Results of field testing with the multi-sensor DEMAND and BIOSENS technology in Croatia and Bosnia developed in the European Union's 5th Framework Programme

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ABSTRACT

This paper presents the development results for three sensor technologies: metal detector (MD) array, ultrawideband (UWB) ground penetrating radar (GPR) array and biosensor sample collection and analysis system. It provides results on explosives findings for demining and demonstrates how the false alarm rate (FAR) of the MD may be reduced while maintaining high probability of detection (PD) through a data fusion (DF) system. The relevance of the results to demining and homeland security is also provided.

Keywords: Demining, multi-sensor technology, biosensor, data fusion, explosives

1. INTRODUCTION

An efficient and fast way to detect landmines is one of the most challenging technical tasks of the present time. Sensor principles providing a good spatial resolution, allowing the recognition of a mine as a specific man-made object, usually fail by the nature of the problem. Inhomogeneous soil and different ground objects mask and cover up typical features which mark a mine. Consequently, a mine appears as a non-structured (respectively a very low structured) point object for most sensor principles. In this way, there is a large cross-correlation and hence a low separation potential between mine and no-mine targets which interact in a comparable way with the sensor. In order to reduce sensor ambiguity one strategy is to try to combine various sensors which are sensible to different phenomena. Mine recognition should be improved as a mine and a non-mine target should not interact with all the sensors in the same way.

Within the DEMAND project a new ultrawideband (UWB) ground penetrating radar (GPR) employing M-sequences, a stacked metal detector array and a biosensor system, co-developed within the BIOSENS-project, have been considered for integration with a data fusion platform. The DEMAND and BIOSENS projects were sponsored by the European Commission within the 5th framework programme for research and technological development. In this paper we will provide a short description of the individual sensor technologies and their main performance merits resulting from the project. We will then present the tests being carried out in Croatia to develop the sampling technique for the biosensor system before moving on to consider the performance of the individual sensors and the combined sensors during field tests in Bosnia in July-September 2003.

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In conclusion the results obtained in the project will be shortly discussed in terms of their relevance for demining and for other risk and security applications. In this short paper we are unable to cover all issues in detail; we encourage any reader with interest in our results or technology to contact us.

2. MERITS OF SENSOR TECHNOLOGIES DEVELOPED

2.1. UWB GPR

The ground penetrating radar technology[1] developed in the project is based on radar electronics using the M-sequence technique from MEODAT. IDS provides the antenna[2] and signal processing solution. These two companies along with TUI have worked together to construct the radar solution. A 15 Tx - 20 Rx full polarimetric linear antenna array has been constructed in the project. Fig. 1 and Fig. 2 provide an impression of one UWB module and on the complete array. An overview of individual technical merits is provided in Tab. 1.

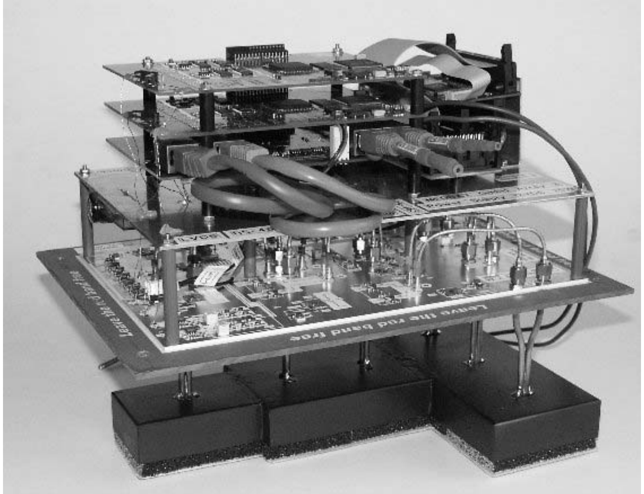


Fig. 1 shows a completed GPR module with the mounted digital processing unit (DSP). The DSP consists of three boards, two processing boards and one power supply and interface board. The three boards are connected by a back plane. The aluminum plate is used as shielding and mechanical carrier for the DSP boards.

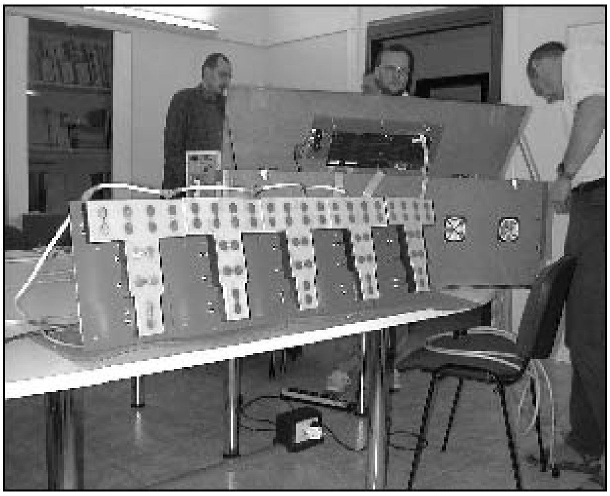


Fig. 2 shows the underside of the polarimetric antenna array with its all five modules in the foreground. The radar demonstrator packaging is in the background.

Technical parameter	Merit
Radar Chip Technology	0,25 µm SiGe:C BiCMOS
Acquisition Speed	The acquisition hardware (ADC and FAP) provides for 68 Msamples/s.
Power Consumption	TX 475 mW, RX 440 mW
Antenna Type	Modified bow tie 80 degrees × 106 degrees at -3 dB
Array Polarisation	HH,VV,HV

Technical parameter	Merit
Array width	1m (multiple combinations possible for further width)
Resolution	5 cm cross-range, 4.4. cm range.
Antenna Bandwidth	3.7 GHz
SCR	>20 dB with a processing gain of >20 dB.
Primary detection algorithm	Full 3D Kirchhoff migration
Feature extraction	• Geometrical characterization of putative targets (e.g. reflectivity, size, shape compactness). • Polarimetric characterization (e.g. orientation, elongation factor) • Semi-automatic estimation of propagation speed

Tab. 1 Overview of Ground Penetrating Radar results

2.2. VAMIDS MD

The commercially available VAMIDS MD technology[1] from Schiebel elektronische Geraete GmbH was further developed in the project to provide improvements in terms of lateral resolution, depth estimation, feature extraction, probability of detection and sensitivity. Fig. 3, Fig. 4 and Fig. 5 illustrate the array configuration and depth estimation results. An overview of individual technical merits is provided in Tab. 2

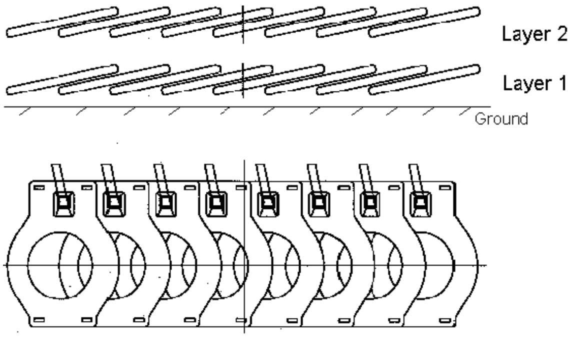


Fig. 3 Principle of VAMIDS stacked array

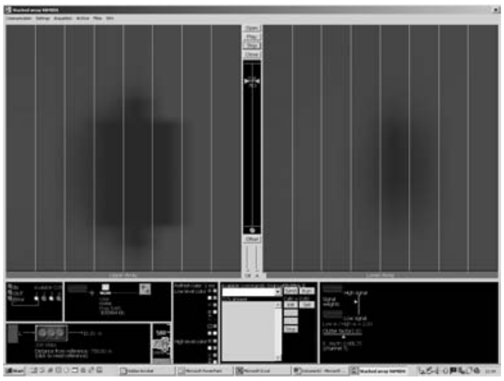


Fig. 4 Signals for stacked coils providing the basis for depth estimation

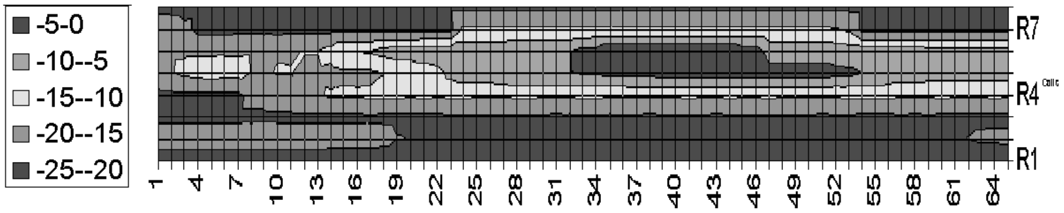


Fig. 5 Graphical representation of depth estimation

Technical parameter	Merit
Lateral resolution	Better than 2 - 3cm
Depth estimation	Down up to 23 cm under ground; resolution 3-5 cm (depending on calibration and type of soil)
Feature extraction	Feature extraction, principle and models built
Probability of Detection	Same standard as commercial product
Sensitivity	The sensitivity improved to 150 mg steel cylinder at 12 - 13 cm

Tab. 2 Overview of Metal detector results

2.3. Biosensor technology

The biosensor explosives detection system consists of two separate sub systems: A) the vapor/particle sample collection system (Fig. 9) and B) the biosensor analysis system (Fig. 7)[1].

The sample collection system is a light weight battery operated air fan using the principle of a vacuum cleaner to draw air from close to the ground through a single use vapor/particle filter. The vapor/particle filter concentrates explosive vapor as well as catches particles that can contain adsorbed explosives. This filter is then transferred for analysis either on site to the biosensor analysis system or to a remote laboratory for analysis by gas chromatograph (GC). The nominal air flow of the sample collection system is 100-200 l/min.

The biosensor analysis system utilizes a specific antibody reaction that takes place on the surface of a piezo electric crystal (QCM) in the BioCell. The QCM-technology, acting as the transducer of the bio-specific reaction, allows minute changes in mass on the surface of the QCM crystal to be monitored as a change in frequency. The analysis system also contains an integrated sample transfer unit for transferring the analyte molecules on the filter to the fluid buffer of the system. Overall analysis time for a filter is 90 seconds and the presence or absence of explosives is indicated on the front panel of the system. Optionally, an attached computer can be used to monitor the frequency response of the QCM-cells. Tab. 3 shows the analysis unit to have a sensitivity of 2 ng or better. Fig. 6 shows response curves (raw data) when 2 ng and 0 ng TNT on filter are analysed. An increase in frequency after 50 seconds is expected as the target analyte (TNT) enters the BioCell.

	2ng	1ng	0,5 ng
Response: mean value (Hz)	3,3	2,4	1,2
PD	0,94	0,79	0,38
No. of runs	18	24	8

Tab. 3 PD and response in Hz for 3 different amounts of TNT on filter

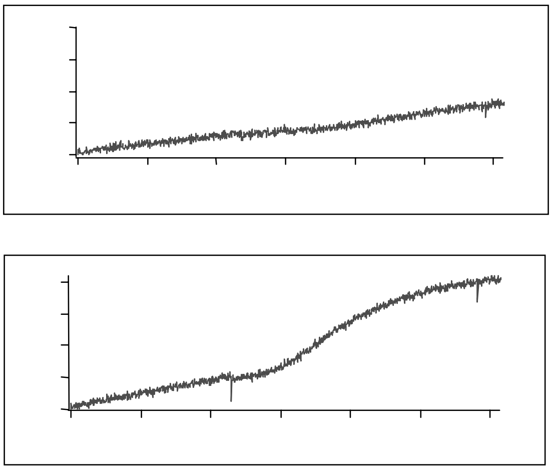


Fig. 6 Response curves for blank filter (top) and 2 ng TNT on filter (bottom)

Fig. 7 The field deployable biosensor analysis system

Technical parameter	**Merit**
Analysis unit	
Probability of Detection	>95% at 2 ng on filter
Sensitivity	0.5 -1 ng on filter, 10 pg in cell
Analysis time	90 seconds
Explosives detected	TNT, DNT, Tetryl
Weight	17 kg (analysis unit);
Sample collection system	
Collection efficiency (%)	75 % for TNT vapor
Weight	5-6 kg

Tab. 4 Overview of the biosensor technology merits

3. BIOSENSOR SAMPLE COLLECTION SYSTEM TEST RESULTS IN CROATIA

3.1. Methods

The air samples were collected using the above described sample collection system (Fig. 9). It was fitted with a mouth-piece (plastic cone) to the filter holder. Its widest part (21 cm in diameter) was placed on the ground surface to be tested. The air-turbine is set to continuously draw air through the filter during 3-6 minutes. After each collection the filter was removed and either put in a small glass vial with screw cap or put in a sealable plastic bag. The samples were stored cool (<4 degrees) and dark until analysis.

During the field test the mouth-piece and the filter holder was cleaned with ethanol (70%) before each collection. After insertion of the filter, the collection equipment was carried to the box and the mouth-piece was placed over the position to be sampled. Once the collection was finished (3-6 minutes) the collection equipment was carried to the automobile where the filter was removed and stored. After cleaning and insertion of a new filter, the next collection was started.

Filters were extracted with tert-Butylmethylether (LiChrosolv, Merck, Germany). Hexachlorobensen was included as internal standard substance in the extraction solvent to verify GC performance. For GC analysis of extracted filters, a HP 6890 Series GC system was used with an accompanying µ-ECD detector. The separation column was either an Agilent HP-1 (25 meter) or a Varian VF-5MS (30 meter). Quantification of sample peaks were made by comparing to known standard explosives in solution. Normally 2,4,6-TNT and 2,4-DNT were quantified. In some tests tetryl, 4-amino-2,6-DNT and 2-amino-4,6-DNT were also quantified. Detection limit on filter is 0.05-0.1 ng for TNT and DNT and 0.5 ng for tetryl, 4-amino-2,6-DNT and 2-amino-4,6-DNT.

3.2. Methodology study results

SRSA and BAAB have conducted several tests in a mine test field situated outside Skabrnje in Croatia since April 2002. The field contains brown skeleton (stony) soil mainly of loam or clay loam type. The mines in the field are placed in mainly two parts of the field:

1) The SRSA part including an array of 16 boxes (each box 10x10 meters) with a distance of at least 30 meter from the side of each other and 4 test lines. In each of these boxes one mine is planted in the center of each box. The types of mines planted are 6 PMA1, 4 PMA2 and 6 TMA5 mines, all from former Yugoslavia having plastic casings. The mines have modified fuses.

2) The BAAB part is an array of 20 boxes with a distance of 20 meters from the side of each other. A single mine is planted in the center of each box. The mines are 7 PMA1, 7 PMA2, 2 PMA3, 2 TMA2 and 1 TMA5 all having a plastic plug instead of the fuse. The shortest distance between the mines in the SRSA part and the mines in the BAAB part is at least 60 meters.

Collection test studies are still ongoing in this field and the results will be fully presented at the end of the BIOSENS project in the autumn of 2004. However, some of the findings will be presented in this report.

The hit ratio when collecting air above mines is defined as the number of samples with explosives (2,4-DNT or TNT) divided by the total number of samples collected above mines. In the SRSA part this ratio ranges between 6% and 59% during 9 test periods. Sample collections between boxes taken in study 7, 8 and 9 indicates a background hit ratio between 4% and 22%. Control samples from collection of "clean" air (1 meter above ground) sometimes indicates a presence of explosives

The corresponding values found for samples collected in the BAAB part are 0-15% for samples above mines. In 2 out of 6 test periods no explosives was found at all above mines and for samples collected between boxes only one finding in 5 test periods was made.

We have found that there is always a probability (although small) of finding explosives in the SRSA part in air samples collected above mines. On an average we estimate this probability to 10-20 % for samples collected in the SRSA part. The number of explosive findings in the BAAB part is consistently much sparser. In the SRSA part explosives can usually be found also in air samples collected between boxes. This occurs at a probability which is lower to or at the same level as to that for collections above mines. It is likely that when explosives have migrated to the surface above a mine it can be transported, by wind or mechanical factors (e.g. grass cutting machines), to other places. This may also partly explain the absence of positive findings for air sample collected above mines in most of the samples. The number of findings of explosives in air samples collected above mines is significantly lower in the BAAB part than in the SRSA part of the field. While the same methodology and type of equipment is used in both parts we suggest that the difference is due to the replacement of the fuses with plugs in the BAAB set of mines. The use of a plastic plug instead of a modified fuse may retard the release of explosives from the mines. This can be confirmed by investigating explosive flux in laboratory conditions.

4. DATA FUSION SYSTEM

The DF system is a generic and flexible solution for the fusion of heterogeneous data (spatial and non spatial) from sensors and also from human knowledge available from domain experts. It is designed with a multi-agent and blackboard pattern. The Data Fusion Engine (DFE) handles a dynamic catalogue of Automatic Target Recognition (ATR) agents which interact with the registered geographical feature objects in the Virtual Scene Blackboard (i.e. a GIS database). The system has been implemented through a number of commercial-off-the-shelf components and proprietary developments. The GIS system is based on ESRI¥s products ArcGIS and ArcSDE, which provide a powerful platform for the integration of the spatial data from the sensors. The combination of the DFE with this GIS system results in an advanced spatial decision support system (or intelligent GIS). The knowledge representation capabilities combine spatio-temporal relations and fuzzy rules. All of this enables the system expert to calibrate the data fusion performance in a flexible way with advanced qualitative spatial reasoning capabilities[1].

The system has been designed in such a way that the data from any number of sensors could be inputted into the system i.e. not just the three in this project. The advanced system enables the optimal analysis of different sensor features and their impact on PD and FAR and provides for selfñlearning. The system analysis capability was key to interpreting the results from the various laboratory and field tests. The relatively small amount of data provided in the field tests in terms of objects scanned did not allow for extensive testing of the self-learning capability and the data fusion system was used rather conservatively during the field tests reported. Further field tests will allow for increased self-learning and we forecast that further improvements in terms of the reduction of FAR can be achieved while maintaining the highest PD.

5. BOSNIAN PERFORMANCE EVALUATION SCENARIO

The test field is located outside Sarajevo, Bosnia. It consists of arable land with grass comparable to the grassland scenario[3]. It is used by Norwegian Peoples' Aid (NPA) to train their mine detection dogs. The test field has been built with a large number of boxes. Each box contains different numbers of targets with different depths. The targets are mainly mines found commonly in the Balkans. The mines boxes that we used had been prepared for more than a year. The following anti-personnel and anti-tank mines were used as targets in the test area: PMA1s, PMA2s, PMA3s, PMR-2As, PROM1s, TMA3s, TMA4s, TMM1s and TMA5s. All mines are stated by NPA as being live but without fuses. In mines with plastic cases, the fuses were replaced with a peace of metal. All AP mines were planted at a depth of 2-4 cm and all AT mines were planted at a depth of 4-10 cm. The following objects were planted as false alarm targets in the test area: cartridges, tin/cans, bottle-caps, roofing tiles and bricks. The objects were chosen because they are rather common in minefields in the Balkans. All false alarms where at a depth of 2-10 cm.

The first phase of the performance evaluation was set up as trials where the exact location and depth of the targets were known by the personnel operating the sensors. The second phase was set up as a blind test. The exact place and depth of the targets was known only by the test leaders. During the trials a total of 200 sqm were scanned and 500 sqm during the tests. During the trials a total of 16 mines and 22 false alarms were scanned and during the tests 50 mines and 50 false alarms. The biosensor system took a total of 200 samples. During both test periods all equipment functioned stably.

The tests were carried out between July and September 2003. In the first stage the MD and GPR were mounted on a trolley and pulled along a well marked line. In the second stage of the tests the biosensor took samples over targets and non-targets.

Fig. 8 Trolley pulling

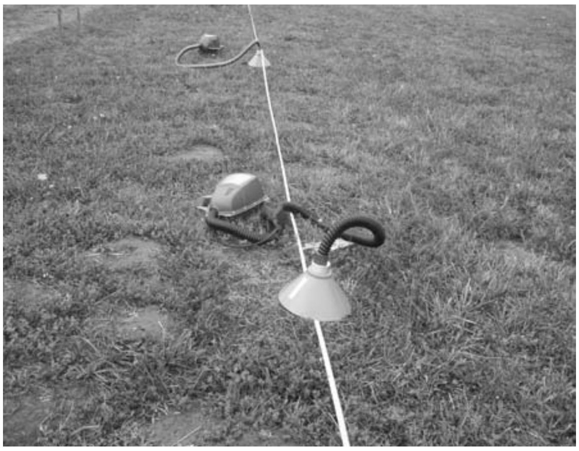


Fig. 9 Taking air samples

6. BOSNIAN PERFORMANCE EVALUATION RESULTS

6.1. MD and GPR fusion strategy and performance metrics

Previous performance evaluation of the MD and GPR during laboratory tests[1] led us to follow a fusion strategy which relied on the MD as the initial detector and the GPR as a sensor to reduce the false alarms from the MD. This was with the goal of keeping the PD of the system high while reducing the false alarm rate. The performance of an individual sensor or sensor combination is evaluated on the basis of the performance metrics in:

PD = (number of detected mines / total number of mines)
PFA = (number of false alarms / total number of mines
FAR = (number of false alarms / total area) (alarms/sqm)
FARA = (false alarm area / total area) (%)

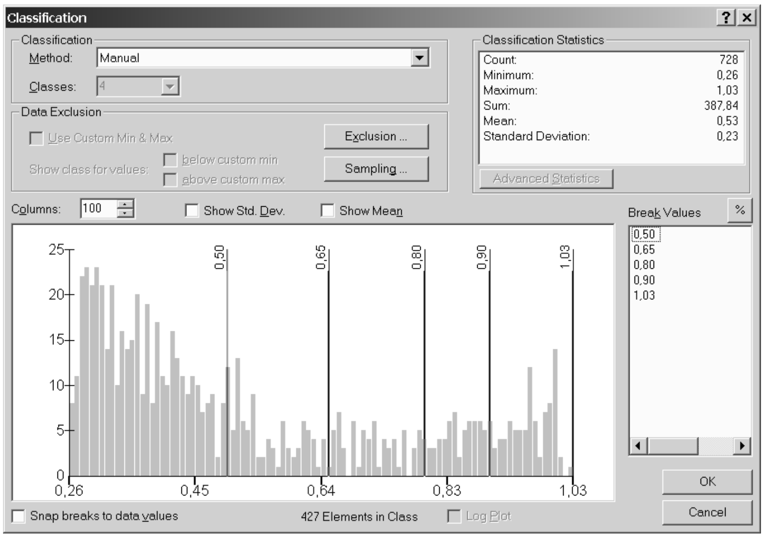
The function ***PD=f(FAR)*** (or ***PD=f(FARA)***) constitutes the Receiver Operating Characteristic (ROC) curves of the system. For each system version there is a characteristic ROC curve. Within each system version, there are one or a set of parameters governing the system sensitivity. Increasing the sensitivity increases the potential PD but also the FAR.

6.1.1. MD Performance in the trial area

The objects in Tab. 5 have been extracted from the Geographical Information System (GIS) of the data fusion system by using different thresholds. Thus, a threshold of 0.5 means that objects with values below 0.5 are removed. A threshold of 0.0 means that all objects will be shown. The thresholds used are derived from the ROC curves estimation calculated with the trial scans (Fig. 12).

Threshold	PD	PFA	FAR	FARA	Number of Alarms
0	**0,9375**	0,59	0,81	5,30%	449
0,5	**0,9375**	0,55	0,26	2,60%	200
0,65	**0,8125**	0,5	0,15	2,10%	150

Tab. 5 PD, PFA, FAR and FARA (PD Conf.: 95.0, PFA Conf.: 95.0, FAR Conf.: 95.0).



Classification

Classification

Method: Manual

Classes: 4

Classification Statistics

Count:	728
Minimum:	0,26
Maximum:	1,03
Sum:	387,84
Mean:	0,53
Standard Deviation:	0,23

Columns: 100

Break Values

0,50
0,65
0,80
0,90
1,03

427 Elements in Class

Fig. 10 histogram of MD values for the full trial area.

6.1.2. GPR feature used to reduce the MD alarms

The total number of GPR focalized features in the trial area was 11.617. In order to reduce this huge quantity of GPR objects, rules on the GPR feature attributes were applied providing compactness features used to reduce the number of GPR objects. Intersections between the remaining GPR objects and MD objects were then used to validate the MD alarms. This resulted in 732 GPR focalization objects in the trial area (and 4605 objects in test area). Fig. 11 shows the final MD objects and intersecting GPR objects in the trial area.

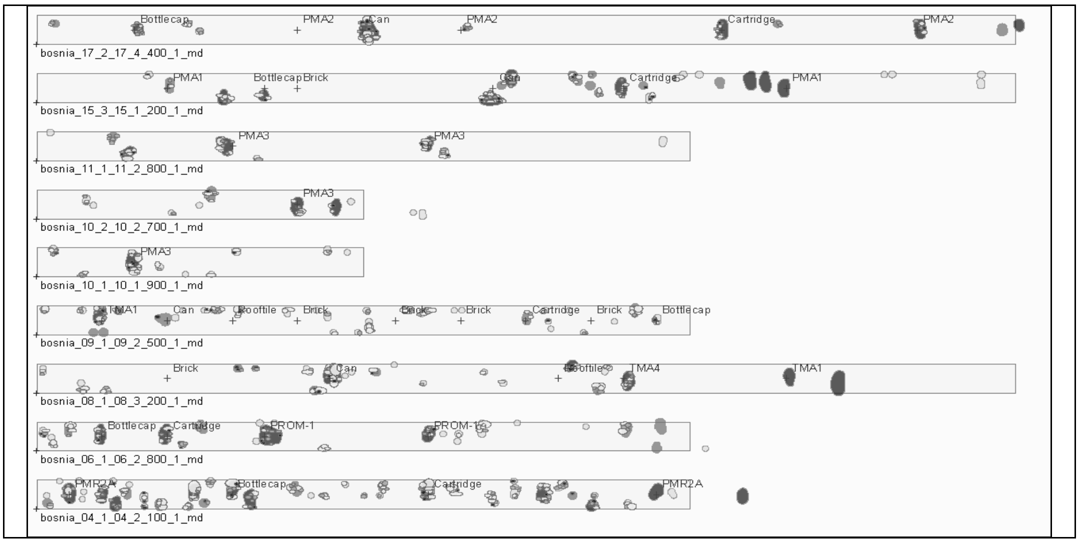


Fig. 11 Final MD objects and intersecting GPR objects in the trial area

6.1.3. Combined MD and GPR

Given that the MD is the primary detector sensor our strategy was to use it at the minimum sensitivity that would yield the maximum PD. On this basis the space for improvement could only come from a reduction in the FAR. Given the three points from the MD ROC in the trial area were:

Threshold>0.0: ROC: PD=0.9375; FAR=0.8126; FARA=0.05276
Threshold>0.50: ROC: PD=0.9375; FAR=0.2585; FARA=0.02638
Threshold>0.65: ROC: PD=0,8125; FAR=0,15; FARA=0.021

By using the threshold of 0.5 we kept a maximum PD for the MD with a reduced FAR. The GPR was then used to assess the objects between the thresholds 0,0 and 0,5 providing a system with a reduced FAR compared to the MD on its own with a threshold of 0,0, this is represented in Fig. 12 and Fig. 13.

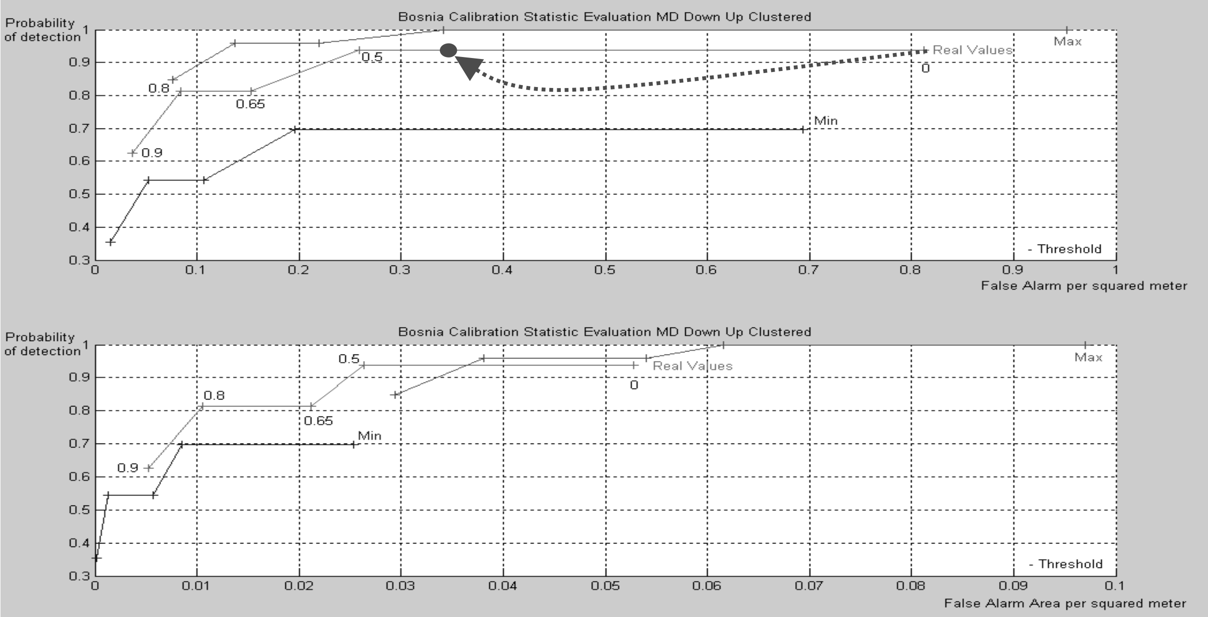
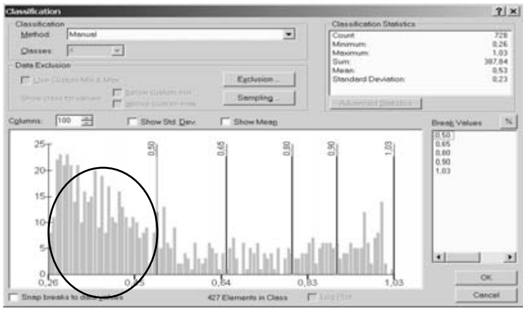


Fig. 12 DF ROC Improvement in trial area



Method: Manual
Columns: 100

Classification Statistics	
Count	728
Minimum	0.26
Maximum	1.03
Sum	387.84
Mean	0.53
Standard Deviation	0.23

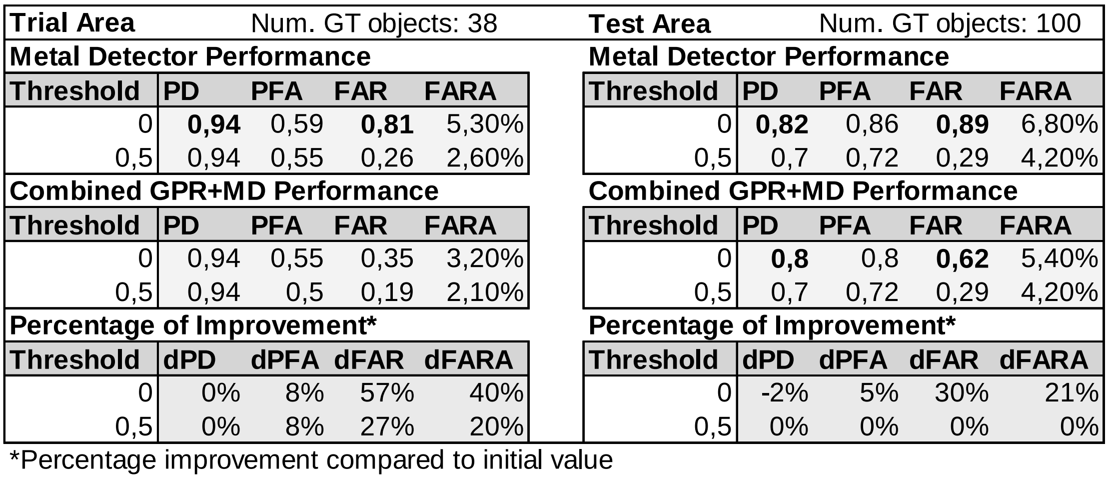
Break Values
0.50
0.65
0.80
0.90
1.03

427 Elements in Class

Fig. 13 The alarms highlighted are the MD alarms to be confirmed by the GPR between the threshold of 0,0 and 0,5

6.2. MD and GPR in blind test area

Following the strategy as highlighted in the previous sections we obtained the following results in the blind test area. 529 MD detections of which 218 were strong detections over the threshold of 0,5 and 311 below the threshold. Of the 311 combined with the GPR in order to reduce false alarms, 181 were rejected, leaving 348 alarms. The 348 alarms therefore consisted of the 218 direct strong metal detector alarms and the further 130 alarms confirmed by the GPR. Fig. 14 presents the results for the combined MD and GPR with data fusion for the trial and test area.



Trial Area	Num. GT objects: 38			
Metal Detector Performance				
Threshold	**PD**	**PFA**	**FAR**	**FARA**
0	**0,94**	0,59	**0,81**	5,30%
0,5	0,94	0,55	0,26	2,60%
Combined GPR+MD Performance				
Threshold	**PD**	**PFA**	**FAR**	**FARA**
0	0,94	0,55	0,35	3,20%
0,5	0,94	0,5	0,19	2,10%
Percentage of Improvement*				
Threshold	**dPD**	**dPFA**	**dFAR**	**dFARA**
0	0%	8%	57%	40%
0,5	0%	8%	27%	20%

Test Area	Num. GT objects: 100			
Metal Detector Performance				
Threshold	**PD**	**PFA**	**FAR**	**FARA**
0	**0,82**	0,86	**0,89**	6,80%
0,5	0,7	0,72	0,29	4,20%
Combined GPR+MD Performance				
Threshold	**PD**	**PFA**	**FAR**	**FARA**
0	**0,8**	0,8	**0,62**	5,40%
0,5	0,7	0,72	0,29	4,20%
Percentage of Improvement*				
Threshold	**dPD**	**dPFA**	**dFAR**	**dFARA**
0	-2%	5%	30%	21%
0,5	0%	0%	0%	0%

*Percentage improvement compared to initial value

Fig. 14 Field test data fusion improvement

According to the data as analysed so far, the MD/GPR detector did not detect 10 mines (8 AP and 2 AT) which results in a detection rate of 79% for AP mines and 82% for AT mines respectively 80% overall detection rate. 9 of these mines were seemingly not detected by the MD even with a threshold of 0,00. This result was initially surprising as we expected better results based on the measurements at the trial lanes and also from another batch of tests carried out in Spring 2003 at the Mine Test Field of the European Commission Joint Research Centre (Ispra, Italy)[1]. In the trial area a probability of 94% was measured. In order to exclude errors or mistakes, we re-checked the data and reconsidered the testfield. The test lanes were partially situated directly below a 250 KV power line. Power lines perturb the metal detector and reduces its sensibility. Thus, the mines could also be lost by this interference which is most critical at the edges of the array. By reviewing the data and the test lane positions we could detect that 7 of the lost mines were directly located under or close to the vicinity of the power line. In addition, we cannot rule out that one of the mine(s) is no longer present or did not contain metal. We are organising with NPA to verify all the missed mines can be located by a deminer with a handheld detector. This last point also highlights how close we were to a real field conditions.

6.3. Biosensor system in blind test area

The biosensor collection system took samples above 44 mines and 48 planted false alarms for GC analysis. Explosive was found at 8 positions, this is an equivalent PD of 19%. Explosive was also found above 5 planted false alarm positions, this is an equivalent PFA of 10%. The false alarms are unlikely to have occurred during handling or through contamination as 6 samples collected at an empty reference box were all negative, 8 samples collected 1m above the ground outside the field were all also negative as were 9 blank control filters handled in the teams car. Soil samples confirmed the presence of explosive at 2 false alarm objects where air samples were also positive. The biosensor collection system took samples above 45 mines and 50 planted false alarms for analysis with the biosensor analysis unit. Of the 45 samples above mines, 1 was detected. There were also no false alarms. The positive filter sample analysed by biosensor corresponds to positive samples both for air and soil analysed by GC (TMM-1). LoD of biosensor analysis unit in this series of samples was <2 ng TNT. The corresponding sensitivity for samples analysed by GC in above was 50 pg TNT.

7. CONCLUSIONS

The results in the project with the MD and GPR have validated the ability to reduce the FAR from the MD with the GPR while keeping a high PD. We were quite conservative in the thresholds we used in the field tests and believe that future tests and analysis could lead to a higher reduction in FAR. Market and demining operational cost analysis in the project (not presented here) has highlighted the possibility of the combined MD/GPR increasing demining operational performance but that the size of the market for humanitarian demining represents a considerable risk to the companies in this project for further product engineering. A fast and very sensitive fieldable biosensor analysis system for explosives has been developed. Explosive is however spread in minefields and from our findings there would seem to be no direct correlation between explosive amount collected and individual mine location. By this we mean explosive collected between mines is at a similar level to above mines and in some cases no explosive is collected above mines. In all minefields explosives were however detected. This means that on the basis of present technology and knowledge of explosive findings the biosensor would not seem to be suitable as a confirmation sensor. As explosive was however always collected in minefields the sensor is however still very promising as an area reduction sensor. The BIOSENS project is trying to develop operational procedures for area reduction / marking the boundaries of minefields.

A number of the sub-systems or component results developed in this project can find direct application in homeland security applications. The results with regards to the biosensor collection and analysis system are being directly implemented into BAAB's core drug detection technology and will be the basis for an explosive detection system for airports and general security to be launched in 2006-7. The UWB technology is capable of gathering a great deal of information in application scenarios due to the large bandwidth which results in high spatial resolution. Furthermore, the stimulation band is usually placed at low central frequencies so that the waves can penetrate most materials and are difficult to detect. One security application is for example through wall radar for the law enforcement and rescue services. The generic and flexible data fusion system may also be applied for example in hazardous process or situation monitoring.

8. DISCLAIMER

The information appearing in this document has been prepared in good faith and represents the opinions of the authors. The authors are solely responsible for this publication and it does not represent the opinion of the European Community. Neither the authors nor the European Community are responsible for any use that might be made of data including opinions appearing herein.

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10. REFERENCES

1. S.Crabbe, J.Sachs, G.Alli, P.Peyerl, L.Eng, R.Medek, J.Busto and A.Berg; "Recent Results achieved in the 5th FP DEMAND Project"; *EUDEM2-SCOT-2003, International Conference of Requirements and Technologies for the Detection, Removal and Neutralization of Landmines and UXO*; H.Sahli, A.M. Bottoms, J.Cornelis (Eds.), Volume II, p.617-625, VUB-ETRO, Brussels, 2003.

2. S. Sensani, A. Sarri, R. Cioni, G. Alli: "A combined measurements and simulation based design of a novel polarimetric array for de-mining applications", *AMTA 2002 Conference Proceedings*; AMTA, Tiburon 2002.

3. A. R. R. McAslan and A. C. Bryden: "*Humanitarian demining in SE Europe, An analysis of capability shortfalls and user needs*" Geneva International Centre for Humanitarian Demining, Geneva, 2000.