

# Mines and human casualties, a robotics approach toward mine clearing

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## **ABSTRACT**

An estimated 100 million landmines which have been planted in more than 60 countries kill or maim thousands of civilians every year. Millions of people live in the vast dangerous areas and are not able to access to basic human services because of landmines' threats. This problem has affected many third world countries and poor nations which are not able to afford high cost solutions. This paper tries to present some experiences with the land mine victims and solutions for the mine clearing. It studies current situation of this crisis as well as state of the art robotics technology for the mine clearing. It also introduces a survey robot which is suitable for the mine clearing applications. The results show that in addition to technical aspects, this problem has many socio-economic issues. The significant of this study is to persuade robotics researchers toward this topic and to peruse the technical and humanitarian facets of this issue.

**Keywords:** Mine clearing, robotics, survey robot

## **1. INTRODUCTION**

The first generation of mines were pressure-activated and large and used to stop or destroy enemy's vehicles. They could be found and neutralized easily by infantry. As a counter measure, armies developed anti-personnel mines to keep enemy mine clearers away from anti-vehicle mine fields. It is estimated that 75% of all uncleared mines are anti-personnel mines, and this is the category that has created most problems.<sup>1</sup>

Landmines do not distinguish between a soldier, a child or an animal. They can not be aimed and their deadly force is indiscriminant. That's why they are so horrible.

According to International Campaign to Ban Landmines (ICBL) leading producers and exporters of antipersonnel mines in the past 25 years include China, Italy, the former Soviet Union, and the United States. More than 50 countries have manufactured as many as 200 million antipersonnel landmines in the last 25 years and more than 350 different types of antipersonnel mines exist. Even if no more mines are ever laid, they will continue to maim and kill for years to come. In fact, they kill or injure more than 2000 people a month and with the current mine removal technology it may take about 1000 years to remove all mines if no new mines are buried in the war zones.<sup>2</sup>

The 1997 Ottawa treaty bans the use, production, stockpiling, and transfer of antipersonnel landmines. Since the treaty became law, countries may no longer sign it, they must accede. Those countries which have already signed must still ratify in order to be fully bound by the ban provisions. By the end of 2002, a total of 146 countries had signed the Mine Ban Treaty and 130 had ratified or acceded to it and More than 30 million stockpiled mines have been destroyed according to ICBL which monitors the treaty compliance.<sup>3</sup>

Landmines have many social and economical impacts which can not be described by simple quantitative measures. Many communities have not been involved in proper clearance activities and have adapted to situation in their own ways. Global Landmine Survey is an international effort to understand the socio-economic impact of landmines and unexploded ordnance (UXO). Without knowing the impacts it is difficult to develop strategies to allocate limited resources to minimize the effect of landmines. Landmine resources compete with other humanitarian activities. The low and decreasing mortality from landmines is often compared to high and soaring mortality from epidemic disease. This has provoked an all-over-nothing debate over the costs and benefits of demining.<sup>4</sup> It is becoming clear that complete clearance is not a feasible solution of the worldwide landmine problem when the size of contaminated area is considered into account. That is why it is essential to understand the social and economical impacts of landmines.

## 2. MINE TECHNOLOGY

### 2.1 Different Mines

The Mine Ban Treaty defines a mine as follow:

*Anti-personnel (AP) landmine:* "A mine designed to be exploded by the presence, proximity or contact of a person and that will incapacitate, injure or kill one or more persons."

*Anti-tank (AT) landmine:* An AT mines is a device designed to detonate by more than 100 kilograms of pressure -AT mines cannot distinguish between a tank and tractor.

ICBL categorize mines as follow:

*"Blast mines:* usually hand-laid on or under the ground or scattered from the air. The explosive force of the mine causes foot, leg, and groin injuries and secondary infections usually result in amputation.

*Fragmentation mines:* usually are laid on or under the ground and often activated by tripwire or other means. When detonated the explosion projects hundreds of fragments at ballistic speed of up to 50 meters resulting in fragmentation wounds. Some fragmentation mines contain a primary charge to lift the mine above the ground (about 1 to 1.5 meters) before detonating which can injure an adult's abdomen, genitals and take off a child's head.

*Plastic mines:* Undetectable by metal detectors used by deminers.

*Remotely delivered (R/D) or scatterable mines:* Usually disseminated from aircraft, helicopters or artillery. Accurate mapping, recording and marking mines laid in this manner is impossible.

*Anti-handling devices:* A device intended to protect mine and which activates when an attempt is made to tamper with or otherwise intentionally disturb the mine (Mine Ban Treaty definition).

*Self-destruct (S/D) mines:* So-called "smart" mines are designed to self-destruct after a designated period of time. If they fail to self-destruct, these mines are also sometimes designed to self-deactivate. There is nothing smart about these mines though - while armed they cannot discriminate between the footfall of a soldier and a civilian."

Most of mines are plastic or wooden mines with a small metal needle which is hard to detect using the well know metal detectors. Other metal objects in the same minefield create many false alarms. There are other technologies to detect mines. Neutron activation imaging, ion spectroscopy or x-ray tomography which are used for detection of explosive inside the luggage are not practical for mine detection yet. Ground penetrating radars can be used along with the metal detectors. Odor detectors also seem a promising technology for mine detection. Some use dogs to double check a cleared area and sometimes to survey the extent of a minefield before clearance begins. Their main use is to confirm suspected mined areas.

Cost is an important issue in the mine clearing. A clearing cost close to the cost of mine could also decrease the use of mines. It is estimated that even with the traditional demining technology average cost of demining is \$800 per mine found.<sup>5</sup>

There are also important differences between military and civilian demining efforts. In many military applications speed of operation is more important than the safety of soldiers since the objective is to punch a path though the minefield, with the acceptable losses. This is called "breaching". In this case typically a tank pushes a heavy demining system and troops follow and a removal of 80% of mines is acceptable.<sup>6</sup> Figure 3 shows an example of such device.

The UN requirement of civilian mine clearing is 99.6%. Simple large rollers are not sufficient to meet the UN requirement. They leave most mines on the side berm they create, where the mine are more difficult to find.<sup>6</sup>

Besides, many poor nations and civilian groups are not able to afford high cost military solutions. To be practical in large scale demining efforts the cost of demining system should be less \$10,000 in mass production. This is some kind of threshold, suggested by some researchers.<sup>5</sup> This cost is mainly influenced by sensors.

### 2.2 Mine clearing technology

The current mine clearing technology reflects a varied and diverse approach to diffuse anti-personnel land mines. They range from the old fashioned sniffer dogs to highly sophisticated polarized infrared technology. The costs of landmine clearing using sophisticated techniques are prohibitive for poor third world countries which have the majority of the dormant mines. The relatively primitive techniques of detecting mines using a trained sniffer dogs and a trained deminer and has a high human costs. It is estimated that for every 2000 mine cleared there is a fatal human error. The training required for personnel to disarm mine is even more complicated by the fact that there are almost thousands types and makes of anti-personnel mines. For example during the last days of Persian gulf war in 1991 they were many different kinds of mines were used like MK-118, Blu-77b, Blu-97, M-42 and 46, Blu-61-a-b, Blu-63-b, 86-b, Blu-91-b, Blu-92-b and bluga.<sup>7</sup>

None of the technologies available seem in fact capable of reaching, in a very large number of situations, good enough detection while maintaining a low false alarm rate. Rather, each one will probably have to find, if it exists, a specific area of applicability, determined by technological as well as economical or even social factors, and possibly other sensors to work with using some form of sensor fusion. The need for a better exchange of information between the specialists in each category is obvious, using options such as data sharing on the Internet.<sup>8</sup>

The following table lists the current technologies available or are in the process of being developed. These technologies can be leveraged to find the ‘best of breed’ which works for most mine clearing scenarios.<sup>8</sup>

**Table 1.** Mine detection technologies

Sensor technology	Maturity	Cost and Complexity
Passive infrared	Near	Medium
Active infrared	Near	Medium
Polarized infrared	Near	Medium
Passive electro-optical	Near	Medium
Multi-hyperspectral	Far	High
Passive mm-wave	Far	High
mm-Wave radar	Near	High
Ground penetrating radar	Near	Medium
Ultra-wideband radar	Far	High
Active acoustic	Mid	Medium
Active seismic	Mid	Medium
Magnetic field sensing	Near	Medium
Metal detection	Available	Low
Neutron activation analysis	Near	High
Charged particle detection	Far	High
Nuclear quadrupole reson.	Far	High
Chemical sensing	Mid	High
Biosensors	Far	High
Dogs	Available	Medium

There are different approaches to detecting mines. Robots which can be equipped with different kinds of sensors and actuators depending on the mines that are being cleared seems to be a realistic option. The costs of these robots are reasonable if we consider the lives that can be saved.

### 2.3 Examples of Robots

The robots that are available in the market for detection and clearing mines are very different in their approach. Here we list a few which represents some of the typical approaches for mine clearing robots.

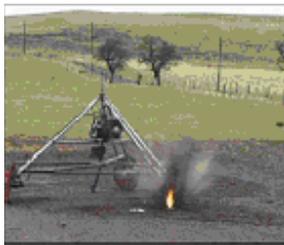
*Pemex –BE*: is a lightweight 2-wheels robots developed as a first cross-country test vehicle for searching anti-personnel mines as shown in Figure 1. The sensors are located inside a half-sphere which acts as a third supporting point. It weights less than 16 kg and can easily be dismantled and carried out as hand luggage. It is battery operated with autonomy of 60 minutes and can move at a speed of up to 6 km/h.<sup>9</sup>

#### *Advantages:*

- The cheaper of all the robots
- Easiest to navigate across difficult terrain
- The very light weight robot

#### *Disadvantages:*

- The not safe for the operator.
- No sophisticated sensors



**Figure 1.** Pemex –BE



**Figure 2.** Dervish

#### *Dervish:*

The Dervish, shown in Figure 2, is a remote-controlled vehicle designed to detonate anti-personnel mines with charge weights up to 250 gm, equivalent to the largest size of anti-personnel mine. The Dervish detects and detonates anti-personnel mines by mimicking the ground loading of a human foot. It sweeps a path, 5 meters wide, covering ground at intervals of only 3cm.<sup>10</sup>

#### *Advantages:*

- It can detonate the landmines
- Extremely safe for the operator
- It is very easy to use

#### *Disadvantages:*

- No sophisticated sensors
- Difficult to navigate



**Figure 3.** ILDP system

*ILDP:* The ILDP system consists of a teleoperated vehicle carrying three scanning sensors which operate while the system is in motion; a metal detector array (MMD) based on electromagnetic induction (EMI), an infrared imager (IR), ground penetrating radar (GPR), and a confirmatory sensor which requires the system to be stationary and near a target of interest, consisting of a thermal neutron analysis (TNA) detector.<sup>5</sup>

*Advantages:*

- Highly sophisticated sensors
- Fastest land mine clearing robot
- Highly safe for the operator

*Disadvantages:*

- Training the operator is expensive

**SHADOWDEMINER**



**Figure 4.** SHADOWDEMINER

Shadow Deminer is a robot capable of traversing an anti-personnel minefield carrying mine detecting sensors or video cameras. The robot is able to traverse rugged terrain and degrade gracefully in the event of damage. The Shadow Deminer for an eight-legged vehicle with emergent walking behavior using pneumatic actuators and local materials where possible. These factors contribute to the simplicity of the basic vehicle and low cost if destroyed. 6

*Advantages:*

- Highly efficient sensors
- Can climb inclines.
- High resolution area

*Disadvantages:*

- High cost of maintenance
- High initial investment

There are different ways that robot could help human in mine detection and mine clearing. Small autonomous vehicles equipped with different sensors could scan an area and determine the contaminated area. This phase when is done manually is very dangerous because deminers are working faster and talking more risks in compare to systematic search.<sup>11</sup> Once the polluted area or the actual location of a mine was specified then the systematic search and neutralizing

process can begin. Even a robot can go to a pre-specified location by avoiding obstacles and place a detonator or some chemical to destroy the mine.

A light weight small autonomous robot is an option for the mine clearing. Such robot could be cheap enough in mass production for many humanitarian applications. It should carry small weight and size sensors (which is still an unsolved problem). There are major subsystems for the robot.

### 3. SURVEY ROBOT

A survey robot was developed by the Center for Robotics Research at the University of Cincinnati which can be modified for mine clearing purpose. The robot has several subsystems.

Autonomous navigation is a challenging area with promising results.<sup>12</sup> The survey robot shown in Figure 5 is equipped with the GPS navigation system with supervised remote control ability.

The overall function of the robot is to carry the soil sampling device to a targeted waypoint. Stop and let the soil sampling device sample the soil, and then send back sample data to the remote base.

The computer communicates with the soil sampling tube via two RS232 ports. There are two motion units in the robot. The robot is guided by the GPS receivers with a bounded error of approximately 10 feet. On the robot navigation side, both wheels rotate a that navigate the robot from one spot to the next; on the soil sampling unit side, the linear actuator pushes the penetrometer down for soil sampling and lift up after that. The sampling unit could be equipped with chemical sensors or it the whole sensors could be replaced by other mine detecting sensors. The original robot platform is a Friendly Robot lawnmower which cost only \$500. The GPS system and the sensors will add an additional cost.

The proposed sensor system for soil sampling was constructed and fully verified the concept of sample soil properties with autonomous mobile robot is feasible. The soil sampling system was demonstrated to the air force officers at Hurlburt Air force Base in November 2002. The robot finished designated tasks on site with a better than expected accuracy. This is the first time an autonomous soil sampling sensor system was successfully integrated with a GPS guided mobile robot. The performance of this robot verified the concept that robot can take place of personnel for the soil sampling operation in unstructured environments. However, more needs to be done to add mine detecting sensors and proof the concept in a real mine field.



Figure 5. Survey robot

### 4. CONCLUSION

Landmines are great treats to lives of millions of people and no perfect solution exists. In this paper several state of the art mine clearing methods were investigated and some mine clearing robots were introduced. It also current status of international mine clearing activities were presented. The survey robot, which was developed by the authors, briefly was explained and its applicability in mine clearing was discussed. It can be concluded that much more research and development is needed to solve the global crisis of landmines.

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