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Mine Clearance Techniques and Technologies for Effective Humanitarian Demining

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To improve mine clearance performance and to enhance safety of demining personnel, there is a need for efficient humanitarian mine action equipment. Accurate and reliable mine detection techniques and technologies capable of area detection and clearance are crucial for successful demining.

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Introduction

The removal and the destruction of all forms of dangerous battlefield debris—particularly landmines—are vital prerequisites for any region to recover from their impact. These tasks involve a great deal of effort and time, and high risk, all of which result in high clearance cost per surface unit. Many conditions have to be observed, such as soil, topology and type of contamination [1–7, 10, 11].

The major effect of mines is to deny access to land and its resources, causing deprivation and social problems among the affected populations. In addition, the medical, social, economic and environmental consequences are immense. The United Nations Department of Human Affairs (UNDHA) assesses that there are more than 100 million mines that pose significant hazards in more than 68 countries around the world. Many types of mines exist around the world, including more than 650 types of AP landmines [1,2,5]. AP mines are harmful because of their unknown position and because of the variety in explosive load, the activation means, the action range and the effect on human bodies. Landmine technology ranges from simple to highly technical devices. Pressure, tripwires, tension or pressure release, electromagnetic influence and seismic signals can detonate mines. Some landmines are "hardened" against neutralization by explosives, and other landmines have anti-disturbance mechanisms. In addition, a mine may have a booster charge to enhance the power released by the detonator to a level that is enough to initiate the main charge. Mines may have been in place for many years; they may be corroded, waterlogged or impregnated with mud or dirt, and they can behave quite unpredictably. Some mines were buried deep in the soil in order to prevent more organized forces from finding them with metal detectors. Deeper mines may not detonate when the ground is hard, but rain may later soften the ground to the point where even a child's footstep will set them off. Modern landmines are fabricated from sophisticated non-metallic materials and incorporate advanced electronics. They are harmful because of their unknown position and because they are often difficult to detect.

Demining in Afghanistan.

Humanitarian Mine Clearing "Demining" Phases

The landmine clearance process can be divided into the following basic parts:

1. Locating and identifying a mine field in order to map it.
2. Preparing the mine field for the clearance operation, which can include cutting vegetation, collecting metal fragments from the surface, etc.
3. Locating and marking individual mines within the identified area.
4. Removing the threat of the detected mines by neutralization (either removal or detonation).
5. Enforcing quality control measures.

There is a need to verify that the cleared area is free from mines with a high level of confidence.

A clearance priority rating should be given to each mapped mine field by taking into consideration factors of a social and economical nature, as well as those related to weather and ground conditions. It is necessary to associate this step with a mine awareness program, which aims at reducing civilian casualties caused by mines and other explosive devices. Locating the contaminated land will help to separate the danger from people and to make the uncontaminated land available for use immediately.

Solutions and Priorities

Current demining technology is slow, expensive and dangerous, and it can only cover a few hundred square meters per day. It becomes urgent to develop detection (individual and area), identification and removal techniques to increase the efficiency of demining operations by several orders of magnitude to achieve a substantial reduction to the threat of AP mines in a reasonable time frame and at an affordable cost.

The priorities for research and development in the humanitarian demining field require strategies that should start with the following needs:

- To develop reliable and accurate techniques that can enhance the performance of the demining process and allow efficient area detection of mine fields. There is an urgent need to recognize and reliably locate mine fields and isolate them by defining proper signs and limits to make the public aware and to avoid further accidents.
- To have quality training programs that fit the needs of local environments. Such training programs need to integrate cultural, environmental and operational considerations when developed.
- To enhance the safety of deminers by providing them with suitable clothing and equipment and by isolating them from direct physical contact with the mine.
- To enhance the performance of the sensor and the deminer.
- To have light, reliable, easy-to-use handheld multi-sensor systems to support clearance in difficult and narrow environments (woods, uneven terrain, residential, etc.) and vehicle-based systems to support mine clearance in open areas.
- To use information and communication technologies to enhance contact, experience, research, planning and to share results and data among all parties and personnel within the demining community.
- To have mechanized vegetation cutting; however, it would be better to find a technology that can detect and mark mines without having to cut vegetation.
- To speed up the mine detection process with an array of sensors that can be integrated to cover wider areas.
- To automate/mechanize detection and removal of mines and to improve deminer safety through the use of efficient, reliable and cost effective humanitarian mine action equipment (such as robots, flexible mechanisms, etc.) with minimum environmental impact.
- To have efficient quality control methods that are reliable and accurate in ensuring that an area is clear of mines.

Demining Approaches and Techniques

The demining methods currently being used are not safe for those clearing the mines or for those who must occupy the land after it has been cleared. The methods are neither cost effective nor efficient. Mine clearance itself can be accomplished through different methods with varying levels of technology, but the most laborious way is still the most reliable. We should favor technologies that can be manufactured in mined countries, that are transferable and that provide employment and economic infrastructure where it is most urgently required.

Manual Demining

Manual Demining is a procedure in which mines are manually detected and neutralized by a human deminer [1–5]. The deminer first scans the ground with a metal detector. Then the deminer uses a prodder in order to feel, locate and identify the object causing the signal, after which the deminer carefully uncovers it. When operating in this way, the detection phase still relies heavily on metal detectors, whereby each alarm needs to be carefully checked until it has been fully understood and/or its source removed. Most mines contain enough metal to be detected by this method; however, only about one in every 1000 signals detected belongs to a mine or UXO. In general, the ground being cleared is often saturated with metal fragment, shrapnel and cans, making manual demining methods slow, extremely dangerous and expensive. Complicating matters more, about one-third of all AP landmines currently deployed are metal free. The accuracy of metal detection depends heavily on the level of mineralization and debris in the ground, the type of mine used and the time needed to clear land varies enormously, depending on local conditions.

The Use of Animals, Insects and Bacteria

So far, dogs are considered the best detectors of explosives. Their sensitivity to this kind of substance is estimated to be 10,000 times higher than that of a man-made detector. Specially trained dogs are used to detect the characteristic smell of explosive residue that emanates from mines regardless of their composition or how long they have been implanted. This enables the dogs to detect mines with low metal content that are undetectable by metal detectors. In addition, because dogs do not respond to metal, soil or non-explosive objects, they eliminate much of the time-consuming shortcomings of manual detection techniques. Mine detection dogs can work in almost all types of terrain. They are also easy to transport and highly reliable, and they can screen land up to five times faster than manual deminers. South Africa and Afghanistan have reported success, but it was more in locating the edges of mine fields than in finding individual mines. Dogs can be overwhelmed in areas with dense landmine contamination. Moreover, they can only work for short periods each day (about a couple of hours a day). Dogs can become confused if they can smell explosive coming from several sources at once. The effectiveness of the dogs depends entirely on their level of training, the skill of their handlers and on their correct use.

Trained rats may be the best and cheapest form of landmine detector. Rats have certain advantages over dogs. They have a better sense of smell, are cheaper to keep and maintain and they are more

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resistant to tropical disease. Since they are smaller, they can be transported even more easily. In addition, they are very suitable for repetitive tasks. African Pouched Rats in particular have sensitive noses and can be trained like dogs to detect explosive vapors. The Geneva International Center for Humanitarian Demining (GICHD) is examining the use of rodent detection as part of a dog study.

Besides dogs and rats, other animals are being considered for their possible use as mine detectors. Researchers at Sandia National Laboratories and the University of Montana are trying to determine whether foraging bees can reliably and inexpensively detect buried landmines. They are trying to see if bees can be trained to find residues of TNT (the primary ingredient of most landmines) and bring the evidence home. Also, pigs are thought to be better at "sniffing" than dogs and might be better at finding mines. So far, no open literature has been seen describing any tests or trials. An additional technology for getting rid of landmines and UXO that is now under study at Oak Ridge National Laboratories (ORNL) could take advantage of the same microscopic, genetically engineered bacteria that are also being used in waste management technologies. These bacteria can be genetically engineered to glow in the presence of certain compounds, including explosives.

Mechanical Demining

Mechanical approaches rely on the use of motorized mine-clearers whose design is influenced by military demining requirements. Military devices are designed to clear only a navigable path through a field rather than remove all the mines in the area. A number of mechanical mine clearing machines have been constructed or adapted from military vehicles or armored vehicles of the same or similar type, with the same or reduced size [4–6, 15]. Mechanical mine clearance systems (such as armored vehicles, plows and flails) unearth mines or force them to explode under the pressure of heavy machinery. Mechanical clearance may be used on large areas (agricultural areas, for instance) and favorable terrain such as flat, sandy areas with no dense vegetation. In small paths or thick bush, such machines simply cannot maneuver. These systems are employed for mine verification and area reduction tasks as well as actual mine field clearance. Large mechanical systems—in particular the flail and tiller machines— do require substantial investments, not only for machine costs, but also for logistics and maintenance, and they can only be employed on a fraction of the total mined areas.

The mechanical approach is fast, but it cannot achieve the humanitarian demining accuracy and safety standards, nor will it in the near future. With this technique, machines often do not destroy all mines in a contaminated area, and AP mines may be pushed to the side or buried deeper or partly damaged, making them more dangerous. However, mechanical clearance in support of manual clearance can be cheaper and significantly safer for deminers (if they operate such machines remotely). In some terrains and circumstances, it is difficult to imagine mechanical methods being applicable (e.g., in defensive ditches, around large trees, inside residential areas, on soft terrain, etc.) However, machines can speed the clearance process when used in combination with manual clearers, and they may also be useful for quickly verifying that an area is clear of landmines so that manual clearers can concentrate on those areas that are most likely to be infested.

Environmental effects due to exploded mine residuals (such as erosion and soil pollution) have not been sufficiently studied. There are logistical problems associated with transporting heavy machinery to remote areas in countries with little infrastructure. Other critical limitations are mobility and maneuverability, since wheeled vehicles cannot travel efficiently on anything other than flat surfaces, while tracked vehicles cannot travel in areas with steep vertical walls. Also, machines in general cannot climb undefined obstacles or get through narrow entrances. Additionally, it is important for such machines to work in a wide range of operational conditions (such as temperature and humidity), and there is a need for protection against dust for engines and crews.

Robots and Humanitarian Demining

Most people in the mine clearance community would be delighted if their work could be done remotely or, even better, robotically. The benefits of mounting a mine detector on a remotely controlled vehicle must be balanced against the added cost and possible reduction in efficiency. A cost analysis should be conducted to determine to what extent remotely controlled vehicles are justified.

Properly sized robotic solutions with a suitable modularized mechanized structure that are well-adapted to local conditions of mine fields can greatly improve the safety of personnel as well as the efficiency, productivity and flexibility of the work. Solving this problem presents challenges in robotic mechanics and mobility, sensors and sensor fusion, autonomous or semi-autonomous navigation and machine intelligence. Furthermore, the use of many robots coordinating their movements will improve the productivity of overall mine detection processes through the use of team cooperation and coordination [7, 8, 14]. One benefit would be increased safety by removing the operator from the hazardous area. There are still some doubts whether such equipment will operate as effectively when the operator is at a distance or has been removed altogether. There is little value in a system that makes life safer for the operator but that is less effective at clearing the ground. Accordingly, a serious evaluation and analysis should be conducted, and efficient designs and techniques should be developed.

A reasonably cheap but reliable robot platform is required as the ultimate solution. The target robot should have the capability to operate in different control modes, including the tele-operated and semi-autonomous mode. The robot should have reliable navigation capabilities over an area to be cleared with efficient and flexible locomotion capability. It will have to be designed to not exceed the threshold that sets off the mines in question. Lastly, it should be easy to use; even someone with only basic training should be able to operate the system.

The possible introduction of robots into the demining process can be done through surface preparation and marking, verification, sped-up detection and mapping, and mine removal or neutralization. Clearly, it is difficult to design a universal robot/machine that is applicable to different terrains and works under different environmental conditions to meet demining requirements. The high cost and sophisticated technology used in robots that require highly trained personnel to operate and maintain them are additional factors limiting the possibilities of using robots for humanitarian demining. In spite of this, many efforts have been made to develop effective robots for cheap and fast solutions.

Mine Detection and Sensing Technologies

Mine detection represents the slowest yet most important step of the demining process, and the quality of mine detectors affects the efficiency and safety of this process. Mine detection targets need to achieve a high probability of detection while maintaining a low probability of false alarms. It is important to develop effective detection technologies that speed up the detection process, maximize detection reliability and accuracy, reduce the false alarm rate, improve the ability to positively discriminate landmines from other buried objects and metallic debris, and enhance the safety and protection of deminers. In addition, there is a need to have simple, flexible and user-friendly interaction that allows safe operation without the need for extensive training. Furthermore, careful study of the limitations of any tool with regard to the location, environment and soil composition is critical. Knowing the required technical operation and maintenance skills is important, as is remembering that not all high-tech solutions may be workable in different soil and environmental conditions. The development phase of such new technologies requires a well-established set of testing facilities that simulates conditions closely resembling those of the mine-affected area. The testing phase should be followed by extensive field trials in real scenarios to validate the new technologies under actual field conditions to specify benefits and limitations of different methods. The work must be performed in close cooperation with end-users of the equipment, and real deminers should carry out the test at a real site. This will ensure that the developments are consistent with practical operational procedures in the context of humanitarian demining and that the technology is fulfilling user requirements. Also, there is a need to have a reliable set of global standards for assessing the availability, suitability and affordability of technology with common information tools that allow for these assessments and evaluations. This can be enhanced by benchmarking the performance levels to develop equipment, systems and algorithms. [5, 11–13].

The idea of developing multi-sensor solutions involving two or more sensors linked to computer-based decision support systems with advanced signal processing techniques is attractive and is advocated by many as a fruitful line of development. Because of this, there is a need to use complementary sensor technologies and to have an appropriate sensor data fusion. A critical need is the ability to distinguish fragments or stones from the target material in real time.

Conclusions

Due to the complexity of the landmine problem and poor coordination of new technologies, development and field requirements, a well-coordinated plan needs to be developed at international, regional, national and organizational levels to address the issue of humanitarian mine clearance. Any single breakthrough in technology should be viewed as yet another tool available for use in the demining process, but we must realize that that particular tool may not be appropriate under all conditions. All of the above-mentioned approaches of humanitarian mine clearance are effective and practical in specific circumstances. A Tool Box approach has to be adopted, and different procedures and technologies have to be used for the clearance of different types of land under different conditions. The international community must act to foster and further these research programs and coordinate their efforts in order to provide mine clearance personnel in the field with technologies, procedures and standards that could enhance the effectiveness, cost efficiency, reliability and safety of humanitarian mine clearance. ■

References

1. T.J. O'Malley, "Seek and Destroy—Clearing Mined Land," Armada International, 1993, pp. 6-15.
2. M. K. Habib, "New Potential and Development of Mine Detection and Sensing Technologies in the Context of Humanitarian Demining," 5th International Conference on Mechatronics Technology ICM2001, Singapore, 2001.
3. P.M. Blagden, "Summary of UN Demining," Symposium on Anti-Personnel Mines, Montreux, April 1993, CICR/ICRC, pp. 117-123.
4. Humanitarian Demining Development Technologies 1998, Department of Defense, USA, 1998.
5. C. Bruschini, K. De Bruyn, H. Sahli and J. Cornelis, "EUDEM: The EU in Humanitarian DEMining," EU report, Brussels, 1999.
6. Humanitarian Mine Action Equipment Catalogue 1999, German Federal Foreign Office, 1999.
7. M. K. Habib, "Service Robots in Humanitarian Landmine Clearance," International Symposium on Robots (ISR2001), Seoul, Korea, April 2001.
8. J.D. Nicoud, "Vehicles and Robots for Humanitarian Demining," The Industrial Robot, Vol. 24, No. 2, 1997, pp. 164-168.
9. B. Gros, C. Bruschini, 1996, "Sensor Technologies for the Detection of AP Mines: A Survey of Current Research and System Developments," ISMCR'96, Brussels, May 9–10, pp. 564-569.
10. C. King, "Mine Clearance in the Real World," SusDem97: International Workshop on Sustainable Humanitarian Demining, Zagreb, 1997, pp. S2.1-8.
11. M. Hewish, and L. Ness, "Mine-detection Technologies," Intl Defense Review, October 1995, pp. 40-46.
12. J. E. McFee, "Multi-Sensor Mine Detector for Peacekeeping: Improved Landmine Detector Concept," SPIE Technical Conference 2765, March 1996.
13. B. Cain, and T. Meidinger, "The Improved Landmine Detection System," EUREL, 1996, pp. 188-192.
14. J. D. Nicoud and M. K. Habib, "PEmex-B Autonomous Demining Robots: Perception and Navigation Strategies," IROS'95, Pittsburgh, Aug. 1995, pp. 419–424.

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