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RECENT RESULTS ACHIEVED IN THE 5th FP DEMAND PROJECT

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Abstract

The DEMAND project is sponsored by the European Commission in the fifth framework programme. This paper describes the background which led to the initiation of the DEMAND project. It goes on to describe the technical concept behind the project. Technical results are then provided to illustrate the breakthroughs achieved for each of the main sensors in the project; metal detector array, ground penetrating radar and biosensor as well as the data fusion system. The most recent results from the testing of the sensors are presented as is an overview of operational procedure tests. The paper concludes with an overview of how the technology may be further exploited especially for humanitarian demining.

1. Introduction

DEMAND is an acronym for the correct title of the project: "*Enhancement of three existing technologies and data fusion algorithms for the test and DEmonstration of Multi-sensor lANdmine Detection techniques*". It contains seven partners from five European countries, commenced in February 2001 and is scheduled to be completed towards the end of 2003. The project has been able to increase the state of the art for the three sensor technologies in the project: metal detector array, ground penetrating radar and biosensor explosive detector as well as implementing a novel generic data fusion approach. The system is currently undergoing tests in near real field scenarios. This paper will provide an overview of the background which led to the initiation of the project, the results which have been achieved the further tests which are planned and the preliminary conclusions with regards to the implementation of the project results in humanitarian demining operations.

2. Background leading up to DEMAND

The DEMAND project was submitted to the European

Commission in 2000 as a result of a Call published within the Information Society thematic area of the European Union's 5th Framework Programme. The call targeted technology for humanitarian demining for the South East Europe Stability Pact Region. In preparing the project concept the project partners sought to help provide a way towards a solution in answer to the requirements highlighted in the report, "*Humanitarian demining in South Eastern Europe, An analysis of capability shortfalls and user needs"* from the Geneva International Centre for Humanitarian Demining (GIHCD). The project partners were also able to integrate knowledge which had been gained from the EUREKA project entitled ANGEL as well as state of the art radar technology, the concept for which had been proved in the previous 4th Framework DEMINE project, also fed into the conceptual planning.

3. DEMAND development concept

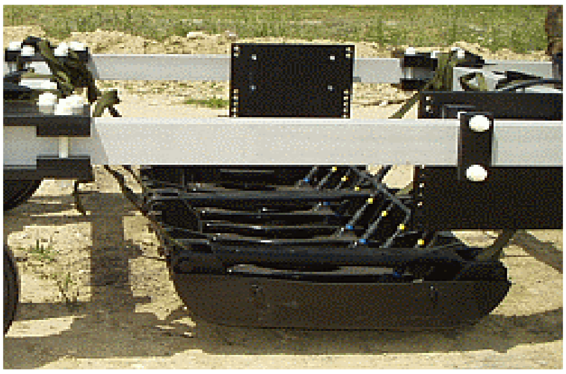
The partners initializing the DEMAND project saw the potential of combining three advanced sensor technologies with data fusion to provide a tool for humanitarian demining which could show that advanced technology is able to carry out demining in a safer and more effective way than present demining techniques. The basic idea is that knowledge from three sensors enhanced with data fusion can reduce false alarms. However, as every practical deminer is at pains to point out, the use of technology for safer and effective humanitarian demining is dependent on operational procedures. The work in the project includes a series of tests to assess operational concepts proposed at the beginning of the project. An assessment of the performance of the system in the near real field tests will provide a basis for proposing detailed operational procedures. Extensive evaluation and tests will be required after the end of the project to bridge the gap between research and development and actual operative demining. The system performance assessment will provide a basis to assess the economic effectiveness of an implemented system. This is a key issue with demining organizations reporting costs as low as €0,1 per sqm in SE Europe.

4. Sensor Technologies

In what follows we provide an overview of the sensor technology developments in the project.

4.1. Metal Detector Array (MD)

The basic metal detector technology which was chosen for the project was the commercially available VAMIDS system available from the company Schiebel Elektronische Geraete. Development work in the project has provided for i) increased sensitivity under noise conditions, ii) increased detectability of small targets and iii) support for an arrangement of stacked coils. The signal input of the system has been increased by over 20%, the S/N ratio increased from 7.5 dB to more than 10 dB and low frequency noise is also rejected by the system.

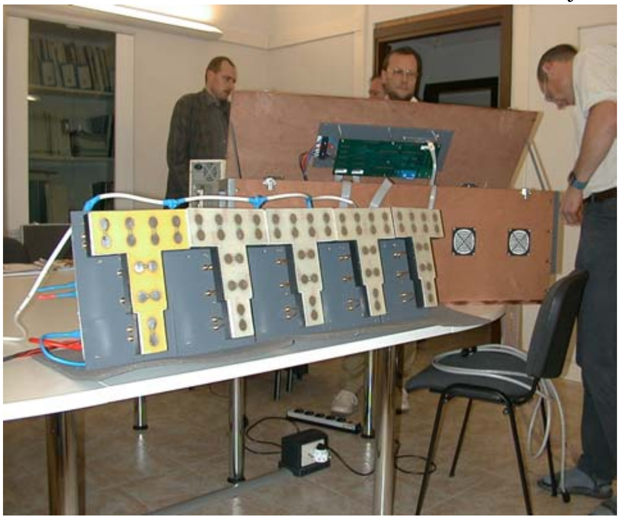


The figure shows the metal detector on the DEMAND test vehicle.

4.2. Ground Penetrating Radar (GPR)

The ground penetrating radar technology which was chosen for the project is based on radar electronics using the MLBS or M-sequence technique from MEODAT GmbH. IDS S.p.A. provides the antenna and signal processing solution. These two companies together with the Technical University of Ilmenau have worked together to construct the radar solution. A 15 Tx - 20 Rx full polarimetric linear antenna array has been constructed in the project.

The figure shows one DEMAND radar module. Five such modules are used in the radar array.



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

The antenna bandwidth (-10 dB) is 4 GHz and the GPR range is equivalent to 2.5 cm in e=9 soil.

4.3. Biosensor

The biosensor technology chosen for the project is that developed by Biosensor Applications AB. This technology is based on a novel Quartz Crystal Microbalance (QCM) weight loss technology and advanced surface chemistry. The biosensor system has two main components, the sample collection system and the analysis unit.

The figures show the main unit from the sample collection system which may be carried in a similar manner to a backpack and the use of a sampling probe.

The figure shows a prototype biosensor system used in DEMAND.

The biosensor system used in DEMAND is a TNT detection system. Its sister project BIOSENS also partly funded through the European Commission has the goal of improving the DEMAND biosensor analysis system to also be able to detect the explosives RDX and PETN. Traces for TNT, RDX and PETN may be analyzed simultaneously by the technology. Analysis time for the sensor is at present 2,5 minutes. The sensitivity of the QCM sensor technology is approximately 2-10 pg TNT/μl.

5. Data fusion (DF)

GTD from Spain is the partner responsible for developing the data fusion system in the project, the concept for which was one of the results from the EUREKA ANGEL project mentioned earlier. The DF system represents a generic and flexible solution for the fusion of heterogeneous data (spatial and non spatial) coming from the sensors on the platforms, and also from human knowledge available from domain experts.

6. Performance Evaluation of the system

6.1. JRC Tests in May 2003

(Tests are planned for May 2003. This section will include a description of tests and results.)

6.2. Biosensor Tests in Croatia in May 2003

Introduction: The first field tests in Croatia of the Biosensor Analysis Unit were performed in February 2003. It was found that although the instrument was working it was not stable enough to perform satisfactorily under field conditions. After several improvements of the instrument design and cell chemistry the performance was increased. In laboratory conditions the instrument has been shown to be able to perform reliably when analysing filters to which 10 ng of TNT had been added. Blank filters (containing no TNT) normally do no not cause false alarms. In the end of May 2003 we performed a second field test of the instrument in Croatia analysing both blank filters, filters with added TNT (10 ng) and filters collected over mines.

Instrumentation: The complete equipment consists of the sample collector and the biosensor analysis unit. The collector runs a a speed of 150 liters/min. Single use filters are used both for sample acquisition and standard control of the analysis unit. The analysis unit holds 4 cells equipped with crystals for TNT. Data analysis is performed by the internal CPU of the analysis unit but during the development phase an external computer is connected to allow for visual inspection of the signals from the cells. The analysis time for a filter is 90 seconds.
In some collections a double-filter holder was used. This permits analysis by both the biosensor analysis unit and by a GC-μECD system. The GC-μECD system has higher sensitivity than the biosensor system. It also permits quantitative analysis of TNT on filters but requires more elaborate and time consuming sample preparation and can not be used in the field.

Initial performance test: Initial performance of the analysis unit was tested at the Hotel Villa Nico just outside Zadar. 6 filters to which 10 ng of TNT had been previously added and 1 filter to which 10 ng of 2,4-DNT had been previously added were analysed. Of the 6 filters to which 10 ng of TNT had been previously added all gave positive response on all 4 cells. Also the filter to which 10 ng of 2,4-DNT had been added gave rise to positive response on all 4 cells. This showed that the biosensor analysis unit was performing satisfactorily at the 10 ng level with a PD of 100%.

Analysis of filters collected above a mine: Collections above a mine (anti tank; TMA5) were performed using a double-filter holder. A collection time of 6 minutes was used. A total of 9 collections at positions above and around the mine was performed covering a surface of 60x60 cm. A collection was also performed at a position with no mine. For each collection one filter was analysed on the biosensor analysis unit at the hotel and the other filter was saved for later analysis in a GC-μECD system. During the analysis with the biosensor analysis unit the biosensor sensitivity was checked by also analysing a total of 5 filters to which 10 ng of TNT had been previously added. Also a filter containing no TNT was analysed. None of the 9 filters collected on and around the mine position nor the filter collected above a no-mine position gave rise to a TNT/DNT indication when analysed on the biosensor analysis unit. All 5 filters to which 10 ng of TNT had been previously added gave rise to positive indications. These TNT-containing filters were analysed at the start; after about every 3'rd collected filter and at the end of the test series to certify that the performance of the biosensor analysis unit. The absence of TNT indications above the mine when filters were analysed by the biosensor analysis unit is not unexpected. Previous tests with the collection system at the test field has indicated the presence of very low levels of TNT above mines when filters were analysed by GC-µECD. At best 5 ng of TNT has been discovered. During the tests in May at the Skabrnje test site the wind was perhaps too strong. The efficiency of collection as well as the presence of TNT at the surface above a mine may not be optimal when winds are strong. We are awaiting the analysis of the accompanying filters by GC-µECD to see the actual amount of TNT on the collected filters. Until this analysis has been achieved it is difficult to draw detailed conclusions about this test.

Performance at field test site: A series of filters were also analysed at the test field site at Skabrnje. The biosensor analysis unit was set up inside a container at the site and a total of 10 filters to which 10 ng of TNT previously added were analysed. The 10 filters containing 10 ng of TNT that were analysed in the container at the filed test site all gave rise to positive indications on the biosensor analysis unit. This shows that the biosensor analysis unit basically performs also at the test field conditions.

A large number of samples above and around mines were collected for analysis by GC-µECD and have not been analysed at the time of writing. If the amount of TNT collected on these filters is found to be above the sensitivity of the instrument we can draw the conclusion that the biosensor will certainly be useful for fast on site analysis.

7. Operational Procedures

The DEMAND system could be potentially used in a number of demining operations, including supporting mechnanical demining and for Quality assurance. In what follows we describe two possible procedures.

Procedure 1: Close in detection

This procedure would be used at areas confirmed to be mined. The borders of the minefields are known by technical surveys, e.g. area reduction, and the whole must area be cleared. For the safety of the operators and of the DEMAND-equipment, the procedures will be the same whether it is a low-density or a high-density minefield.

1. The ground will first be controlled by MD and GPR.
2. All alarms must be evaluated if the GPR and MD can not discriminate the alarm as false, the Biosensor must verify existence of TNT or classify the object as a false alarm.
3. If the alarm is verified as a mine, it must be marked out. Before going further on that lane with the DEMAND-equipment, the mine must be destroyed or removed. If the mine is destroyed in situe, one must be aware that the biosensor will not be useful in the surrounding area.
4. Each lane must be well marked so that the operators know exactly where the border s are between the safe area (cleared) and minefield.
5. When the next lane is started an overlap of for example 10 cm is recommended.

Procedure 2: Area reduction

This procedure will be used at areas which are suspected but not confirmed minefields. It can also be used as a technical survey method to reduce the suspected area and to find the borders of minefields.

1. The same procedure as in "close in detection" point 1-4 is used except that the mine must not be destroyed or carried away. This provides safety for the operators of the DEMAND-equipment.
2. In case no mines are found the Biosensor collects air samples in steps of x m. One filter will

represent x m of the lane.
3. If a filter proves to contain TNT this lane will be closed at the point where the sample was taken.
4. A new lane will be cleared x m away from the last.
Today it is unknown how far from a mine Biosensor will be able to detect a mine. This is the reason why x m is mentioned above, instead of an exact figure.

It should be noted that the greatest benefit that a DEMAND system is believed to offer is a reduction on false alarms. If the system is however used as primary detection method this benefit will only be obtainable if a demined area is not expected to be also metal free.

8. "Real Field" Test Plan in Bosnia

During the second half of 2003 system tests will be carried out at Norwegian People's Aid test and training facilities at Raljevo just outside of Sarajeo in Bosnia. The "Real Field" Test Plan has been designed in order to provide the basis for the final evaluation of the DEMAND system i.e. evaluate technical progress made in the project and to give the project input for further system iteration. The test campaign will be set up as a mine localisation/ identification probability test. In the test area there will be both AP/ AT-mines containing explosives but disabled and also false alarms clutter objects). The ground conditions in the test field are well known and most similar to grassland.
The test will focus on "close in detection" with the MD and GPR first to locate objects and reduce false alarms, secondly the Biosensor will verify if the objects contain TNT or reduce them as false alarms. Before the tests take place the sensors will be calibrated in an area with similar targets to the test area. The first part of the tests will be set up as trials, where the exact place and depth of the targets are known by the personnel operating the sensors. This in order to provide more data to let the system "learn" before it is tested. Following these trials tests will be undertaken where the personnel operating the system do not know where the targets are. The number of targets will be approximately 50 mines (Original HE and substitute detonators) and 50 false alarms.

9. Exploitation of the results

The key concept behind DEMAND is as mentioned previously to show that an improvement on state of the art technology can achieve better accuracy than current APL detection techniques used in the field for close in detection while considerably increasing speed and decreasing false alarms. The technical work in the project has resulted in a prototype system composed of a simple trolley like platform with three enhanced sensors, i.e. Metal Detector, Ground Penetrating Radar and a biological vapour sensor (Biosensor), whose measurement results are strengthened through Data Fusion. The limiting of the mechanical integration of the system to a minimum was seen as a crucial factor to keep the resources for the project focused on the key technological issues to reach the above mentioned objectives. The main tasks of integration have been those connected to Data Fusion and developing of the survey strategy and performance evaluation parameters. The system performances will be initially evaluated in field tests in Bosnia. Only with good test results in terms of both detection performance and potential cost effectiveness will the project partners be able to press ahead with engineering of a DEMAND system for humanitarian demining. Less than good results in terms of detection or cost effectiveness will put a question mark over the exploitation of the project results as a complete system. Nevertheless, the individual sub-system and component results which have already been achieved in the project will be and in some cases are already being successfully exploited.

10. Summary and Conclusions

This paper has presented the conceptual reasoning behind the DEMAND project. It has also described the key sensors and data fusion system implemented and the breakthroughs achieved. Recent results from JRC tests have illustrated the ability for the combined metal detector and ground penetrating radar to reduce false alarms. The results of tests with the biosensor have also shown its sensitiveness to TNT. We have provided an overview of an operational concept and described how we intend to test this in Bosnia later in 2003. The opportunities for the exploitation of the project results have been described in particular with regards to humanitarian demining.