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Roadmap for Mine Action Robotic Technology Development

Pedro Santana
Integrators for Robotic Systems

António Mestre
Integrators for Robotic Systems

José Barata
New University of Lisbon

Luís Flores
Integrators for Robotic Systems , S.A

Country and Technical Surveys, which are carried out before clearance activities start. The STEMD project should provide enough empirical data to study the possibility of extrapolating detector performance under different conditions and recommending detectors for particular targets under those conditions.

Conclusion

The STEMD project now is well under way and already has returned useful data. A substantial body of laboratory results has been collected and the first field trial has been completed. From this data, it is possible to compare the performance of the individual detectors in the key areas of interest, including maximum detection depth for various targets, soil compensation ability and probability of detection as a function of depth. It is also possible to compare the large-head detectors as a group to the small-head detectors as a group. The next field trial in Mozambique is scheduled for April 2005 and will focus on detection capability tests for AP mines of interest there. The third field trial in southeast Europe is scheduled for the summer of 2005. After STEMD, trials of the emerging ground-penetrating radar/metal detector dual sensors are planned under the title "Test and Evaluation of Dual Sensors" (TEDS). ❖

See "References and Endnotes" on page 108

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Contact Information

D. M. Guelle and A. M. Lewis
Sensors, Radar Technologies and Cybersecurity Unit
Institute for the Protection and Security of the Citizen
EC Directorate General JRC
TP 723 Via Enrico Fermi 1
Ispra (VA) 21020 Italy
Tel: +39 0332 785576, 785786
Fax: +39 0332 785469
E-mail: Adam.Lewis@jrc.it
Website: http://serac.jrc.it/tethud

Roadmap for mine action robotic technology development

by **Pedro Santana and António Mestre** [IntRoSys, S.A.]
José Barata [New University of Lisbon] **and Luís Flores** [IntRoSys, S.A.]

This paper presents some of the AMI-02 project preliminary work. The project is being developed by Integrators for Robotic Systems (IntRoSys) with funding from the Portuguese National Defence Ministry. The strong bond between Portugal and some African countries (i.e., former Portuguese colonies) is the main drive for the application of this project.

African countries are usually underdeveloped, requiring a sustainable approach to the mine action (MA) problem; in fact, the MA community shifted from a number-based approach to an impact-based approach,[1] targeting the locals' priorities.[2] This means that the success of a demining campaign is not measured by the quantity of demined land but whether its output is used by the community,[3] which has other problems besides landmines, such as starvation. In this sense, research and development (R&D) and technology applied to this specific domain should address this concern. Thus, the motto of this paper is to provide analysis, design and template tools to attain sustainable development.

Problem Definition

Unfortunately, as it will be shown below, demining is spread in both time and space, resulting in a high number of opportunities for the application of technology in demining operations. However, an incorrect assessment of the available opportunities in a given scenario for the application of a certain technology may end up in non-acceptance of the referred technology. Taking this into account, this section contributes a catergoristation of opportunities in a three-dimensional framework, composed of a temporal, a geographical and an economic component.

Temporal component. The temporal component can be described in terms of the different phases of an MA process, which are as follows:

1. Conflict and immediate post-conflict (humanitarian emergency)
2. Post-conflict (reconstruction)
3. Development (development assistance)

The different characteristics of each phase require different approaches; for instance, during the first phase, the international community is usually impelled to contribute strongly, empowering high-tech applications. In long-term phases, low-cost, simple and locally available resources for demining are required. However, for specific commercial applications (e.g., clearance of primary roads), there should be enough incentives to implement high-cost *nouvelle*—modern—solutions such as the one presented in the *International Conference on Requirements and Technologies for the Detection, Removal and Neutralization of Landmines and UXO* (pp. 32–40),[4] which defines a model of agricultural exploitation in which the machinery is mine-resistant and therefore exploration of the land can be carried out even in the presence of the mine risk.

Geographical component. The geographical component can be categorized as follows:

- **Military actions.** Militaries are usually provided with high-tech tools; thus, they are potential buyers of technology.
- **Third-world affected countries.** The demining process has to be low-cost, locally maintained, and operated by local people trained and supervised by non-governmental organizations,[5] hindering massive use of high-cost technology. Nevertheless, high-cost approaches may be applied on area-reduction since there is less danger of damaging equipment and the total cost of performing close-in detection in a wide area may supersede the high-cost solutions for area reduction.
- **Developed countries as affected countries.** Countries that can better afford high-cost technology are interested in R&D programmes and high-tech solutions to handle today's problems, such as terrorism or internal conflicts.
- **Developed countries as humanitarian helpers.** The donor community provides training, logistical support and operational support to countries in need. In specific short-term situations, the application of high-tech tools may be attained.

According to the *Guide to the Procurement of Mine Action Equipment*,[6] the nature of the environment is also an important factor in the geographical component, and a set of improvements that would augment demining productivity in 12 operating scenarios has been identified.

Economic component. The economic component could have the following motivation: economic interests in third-world affected countries (e.g., clearing access to oil wells). In this case, economic interests may be enough to acquire high-tech equipment for fast demining. Market studies[7, 8] were produced, and the main conclusions are that humanitarian demining is not an efficient market. It is small and shrinking;[8] henceforward, the product's development usually requires direct or full funding.[7]

Demining Technology Development Roadmap

Previous work has identified opportunities[9–11] and guidelines for the development[12] and procurement[6] of technology applicable to the MA domain. IMAS 3.10[6] and "Demining Trends and R&D Challenges"[13] refer to close-in detection and area reduction as priority domains with significant benefits for demonstrating progress on R&D. It is important to augment mine-detection rates and mine detection accuracy and to reduce false alarms. The improvement of prodders, protection material, and comfort on the operations is also important, and is more intensively mentioned in *Deminer's Needs*.[10]

The following paragraphs introduce a set of recommendations to the development of technology (with special focus on robotics) for the MA domain. Due to the importance that both close-in detection and area reduction have, special attention is focused on them. Note that this roadmap is not claimed to be **the** optimum solution; it is a solution that increases the confidence in terms of technology acceptance in the minefield.

Cost and complexity. Usually, "high-tech" means high cost and high complexity, which are drawbacks when the technology is to be applied in a domain where people have little formal education, the danger of damaging equipment is high, and the sites are remote and hazardous, hindering easy maintenance and repair. Local equipment has the advantage of being low-cost, readily available and easily maintained or repaired; in fact, this equipment exists and is widely used,[14] and its use stimulates the local economy.

Suggested Actions

Suggestion 1: Focus should be on the part of the MA process to which robotics provide added value, i.e., where cost and complexity are minor factors in the overall performance.

Lessons learnt from previous unsuccessful attempts to produce robots for mine detection and/or removal usually have to do with getting them into the field or having them operate properly. Such difficulties are mainly due to their weight (intricate logistics), complexity (difficult maintenance and operation) and high cost (unaffordable by locals). Making them lighter would not be such a problem, but high cost is a reality of product development for small markets. The arising question is if reducing complexity reduces application. Sensible remote operations usually require intricate mechanisms. Therefore, complexity, high cost and remote operations do not go well with close-in detection; in fact, it has not been well-accepted in the past. The growth of machinery[15] (see "Landmines—Some Common Myths"[16] for a contradictory voice on the application of machines) used for area reduction, terrain preparation and post-clearance tasks indicates that high cost is accepted in these tasks. Although machines and respective logistics are expensive, machine-based demining can be more affordable than manual-based demining.

Suggestion 2: What history says, to some extent, is that area reduction is more receptive to high-cost technologies than close-in detection.

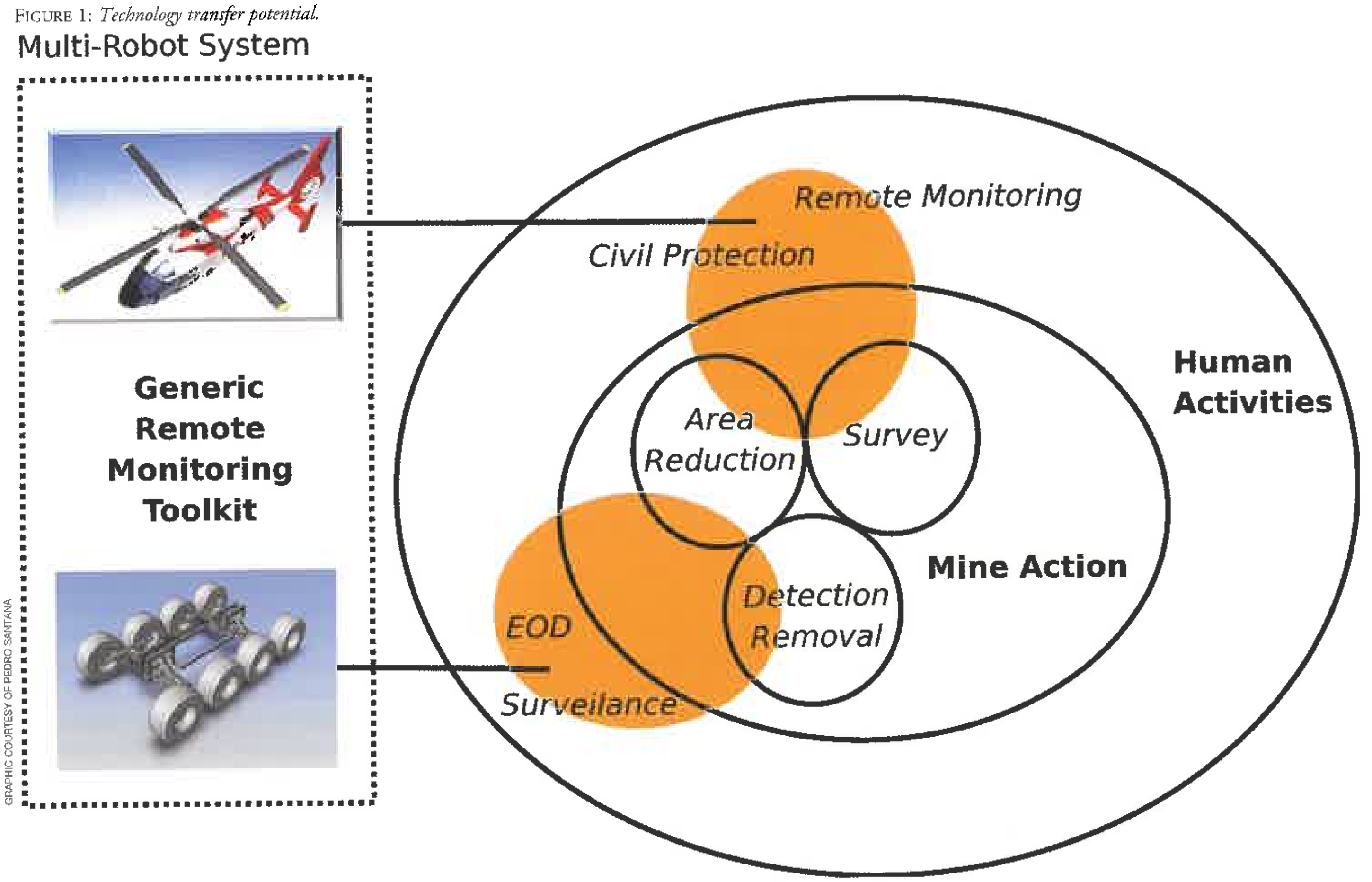
In life-threatening tasks such as detection and clearance, probabilities are something to be discarded as much as possible, giving place to (quasi-)deterministic approaches. Despite all R&D efforts in multi-sensor fusion and respective envisioned advantages (e.g., reduction of false positives), multi-sensor fusion remains unsatisfactory with respect to robustness;[2] moreover, field personnel are conservative regarding these innovations.

Due to these two factors, metal detectors and the man with a probe continue to be the current practices, since they are believed to be highly procedural and conservative approaches. Therefore, enormous effort would have to be put into reversing this tendency in the near future, reflected in *nouvelle* techniques with low probabilities of acceptance.

Suggestion 3: Focus should be mainly on the parts of the MA process in which probabilities and risk assessment are already taking place.

As mentioned before, the MA market is small and shrinking; its nature is not that of a regular market since end-users are not usually the buyers—donors are. Hence, a conventional product's life-cycle and return on investment is often hard to achieve.

FIGURE 1: *Technology transfer potential.*



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Suggestion 4: The product's development should be (at least) partially funded. In order to guarantee a return on investment, technology transfer should be attainable.

Area reduction is preceded by an Impact Study, which selects potential minefields and prioritizes the actions in terms of a set of socio-economic factors. Therefore, a set of assumptions about cleared land has already been made, which could be modelled with probabilities. Area reduction can be performed using machines, dogs and other methods that do not meet manual demining requirements. Once more, probabilities are in play. Thus, area reduction has tacitly embedded the concept of probabilistic risk assessment in its procedures.

Suggestion 5: Area reduction is, by its own nature and current practices, a probabilistic process. The justification for Suggestion 3 applies here as well.

Suggestion 6: Close-in detection tends to be a deterministic task, which is achieved by systematic and conservative (pessimistic) approaches.

An Architecture Proposal

From the previously derived set of suggestions, one can conclude that the task more prone to accept high-tech tools is area reduction. Paying special attention to Suggestion 4 (product's life cycle), it seems that technology transfer should be rewarded as much as possible. If one sees area reduction as a subset of remote monitoring, its solution could be applied to the following domains: civil protection, surveillance, remote environmental monitoring, law enforcement, etc.

Figure 1 depicts two possible main robotic applications and their extensions to domains beyond MA. A ground robot, for instance, can help in area reduction (e.g., carrying an odour sensor) and in detection and removal (e.g., carrying metal detectors). In addition, the same robot can be transferred to other domains, such as surveillance. Aerial vehicles can be used in area reduction (e.g., carrying thermal cameras) and during surveys (e.g., taking aerial pictures), while being applied for remote monitoring (e.g., fire location) or in civil protection (e.g., disaster area assessment). The whole system can be seen as a "Generic Remote Monitoring Toolkit," emphasizing the potential technology transfer.

Design Feasibility. Ground locomotion is a well-established technology, the most challenging task being making the robots light and cheap, yet reliable. Controlling helicopters is difficult yet feasible (the interested reader may find a related survey in "Control and Perception Techniques for Aerial Robotics"[17]). In conclusion, despite the project's high ambitions, it is feasible.

Domain Applicability. In order to demonstrate the advantages of a system like the one described above for humanitarian demining, imagine the following potential scenarios:

- During the Impact Survey, an unmanned helicopter could be used to take aerial pictures to be compared with pre-war information in order to uncover possible sites of former conflict.
- During the area reduction process, an unmanned helicopter could be used to carry multi-spectral cameras to detect mines by their thermal signature. A ground vehicle could transport ground-penetrating radar, metal detectors and odour sensors to detect TNT, all in order to have a more comprehensive and detailed view of the soil. Hence, vehicles are remarkable tools used to gather information for risk assessment.
- During the detection and clearance process, a generic remote monitoring toolkit could be used as a remote extension of the deminer for removal (ground vehicle), or to provide an aerial perspective of the operations.

A set of previous projects demonstrates the interest in aerial vehicles for MA (see for instance the SMART Project,[18] the ARC Project[19] and the Mineseeker Foundation Airship[20]). Note that these scenarios have to be considered in the previously presented three-dimensional framework; for instance, ground vehicles may not be affordable in certain situations.

Conclusion

A three-dimensional framework was presented to categorize several potential scenarios for high-tech applications in the MA domain. It was concluded that MA is a wide domain with available niches for several types of technologies, provided that a correct assessment is performed (R&D embedded in a sustainable development process, highly tied to the end-user, donors and MA programmes). Furthermore, a possible roadmap presenting a success-oriented market introduction was presented, which led IntRoSys to conclude that area reduction is the most promising niche for introducing high-tech tools; technology transfer of the developed product is also an important asset in a development program. Finally, a robotic architecture that takes into account the proposed roadmap, mainly the technology transfer component, is proposed. ❖

See "References and Endnotes" on page 108

Contact Information
Pedro F. Santana, Eng.
Integrators for Robotic Systems, S.A. (IntRoSys)
Quinta da Torre, Campus FCT-UNL
2829-516 Caparica
Portugal
Tel: +351 966 726 671
E-mail: pfs@uninova.pt
Website: http://www.introsys-online.com

Cities in Yemen Declared Mine Safe

The cities of Aden and Al-Hodeidah, located in Yemen, were declared mine safe in April 2005. The city of Aden consists of several small towns and was the former capital of Yemen, while Al-Hodeidah is an important Yemeni port city. The landmine problem in Yemen is a result of intermittent civil wars in the country, occurring from 1962 to 1994. The National Mine Action Committee has been working towards the goal of making the country safe from landmines by 2009, and receives funding through foreign countries—Canada, the United States, Japan and Germany—and non-governmental organizations. Already one of the most successful landmine-clearing operations, the Yemeni program will receive an extra 29 million Yemen Rial (the equivalent to $160,000 [U.S.]) from the United Nations Development Programme.

Fundraising for Mine Detecting Dogs Begins

The Children Against Landmines Program (CHAMPS), an initiative of the Marshall Legacy Institute, a United States-based nonprofit organization, has helped Illinois begin an effort to raise $20,000 to support a mine detecting dog. CHAMPS has been touring the United States to spread awareness and to gain assistance for the program. Since 2004, CHAMPS has already raised enough money to sponsor 30 dogs. The program also teaches children about their abilities to impact the demining situation and to help other children affected by landmines.