

Various Landmine Detection Techniques: A Review

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ABSTRACT: This paper presents a review of all the existing and latest techniques devised for the detection of landmines. Electronics has played an important role in the development and efficient use of some of these techniques. Few techniques that are discussed here include the use of metal detectors, acoustic sensors, infrared imaging, nuclear magnetic resonance (NMR), nuclear quadrupole resonance (NQR), X-ray backscatter, electric impedance tomography (EIT), mechanical methods, vapor sensors and microwaves. Working, advantages and limitations of each technique are discussed. The performance of the detection system can be enhanced by using multiple techniques. The ground penetrating radar (GPR) is one of the latest microwave technologies that are being used for the detection of landmines.

KEYWORDS: Ground Penetrating Radar (GPR); Landmine, Metal Detectors, Acoustic Sensors, NQR, EIT, NMR.

I. INTRODUCTION

Landmines are the marks left behind by the world wars. This invention was designed for the protection of countries and people, but it soon turned out to be a threat to everyone. It not only harmed the enemies, but also the innocent people. One of the biggest problems humanitarian's faces is the clearance of landmines.

One of the most terrifying legacies of war is a landmine. According to the International Campaign to Ban Landmines (ICBL), there are 15,000 to 20,000 casualties every year caused by landmines [1]. Most of the people are killed or injured and many of them are children. The landmines are developed to be used by the armed forces to disable any person or vehicle that comes in contact with it by an explosion. Some mines contain fragments of metal or bearings or bolts which causes fatal damage to people who triggers it.

The families of the injured suffer from the great deal of pain and suffering along with the injured one. Most of the time the physical damage is not recoverable. And even though it is recovered the trauma caused by the explosion disturbs the normal behavior of the injured. This is the reason why Landmines pose as a great threat to humanity.

II. TYPES OF LANDMINES

There are two forms of landmines:

- 1) Antipersonnel (AP) mines
- 2) Antitank (AT) mines.

The anti-personnel mines are designed to disable and kill the target. The AP mines contain a small amount of explosive than AT mines. The AT mines are designed to disable the Tanks and hence the pressure required to trigger these mines is more.

The AP mines are divided into following three categories:

- 1) *Blast:*

This type of mines is mostly buried nearly at the surface of the land so that can be easily triggered if someone steps on the pressure plate. If the blast mine is exploded, it breaks the targeted objects into fragments and can cause severe secondary damage like amputation and infection.

- 2) *Fragmentation:*

This mine is the most dangerous type of landmine. It contains small fragments of metals or bearings or bolts. So when the explosion is triggered the fragments are released in all the directions causes damage to all the people in the range of the explosion. The construction can also be done in such a way that can cause directional release of fragments.

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3) *Bounding:*

This type of mine is designed to cause an injury to a person's head and chest. When triggered, the igniter sets off the propelling charge. This in turn lifts the mine at about 1 meter in the air and caused the damage to the target. [1]

III. MINE DETECTION TECHNIQUES

The detection of landmines and their clearance is a very time consuming process. Not only that, but it is a very unsafe task. There is still no single technique that is efficient and accurate.

The research has been going on in the development of landmine detection techniques with very low false alarm rate. But still the widely used approaches are metal detection and hand prodding. Some of the existing techniques are discussed here :

1) *Metal Detectors :*

Metal detectors are used to detect the buried landmines. It works on the principle of electromagnetic induction. The coils present in the metal detectors create an electromagnetic field. The mines are usually made up of metal and this electromagnetic field induces an eddy current in the metal objects. This eddy current in turn creates its own electromagnetic field. Due to this field an opposite current is generated in the coils of metal detector. The metal detector controller senses this current and generates a signal indicating presence of mine. Even though this technique is very efficient when the mine is made up of metal, it fails to detect the landmines made up of plastic which may have a very small amount of metal or no metal at all.

2) *Acoustic Sensors :*

Acoustic sensors are used for landmine detection in some approaches [2]. The acoustic wave is projected on the ground by the acoustic sensors. The sound wave gets reflected on the boundaries that are present in between the materials of different acoustical properties. Using these reflected waves the location and identity of the target body can be found [3]. The ultrasound detection is affected by the density and bulk modulus of the soil as well as the systems operating wavelength. The study of these sensors has revealed that it is very powerful in the wet and heavy ground such as clay. But it is inefficient in sandy soils.

3) *Infrared Imaging Systems:*

Infrared imaging can be used to detect anomalies in the ground, which might be introduced by the presence of landmine [4]. It requires the images with sufficient spatial and temperature resolution. Depending on the temperature of the body all emits the Infrared radiation. This radiation gives the information about the temperature of the body. The difference in emitted IR radiation is required to detect the target by using thermal imaging. This can happen due to the temperature difference between the target and the background. Every object or body emits different IR radiation depending on its properties even though the temperature is same. The thermal properties of the landmine are different from the surrounding and hence its signature can be isolated [5]. But this also means that if the mine has been buried for a very long period of time, Thermal signature is faded. The only detectable landmines are those which are buried near the surface at a depth of about 10 cm [6]. The vegetation greatly affects the discrimination of landmines from the surroundings as it also emits IR radiation.

4) *Nuclear Magnetic Resonance:*

The detection of target is efficient by using this technique only if the target object is placed inside the coils. This does not work properly for the buried landmines. It can be configured to detect the buried landmines, but it is very difficult to read the resulting DC and RF fields as that are very weak and non-uniform. This results in poor detection. This technique is not feasible for handheld applications because of the superconducting coil. This coil requires a cooling system and a high power source. Alone, this technique is useless for metallic mine detection and hence it should be used along with metal detectors. Efforts are made by researchers to develop NMR sensors to detect explosive materials. One such sensor is developed by Markus Nolte at Darmstadt University in Germany, and colleagues, that can detect nitrogen present in the TNT [7].

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5) Nuclear Quadrupole Resonance (NQR):

The Nuclear Quadrupole Resonance technique takes advantage of quadrupole moment. Quadrupole moment is the spinning property possessed by nitrogen atom nuclei which is present in the TNT. Hence it is effective in the detection of actual explosive materials like TNT or RDX. The externally applied radio frequency pulse at the precession frequency generates an oscillating Nuclear Magnetic Moment [8]. The sensitive receiver detects this moment and depending on it, presence of explosive is detected. Research is still going on in the development of electronics required to generate precisely timed spins at the correct frequencies and to detect even very weak signals. The time required to detect explosives varies in between 0.1 to 1 second for hand held mine detection systems at present [6].

6) X-ray Backscatter:

The object can be detected by passing the photons through the object in this technique[9]. X-ray have a variety of wavelengths as compared to the size of landmine. This in turn results in high resolution images of buried landmines. In this technique, photons are passed through the object and the backscatter of X-rays is used to provide information about target object. The landmines and soils have slightly different mass densities and effective atomic numbers. This fact is exploited by the X-ray backscatter. Low energy incident photons are required to detect buried objects, but for such photon backscatter devices soil penetration is poor. Due to this it becomes difficult to locate shallowly buried objects at depths less than 10 cm deep. It is hard to acquire high spatial resolution images by using X-ray, and the time required is long [10].

7) Electric Impedance Tomography (EIT) :

Electric impedance tomography works on the basis of conductivity distribution. It uses electricity to generate an image of the conductivity distribution. The system is simple, cheap and lightweight. It consists of bi-dimensional array of electrodes which is placed over the surface to capture signals from the distribution of the conductivity. This information can be used for the detection of mine. There will be conductivity anomalies where mine is buried, hence this system can detect metallic as well as non-metallic mines. This works well in wet soil but because of the weak conductivity, does not work properly in dry soil like deserts or rocky surfaces. The biggest disadvantage is that sensors must be in close contact with the surface. This increases the risk of triggering the explosion of the mine. It is only useful for the detection of objects that are close to the surface [11].

8) Mechanical Methods:

i) Prodders and Probes:

Prodding is one of the basic approaches for the detection of landmines. It is done by using a metal stick of about 25 cm long called a probe. The scanning of the area is done at a shallow angle of 30 degrees by the deminer. Whenever there is a presence of an unusual object, it accesses the contour of the object and depending on it, the presence of mine can be indicated. Different objects create different sounds and the operator can learn to differentiate between a mine and other objects by hearing and experience. But probing is very dangerous, as the mines might be able to explode by prodding [12].

ii) Mine Clearing Machines:

Sometimes it is necessary to clear the mine fields in a short time. During such time the army employs certain machines that can roll through the field and clear the path. As these machines are usually of heavy size it triggers the mines by pressure and causes detonation. The mine clearing machines can also be designed in conjunction with certain mine clearing devices. Several types of mine clearing machines are employed nowadays to clear the minefields [13].

9) Vapor Sensors:

A very small amount of explosive material manages to escape in the form of vapors from the shield structures of mines. Now by using certain technique which can identify and differentiate the vapors from explosive from others, it is possible to detect the presence of mine [14]. The research on this technique is divided into two subcategories: i) biological and ii) chemical.

i) Biological:

Biological methods are employed using animals with sensitive sniffing powers like dogs, insects and microorganisms to do detect the presence of explosives. It is found that, it is an efficient method to track landmines with a very low false alarm rate. This happens because the vapors coming out of rocks or debris are different from the explosives and

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hence it is easy to isolate the mine [14]. Use of bees and other microorganisms is not much fruitful, but the dogs proved to be very efficient as it can sense even the very low concentration of vapors [15]. One of the disadvantages of this method is that the performance of dogs is different for different dog and species.

ii) Chemical:

The chemical methods mainly concentrate on the detection of vapors from the explosives like TNT, PET and RDX. By using techniques like molecular diffusion and turbulence processing, these vapors can be transported [16]. The objective of this method is to create some sensors that can identify the explosive vapors by employing electromechanical, espectorial or piezoelectric principles [17]. But as the sensitivity towards vapor detection of such sensors is very low, detection of mines becomes very difficult.

10) Microwave Techniques (G.P.R.):

Microwaves can be used to detect the buried mines or objects by radiating microwaves and analyzing the returning signal from the target. The microwaves return or get reflected when it encounters a subsurface discontinuity. Depending on the frequencies the depth of penetration varies. Higher frequency signals are highly attenuated in soil, even though it provides high resolution. Hence it is used for detection of shallowly buried objects. Whereas low frequencies are less attenuated in the soil and hence can travel deep in soil and can be used to detect the deeply buried objects. The latest technology working on this principle is ground penetrating radar (GPR). It transmits the signals of high and low frequencies at the same time from the transmitting antenna and collects the reflected signal. After analyzing this returned signal, presence of mine can be detected. This is a promising technology that can be used for the detection of metallic as well as plastic mines. One of the disadvantages is that it is inefficient in wet soil and its performance varies with the variation in the type of soil [1].

IV. CONCLUSIONS

Over the years there is a development of several landmine detection techniques. There are some techniques that are suitable for detection of metallic mines only like metal detectors, whereas some can detect plastic mines as well like GPR and EIT. Few are able to detect explosives by vapor analysis as well. No single technique is powerful enough to provide good performance. But if used to combine two or more techniques the desired performance can be achieved. All the methods suffer from some disadvantage, but by using in conjunction those limitations can be compensated.

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