Detection Technologies and Systems for Humanitarian Demining: Overview of the GICHD Guidebook and Review of Conclusions

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The GICHD Guidebook on Detection Technologies and Systems for Humanitarian Demining (`http://www.gichd.ch/1248.0.html`) presents a schematic, non-exhaustive overview of several landmine detection and area reduction sensing technologies and systems for humanitarian demining. The operating principle of each technology is presented first, followed by a schematic summary of the possible application type, the strengths and limitations, the potential for humanitarian demining, and the estimated technology readiness. Specific systems are described in terms of the R&D programmes, the present specifications and available results. Where possible the Guidebook focuses on the most promising developments. The Guidebook concludes with a first analysis of: (i) the general lack of progress from R&D to field use and reasons for failure, (ii) some of the most notable developments during the past 10 years, as well as (iii) a brief analysis of the individual technologies and systems featured. The Guidebook can be ordered free of charge from the previously indicated GICHD Website.

1. Introduction and Overview

The aim of the Geneva International Centre for Humanitarian Demining (GICHD) **Guidebook on Detection Technologies and Systems for Humanitarian Demining** [1] (`www.gichd.ch`, `http://www.gichd.ch/1248.0.html`) is to provide the mine action community, and those supporting mine action, with a consolidated review and status summary of detection technologies that could be applied to humanitarian demining operations. **The Guidebook can be ordered free of charge from the previously indicated GICHD Website**.

The Guidebook presents a schematic, non-exhaustive overview of several landmine detection and area reduction sensing technologies and systems for humanitarian demining. These systems have been selected according to their development and test and evaluation status. The *operating principle* of each technology is presented first, followed by a schematic summary of the possible *application type, the strengths and limitations, the potential for humanitarian demining (HD), and the estimated technology readiness.*

The *potential for HD* has been mostly evaluated with respect to the mainstream applications within humanitarian demining. The *technology readiness* estimation is a qualitative measure based on the known state of advancement of R&D, the demonstration of detection capabilities useful for humanitarian demining, as well as the demonstration of building a practical system.

Specific systems are described in terms of the research/development programmes, the developers, the present specifications and available results. Where possible the *Guidebook* focuses on the most promising developments (high Technology Readiness Level – TRL – value, evaluated for HD applications, and recent systems), complemented by information on a few less mature systems, particularly when this was deemed necessary to illustrate a specific detection approach.

It is however worthwhile to point out that, while an increasing TRL number indicates that the technology is maturing and progressing towards a fieldable system, even a relatively high TRL obviously does not present a guarantee that this will ever happen, nor that the resulting system would be really useful in a humanitarian demining context (for example, because, although effective, it is not sufficiently efficient).

2. Notes

A number of ground penetrating radar (GPR) systems presented in the *Guidebook* are components of multi-sensor systems. In the *Guidebook* we concentrate only on GPR while providing basic information on the other sensor(s) used with it. Further information on metal detectors may be found in the *Metal Detectors and PPE Catalogue 2005* published by the GICHD.

It should also be noted that although the emphasis in the *Guidebook* is on sensor technologies, a substantial contribution to improving the efficiency of the demining process has come from Information and Communication Technologies (ICT), such as information management (e.g., IMSMA – Information Management System for Mine Action) or positioning systems (global positioning system [GPS], differential GPS [DGPS]). In future we can expect to move towards a coherent framework in which all available information over a given area is integrated and used, with ICT such as integrated geographical information system (GIS) environments, image interpretation methods and decision-support systems playing a prominent role [2].

Finally, given that the *Guidebook* is easily available and free of charge, we prefer in the following to review some of the most relevant conclusions, and refer to the full publication for details on the individual technologies and systems.

3. Review of Conclusions

Over the last 10 years considerable funding and effort has been invested worldwide in order to develop new technologies for humanitarian demining. A first analysis of the general disappointment that only few of these technologies have progressed quickly from research and development to field use points to:

(i) the complexity of the problem, including environmental and operational aspects;
(ii) the mismatch between research ideas and application requirements in the field, and
(iii) the significant non-technological problems in funding the resources to turn prototypes into fully tested commercial products ready to use in the field.

The GICHD *Guidebook* is an attempt to present and summarize emerging sensing technologies and systems, not only for close-in landmine detection but also for area reduction, which could be applicable to humanitarian demining operations. Systems which seemed to be primarily targeted at defense applications have in general not been included. However, it is acknowledged that military detection requirements are moving to some extent towards those expected for humanitarian demining. It is therefore possible that such systems could find application, in a suitably modified form, in humanitarian demining scenarios, or at least in peace-keeping operations. This is particularly true for sensing platforms aimed at road clearance, where the R&D drive is mostly coming from the defense sector.

Profiting from the developments in the military sector is on the other hand less likely for technologies and systems where military and humanitarian requirements show less overlap. This could be the case for example for simple contact seismic/acoustic systems, which are probably less acceptable in military scenarios and therefore subject to relatively little funding.

3.1. Summary of Developments

Although a host of physical principles have been investigated to detect landmines, only electromagnetic-based technologies, in particular enhanced metal detectors and ground penetrating radars, have seen significant advances and are being introduced into the field. Test results consistently confirm that some of these technologies can indeed increase the productivity of humanitarian demining, while at least maintaining the current high levels of safety. Several development groups have shown this is the case for the combination of a metal detector with ground penetrating radar. The first such combined system, the AN/PSS-14 (the military version), has now been fielded and others are expected to follow in the short term, such as the VMR1- MINEHOUND (see the corresponding descriptions in Ref. [1]).

3.2. Individual Technologies and Systems

Concerning the individual technologies and systems featured in the Guidebook, from the analysis of the technology readiness one can conclude the following:

3.2.1. Electromagnetic-based Systems

Metal detectors are definitely better now than 10 years ago (higher sensitivity, improved ergonomic design, man-machine interface and soil signal rejection). Enhanced metal detectors (MDs), for example with discriminatory capabilities, show interesting potential but are still fielded only in small numbers, for example on vehicle-based systems for “wide area detection”.

Ground penetrating radar technology reached the stage of production and intensive testing, and some deployment in the field. These developments did definitely profit from the expertise gained from other applications of GPR (such as non-destructive testing and subsurface sensing), the well known basic theory and limitations, as well as the operational use. Most of the GPR systems being developed or used are combined with metal detectors and employed as confirmatory sensors. Combined MD and GPR systems are nowadays used as hand-held or vehicle-mounted systems. Most of the presented vehicle-based systems are in a stage of testing for applications such as road clearance, and moving from prototype to real production could take a few years for some systems (Japan, US).

3.2.2. Trace Explosive Detection

Great progress has been made in this domain, with several systems being tested and available as pre-production units. Rather than the pure performance of the sensors themselves, the main problem seems to lie with their use within an appropriate operational procedure, deciding whether to employ them either as area reduction sensors, or in selected scenarios for confirmation purposes, or still as training or benchmarking tools in combination with mine detection dogs, taking in due account the sampling issue and the influence of environmental parameters. Answers are likely to be forthcoming once there will be a clear commitment from donors and end-users for extensive testing. Much more R&D seems to be appropriate, given the potential impact of this type of systems, such as being able to declare an area free from explosives.

3.2.3. Bulk Detection Systems

The possibility of directly detecting a macroscopic amount of material, and possibly of classifying it as explosive, is *per se* quite appealing. In practice two routes have been taken, either by employing radiation capable of penetrating the soil (and the mine case), typically using neutrons and/or x rays or gamma rays, or electromagnetic radiation capable of being highly compound specific (nuclear quadrupole resonance –NQR– systems, which present no radiation danger).

A number of problems have been encountered, related for example to the one-sided sensor configuration, the reduced amount of explosives in small anti-personnel (AP) mines and/or the depth of anti-tank (AT) mines, and the need for appropriate and often intense (neutron) sources and corresponding detectors to detect the weak and/or complex return signals.

Concerning penetrating radiation systems, no breakthroughs seem to have occurred, although selected applications are possible, such as for the confirmation of AT mines on roads, or for the characterization of the contents of unexploded ordnance. R&D investments seem to have been substantially reduced in this area. Time will tell if new versions of existing systems, e.g., neutron moderation, will find their way. NQR is still being pursued by a number of research groups, trying in particular to surmount the TNT[1] detection problem for small buried anti-personnel mines, and to quantify exactly the minimum amount of detectable explosive.

Significant R&D and test and evaluation seems to be still required to get to a fieldable system, which would however have the great advantage of really being sensitive to a physical parameter characteristic of a mine, i.e., its explosive content (for non-metallic mines).

[1] Trinitrotoluene, one of the most widely used military explosives, and quite common in landmines.

3.2.4. Remote Sensing

These systems are based on off-the-shelf opto-electronic technologies, ranging from visible to thermal infra-red and multispectral sensors. They have the characteristic that they could be mounted on vehicles, or on airborne platforms, and used for area reduction. Airborne survey in particular is shifting from experimental towards "production survey": a *coherent framework emerges* with opportunities for improvement, both on the sensor (e.g., polarized infrared cameras) and on the software side (e.g., integrated global information system environments, or image interpretation methods). It involves the total use and integration of all available information over an area – aerial and satellite multimodal data, ground surveys, interviews and local knowledge about land use – ranging from small-scale to large-scale, from the past to the present status. The means to obtain all this information are generally known, whereas the integration and structuring schemes are emerging and being validated, often in collaboration with national mine action centres.

3.2.5. Other Detection Principles

The other detection principles illustrated in the Guidebook, in particular seismoacoustic (which has seen a substantial increase in interest level during the past 10 years), have shown potentially interesting R&D results, which should be turned into test and evaluation criteria. A collaboration between developers and end users would allow to clarify the potential, the operational use as well as the developments to be undertaken.

Increased efforts are also being allocated to better understand the soil influence and environmental limitations, which do represent in many cases the limiting factor. These aspects were unfortunately somewhat neglected in the past.

3.3. Concluding Remarks

From a general point of view we can summarize some of the most notable developments which have taken place in humanitarian demining sensing related R&D during the past 10 years with: (i) an increased understanding of the problem, (ii) a shift from a focus on the individual sensor as a solution towards the individual sensor as part of a set of tools, (iii) an increased emphasis on area reduction and the detection of minefield indicators rather than individual mines, (iv) an increased emphasis on trace explosive detection, (v) the gaining of importance of systematic test and evaluation (in particular via the International Test and Evaluation Programme, ITEP).

Finally, expanding on what was discussed at the beginning of this section we note that in a number of cases demining related developments have been terminated or at least put on hold[2]. This is usually due to a combination of factors such as:

- insufficient funding or system performances,
- incorrect evaluation of the problem and/or excessive expectations on the system performance (due for example to lack of precise equipment specifications, lack of precise benchmarks and/or a baseline to which new technology has to be compared),
- focusing on the wrong target application,
- lack of communication between the concerned actors, or
- a re-evaluation of the expected return on investment.

With respect to the latter, without going into a detailed market analysis, it has become clear in the past years that the market for humanitarian demining sensing technologies and systems is nowhere as large as initially assumed. Other markets, such as security, are likely to draw the largest share of the sensing equipment developers attention, together with military mine clearance, where investments are likely to continue to be relevant in the years to come[3]. The landmine problem is, however, far from solved and landmine detection and area reduction are still the most important elements in the humanitarian demining equation. Research and development of practical detection technologies and systems that are appropriate for humanitarian demining, duly taking

[2] Applications in other domains, such as non-destructive testing, remote sensing or security, might however very well be pursued and in turn be profitable to humanitarian demining in the future.

[3] Similar arguments are likely to apply to UXO detection vs. the military requirements for range remediation.

into account the lessons learned and the developments outlined in this section, continues therefore to represent one of the most significant contributions to the solution of the landmine problem.

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REFERENCES

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