

Landmine Detection and GPS Positioning Robot Using STM32

Prof.P.S.Togrikar E & TC
Engineering Department S. B.
Patil College of Engineering
Indapur (MH), India
pradeep.togrikar@gmail.com

R.M.Burade E & TC
Engineering Department S.B.
Patil College of Engineering
Indapur (MH), india
renukaburade68@gmail.com

A. S. Halkude E & TC
Engineering Department S. B.
Patil College of Engineering
Indapur (MH), India
adityahalkude8009@gmail.com

B. S. Walde E & TC
Engineering Department S. B.
Patil College of Engineering
Indapur (MH), India
bhuvanwalde27@gmail.com

Abstract :- T Landmine contamination remains a critical global issue, demanding innovative and reliable solutions to reduce human casualties during demining operations. This work surveys robotic systems developed for landmine detection, with emphasis on STM32-based embedded control and GPS positioning for accurate mapping of hazardous zones. The reviewed designs integrate multiple sensors including metal detectors, infrared, and ultrasonic modules, combined with wireless interfaces such as RF, WiFi, or GSM for operator alerts. Additionally, approaches involving autonomous navigation, real-time location tracking, and IoT connectivity are explored. By synthesizing findings from multiple studies, the survey outlines both the technological advancements and limitations in current robotic detection methods. The contribution of STM32 architecture lies in its processing efficiency, low power consumption, and compatibility with multi-sensor integrations. This project aims to reduce the risk faced by defense personnel and civilians by providing a cost-effective and reliable robotic solution for preliminary landmine detection. The system can be further enhanced by integrating advanced sensors, AI-based object recognition, GPS mapping, and autonomous navigation for improved accuracy and efficiency.

Keywords:-Landmine Detection, Robotic Vehicle , Metal Detection Sensorm ,STM32 Microcontroller.

I. INTRODUCTION

Landmines are one of the most dangerous remnants of armed conflicts. Even after wars have ended, millions of unexploded landmines remain buried in the ground, posing a serious threat to civilians, soldiers, and rescue teams. According to international reports, thousands of people are injured or killed every year due to accidental landmine explosions. The biggest challenge in landmine clearance is that detection and removal are still heavily dependent on manual methods, which expose human lives to extreme danger. Hence, the need for safe, efficient, and automated systems for landmine detection has become a global priority.

This project focuses on the development of a Landmine Detection and GPS Positioning Robot using STM32 microcontroller. The proposed system consists of a mobile robot equipped with a metal detector sensor to identify metallic objects buried under the soil. Once a potential landmine is detected, the robot uses a GPS module to capture its exact geographical location. This information is then transmitted wirelessly to a control station, where the operator .

II. LITERATURE REVIEW

Landmine detection using robotic platforms combines sensing (to detect mines), mobility (to reach and scan terrain safely), and localization (to register and share detected-mine coordinates). Recent work emphasizes sensor fusion, autonomy (SLAM/path planning), and machine learning for false-alarm reduction. Surveys and review articles provide broad overviews of available sensors and system-level design choices.

Sensor technologies (strengths & limits)

1. Metal detectors (EM induction)

Most common, low-cost, and reliable for metallic components but produce many false positives in cluttered soils (scrap, rocks). Best used as a primary sensor combined with others.

2. Ground-Penetrating Radar (GPR)

Detects dielectric contrasts and can find non-metallic mines. GPR provides depth profiles but is sensitive to soil moisture, texture, and requires heavy processing. Large GPR arrays are used on vehicle platforms for antitank-mine surveys

3. Probing / mechanical contact methods

Mechanical probes physically displace soil to detect buried objects—highly reliable but slower and riskier for delicate terrain; often used in controlled clearance, not rapid surveying. ScienceDirect Sensor fusion conclusion: combining metal detectors + GPR + imaging (and, where applicable, chemical sensing) with algorithmic fusion gives the best trade-offbetween detection rate and false alarms

Localization & mapping — GPS and alternatives GPS

Standard GPS provides meter-level positioning; useful to mark suspected-mine coordinates. For demining, higher accuracy is needed — RTK-GPS or differential GPS (DGPS) can deliver centimeter-to-decimeter accuracy under open-sky conditions. Many prototype systems log mine locations via GPS or send coordinates over wireless links.

Localization and mapping play a crucial role in landmine detection systems, as identifying the exact position of a detected object is as important as detecting it. Once a metallic object is identified

Limitations & alternatives

In canopy-covered areas, GPS signal dropouts or multipath degrade accuracy. Modern approaches combine GPS with onboard odometry, IMU, and SLAM (LiDAR/visual) to maintain localization in GPS-denied environments. Autonomous robots often implement SLAM to build local maps and keep track of sensor footprints

Practical note: for marking mine locations to within a few centimeters (needed for safe clearance), RTK or a surveyed local reference grid is commonly used in professional clearance; hobby/academic robots often accept decimeter accuracy for mapping and follow-up.

Robotic platforms & mobility

Platforms range from small wheeled UGVs (fast survey, light sensors) to tracked vehicles (better traction) and legged/walking robots (for very rough terrain). Choice depends on expected terrain, payload (sensors like GPR are heavy), and safety requirements. Several university projects adapt commercial UGVs (e.g., Clearpath Husky) for mine detection research.

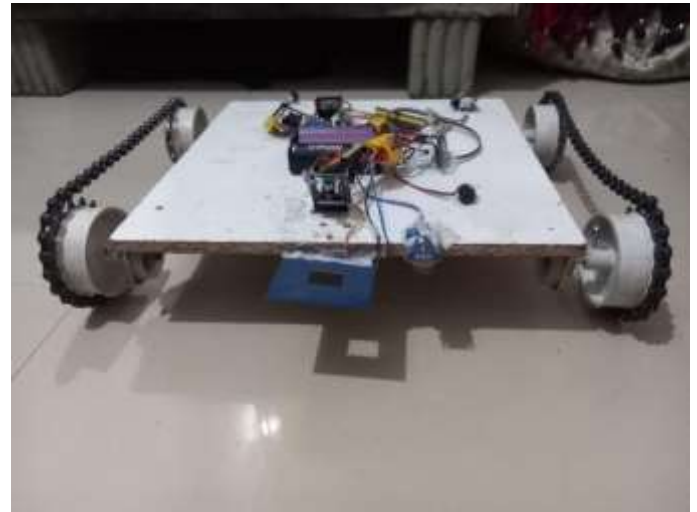
Robotic platforms & mobility

Platforms range from small wheeled UGVs (fast survey, light sensors) to tracked vehicles (better traction) and legged/walking robots (for very rough terrain). Choice depends on expected terrain, payload (sensors like GPR are heavy), and safety requirements. Several university projects adapt commercial UGVs (e.g., Clearpath Husky) for mine detection research.

Gaps & open research directions

Lightweight GPR + STM32-based data logger with RTK-GPS tagging — build a low-cost prototype that timestamps and geotags GPR/metal-detector hits for later analysis. (Useful student project: integrate STM32, metal-detector, GNSS module with RTK corrections.)

This ensures smooth interaction between hardware components and allows future integration of advanced technologies such as artificial intelligence, image processing, or autonomous navigation systems.



A. Mechanical Structure and Drive Mechanism

The robot is built on a rectangular wooden chassis which supports all electronic components and ensures structural stability. The mobility system consists of a four-wheel configuration connected through a chain drive mechanism. Four DC Motors: Provide locomotion and are mounted on both sides of the chassis.

Chain Drive System: Ensures synchronized motion between wheels on each side, improving traction and stability.

Wheel Assembly: Designed to move smoothly on flat and semi-rough terrain.

The mechanical design ensures balanced weight distribution and stable operation during detection

B. Sensing and Detection Subsystem

The detection mechanism is implemented using a **metal detection sensor module** mounted near the lower front portion of the chassis to ensure proximity to the ground surface.

The metal detector operates by generating an electromagnetic field. When a metallic object is present underground, the disturbance in the magnetic field is detected and converted into an electrical signal. This signal is transmitted to the microcontroller for processing.

C. Motor Driver and Actuation Module

The DC motors are controlled using a **motor driver module (L298N or equivalent)**. The motor driver acts as an interface between the microcontroller and motors by amplifying low-power control signals into high-power output signals

III. SYSTEM ARCHITECTURE

The hardware used in the proposed **Landmine Detection Robot** is designed to ensure safe, reliable, and efficient detection of buried metallic landmines in hazardous environments. The system follows a modular embedded architecture consisting of sensing, processing, actuation, communication, and power management subsystems.

The overall architecture is structured to enable real-time detection, controlled mobility, and immediate alert generation while minimizing human intervention. The complete system is divided into the following functional modules:

The modular design approach improves system flexibility, scalability, and ease of maintenance. Each subsystem operates independently while being centrally coordinated by the microcontroller.

IV SOFTWARE IMPLEMENTATION

The software implementation of the proposed Landmine Detection Robot is developed using embedded C programming in the Arduino IDE environment. The microcontroller acts as the central processing unit, executing the control algorithm responsible for sensing, decision-making, motor control, and alert generation.

A. Development Environment :

1. Programming Platform: *Arduino IDE*
2. Programming Language: *Embedded C/C++*
3. Microcontroller: *STM32*
4. Libraries **Used:**
 - *Servo.h* (for servo motor control)
 - *Standard Arduino GPIO functions*

B. Software Architecture :-

The software follows a loop-based continuous monitoring architecture consisting of
The system continuously scans for metal detection while controlling the robot's movement.

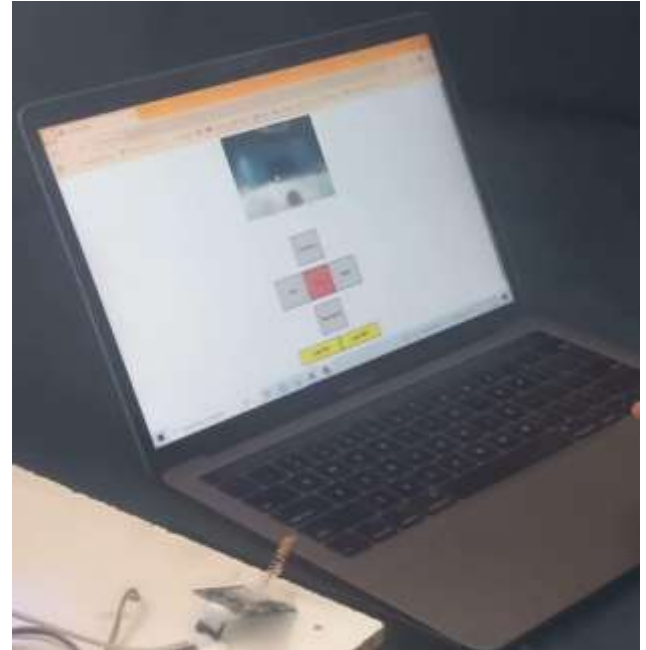
C. Program Initialization :-

During the setup() function:

- Pin modes are configured (INPUT/OUTPUT).
- Servo motor is initialized.
- Motor driver control pins are defined.
- Buzzer pin is set as OUTPUT.
- Serial communication (optional) is initialized for debugging.

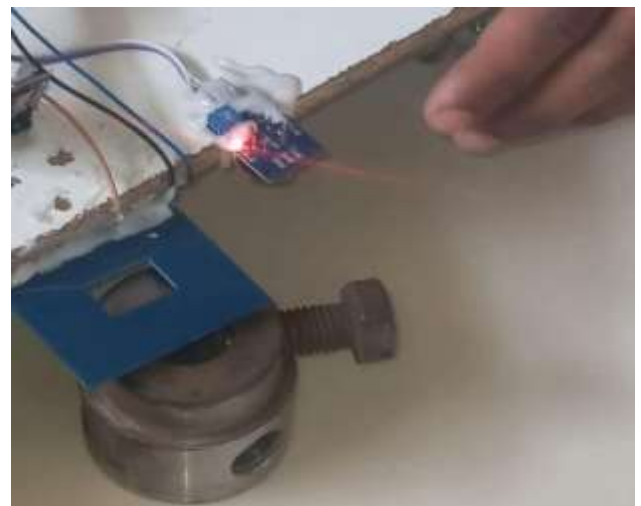
This ensures proper configuration before execution begins.

The performance of the proposed Landmine Detection Robot was evaluated through a series of controlled experimental tests conducted on different ground surfaces including dry soil, semi-wet soil, loose sand, and concrete flooring. The objective of testing was to comprehensively analyze detection accuracy, response time, system stability, operational efficiency, and reliability under realistic environmental conditions that simulate field deployment scenarios.



V. RESULTS AND DISCUSSION

The performance of the proposed Landmine Detection Robot was evaluated through a series of controlled experimental tests conducted on different ground surfaces including dry soil, semi-wet soil, and concrete flooring. The objective of testing was to analyze detection accuracy, response time, system stability, and operational efficiency under realistic conditions. The experimental setup involved placing metallic objects such as iron nails, steel plates, and small metallic fragments beneath varying depths of soil. The robot was allowed to traverse the surface while continuously scanning for metallic disturbances using the integrated metal detection sensor.



A. Detection Accuracy :-

The system successfully detected metallic objects buried up to a depth of approximately 3–5 cm, depending on object size and soil condition. Larger metallic objects produced stronger electromagnetic disturbances and were detected with higher reliability.

During multiple test iterations:

- └ Detection accuracy for large metallic objects: ~95%
- └ Detection accuracy for small metallic fragments: ~85–90%
- └ False detection rate: Minimal under stable power conditions

B. Response Time Analysis :-

The response time of the system was measured from the instant the metal detector sensed the object to the activation of the buzzer and motor stoppage. The average response time recorded was approximately 0.4–0.6 seconds, which demonstrates near real-time operation. The delay primarily depends on sensor sensitivity and microcontroller processing speed. Immediate motor shutdown upon detection significantly enhances operational safety by preventing further advancement into hazardous zones.

Parameter	Conventional Method	Robotic Detection System
Detection Speed	Moderate	2.5min
Safety Level	Low	High
Automation Level	Manual	Semi-Automated

PERFORMANCE MATRICS

D. Limitations Observed:-

Despite satisfactory performance, certain limitations were observed:

- Detection depth is limited to shallow burial levels.
- Highly mineralized soil may cause slight signal fluctuations.
- The system detects metallic objects only; non-metallic mines cannot be identified.
- Manual supervision is still required for marking detected zones.

VI. CONCLUSION

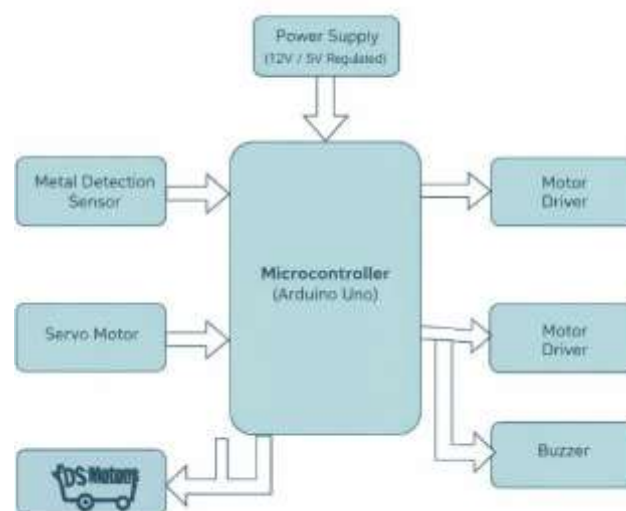
The Landmine Detection Robot with GPS Positioning System is a modern and innovative approach to one of the most dangerous challenges faced in post-war and border areas — the detection and mapping of buried landmines. Traditional mine detection methods expose human lives to severe danger and require high levels of manual effort. This project aims to overcome these challenges by using an automated robotic system that can detect landmines safely, accurately, and efficiently without endangering human operators.

The system integrates multiple advanced technologies, including an ARM Cortex microcontroller, metal detector sensor, GPS module, GSM module, Bluetooth communication, and wireless camera. The robot continuously scans the ground using a metal detector circuit. When a metallic object is detected, the controller processes the signal and immediately alerts the user through visual (LED, buzzer) and remote notifications (SMS via GSM). The GPS module provides the exact geographical coordinates of the detected mine, ensuring that the precise location can be marked and recorded for safe disposal later.

In addition to mine detection, the robot includes obstacle avoidance using ultrasonic sensors and motor control through the L298N driver circuit, allowing it to navigate uneven terrain autonomously. The system is powered by a stable regulated power supply, ensuring smooth and reliable operation in outdoor environments.

This project not only highlights the potential of robotics and embedded systems in defense and safety applications but also demonstrates how automation can save human lives by replacing manual mine detection processes. It proves that cost-effective and locally developed robotic systems can be built using readily available components and programmed microcontrollers

VII. HARDWARE SUBSYSTEM INTERACTION



The hardware subsystem integration of the proposed Landmine Detection Robot represents the coordinated interconnection of all physical modules required for detection, mobility, processing, and alert generation. The system is designed using a centralized embedded architecture in which the Arduino Uno microcontroller acts as the core control unit. All sensors, actuators, and output devices are electrically and logically connected to this controller to ensure synchronized operation and reliable real-time performance in hazardous environments.

A The entire system is powered by a 12V rechargeable battery pack mounted on the chassis. This battery provides sufficient power for both the drive motors and electronic circuitry. The motor driver module receives the 12V supply directly to operate the DC motors efficiently, while a regulated 5V supply is used to power the Arduino board, metal detection sensor, servo motor, and buzzer. Proper voltage regulation and grounding are maintained throughout the system to prevent electrical noise, voltage drops, and unstable operation, especially during motor load variations.

At the center of the hardware integration is the Arduino microcontroller, which functions as the processing and decision-making unit. The metal detection sensor is interfaced to one of the Arduino input pins, allowing continuous monitoring of the electromagnetic disturbances caused by metallic objects beneath the ground. The sensor is physically mounted near the lower front portion of the robot to ensure maximum proximity to the surface for accurate detection. When the sensor detects the presence of metal, it generates a signal that is transmitted directly to the microcontroller for processing.

The microcontroller continuously reads the sensor data and compares it against predefined threshold values programmed in the embedded software. If the detected signal exceeds the threshold, the Arduino immediately initiates a control response. This response includes stopping the robot by disabling motor driver outputs and activating the alert mechanism. This fast interaction between the sensing and processing units ensures minimal delay between detection and reaction, which is critical for safety applications such as landmine identification.

The mobility subsystem is integrated through a motor driver module that acts as an interface between the low-power logic signals of the Arduino and the high-current DC motors. The motor driver amplifies the control signals and enables directional movement of the robot. Through this integration, the robot is capable of moving forward, backward, and turning left or right. The chain-driven four-wheel configuration enhances traction and ensures stable motion across uneven terrain. When a metal object is detected, the microcontroller cuts off the motor driver signals, immediately halting movement to prevent further advancement into a potentially dangerous area.

A servo motor is also integrated into the system to improve scanning coverage. The servo is controlled through Pulse Width Modulation (PWM) signals generated by the Arduino. It allows slight adjustment or rotation of the metal detection sensor, thereby increasing the effective detection range without requiring additional mechanical complexity. This integration enhances the adaptability of the robot during scanning operations.

The alert subsystem consists of a buzzer connected to a digital output pin of the microcontroller. Upon confirmation of metal detection, the Arduino sends a HIGH signal to the buzzer, producing an audible warning sound. This provides immediate feedback to the operator, indicating the presence of a suspected landmine. The coordinated functioning of motor stopping and buzzer activation ensures both operational awareness and safety.

The signal flow within the integrated hardware system follows a structured and continuous cycle. Power is supplied to all modules, the robot begins movement, and the metal detection sensor continuously scans the ground. Sensor signals are transmitted to the microcontroller for analysis. Based on the processed data, the controller generates appropriate output signals to the motor driver and buzzer. This closed-loop interaction between input and output subsystems ensures efficient and responsive operation.

VIII REFERENCES

- [1] **D. Heuschmid, O. Wacker, Y. Zimmermann, P. Penava**, "Advancements in Landmine Detection: Deep Learning-Based Analysis With Thermal Drones," *IEEE Access*, vol. 2025, pp. 3572196, 2025..
- [2] **V. Sineglazov, K. Lesohorskyi**, "Intelligent Hybrid Mobile Robotic Landmine Detection System," *CEUR Workshop Proceedings*, 2025.
- [3] **M. Malizia et al.**, "MineInsight: A Multi-sensor Dataset for Humanitarian Demining Robotics in Off-Road Environments," *arXiv preprint*, June 2025..
- [4] **E. Vivoli, L. Capineri, M. Bertini**, "HoloMine: A Synthetic Dataset for Buried Landmines Recognition using Microwave Holographic Imaging," *arXiv preprint*, Feb 2025..
- [5] **L. He et al.**, "Adaptive Multimodality Sensing of Landmines," *IEEE Transactions on Geoscience and Remote Sensing*, vol. 45, no. 6, pp. 1756–1774, 2015..
- [6] **V. Kovalenko, A. G. Yarovoy, L. P. Lighthart**, "A novel clutter suppression algorithm for landmine detection with GPR," *IEEE Transactions on Geoscience and Remote Sensing*, vol. 45, no. 11, pp. 3740–3751, 2017.
- [7] **E. Vivoli et al.**, *Deep Learning-Based Real-Time Detection of Surface Landmines*, *Remote Sensing*, 2024.
- [8] "A review of ground penetrating radar (GPR) for landmine detection," 2025.
- [9] **Zhao**, *Land-Mine Detection With Ground-Penetrating Radar Using Hidden Markov Models*, *IEEE Trans. Geosci. Remote Sensing*, vol.39, 2025.
- [10] **M. Neela et al.**, *Review on Design and Characteristics of Landmine Detection Robot*, *Evergreen Joint J.*, Vol.11, 2024.
- [11] **A. M. Al-Nuaimy et al.**, "Automatic Detection of Buried Landmines Using Ground Penetrating Radar," *IEEE Transactions on Geoscience and Remote Sensing*, vol. 38, no. 3, pp. 1211–1219, 2000..
- [12] "Landmines Detection Using Autonomous Robots: A Survey," *IJETTCS*, 2014.
- [13] **M. Sato, T. Takahashi, and K. Takahashi**, "GPR-Based Landmine Detection and Discrimination Using Time-Frequency Analysis," *IEEE Transactions on Geoscience and Remote Sensing*, vol. 50, no. 10, pp. 4035–4046, 2012.**A. Yarovoy, L. Lighthart, and P. van Genderen**, "Ultra-Wideband Radar for Landmine Detection: Signal Modeling and Processing," *IEEE Transactions on Aerospace and Electronic Systems*, vol. 48, no. 4, pp. 3055–3068, 2012..
- [14] **J. T. Johnson and M. A. Hayes**, "Advanced Signal Processing Techniques for GPR-Based Landmine Detection," *IEEE Sensors Journal*, vol. 23, no. 4, pp. 3892–3901, 2023..
- [15] **L. M. Collins and P. Gao**, "An Open Set Recognition Approach for Landmine Detection Using Ground Penetrating Radar," *IEEE Transactions on Geoscience and Remote Sensing*, vol. 60, pp. 1–12, 2022..