogs should be to strive for proper selection and training, to deploy the "right" dog to the "right" area and to care for the animals, before, during and after deployment.

2.   Selection of MDD's

Compared to other working dogs like police dogs, MDD's have to work in harsh conditions like extreme heat, humidity, dust and cold. Even when they are not working, during stand down periods, they remain at the mercy of the environment. Due to these reasons, only dogs that are mentally and physically fit to withstand these harsh conditions should be deployed to demining contracts.

Breeds best suited for demining work are German Shepherds (GSD's), Malinois, Labrador, Springer Spaniel and Golden Retriever. Other breeds that have also been used, but with less success, are Australian Cattle Dog, Border Collie, Cocker Spaniel, Jack Russell Fox Terrier and Kelpie. Perhaps we have not found the ideal MDD yet and breeders could look at cross breeding with existing breeds. The GSD/ Malinois combination and Border Collie/ Labrador combination could be possibilities to explore. The author is, however, hereby not promoting indiscriminate cross breeding.

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Once a specific breed has been decided on, a further selection has to be made regarding the physical characteristics of each individual dog. A lot of time and unnecessary effort can be saved by following a thorough pre-deployment policy:

- Dogs must be properly trained at local training facilities and be ready for accreditation, according to IMAS standards [3], when they reach their respective working areas.
- Females must be spayed and it is recommended that males are castrated to prevent inter-male aggression and urine marking. Decisions also have to be made whether to deploy males or females.
- Other than their ability to search for- and find landmines and ERW, MDD's must also be subjected to a noise sensitivity test.
- Skin pigmentation, coat colour, coat type within breeds must be taken into consideration.
- Preventative vaccinations must be up to date.
- Age of the dog must be considered. It is not advisable to deploy dogs eight years and older, depending on the duration of the contract.
- Recent results of hips- elbows- and back X-rays should be considered before every deployment. Especially concerning dogs older than 6 years.

The following aspects should be adhered to during deployment of MDD's:

- Daily feeding, grooming, human contact/ companionship. The latter is often neglected.
- Regular re-training and re-assessment of MDD's and handlers by qualified K9 trainers and assessors.
- Daily, weekly, monthly health- and condition checks on dogs and preventative vaccines.
- Dogs should have access to proper veterinary care during emergencies.
- The biggest concern for the care and welfare of dogs is during stand down periods. Dogs are often left for weeks, under the supervision of an unqualified person, who merely sees to it that dogs are fed and kennels are cleaned, but does not understand that dogs need human companionship, that they need to be taken out of their kennels daily. These people are also not trained to recognize the first signs of dog illnesses. The guidelines of IMAS 09.44 are not complied with [5].

The following aspects should be adhered to after the contract has expired:

- It should never be allowed that dogs are left behind when a company's contract expires, unless:
- Dogs are sold to the company taking over the contract and it is certain that the new owners will take proper care of the animals.
- Dogs too old or unhealthy to travel long distances should be euthanized by a registered veterinarian.
- Dogs that are not too old or unfit for duty, should be shipped back to the company's operating premises and then re-deployed or re-homed.

3.   MDD Breeding

Good quality dogs that possess the characteristics to be trained as MDD's are hard to find. If suitable dogs are found, they are expensive. Demining companies have to rely on the same suppliers as police canine units and security companies. The majority of demining companies purchase adult "green" dogs and train them as MDD's. Most of these dogs are bought in The Netherlands. These dogs are mainly redundant sport dogs.

Despite the shortage and high costs of potential MDD's, only a few companies breed their own dogs. The author is only aware of the following companies who breed their own MDD's:

- NPA – Global Training Centre (Bosnia)
- Fjellanger Dog Training Academy (Norway)
- MECHEM (Pty) Ltd (South Africa) and
- Mine Dog Centre (South Africa)

Working dog breeding is a long, slow and labor intensive process. If it is not done scientifically, a lot of time and money will be wasted. But the financial rewards and the large number of good quality dogs at ones disposal are great [6], [7], [8].

4.   Conclusions

MDD's are undoubtedly an effective and indispensable tool in mine and ERW – clearance. They are, however, not machines and need to receive constant care and re-training. They have to be managed by experienced personnel. It is often reported that MDD's are assessed and even certified by people with very little, or no K9 training. This leads to frustration amongst dog handlers.

More effort should be put into task specific MDD breeding programs and companies should share their expertise in an effort to produce the ultimate dog for mine detection work.

Demining companies who use MDD's should not only concentrate on pre-deployment strategies, but also have good systems in place for the caring and retraining of MDD's during contracts. More should be done regarding the care and welfare of MDD's during stand down periods and after contracts expire.

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Egypt Landmine Problem: History, Facts, Difficulties and Clearance Efforts

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Abstract

Egypt is contaminated with Landmines, UneXploded Ordnances (UXO), and Explosive Remnants of War (ERW) which are normally buried under deep layers of sand and mud from World War II. Most of the battles took place in the area between the Quattara Depression and Alamein at the Mediterranean coast. Other affected areas lie around the city of Marsa Matruh and at Sallum near the Libyan border. In addition, Explosive Remnants of War and Mines Other Than Anti-Personnel Mines (MOTAPM) from armed conflicts between Egypt and Israel in 1956, 1967, and 1973 remains unclear, especially in the eastern areas (Sinai Peninsula and Red Sea coast). No reliable figures for the extent of contamination exist. The joint Egypt/UNDP project document of November 2006 referred to 2,680 km² of contaminated area, which is almost four times the estimated contaminated area in Afghanistan. Similarly, the number of landmines, UXO, ERW and MOTAPM that remaining unclear can be little more than speculation. The Egyptian army has estimated that 16.7 million explosive items have still to be found, including both antipersonnel landmines (APL) and anti-tank landmines (ATL) and much larger quantities of UXO. This problem has a serious impact on Egypt National Income. This paper presents the scope of Egypt landmine problem, and clearance efforts. The paper is organized in the following main sections:
- *· Scope of Egypt Landmine Problem*
- *· Egypt Socio-Economic Effects*
- *· Egypt Landmine Monitoring Reports.*
- *· Difficulties in Humanitarian Demining*
- *· Egypt Landmines Clearance Efforts*

Keywords: *Egypt Landmine Monitoring Report, Detection, Clearance*

1. INTRODUCTION

Landmines represent a serious danger in a number of regions of the whole world. Many Landmine fields are known, mapped and mostly even fenced-in. Other Landmines, however, no information exist so that they pose the greatest threat. The problem of Landmines at these regions has a serious effect on their national incomes and on the safety of personal living in such regions. According to the Civil Right Organization, "a Landmine is some object placed on or under the ground or any surface, conceived for exploding by the simple fact of the presence, the proximity or the contact of a person or a vehicle". There are more than 100 countries affected by Landmines, UXO and/or ERW. Approximately 20 countries are heavily-affected, including Angola, Afghanistan, Croatia, Egypt, and Cambodia. More than 12 countries produce Landmines, including Cuba, Egypt, Singapore, and Vietnam; and almost 20 countries or rebel groups use Landmines, including some countries that produce them. As estimated 45-50 million Landmines infest at least 12 million km2 of land around the world.

These Landmines:
- kill or maim a reported 10,000 people annually;
- create millions of refugees and internally displaced persons;
- prevent hundreds of thousands of square kilometers of agricultural land being used;
- deny thousands of kilometers of roads for travel;
- create food scarcities, causing malnutrition and starvation;
- interrupt health care, increasing sickness and disease;
- inflict long-term psychological trauma on Landmine survivors;
- hinder economic development;
- undermine political stability.

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Table 1 lists the most important areas around the world infected with Landmines, UXO and/or ERW with their field type.

Table 1: Estimated Number of Landmines in the Most Infested Countries

Country/region	# Landmines(Million)	Field type (NA= Not available)
Egypt	22	Sandy desert
Angola	10-15	NA
Afghanistan	9-10	Dry, desert, rocky, clay, vegetation, Residential
Cambodia	8-10	Vegetation
Kuwait	5-10	Sandy desert
Yugoslavia	6	NA (without Kosovo)
Bosnia & Sarajevo	NA	Vegetation wild among ruined houses
Lebanon	NA	Rocky high ground
Mozambique	2	NA
Somalia	1	NA
Latin America	0.3-1	NA
Croatia	NA	Vegetation, residential/ industrial, machinery
Iraq	NA	Semi-arid region
Other countries	6.7-33	NA
Total	70-110	

2. SCOPE OF EGYPT LANDMINE PROBLEM

The Egyptian government cites a figure of 22 million Landmines: 16.7 million affect 268,000 hectares (km2) in the western desert area and 5.1 million affect 20,000 hectares (km2) in the eastern areas. Other Egyptian officials have stated that: Only 20-25% of these Landmines are really Landmines, the remainder being other types of UXO and ERW. In the next paragraphs, the available information about Egypt Landmine Maps, time Effect on landmines characteristics and its Socio-Economic Effects.

Egypt Landmines Maps: There are different and inaccurate maps for the Landmines in Egypt as indicated in Figures 1 and 2 with the Maps of Alamein area drawn from memory indicative only of Landmine field records. These Maps are partly misleading because of the limited accuracy of those records. UXO and some Landmines lie scattered across entire area so that the entire area has to be cleared. Clearance activities are severely hampered by having only limited maps, sketches and minefield records. Maps and data sources that have been provided by Germany, Italy and Britain have proven to be inaccurate or incomplete.

Landmine Types: Table 2 gives the types of landmines used in World War II and Israeli-Egypt conflicts. There is also a wide variety of ERW in the infested land of Egypt including air dropped bombs.
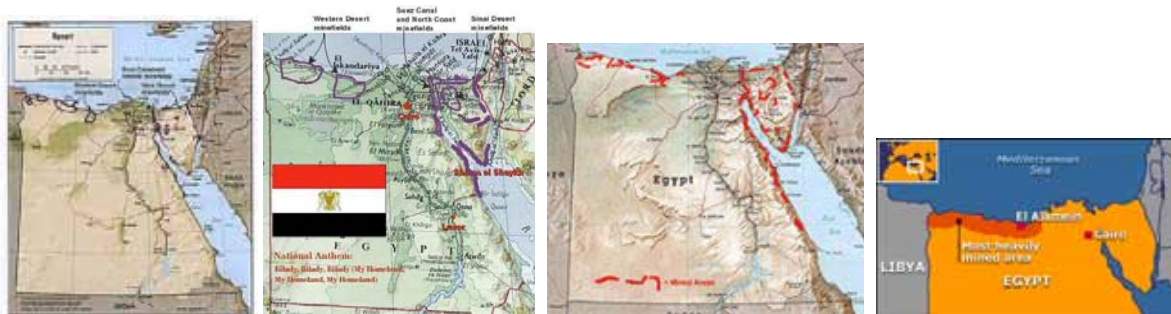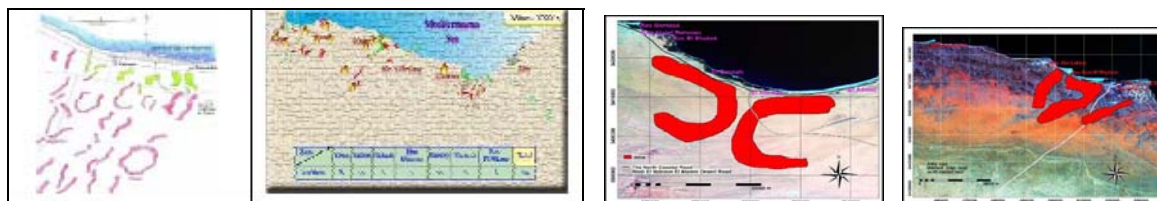

Fig. 1: Egypt Landmines Distribution Maps

Fig. 2: Alamein Landmines Affected Areas

Maps Data Sources
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- Land Master Pla: Euro consult-pacer Consultants (LMP, 1986).
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- Landsat ETM+ of 5 scenes of year 2001 (P178 R039, P179 R038, P179 R039, P180 R038, and P180 R039) and Mosaic Landsat TM of zone 35 year, 1990
- Water Science Department, Alexandria University.

Table 2: Types of Landmines in Egypt

World War II	Israel-Egypt Conflicts
British: MK5, MK7	Israelian: MOTAPM
German: Rieglmine 43, S mines, and Tellermine 35, 42, 43	Egyptian: M71, TM46, T79 , TS50, MOTAPM
Italian: B-2, V-3.	

Time Effects on Landmines Characteristics: The time has many unpredictable effects on landmines characteristics especially under sand contaminations. The age of much of these Landmines is up to 66 years. Much of Landmines, UXO and ERW are covered by thick deposits of mud or sand so that conventional detection techniques are often of little value. The military analysts said that storms have increased the depth at which many Landmines are buried by 8 meters, thus ruling out the use of normal mine-detection methods. The trigger mechanisms on many of the weapons have been corroded. Mines that were intended to be set off by the hefty bulk of a tank may be detonated by weight of a baby. Some mines may explode by themselves. All surveys and researches state that the mines status is totally unpredictable especially under sand contaminations.

3. EGYPT SOCIO-ECONOMIC EFFECTS

According to Egypt Landmine monitoring Reports (www.icbl.org), the mine/ERW causalities include men, women, boys, girls, children under the age of 18, civilian and military people. Among, 50 accidents cases: (16 accidents were reported at suspected areas (32%) and 34 accidents were reported outside the infected areas (68%)). An Egyptian Non-Governmental Organization (NGO) gathered data on ERW and landmine casualties reported similar data. There is no national mechanism to record victims of Landmines, UXO, ERW and MOTAPM. Table 3 presents the reported mine/ERW causalities as reported in Egypt Landmine Monitoring Reports for the period 1999-2009.

Table 3: Estimated and reported number of Mine/ERW causalities in Egypt

Year	Causality Analysis						
	Total	Killed	Injured	Men	Women	Boys	Girls
1945-1999[1]	8313	696	7617	NA	NA	NA	NA
2000	12	NA	12	NA	NA	NA	NA
2001	11	NA	11	NA	NA	NA	NA
2002	18	5	13	NA	NA	NA	NA
2003	14	NA	14	NA	NA	NA	NA
2004	10	NA	10	NA	NA	NA	NA
2005	16	6	10	NA	NA	NA	NA
2006	22	9	13	NA	NA	NA	NA
2007[2]	25	8	17	NA	NA	NA	NA
2008[3]	40	14	26	28	1	11	0
2009[4]	22	13	9	13	0	8	1
Total	8503	751	7752	NA	NA	NA	NA

1. Year 1999: Estimation by the Egyptian Official Authorities and Egypt Landmine Monitoring Report.

2. Year 2007: 1 incident in May 2008 in Alexandria governorate, the explosion of a World War II SHELL that was being dismantled for scrap metal caused 17 casualties (4 killed and 13 injured).

3. Year 2008: 40 Landmine/ERW causalities in eight governorates from 11 incidents. ERW caused 33 of casualties, landmines caused 6, and an unknown device caused 1 casualty. 3 incidents involving 4 casualties in Matruh governorate, 2 incidents in Ismailia, and 1 incident in each of Albihira, Al Suez, Alqaliobia, Alexandria, North Sinai, and Alsharqia governorates. 2 incidents causing 5 casualties occurred while people were illegally crossing Egypt-Libya border and 29 casualties in scrap metal trade. 3 casualties in each of playing with ERW, playing/recreation, and travel, and 1 casualty in each of agriculture and fishing/hunting.

4. Year 2009: 4 causalities in each of agriculture, fishing/hunting, 3 causalities in each of travel, playing with ERW, and playing/recreation, and 1 causality providing security; in addition to 4 unknown causalities. In May 2009, a police officer was injured when he handled a landmine while working at the Egypt-Israel border.

The impact of contamination is significant on the following activities in Egypt:

1. Irrigation projects, which represent one of the essential facets of national development projects in desert areas, have experienced delays. This prevents the establishment of new communities in the northern coast area.

2. Oil and gas extraction are delayed from reserves estimated at 4.8 billion barrels of oil and 13.4 trillion cubic feet (379 billion m3) of natural gas in the western desert.

3. Tourist projects have been hindered on the northern coast. New kinds of tourism, such as safari and eco-tourism, can encroach on affected areas, increasing the risk of incidents. It is necessary to warn people of potential hazards, but there is a fear of discouraging travel to the country.

Peace Gardens Survey: The Ministry of Planning and International Cooperation (Egypt) with UNDP and the local NGO Peace Gardens conducted a mine/ERW survivor survey from January to May 2008, on the North West Coast (primarily in Matruh governorate). The primary objective of the survey was to verify existing information on survivors collected by the Office of the Governor of Matruh and the governorate Social Solidarity Department.

Interviews were also conducted to identify previously unknown survivors in cooperation with local authorities. It should be noted that this survey included only those injured and those who still lived on the North West Coast at time of survey. It is estimated that some 80–90% of mine/ERW-affected communities were covered by the survey. The survey identified 645 mine survivors living on the North West Coast, 94% of them were males and 3% children. Among the injured, 48% suffered upper body injuries, 37% lower body injuries, and 15% other injuries. The number of people injured annually from 2002 to 2004 was found to be 18, but by 2007 the number had decreased to 3. It should be noted the survey recorded the age of the person at the time of the survey, not when the mine/ERW incident occurred. The number of mine/ERW survivors recorded in the survey was considerably lower than the estimate of 8,000 mine/ERW casualties which, according to UNDP is "understood to relate to casualties in the whole country". A number of survivors particularly from Bedouin communities are assumed to have moved from the area since they were injured by mines/ERW. As a result, the survey does not capture all those injured by mines/ERW in the survey area. The survey did not include military casualties from mines/ERW. The Ministry of Defense estimated that about 700 people, soldiers and civilians, have been killed in mine explosions since 1945.

4. EGYPT LANDMINE MONITORING REPORTS

There are eleven available Landmine Monitoring Reports in the last 11 years (1999-2009) concerning Egypt. These reports indicate that (www.icbl.org):

▪ Egypt has not acceded to the Mine Ban Treaty, insisting that it needs antipersonnel mines for border defense. Egypt has abstained on every annual pro-mine Ban Treaty UN General Assembly resolution.

▪ In 2004, Egypt said that the government had imposed a moratorium on production and export of antipersonnel mines, claiming that it last produced in 1988 and exported in 1984.

▪ Egypt has often participated as an observer in Mine Ban Treaty meetings, most recently in November 2008.

▪ Egypt has made slow progress in setting up a civilian mine action program to support the clearance of mines and explosive remnants of war (ERW) on its territory dating back to World War II. Clearance operations, part of the first phase of a joint government-UNDP project related to the North West Coast, began in February 2009.

▪ There has never been a formal risk education program in Egypt, and only very limited ad hoc activities have been reported in the last 10 years, including in 2008. Progress in recent years has been made in providing

mine/ERW survivors in Egypt with medical care and economic support. However, there is no national victim assistance strategy in Egypt and the majority of survivors did not receive specialized assistance in 2008. Discrimination against persons with disabilities continued to be reported in 2008.

A summary of Egypt Landmines Monitoring Reports 2008 (January-December 2008) and 2009 (January-December 2009) are presented in Table 4. The detailed reports can be found on the website: www.icbl.org.

Table 4: Egypt Landmine Monitoring Reports (2008 & 2009)

	2008	2009
Mine Ban Treaty Status	• Not a State Party	
Production, Transfer and Stockpile	• Unknown, but thought to be substantial	• Egypt has stated that it stopped production of antipersonnel mines in 1988 and export in 1984
Contamination	• Antipersonnel and anti-vehicle mines, UXO and ERW	
Estimated area of Contamination	• 2,680 km^2, to be significantly reduced by technical survey	
Demining progress	• None	• The "Support to the North West Coast Development Plan and Mine Action Project" between Egypt and UNDP was signed in November 2006. • An extension was due to run until December 2009
Mine/ERW casualties	• Total: 25 (2006: 22) • Mines: 10 (2006: 8) • ERW: 14 (2006: 8) • Unknown: 1 (2006: 6)	• Total: 40 (2007: 25) • Mines: 6 (2007: 10) • ERW: 33 (2007: 14) • Unknown: 1 (2007: 1)
Casualty analysis	• Killed: 8 (2006: 9) • Injured: 17 (2006: 13)	• Killed: 14 (2007: 8) • Injured: 26 (2007: 17)
Risk Education capacity	• Inadequate	• Risk Education was included in the joint UNDP/Egypt project signed in November 2006, yet little has been implemented. • In July 2008, the Chair of the State Information Service stated that a three-month RE campaign in Matruh, Alexandria, Suez, Al-Arish, northern and southern Sinai, and Ismailia governorates would take place, but no activities had taken place as of July 2009
Availability of services	• Unchanged-inadequate	
Mine action funding	• $500,000 (2006: none)	• $918,244 (2007: $500,000)
Key developments	• In mid-August 2008, it was announced that demining would begin before the end of the month.	• From 7 February 2009 until 31 July 2009, demining operations were reported to have cleared 210214 items of UXO and 13720 mines from 14474 acres (approximately 58.6 km^2). • It has not been possible to verify these figures, which seem high given the available resources

5. DIFFICULTIES IN HUMANITARIAN DEMINING

The fact that over the years many reference points and landmarks have disappeared by rain and sandstorms added to the complexity of drawing a comprehensive picture of the Landmine situation. The complete marking and fencing of huge areas in the western desert is not considered feasible by the Egyptian Military due to climatic conditions, sandstorms and scrap traders. Demining is the action of removing landmines, booby traps and (UXO) from an area; those are normally hidden and most often buried. Demining process is essentially two steps;

detection and clearing. Landmines are distributed in fields over wide areas, however not all the wide areas are contaminated. For optimum application of demining; contaminated regions should be detected at first, then it is possible to utilize uncontaminated areas for economic and human activities, while contaminated regions are treated for clearance. The process of locating region of interest (ROI) to exclude uncontaminated areas is called **Mine Field Area Reduction**. Therefore, it is usual to use sensors in two levels; wide view to locate region of interest (ROI), and detailed view to locate the specific mines. In military demining, a military force prepares a safe corridor for the troops to move through. Some losses are accepted as an expected part of the conflict.

Therefore a flail machine with an 80% clearance success can be used. This sort of clearance operation is not suited to humanitarian demining, in which, the entire land area must be cleared free of mines to be productive. The United Nations has specified a mine clearance standard of 99.6% for humanitarian demining. Currently the only way to achieve this is with manual demining methods. The main humanitarian demining technical problems are given in Table 5.

Table 5: Difficulties in Humanitarian Demining

Complications	Description
Landmines locations are usually unknown	Because landmines are very cheap and easy to build weapons, they have been largely used in different types of conflict, by military or
Often discovered by accidents	Associations like the Red Cross when they have to provide support for mine victims.
Maps indicating the locations is useful in few cases	Demining operations may not start until years after the minefield was laid and during this time the conditions of the affected lands can drastically change.
Mines that have been in place for years	Can be corroded, waterlogged or impregnated with mud or dirt, and then behave quite unpredictably. Photo: J. Trevelyan
Floods and heavy rains	May cause mines to move from the original place to another or to move deeper into the ground.
Mines placed near buildings	may lie deep under fallen rubble, with yet more mines laid on top)
Stakes supporting Fragmentation mines	May fall over and may rot, leaving the fragmentation mines half buried lying on their sides.
Tripwires may run through	The branches of the scrub & may pull the pins from the fragmentation mine as the branches sway in the wind.
The vegetation grown in many years after the landmines were laid	Border between Croatia and Republika Serbs, 8 years after mines were laid can represent a very big obstacle to demining operations. Photos: J. Trevelyan
Type of terrain itself can cause many problems to mine clearance	Plenty of metal fragments represent an obstacle for the use of metal detector. Uneven rocky terrains add complications to the mine removing operation Photo: MCPA, Afghanistan, Prof. J. Trevelyan

Mines buried in a sandy desert	Can easy move deeper when the wind blows the sand	Photo: Western Desert, near to Al Alamein (Prof. J. Trevelyan)
Mine age implies high sensitivity of mines.	In Western Desert and Sinai Peninsula, age of most of the explosive materials is up to 65 years. (high sensitivity)	
In Western Desert and Sinai Peninsula, the climate is extremely unpleasant for deminers.	Temperatures up to 55°c are common. The conditions are either dusty, sandy or muddy (salty mud and swamps) along the coast: sometimes both. The muddy areas and marshes are particularly difficult to deal with as it is often impossible to stand in the mud.	
Mines state are not expected as well.	Array of mines as those German mines in the World War II waiting for press in order to be activated. Already pressed under certain weight of contaminations and waiting for release in order to be activated.	

6. EGYPT LANDMINE CLEARANCE EFFORTS

Since 1946, according to the Egyptian Official Authorities, 7 million mines have been cleared from the western desert in the past 15 years and 3 million from the Sinai desert. That leaves at least 20 million of Landmines/UXO/ERW/MOTAPM unclear. Egypt has set the year 2017 as the target for finally ridding its sands of Land mines. It is anxious for Egypt to be left alone in paying for and carrying out this huge task. Next are some other official acts:

- In July 2002, the Government of Egypt has established the **"National Committee for the Northwest Coast Development and Landmine Clearance"**. This Committee is headed by the Ministry of Planning and International Cooperation. Demining Programs aim to propose and implement regional developmental programs for the Northwest Coast and its desert back areas up to the year 2017.
- The responsibilities of this National committee are:
  a.) conducting studies and establish programs and plans for landmine clearance in the designated areas,
  b.) revising financial plans for the programs related to Landmine clearance as well as available grants and assistance from countries, agencies, international organizations,
  c.) presenting allocation suggestions within the scope of the designed objective,
  d.) verifying and following-up on the implementation of the programs and plans prepared for Landmine clearance, preparing draft laws and decisions and research necessary for Landmine clearance projects.
- All Demining work is handled by a division of the Ministry of Defense in Cairo the Egyptian Military Engineering Organization **(EMEO)**.
- The Egyptian government is now pursuing a more open policy, recognizing that information is needed to help secure assistance. Until recently, all aspects of minefields and Demining are classified.

7. COMMENTS AND CONCLUSIONS

This paper presents four main points: scope of Egypt landmine problem, socio-economic effects, available official data, and Egypt clearance efforts in addition to the faced difficulties of exploration, localization, mapping, and removal of Landmines in infested areas. Two questions are still with no answer for safe Landmine detection:

1. What is the most efficient technique for exploration, localization, and mapping of such Landmines?
2. What is the most efficient sensor(s) used in the detection process of different Landmines types?
The answers of these questions may be useful to develop safer, faster and cost effective Anti-Personal and Anti-Tank Landmines (APL & ATL) clearance. This will save human lives and will have a very positive impact on the Egyptian National Income.

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The Dilemma of Research and Development for Commercial Demining Companies: a MECHEM Perspective

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Abstract

1.   MECHEM was initially established as the Applied Chemistry Unit of the South African Council for Scientific and Industrial Research (CSIR) in 1960. The company started its involvement in counter landmine research and development in 1966 when the first members of the South African Police (SAP) encountered landmines in the then Rhodesia (now Zimbabwe). From 1966 to 1991 the company primarily concentrated on supporting the SAP and the South African Defence Force (SADF) with research and development projects mainly focusing on counter landmine strategies and equipment. Since South Africa was involved in the Border War in Namibia and Angola sufficient government funding was available for these projects.
2.   Since 1991 the government funds allocated to MECHEM for R and D steadily decreased to the point where it was stopped completely in 2001. MECHEM then had to restructure and the R and D component was transferred back to the CSIR (Defencetek now DPSS) meaning that for all intents and purposes the company no longer had an R and D capability.
3.   This paper will focus on the problems facing commercial demining companies regarding R and D which include aspects such as a lack of funding, stakeholder expectations and the possible financial return for money spent on R and D. Further to this the manner in which MECHEM has addressed this dilemma will be discussed as well as the results obtained by using innovation and a minimal budget. In the final analysis it will be argued that despite many obstacles commercial demining companies do have a responsibility to do limited R and D and plough back some of their profits to make demining safer, quicker and more cost effective.

INTRODUCTION

1.   MECHEM was initially established as the Applied Chemistry Unit of the South African Council for Scientific and Industrial Research (CSIR) in 1960. The company started its involvement in counter landmine research and development in 1966 when the first members of the South African Police (SAP) encountered landmines in the then Rhodesia (now Zimbabwe). From 1966 to 1991 the company primarily concentrated on supporting the SAP and the South African Defence Force (SADF) with research and development projects mainly focusing on counter landmine strategies and equipment. Since South Africa was involved in the Border War in Namibia and Angola and the country was isolated due to international sanctions, sufficient government funding was available for these projects.

2.   The CASSPIR, Mamba and Rinkhals mine protected vehicles, the MECHEM explosives and drug detection system (MEDDS), the NTW multi-caliber weapon, various counter-IEDD innovations such as the nipper and disrupters and minefield breaching systems, to name but a few, were all developed by MECHEM during this period.

3.   Since 1991 the government funds allocated to MECHEM for R&D steadily decreased to the point where it was stopped completely in 2001. MECHEM then had to restructure and the R&D component was transferred back to the CSIR (Defencetech now DPSS) meaning that for all intents and purposes the company no longer had an R&D capability.

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DILEMMAS FACING COMMERCIAL COMPANIES

5.   Lack of Funding. It is a fact that R&D does not come cheaply. Furthermore one does not know what potential income can be arrived at from the results achieved. If a company does not have government or donor funding it has to use its own funds and these come off the bottom line. Most companies coming from developing countries such as South Africa in the case of MECHEM get absolutely no government funding or other support, this is despite being 100% state owned. Donor funding is also almost non-existent since this is usually reserved for NGOs. In exceptional cases commercial companies may be invited to contribute towards R&D efforts mainly initiated by the Departments of Defence of First World countries. The results and fruits of such contracts are usually contractually to the benefit of the contracting party with little or no future gain for the commercial company.

6.   Low Profit Margins. Presently there is such strong competition in the commercial demining market that companies have to cut their profit margins to the bone to obtain contracts. The obvious effect of this is that there are no funds available for R&D once all operating costs have been covered.

7.   Stakeholder Expectations. All commercial demining companies are owned by stakeholders or shareholders to who they have to report. Unfortunately such stakeholders are almost exclusively interested in maximizing profits over the immediate short term. They do not realize that R&D costs a substantial amount of money and that the results or potential income will only come to fruition over the medium to long term. This fixation on short term profits makes it difficult for the management of commercial companies to motivate R&D expenses.

8.   Financial Return. Unfortunately the demining market is so small that any product derived from R&D will scarcely yield a favourable financial return in the short term. The only way in which real profits can be generated is where the product can also be used in other commercial fields. Once again the small market and set up costs for manufacturing make that profits are only realized over the medium to long term.

9.   Suitable Personnel. Finding suitably qualified personnel for R&D is usually not too difficult. Unfortunately one does not only need scientists and researchers, but people with practical knowledge and experience in the demining field. Finding the right balance between qualification and experience is the only way to ensure practical products that can be used in the field are developed. Research for the sake of research cannot be afforded by any commercial demining company working under the financial constraints mentioned above.

10.   Moral Obligation. Although it is difficult and financially not really viable for commercial demining companies to do R&D, it is a moral obligation that each company should have. Commercial companies are often seen as the money making part of demining whilst NGO's are seen as being very altruistic; even though this is often not the case. Through investing in R&D commercial companies can prove that they are not just mercenaries cashing in on the misery of a world contaminated by the scourge of explosive remnants of war.

POSSIBLE SOLUTIONS

11.   Teaming and other forms of Cooperation. The high cost of R&D can be partially countered by teaming with other commercial demining companies, NGOs or research institutions so as to share the costs involved. MECHEM is in the fortunate position that it has a good relationship with the CSIR and at this stage either outsources or collaborates with this institution on certain projects.

12.   Product Development. Instead of doing basic R&D MECHEM decided in 2001 to rather go the route of product development. Although fairly similar to R&D we rather look at our own or other products and see how they can be modified, enhanced or improved to make the demining task easier, safer, cheaper and quicker. Projects are also only undertaken that are initiated by operators in the field. To this end MECHEM established a small in-house capacity consisting of a mechanical engineer, mechanical technician, electronic engineer and an electronic technician.

13.   Multi-tasking. The advantage of such a product development section over a purely R&D section is that they are mainly hands on practical people that can be used for other tasks within the company. MECHEM presently also uses the expertise in this section for minor repairs to electronic equipment, the preventative maintenance of electronic equipment in the field, quality control on the remanufacture of vehicles and sourcing technical equipment, spares and services.

14.   Horses for Courses. It is important that one does not go and look for solutions where they already exist. Research (or product development) for the sake of research is thus never undertaken.

SOME RESULTS OF MECHEM PRODUCT DEVELOPMENT

15.   Deflagration System. The availability, costs and problems encountered with air transportability of explosives in most of the countries in which demining operations are executed necessitated an alternative solution. A standard commercial product was modified and the necessary ignition system developed resulting in a very cheap, safe and effective alternative for explosives that can be transported by commercial airlines. Presently this system has been successfully tested and used for the in situ deflagration of mines and UXOs up to 155mm calibre. The system can also be used to cheaply render small arms inoperative. Further development is being done into multiple ignitions and bulk destruction using the deflagration system.

16.   Mini Incinerator. The problem of destroying large numbers of small arms ammunition in the field led to the development of the very simple incinerator that incinerates up to 14.5mm ball ammunition. The incinerator is simple to operate, cheap and very safe. With this development it is no longer necessary to bury small arms ammunition or try and destroy it by means explosives that actually scatter them over a large area.

Deflagration on 155mm

Mini Incinerator

17.   Magnetic Sweeper. The high amount of metallic clutter found on roads makes electronic detection very difficult and time consuming. The magnetic sweeper was designed to assist in clearing most surface and low sub-surface metal debris from roads so as to make clearance operations faster by eliminating false alarms.

18.   Large Loop Deep Detector. The need for a low cost large loop detector for specific use in African countries with small budgets was identified. Presently this is still a project in process, but excellent results have so far been achieved.

19.   Vehicle mounted Multi-sensor Array. The existing MECHEM vehicle mounted metal detection system (MVMMDS) has successfully been integrated during tests with an existing GPR system. The integration of the MECHEM metal array with its real time marking system and the GPR showed excellent results during testing in South Africa. A lack of funding has forced this project to be halted in the interim.

20.   Newly built CASSPIR Mk2. The last newly manufactured CASSPIRS left the assembly lines in South Africa more than 20 years ago. Since that time redundant defence and police force stock has been either reconditioned or remanufactured for the demining and peace keeping market. MECHEM has now started manufacturing CASSPIR Mk 2 vehicles to the same specifications as the old vehicles with only the armour that has been modernized and bent instead of welding; giving the vehicle a much cleaner aesthetic look. This vehicle will be officially launched on 28 May 2010, whilst a CASSPIR Mk 4, a modernized vehicle that will encapsulate most of the identified improvements required on the existing CASSPIR Mk 2, will be launched at the African Aerospace and Defence Exhibition in Cape Town in September 2010.

21.   Add on Armour. The rise of roadside bombs and ESFs necessitated the use of add on armour to try and reduce the threat. MECHEM performed many tests with different compounds but came to the conclusion that this requires high cost R&D and thus stopped the project. The results are however available for other institutions that plan to do further R&D on this subject.

22.   EOD Arm. MECHEM designed a CASSPIR for on-board demining and EOD operations for a specific client in 1998. The vehicle never went into production and the prototype was later used as a MVMMDS vehicle in Eritrea for road verification and clearance. The present situation in Somalia has again initiated the need for a fairly low-cost and effective tool for EOD operations out of a protective vehicle. The bomb arm designed by MECHEM utilizes various tools to investigate possible IEDs and UXOs and also integrates a proven disruptor system.

23.   Steel Wheels. Whilst steel wheels are a very low technology demining tool, their design has never really been standardized. Furthermore incidents were occurring where large chunks of steel were breaking off in vehicle mine detonations, making for very dangerous shrapnel. Different sizes of wheels as well as different threads also led to additional wear and tear on the vehicles. MECHEM performed various tests on steel wheels in collaboration with the CSIR and have now standardized on a Weldox wheel with a thread that can be used on any wheel and not specifically in a right-left configuration as in the past.

New Steel Wheel ready for Testing

Casspir with EOD Arm

CONCLUSION

24.   The examples given above were all executed and developed on a very low budget and prove that any company can do development. It is however essential to ensure that proper configuration is done and data packs drawn up so as to ensure consistency of quality and repeatability of product.

24.   Personally I feel that despite the costs every commercial demining company should invest a percentage of their turnover into R&D or product development. Furthermore the results of such R&D/PD should be shared within the demining world once it has been proven to make the task safer, cheaper or faster.

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