

Design and Development of Landmine Detecting Robots

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ABSTRACT: The project deals with designing a robotic vehicle which is capable of detecting landmines, marking their locations and stopping itself to avoid those landmines towards a particular location determined by the user. The specific use of this type of robot is to send supplies to soldiers trapped in hard reaching places during war with minimal loss to human life. It can also be used to scout dangerous locations before entering for bombs or weapons. It will have the ability to detect landmines, marking their locations and prevent itself from stepping on to those mines and detonating them. Various researches in this field have inspired us to improve the mine-detecting robots. We, too, hope to inspire and motivate other engineers by our project.

KEYWORDS: Robotic Vehicle, Landmine, Detector, Marking Mechanism, Processing Unit

I. INTRODUCTION

[1] Purpose:

The landmine crisis is globally alarming since there are presently 500 million unexploded, buried mines in about 70 countries. Governments are looking into this situation seriously since landmines are claiming the limbs and lives of civilians every day. Covert transport of military equipment and supplies through a mine infested, enemy region is difficult and usually causes the loss of life.

[2] Objectives:

1. A land mine detection robot is needed to be designed to employ in peace support operations and in the clearance of contaminated areas.
2. The robot shall be able to detect 80-90% of landmines and mark the locations of the mines within a tolerance of 5-10 cm.
3. For the safety of the operator, the designed robot must be able to operate remotely, moreover, must be equipped with wireless data transmitting capabilities.
4. The robot shall not detonate the mines while scanning the area and marking the locations of the mines.

[3] Challenges:

1. Not only is the presence of the mine is required to be discovered, it also needs the robot to mark the location of the mine with an accuracy of 5-10 cm radius. Such accurate location marking system is needed to be designed and installed on the robot.
2. The geographical nature of the mine field is assumed to be sandy because of the terrain of Indian military borders. Therefore, a minimum clearance height from the ground to the bottom of the vehicle is required and a belt drive system is required in the vehicle.
3. To avoid detonating the land mines, either the wheels must be lifted from the ground or the vehicle has to be driven around the mines. At the same time, the robot must be able to mark the locations of the detected mines.
4. To enable a wireless communication system, places for radio transmitters and receivers will have to be incorporated.
5. The budget is constrained to Rs.25, 000 Indian Rupees to create a prototype mine detection and marking module.

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[4] Scope:

Detection and location of antipersonnel landmines is being done at present mainly by human operators handling manual equipment. The robotization of this activity can give so many benefits to the human community in many countries. There is worldwide interest in eradicating deployed landmines, and solutions are coming from new, emerging engineering fields. New kinds of sensors are required to detect landmines efficiently, but current sensors can be carried by mobile robots.

We will be using remote controlled robot with metal detector for land mine detection. In the vehicle, navigation is controlled by the user using remote control & the metal detector is used to detect the mines.

The greatest advantage that this robot offers is the safety for soldiers; since it marks the location of the mine and it also rolls over the places it deems as safe. Thus, the proposed design for landmine detection and marking module has opened up a new area for researchers to explore. Saving lives of innocent civilians becomes on step closer.

II. PROBLEM STATEMENT

There are 50–100 million landmines in more than 80 countries around the world [1]. Governments are looking into this situation seriously since landmines are claiming the limbs and lives of civilians every day. Covert transport of military equipment and supplies through a mine infested, enemy region is difficult and usually causes the loss of life

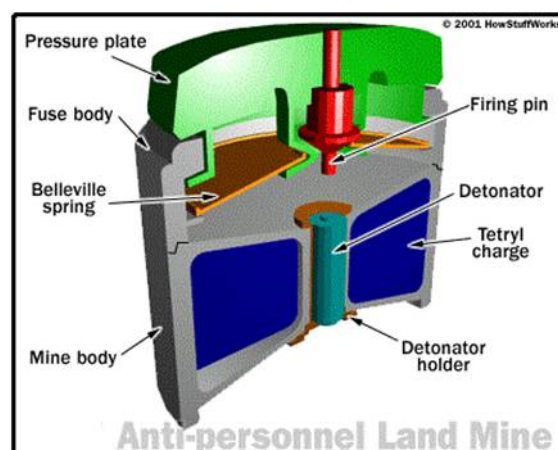
III. LITERATURE SURVEY

[1] Land Mines:

A land mine is an explosive device, concealed under or on the ground and designed to destroy or disable enemy targets, ranging from combatants to vehicles and tanks, as they pass over or near the device. Such devices are typically detonated automatically by way of pressure from the target stepping or driving on it, though other detonation mechanisms may be possible. The device may cause damage either by a direct blast or by fragments that are thrown by the blast.

Anti-personnel mines are a form of land mine designed for use against humans, as opposed to anti-tank mines, which are designed for use against vehicles. Anti-personnel mines may be classified into blast mines or fragmentation mines, the latter may or may not be bounding mines. The mines are often designed to injure, not kill, victims in order to increase the logistical (mostly medical) support required by enemy forces that encounter them. Some types of anti-personnel mines can also damage the tracks on armoured vehicles or the tires of wheeled vehicles.

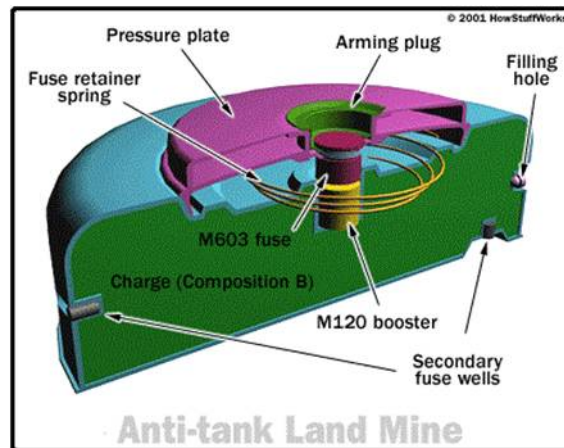
An anti-tank mine is a type of land mine designed to damage or destroy vehicles including tanks and armoured fighting vehicles. Compared to anti-personnel mines, anti-tank mines typically have a much larger explosive charge, and a fuse designed only to be triggered by vehicles or, in some cases, tampering with the mine.



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[2]Current Technologies for Mine Detection:

Various techniques are used for the detection of landmines. There are five main areas the current technologies fall under. The five areas are:

1) Metal Detector Technologies:

The basic metal detector used for mine detection measures the disturbance of an emitted electromagnetic field caused by the presence of metallic objects in the soil. The popular, basic metal detector is easy and cheap to use and has an average success rate. However all metallic objects are identified while the problem is heightened, when using more sensitive detectors for plastic mines.

2) Electromagnetic Methods:

a) Ground Penetrating Radar (GPR): GPR detects buried objects by emitting radio waves into the ground and then analysing the return signals generated by reflections of the waves at the boundaries of materials with different indexes of refraction caused by differences in electrical properties.

b) Nuclear Quadruple Resonance (NQR): An NQR device induces a RF pulse of an appropriate frequency in the subsurface via a coil suspended above ground. This RF pulse causes the explosives' nuclei to resonate and induce an electric potential in a receiver coil.

c) Microwaves: An image is constructed in the computer from the signals that bounce back when microwaves are sent into a minefield.

d) Electrical Impedance Tomography: EIT uses electrical currents to image the conductivity distribution of the medium under investigation.

e) X-Ray Backscatter: Backscattering involves sending X-rays into the ground. Objects with lower atomic numbers, such as plastics, scatter x-ray radiation better due to the electron density.

3) Acoustic/Seismic Methods:

Acoustic/seismic methods look for mines by "vibrating" them with sound or seismic waves that are introduced into the ground. Materials with different properties vibrate differently when exposed to sound waves.

4) Biological Methods:

a) Dogs and Rats: Trained dogs can detect the smell of explosives in a landmine buried in the ground up to 60cm. Rats are also trained using food rewards to signal the presence of explosives by scratching the ground surface with their feet.

b) Bees: Entomologists have trained bees to detect a variety of explosives and have been researching ways to use trained bees in humanitarian demining.

5) Mechanical Methods:

a) Prodders and Probes: The most basic approach to mine detection is prodding. Using prodders, rigid sticks of metal about 25 cm long; the de-miner scans the soil at a shallow angle of typically 30°. Each time he detects an unusual object, he assesses the contour, which indicates whether the object is a mine.

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b) Mine Clearing Machines: When there is not a lot of time for an army to clear a minefield, it will often employ the use of certain machines to roll through and clear a safe path. Military forces employ several kinds of mine-clearing machines to clear out or detonate mines.

The reliability on a landmine searching robot is highly dependent upon the performance of the detector with respect to the landmines, whereas, the purpose of the carrying vehicle is to provide the require pattern of movement in such a way that the detector can do its job.

IV. METHADODOLOGY

A remote controlled robot with metal detector for land mine detection will be used. In the vehicle, navigation is controlled by the user using remote control & the metal detector is used to detect the mines. When a land mine is detected, the microcontroller sends a signal to the motor drive system of the vehicle and stops the robot and marks the location of the land mine by spraying some paint above it. Detection of the land mine is indicated by a buzzer and the completion of marking the position of the land mine is also indicated by the buzzer. After this, the user resumes the desired path of the robot.

[1] Detector:

For the past decade, landmines, both anti-personnel and anti-tank mines, are made in metal casings. Therefore, the detection of landmine by using metal detectors is a simple and workable method. However, nowadays, the mines manufacturers tend to use as little metal as possible to redundant the use of metal detectors and so that their landmines will serve their purpose. Moreover, the metal detectors give out false signals upon sensing every presence of metal pieces instead of only when detecting the real mine.

Due to the above reasons, using a metal detector as a mine detector in the robot has become an unfavourable option.

As mentioned in Section 3.2, various other methods are better than metal detectors. Due to higher efficiency and better accuracy, Acoustic-Seismic method is best. This, though, is a very costly method for mine detection. Due to budget constraints, the idea of employing and experimenting with the Acoustic Laser Sensor is neglected in this project. The same applies for other better options since the equipment is expensive and requires military clearance in order to purchase one. Hence, even though metal detectors may seem inferior in performance, they are the most suitable to be used in this small scale project.

[2] Robotic Vehicle:

A transport system is required to carry and transport the mine detection unit. The mine fields are expected to have a sandy terrain as is the case of Indian military borders.

The very first proposal of transport unit is a walking robot, either four legged or six legged. Using legged robots will give great advantages in walking though rough terrain since it has the ability to balance itself and ability to avoid holes and small obstacles.

However, the drawback is the designing of the robot. It can cost a lot of money to build a smart robot and will take more than a year's time to do so. The robot idea had to be abandoned due to the financial constraint and time constraint. Moreover, the smarter the robot is, the more complex its mechanisms will be, and the main objective of designing a land mine detection unit might be side-tracked and instead more efforts will be put into designing the robot.

Therefore, the goal is a simple yet workable concept. A vehicle with tracks system or wheels hints with a belt system for terrain handling as a correct choice. Since a decent design can give good fraction, enough torque to overcome obstacles and easy manoeuvring ability, this idea seems promising. Moreover, the designing and fabricating a vehicle will be much cheaper and less time consuming than making a robot.

[3] Processing unit:

A processing unit, installed on the robot, will be transmitting data from the robot to the operator and it will receive and process the commands from the operator to the robot. These signals will be transmitted and received through radio channels and the command signals received by the robot will be redistributed to the respective mechanisms to carry out the required processes.

The aim of the processing unit is to synchronize the movements of the mechanisms to perform the desired job. This mine detection robot is intended to detect the buried mines, make a mark on their locations and then continue looking for another mine without disturbing the marked mine.

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Firstly, the detector which is located at the front of the robot processes a metal detector that will scan and clear the path. The scanner will stop scanning if there is no detection of a mine, and the robot will advance one step forward by activating the forward motor. After which, the scanner will restart its scanning sequence. The robot would move forward again with no detection of mine. This scanning loop will continue until the scanner detects a mine.

Once the scanner detects a mine, the robot comes to a standstill and sends out signals back to the operator by both LED lightning and beeping. The operator will then have to decide if it is a false alarm or a real detection of a mine. If the operator takes the warning as a false alarm, he will ignore it and restart the scanning loop. If warning is taken as a real detection of the mine, the operator has to send a command to the robot to mark the location by spraying distinctive colour paint on that spot.

[4] Marking Mechanism:

After the location of a land mine has been exposed, it is required to mark the position of the mine in order to facilitate the follow up demining process or to warn the marching troops. The suggested ideas for mine location marking process will be as followed.

- Use GPS (Global Positioning System) to mark the location digitally.
- Use Flags to indicate the location visibly.
- Use bright colour paints to highlight the location of a buried mine.

The first idea of using GPS to mark the location digitally might have been a good idea if satellite communication system is easily accessible in any region of the world. Moreover, the complexity of communication device that the robot needs to carry will put some negative votes towards the idea. Demining will be difficult since there is no visual indication of the exact location of the mine.

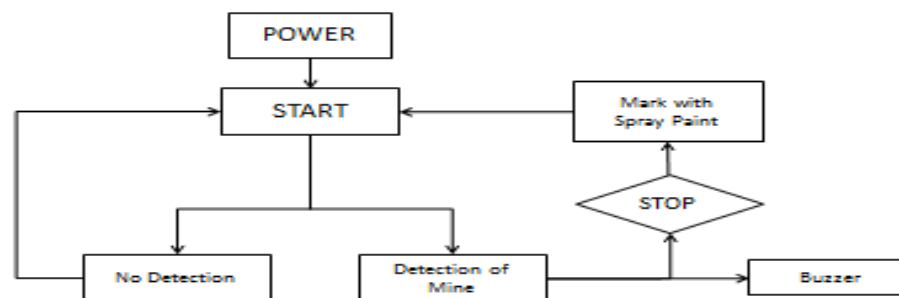
Indicating the location of discovered mines by flagging will be the best way to warn the troops and the best way to initiate the demining. Nevertheless, the mechanism that the robot might possess in order to set up a flag upon finding mine can be quite complicated and can cost a lot of time designing it.

The third idea of using paint to indicate the presence of a land mine could be a simple and workable idea. Droplets of bright colour paint will be dispersed from a nozzle, right onto the soil that is covering a land mine. A simple mechanism comprises of an electric motor, paint container, a few pipes and a nozzle, could be able to perform the desired job. Paint will give out visual warning and indication of the presence of a buried land mine.

V. ALGORITHM AND CALCULATIONS

[1] Algorithm:

Algorithm



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[2] Motor Torque Calculations:

Vehicle Design Criteria:

Gross vehicle weight (GVW):	3 kg
Weight on each drive wheel (Ww):	1.5 kg
Radius of wheel/tire (Rw):	32.5 mm
Desired top speed (Vmax):	0.3 m/s
Desired acceleration time (ta):	0.3 sec
Maximum incline angle (α):	20o
Worst working surface:	Sand(dune)

Total Tractive Effort, TTE= RR + GR + FA

Where,

RR = force necessary to overcome rolling resistance

GR = force required to climb a grade

FA = force required to accelerate to final velocity

Contact Surface	C _{rr}
Concrete (good/fair/poor)	.01/.015/.02
Snow (2 inch/4 inch)	.025/.037
Dirt (smooth/sandy)	.025/.037
Mud (firm/medium/soft)	.037/.09/.15
Grass (firm/soft)	.055/.075
Sand (firm/soft/dune)	.06/.15/.3

Step One: Determine Rolling Resistance

Rolling Resistance (RR) is the force necessary to propel a vehicle over a particular surface. The worst possible surface type to be encountered by the vehicle should be factored into the equation.

$$RR = GVW \times C_{rr}$$

$$= 3 \times 0.15$$

$$= 0.45 \text{ kg}$$

C_{rr} = surface friction (value from Table)

Step Two: Determine Grade Resistance

Grade Resistance (GR) is the amount of force necessary to move a vehicle up a slope or “grade”. This calculation must be made using the maximum angle or grade the vehicle will be expected to climb in normal operation.

To convert incline angle, α , to grade resistance:

$$GR = GVW \times \sin(\alpha)$$

$$= 3 \sin(20o)$$

$$= 1.026 \text{ kg}$$

where:

GR = grade resistance

α = maximum incline angle [degrees]

Step Three: Determine Acceleration Force

Acceleration Force (FA) is the force necessary to accelerate from a stop to maximum speed in a desired time.

$$FA = GVW \times V_{max} / (9.81 \times t_a)$$

$$= 3 \times 0.3 / (9.81 \times 0.3)$$

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$$= 0.3058 \text{ kg}$$

Step Four: Determine Total Tractive Effort

The Total Tractive Effort (TTE) is the sum of the forces calculated in steps 1, 2, and 3. (On higher speed vehicles friction in drive components may warrant the addition of 10%-15% to the total tractive effort to ensure acceptable vehicle performance.)

$$\begin{aligned} \text{TTE} &= \text{RR} + \text{GR} + \text{FA} \\ &= 0.45 + 1.026 + 0.3058 \\ &= 1.7818 \text{ kg} \end{aligned}$$

Step Five: Determine Wheel Motor Torque

To verify the vehicle will perform as designed in regards to tractive effort and acceleration, it is necessary to calculate the required wheel torque (T_w) based on the tractive effort.

$$\begin{aligned} T_w &= \text{TTE} \times R_w \times \text{RF} \\ &= 1.7818 \times 32.5 \times 1.1 \\ &= 63.7 \text{ kg-mm} \end{aligned}$$

where:

RF = "resistance" factor

The "resistance factor" accounts for the frictional losses between the caster wheels and their axles and the drag on the motor bearings. Typical values range between 1.1 and 1.15 (or 10 to 15%).

Step Six: Reality Check

The final step is to verify the vehicle can transmit the required torque from the drive wheel(s) to the ground. The maximum tractive torque (MTT) a wheel can transmit is equal to the normal load times the friction coefficient between the wheel and the ground times the radius of the drive wheel.

$$\begin{aligned} \text{MTT} &= W_w \times \mu \times R_w \\ &= 1.5 \times 0.8 \times 32.5 \\ &= 39 \text{ kg-mm} \end{aligned}$$

where:

μ = friction coefficient between the wheel and the ground

The total wheel torque calculated in Step Five must be less than the sum of the Maximum Tractive Torques for all drive wheels or slipping will occur.

$$\begin{aligned} \text{For two wheel drive, } T_w &< (\text{MTT} \times 2) \\ \text{i.e., } 63.7 \text{ kg-mm} &< 78 \text{ kg-mm} \end{aligned}$$

Therefore, our design assumptions are within safe limits.

Motor Torque Calculations:

$$\text{Wheel Circumference} = \pi \times D = \pi \times 65 = 204.2035 \text{ mm}$$

$$\text{Velocity} = 0.3 \text{ m/s}$$

$$\text{Velocity} = \text{RPS} \times \text{Wheel Circumference}$$

$$\begin{aligned} \text{RPS} &= 0.3 / 0.2042035 \\ &= 1.469 \text{ rev/sec} \end{aligned}$$

$$\begin{aligned} \text{RPM} &= \text{RPS} \times 60 \\ &= 88.147 \text{ rpm} \end{aligned}$$

Therefore, we will be using a motor with speed of more than 88.147 rpm.

Standard motors, which are available with speed of more than above, are of 100 rpm.

VI. ONGOING RESEARCH

1) One research states that instead of using a single, multi-sensor equipped vehicle, multiple simple machines are used, each one carrying a very limited amount of mine detection sensors that cooperate in the identification process [2].

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- 2) One project, considering running on rough terrains, made the robot with four crawlers, and hydraulic motors in front and rear were serially connected by piping so that they could rotate synchronously [3].
- 3) One paper presented the general concept and results of a pilot study on land mine detection based on the application of Time Reverse Acoustics [4].
- 4) One project deals with landmine detection and marking mechanism on the robot [5].

VII. EXPERIMENTAL RESULTS

- 1) Initially, according to calculations, motors of 100 rpm were chosen. But when the first test was performed, only 9 out of 16 times the metal was detected. Hence, we reduced the rpm of the motors for better detection.
- 2) Afterwards, during more testing, there appeared to be a spike in the current of the relay and hence the marking mechanism did not deactivate even after moving away from the metal and the buzzer remained active. So, we connected the relay with a snubber circuit. This cleared our problem.
- 3) Currently the robotic vehicle is operated manually by a manual remote control.
- 4) The detection of landmine is successful with the help of a metal detector.
- 5) Marking of the location is also carried out successfully.
- 6) Further improvement can be done by implementing GPS based location systems and a high end sensor discussed earlier.

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BIOGRAPHY



Prof. (Dr.) Girish Santosh Bagale did his B.E. in Automobile Engineering from D.M.E at Government Poly. , 2001. After that he did his M.Tech in Production Engineering from VJTI in 2006 and did his PhD in Management at Bundelkhand University, 2011. He has various research publications in International Journals and Conferences. He is currently employed as an Assistant Professor in the department of Mechanical/Mechatronics of Mukesh Patel School of Technology Management and Engineering, NMIMS University since 2006.



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