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LANDMINE DETECTION VEHICLE USING ROBOTICS

Ms. Naik S.S*[1]Saee Jagtap*[2], Surabhi Yadav*[3], Tanmayi Sathe*[4], Siddhi Dhankawade*[5]

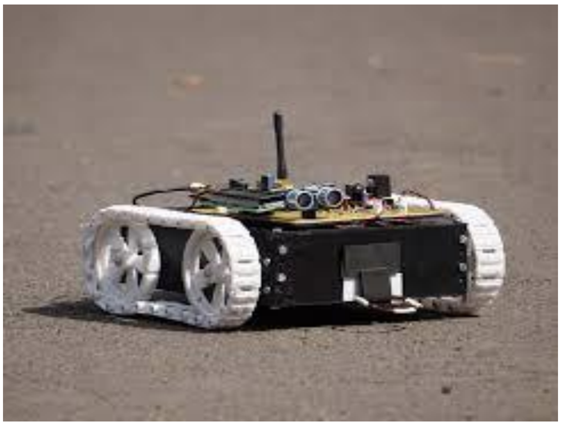
[*1],Lecturer, Dept. Of Computer Technology, B.V.J.N.I.O.T, Pune, Maharashtra, India.
[* 2,3,4,5] Students, Dept. Of Computer Technology, B.V.J.N.I.O.T, Pune, Maharashtra, India.

ABSTRACT

The effects of landmines, which are a serious threat to people and economies in many countries. The main challenge with landmines is that their locations are often unknown, making them difficult to detect. Developing new ways of demining is complicated because they are placed in different types of environments and come in many forms. Right now, landmine detection and removal require trained experts with special equipment. This paper looks at different methods used to detect landmines and explores how robots with sensors can help make detection safer and more effective.

INTRODUCTION

A Landmine is a type of camouflage weapon often used in military operations to cause explosion.
Landmines remain a serious danger, causing injuries and deaths even years after wars or conflicts have ended. The traditional way of demining landmines is done manually, which is not only slow but also extremely risky for those involved. Using robots for landmine detection provides a safer and more efficient alternative by relying on automated systems and advanced sensors. This paper focuses on the design, development, and testing of an autonomous vehicle specifically created to detect landmines.



1] Scanning

Landmine detection vehicles use advanced technology to locate and map buried landmines in a safe and efficient manner. One of the latest innovations in this field is laser-acoustic technology, developed by researchers at the University of Mississippi. This method uses lasers and sound waves to create a vibration map of the ground, helping to detect hidden landmines without disturbing the surrounding environment.
A notable example of this technology is the **Laser Multi-Beam Differential Interferometric Sensor (LAMBDIS)**, which can be mounted on a moving vehicle and detect landmines from a distance of up to 65 feet. By generating real-time vibration maps of the ground, this system is particularly effective in identifying mines made of plastic or other non-metallic materials that traditional metal detectors may fail to detect.
To improve accuracy and efficiency, these vehicles are often equipped with **ultrasonic sensors** to help navigate and avoid obstacles. By combining these technologies, demining operations become safer and more efficient, enabling the rapid clearance of large areas while reducing the risk to human personnel.

1.2] Detection

The effectiveness of any landmine detection system is measured by its ability to prevent accidents, especially with mines that may have shifted from their original positions. To address this challenge, some countries use trained dogs to sniff out the explosive materials inside landmines.

There are various landmine detection methods, but the process of detecting and removing landmines is often dangerous, slow, and expensive. Using autonomous robots for mine detection enhances safety for both civilians and demining teams. These robots scan the ground for buried mines using multiple sensors.

Currently, landmine detection technologies can be categorized into five main types:

1. **Metal detector technologies** – Identify metallic components in landmines.
2. **Electromagnetic methods** – Use electromagnetic waves to detect anomalies underground.
3. **Acoustic/seismic methods** – Detect mines based on vibrations and sound waves.
4. **Biological methods** – Utilize trained animals like dogs or even specially engineered plants to detect explosives.
5. **Mechanical methods** – Use machines to physically clear and detect mines.

1.3] Metal Detection Coil

Landmine detection vehicles are often equipped with **metal sensors** to locate buried landmines by identifying metallic components. When a mine is detected, the vehicle records it and transmits the location to a mobile device or a remote monitoring station using a **GSM module** for further action.

To improve accuracy and reliability, many systems use a **dual-sensor approach**. The metal detector serves as the **primary sensor**, detecting metallic objects underground. However, since landmine-affected areas often contain metal debris, additional sensors are used to distinguish between real landmines and harmless metal objects. This combination of sensors reduces false alarms and increases the overall effectiveness of landmine detection.

1.4] Transmission

The transmission system of a landmine detection vehicle is designed to handle **rough terrains** while minimizing vibrations. This is crucial because sensitive detection equipment, like **Ground Penetrating Radar (GPR) and metal detectors**, can be affected by excessive movement.

Key features of a landmine detection vehicle's transmission:

- **Reduced vibrations** – Ensures accuracy by preventing disturbances to detection sensors.
- **Precision speed control** – Allows the vehicle to move at a slow, steady pace for detailed scanning.

Types of Landmine Detection Vehicles

1. **Mine-resistant vehicles** – Armored vehicles that can withstand explosions while carrying detection equipment.
2. **Unmanned ground vehicles (UGVs)** – Remote-controlled or autonomous robots that scan minefields safely.
3. **Mine detection tanks** – Heavily armored tanks equipped with rollers, flails, or sensors to detect and neutralize mines.
4. **Sensor-Based Landmine Detection Vehicles -** Detect heat signatures from buried mines. Identify anomalies in the magnetic field caused by metallic mines.
5. **Hybrid Multi-Sensor Vehicles-** Combine metal detectors, GPR, and infrared sensors for improved detection accuracy.

Often used in military and humanitarian demining operations.

Strategies for Landmine Clearance

Clearing landmines requires **two main steps**:

1. **Detection** – Identifying the location of mines.
2. **Deactivation or removal** – Safely disabling or removing the mines.

There are three main minesweeping strategies:

1. **Manual minesweeping** – Human deminers use metal detectors and probes to find and remove mines. This method is **slow but highly accurate**.
2. **Mechanical minesweeping** – Heavy machinery rolls over landmines to **detonate or remove them**. This method is fast but **not always 100% reliable**.
3. **Robot-assisted minesweeping** – Autonomous robots use sensors and **computer vision** to detect and identify mines, improving **safety and efficiency**.

2] Modern Landmine Detection Vehicles

Recent research has focused on improving detection technologies to **reduce false alarms** and **increase detection accuracy**. Some innovations include:

- Microwave sensors and artificial intelligence to classify objects underground.
- Hybrid techniques using electromagnetic and acoustic waves for better detection.

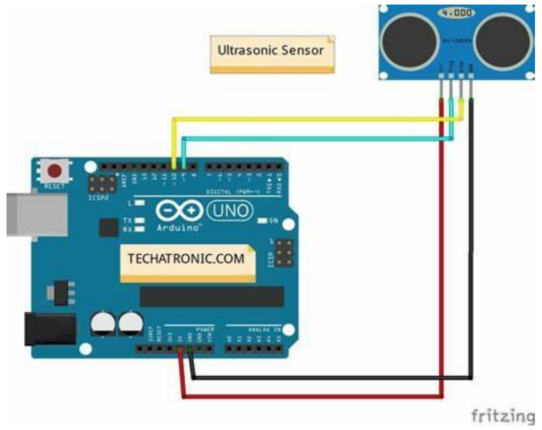
3.] Historical Evolution of Landmine Detection Vehicles

- **1950s–1980s (Cold War Era):**
  - Development of **mechanical mine-clearing vehicles** with plows, rollers, and flails.
  - Early research into **Ground Penetrating Radar (GPR)** and electromagnetic detection.

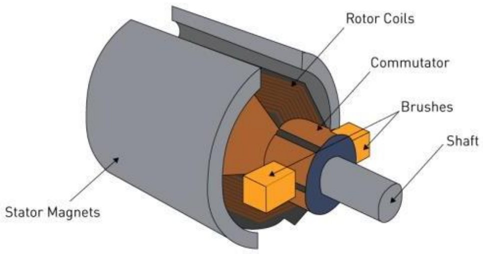
- **1990s–2000s (Post-Cold War):**
  - **Automated and remote-controlled vehicles** like the South African Meerkat and Husky VMMD.
  - **Multi-sensor systems** combining metal detectors, infrared sensors, and chemical sniffers.
- **2010s–Present (Modern Era):**
  - **AI-powered autonomous vehicles** (e.g., U.S. Army's M160).
  - **Hybrid sensor technologies** combining GPR, synthetic aperture radar, and electromagnetic induction.
  - **Drone-assisted detection** using UAVs with thermal imaging.

4.] Hardware Components

1. **Arduino Uno** – A microcontroller used to control the robotic vehicle and process sensor data.

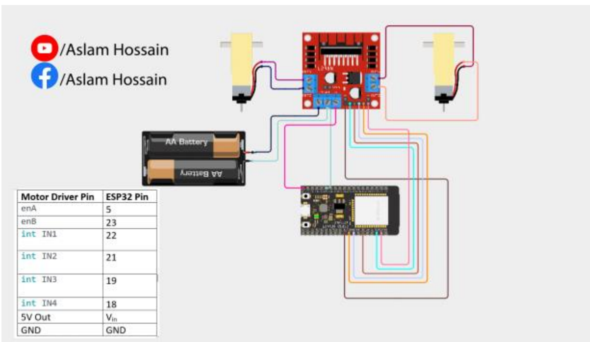


2. **DC Motors** – Provide movement and control for the robotic vehicle.



3. **GSM Module** – Allows communication with mobile networks for **remote monitoring**.

4. ESP32 – A Wi-Fi and Bluetooth-enabled microcontroller used for online data transfer.



5. **Ultrasonic Sensor** :- Incorporating ultrasonic sensors into landmine detection systems can enhance their capabilities by providing complementary detection modalities. It emits high-frequency sound waves and measures the time it takes for the sound waves to bounce off objects and return to the sensor.

5.] Working Principle

The robotic landmine detection vehicle operates as follows:

1. **Movement & Scanning** – The vehicle moves forward while a **metal detector scans the ground**.
2. **Data Transmission** – sends the coordinates to a mobile device via **Wi-Fi or GSM**.
3. **Remote Control** – Operators monitor and control the vehicle from a **safe distance**.

4. The robotic vehicle consists of Arduino uno connected with the wheels of the robot for the movement of the vehicle in clockwise and anti-clockwise direction over the land. In front side of robotic vehicle metal detector is placed which can sense mine ahead of it.
5. The model roams around 10 to 30m in surrounding while connected to remote.

Programming codes

```
ESP32 :#include <Arduino.h>
#include "BluetoothSerial.h"

BluetoothSerial SerialBT;

// Motor Pins
int ena = 5;
int in1 = 22;
int in2 = 21;
int enb = 23;
int in3 = 19;
int in4 = 18;

// Pin to receive stop signal from Arduino
const int stopPin = 16;  // Pin to receive stop signal from Arduino

#define MAX_SPEED 128

void setup() {
  Serial.begin(115200);          // Initialize Serial Monitor for debugging
  SerialBT.begin("ESP32_Car2");  // Bluetooth device name
  delay(1000);                   // Allow time for Bluetooth initialization

  // Set motor pins as output
  pinMode(ena, OUTPUT);
  pinMode(in1, OUTPUT);
  pinMode(in2, OUTPUT);
  pinMode(enb, OUTPUT);
  pinMode(in3, OUTPUT);
  pinMode(in4, OUTPUT);

  // Set stopPin as input to receive the stop signal from Arduino
```

```
    pinMode(stopPin, INPUT);

    stopMotors();  // Ensure motors are stopped initially
}

void loop() {
    // Check if there is any Bluetooth command available
    if (SerialBT.available()) {
        char command = SerialBT.read();
        Serial.println(command);
        controlCar(command);
    }

    // Check if the stop signal is HIGH (coming from Arduino)
    if (digitalRead(stopPin) == HIGH) {
        stopMotors();  // Stop the motors if the stop signal is received
        Serial.println("Received Stop Signal from Arduino! Stopping motors.");
    }
}

// Function to handle Bluetooth commands
void controlCar(char command) {
    switch (command) {
        case 'F': moveForward(); break;
        case 'B': moveBackward(); break;
        case 'L': turnLeft(); break;
        case 'R': turnRight(); break;
        case 'S': stopMotors(); break;
        default: Serial.println("Unknown command");
    }
}

// Function to move the car forward
void moveForward() {
    analogWrite(ena, MAX_SPEED);
    digitalWrite(in1, HIGH);
    digitalWrite(in2, LOW);
    analogWrite(enb, MAX_SPEED);
    digitalWrite(in3, HIGH);
    digitalWrite(in4, LOW);
}

// Function to move the car backward
void moveBackward() {
    analogWrite(ena, MAX_SPEED);
    digitalWrite(in1, LOW);
    digitalWrite(in2, HIGH);
    analogWrite(enb, MAX_SPEED);
    digitalWrite(in3, LOW);
    digitalWrite(in4, HIGH);
}

// Function to turn the car left
void turnLeft() {
    analogWrite(ena, MAX_SPEED);
    digitalWrite(in1, LOW);
    digitalWrite(in2, HIGH);
    analogWrite(enb, MAX_SPEED);
    digitalWrite(in3, HIGH);
    digitalWrite(in4, LOW);
```

```
}

// Function to turn the car right
void turnRight() {
  analogWrite(ena, MAX_SPEED);
  digitalWrite(in1, HIGH);
  digitalWrite(in2, LOW);
  analogWrite(enb, MAX_SPEED);
  digitalWrite(in3, LOW);
  digitalWrite(in4, HIGH);
}

// Function to stop the motors
void stopMotors() {
  analogWrite(ena, 0);
  analogWrite(enb, 0);
  digitalWrite(in1, LOW);
  digitalWrite(in2, LOW);
  digitalWrite(in3, LOW);
  digitalWrite(in4, LOW);
}
```

```
#define trigPin 9
#define echoPin 10

#define motor1A 3  // Left Motor IN1
#define motor1B 4  // Left Motor IN2
#define motor2A 5  // Right Motor IN3
#define motor2B 6  // Right Motor IN4

void setup() {
  pinMode(trigPin, OUTPUT);
  pinMode(echoPin, INPUT);
  pinMode(motor1A, OUTPUT);
  pinMode(motor1B, OUTPUT);
  pinMode(motor2A, OUTPUT);
  pinMode(motor2B, OUTPUT);
  Serial.begin(9600);
}

void loop() {
  long duration;
  int distance;

  // Send ultrasonic pulse
  digitalWrite(trigPin, LOW);
  delayMicroseconds(2);
  digitalWrite(trigPin, HIGH);
  delayMicroseconds(10);
  digitalWrite(trigPin, LOW);

  // Read echo time and convert to distance
  duration = pulseIn(echoPin, HIGH);
  distance = duration * 0.034 / 2;

  Serial.print("Distance: ");
```

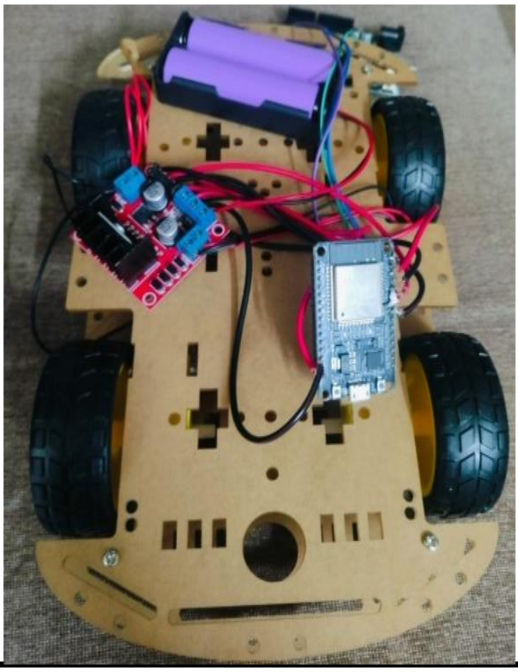
```
    Serial.print(distance);
    Serial.println(" cm");

    if (distance > 20 || distance == 0) { // Safe to move forward
        moveForward();
    } else { // Obstacle detected
        stopRobot();
        delay(500);
        moveBackward();
        delay(1000);
        turnRight();
        delay(1000);
    }
}

void moveForward() {
    digitalWrite(motor1A, HIGH);
    digitalWrite(motor1B, LOW);
    digitalWrite(motor2A, HIGH);
    digitalWrite(motor2B, LOW);
}

void moveBackward() {
    digitalWrite(motor1A, LOW);
    digitalWrite(motor1B, HIGH);
    digitalWrite(motor2A, LOW);
    digitalWrite(motor2B, HIGH);
}

void turnRight() {
    digitalWrite(motor1A, HIGH);
    digitalWrite(motor1B, LOW);
    digitalWrite(motor2A, LOW);
    digitalWrite(motor2B, HIGH);
}

void stopRobot() {
    digitalWrite(motor1A, LOW);
    digitalWrite(motor1B, LOW);
    digitalWrite(motor2A, LOW);
    digitalWrite(motor2B, LOW);
}
```

Arduino uno code

```
ARDIUNO UNO :const int trigPin = 9;
const int echoPin = 10;
const int stopPin = 8;  // Pin to send stop signal to ESP32

long duration;
int distance;

void setup() {
  Serial.begin(9600);  // Start the serial monitor
  pinMode(trigPin, OUTPUT);
  pinMode(echoPin, INPUT);
  pinMode(stopPin, OUTPUT);  // Output stop signal to ESP32
}
```

```
void loop() {
  digitalWrite(stopPin, LOW);  // Default no stop signal

  // Clear the trigPin condition
  digitalWrite(trigPin, LOW);
  delayMicroseconds(2);

  // Trigger the sensor
  digitalWrite(trigPin, HIGH);
  delayMicroseconds(10);
  digitalWrite(trigPin, LOW);

  // Read the duration of the echo pulse
  duration = pulseIn(echoPin, HIGH);

  // Calculate the distance (in cm)
  distance = duration * 0.0344 / 2;
Print the distance for debugging
  Serial.print("Distance: ");
  Serial.print(distance);
  Serial.println(" cm");

  // If an obstacle is detected within 20 cm, send stop signal to ESP32
  if (distance < 20) {
    digitalWrite(stopPin, HIGH);  // Send stop signal to ESP32
    Serial.println("Obstacle detected! Sending stop signal to ESP32.");
  }

  delay(500);  // Small delay before the next measurement
}
```

6.] Actual Model



7.] Future Scope

Landmine detection technology is constantly evolving. Future advancements may include:

1. **Enhanced sensors** – Improvements in **GPR, hyperspectral imaging, and chemical sensors** for better detection.
2. **AI integration** – Machine learning will help automate **mine classification and mapping**.
3. **Miniaturization & Portability** – Future detection vehicles may be smaller and more portable for **use in remote areas**.

8.] Applications

Humanitarian Demining:

- **Clearance of Landmine-Ridden Areas**: Landmine detection vehicles are deployed in conflict zones or areas previously affected by war to clear mines and make the land safe for civilian use. This helps restore agricultural land, residential areas, and infrastructure.

Military Operations:

- **Clearing Pathways for Troops**: In conflict situations, landmine detection vehicles are used by the military to clear minefields and secure safe routes for troops, vehicles, and supply convoys.
- **Minefield Mapping**: Some vehicles are equipped with advanced sensors and systems to map minefields, providing real-time data to military personnel for strategic planning.

Infrastructure Development:

- **Reconstruction and Development**: Before the construction of roads, railways, or other large infrastructure projects, landmine detection vehicles ensure that the area is free of mines. This is particularly important in post-conflict zones where infrastructure rebuilding is essential for economic recovery.

Agricultural Land Reclamation:

- **Restoration of Farmland**: In regions affected by past conflicts, landmine detection vehicles help in safely clearing agricultural lands so they can be returned to productive use, benefiting local farmers and improving food security.

Emergency Response and Disaster Relief:

- **Post-Disaster Mine Detection**: After natural disasters, areas may become contaminated with landmines, and landmine detection vehicles can be deployed to ensure the safety of relief teams and aid deliveries.
- **Collaboration with Aid Organization:**Use landmine detection vehicles to support reconstruction,food supply chain, and disaster relief efforts.

9.] Project Overview

This research aim is to provide a survey for developing the robot that can detect mine, as the robot may employee several sensors in order to help in mining. Incrementally improving existing technologies increasing the probabilities of detection reducing the false alarm rate and planning usable deployment scenarios. There is no single method for efficient landmine detection. Several technologies can be found, but their direct results cannot be generalized. Rather than focusing on individuals technologies operating in isolation, mine detection research and development should emphasize the design from first principles and subsequent development of an integrated, multisensory systems that would overcome the limitations of any single sensor technology. Combining different kinds of sensors would certainly obtain better results in landmine detection. Finally, some more attention should be given to sensor fusion and metal detectors. All of this issues should help to discriminate useful data, which is critical as large numbers of false alarms increase uncertainty and limit future research.

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