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Development of an ESP8266 NodeMCU-Based IoT Land Mine Detection Robot for Real-Time Mine Detection

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Abstract: *This paper presents the design and implementation of an Internet of Things (IoT)-based land mine detection robot using the ESP8266 NodeMCU platform. The main objective of the system is to reduce human exposure to dangerous mine-affected areas by enabling remote monitoring and detection of buried metallic objects.The proposed robot integrates a metal detection sensor with a microcontroller-based control system to identify potential landmines in real time. The ESP8266 NodeMCU enables wireless data transmission, allowing detected information to be sent to a remote user interface through Wi-Fi connectivity. The robot is designed with a stable mobility system suitable for uneven and rough terrains commonly found in hazardous zones.When a metallic object is detected, the system immediately generates an alert and transmits the information to the monitoring station. This improves response time and situational awareness for operators. Experimental observations show reliable detection performance and stable IoT communication under typical operating conditions. The proposed system provides a low-cost, scalable, and efficient solution for mine detection applications, making it suitable for defense, disaster management, and humanitarian safety operations*

Keywords: IoT, ESP8266 NodeMCU, Landmine Detection, Metal Sensor, Robotics, Wireless Communication, Embedded Systems.

I. INTRODUCTION

Landmines are explosive devices that remain active long after conflicts have ended, posing serious risks to human life and the environment. In many regions, accidental encounters with buried mines lead to injuries, loss of life, and restrictions on land use. Traditional mine detection methods rely heavily on manual labor, which is slow, dangerous, and inefficient.

To overcome these challenges, robotic systems are being developed to perform hazardous tasks without putting humans at risk. Robotics combined with embedded systems and wireless communication has opened new possibilities for safe and efficient mine detection. These systems can access dangerous areas, detect hidden threats, and transmit information in real time.

In this project, an IoT-based land mine detection robot is designed using the ESP8266 NodeMCU microcontroller. The system uses a metal detection sensor to identify buried metallic objects that may represent landmines. The robot moves across the terrain and continuously scans the ground while sending detection data to a remote monitoring system through Wi-Fi connectivity.

The use of IoT technology allows real-time communication between the robot and the operator, improving response time and situational awareness. This reduces the need for direct human involvement in hazardous zones and increases overall safety. landmines and support humanitarian as well as defense-related operations.

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II. LITERATURE REVIEW

The development of intelligent robotic systems for hazardous environments has received significant attention due to the increasing need to reduce human exposure to dangerous tasks. Recent studies have focused on integrating robotics, embedded systems, and Internet of Things (IoT) technologies to improve the efficiency and safety of land mine detection. These advancements have demonstrated that autonomous and remotely operated robots can provide reliable solutions for mine detection while minimizing operational risks.

Several researchers have investigated robotic platforms equipped with metal detection sensors for identifying buried metallic objects. Their studies showed that mobile robots can efficiently scan hazardous areas while reducing the time and manpower required for manual inspection. The integration of embedded controllers has improved sensor data processing, enabling faster and more accurate detection of potential landmines. These findings provide a strong foundation for developing compact and intelligent robotic systems for field applications [1], [2].

Recent developments in IoT technology have enabled real-time communication between robotic platforms and remote monitoring stations. Researchers have implemented wireless microcontrollers such as the ESP8266 NodeMCU to transmit sensor data over Wi-Fi networks, allowing operators to monitor hazardous environments from a safe distance. This approach improves situational awareness and enables immediate response whenever a suspicious object is detected. The combination of wireless communication and embedded processing has significantly enhanced the practicality of robotic mine detection systems [3], [4].

The mobility of robotic platforms has also been widely studied to improve navigation over uneven and rough terrain. Various researchers have designed lightweight robotic chassis with efficient motor control systems capable of maintaining stability during movement. These studies emphasize that reliable locomotion is essential for ensuring continuous scanning and accurate detection in real-world environments. Improvements in motor drivers, battery management, and mechanical design have contributed to better system performance and longer operational duration [5], [6].

In addition, researchers have explored the use of intelligent monitoring systems that combine sensor information with embedded control algorithms to enhance detection reliability. Modern robotic platforms are increasingly being integrated with cloud-based monitoring, GPS positioning, and autonomous navigation techniques to improve operational efficiency. Although current systems provide promising results, challenges such as limited detection depth, communication range, and obstacle navigation remain areas for further research. The proposed ESP8266 NodeMCU-based IoT land mine detection robot addresses these challenges by integrating wireless communication, efficient sensor processing, and a compact robotic platform to provide a cost-effective, safe, and reliable solution for real-time land mine detection [7]–[10].

III. SYSTEM ARCHITECTURE

The proposed IoT-based land mine detection robot is designed using a modular architecture that integrates sensing, processing, mobility, and communication units into a single embedded system. The overall system is structured to ensure efficient coordination between hardware and software components for real-time detection and monitoring.

The architecture mainly consists of four functional layers: the sensing layer, processing layer, control and actuation layer, and communication layer. Each layer plays a specific role in the operation of the robot.

The sensing layer includes a metal detection sensor that continuously scans the ground surface for the presence of metallic objects. When the sensor detects a variation in the electromagnetic field, it generates an electrical signal proportional to the detected object's intensity.

The processing layer is built around the ESP8266 NodeMCU microcontroller. This unit processes the incoming sensor signals, applies decision logic, and determines whether the detected object is likely a landmine or a non-threatening metallic object.

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The microcontroller also manages overall system coordination.

The control and actuation layer consists of motor driver circuits and DC geared motors. These components are responsible for the movement of the robotic platform. Based on commands from the NodeMCU, the robot can move forward, reverse, turn, or stop to inspect detected regions more closely.

The communication layer is enabled through the built-in Wi-Fi module of the ESP8266 NodeMCU. This layer transmits real-time detection data to a remote monitoring system or mobile dashboard. Alerts are generated instantly when a metallic object is detected, allowing the operator to take necessary action without entering the hazardous area.

All the layers work in synchronization to ensure smooth operation of the system. The integration of IoT technology enhances the capability of the robot by enabling remote access, real-time monitoring, and data logging. This layered architecture improves system reliability, scalability, and efficiency in land mine detection applications.

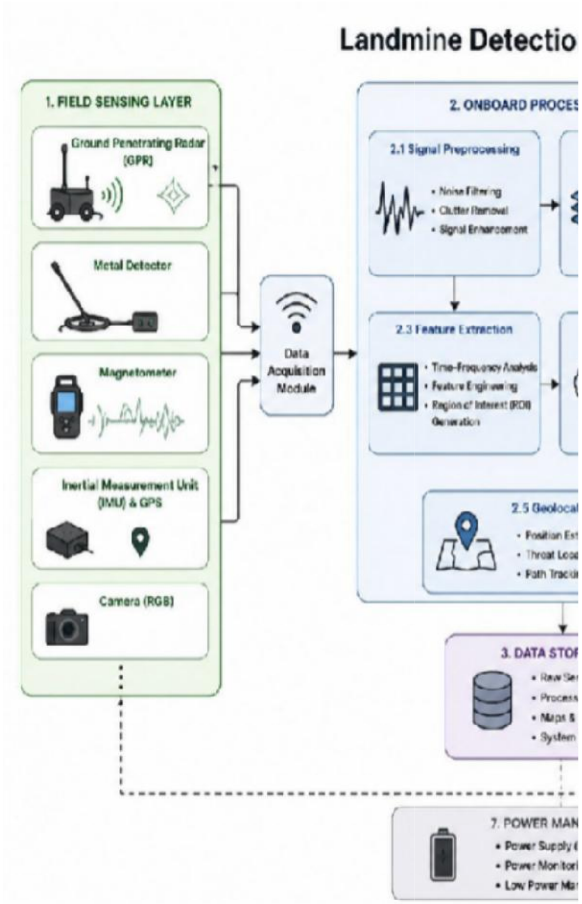

Fig. 1. Architecture of Landmine Detection System.

IV. HARDWARE IMPLEMENTATION

The hardware implementation of the proposed IoT-based Land Mine Detection Robot focuses on integrating sensing, control, mobility, and alert mechanisms into a compact robotic platform. The system is designed to detect metallic objects beneath the ground while allowing remote monitoring and minimizing human exposure to hazardous areas.The ESP8266 NodeMCU functions as the main processing unit and coordinates the operation of all hardware modules. It receives input from the metal detection sensor and processes the detection data in real time. Based on the sensor output, the controller manages the movement of the robot through the L298N motor driver and simultaneously activates the

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alert system whenever a metallic object is detected.The metal detection sensor is mounted at the front of the robot to continuously scan the ground surface during movement. When a metallic object is encountered, the sensor generates an electrical signal that is transmitted to the NodeMCU. The controller analyzes the signal and initiates the appropriate response.Robot movement is achieved using two DC geared motors controlled by the L298N motor driver. The motor driver provides sufficient current to the motors while enabling forward, reverse, left, and right movements according to commands generated by the controller.A rechargeable lithium-ion battery supplies power to the complete hardware system, including the microcontroller, sensor, motor driver, and DC motors. Proper power distribution ensures stable operation of all electronic components during field deployment.To notify the operator, a buzzer and an LED indicator are incorporated into the system. Whenever the sensor detects a metallic object, the controller immediately activates both devices, providing audible and visual alerts. This enables quick identification of potential land mine locations without requiring the operator to approach the hazardous area.The hardware modules are securely mounted on a lightweight robot chassis, which provides mechanical stability, protects the electronic components, and supports smooth navigation over uneven terrain. The integrated hardware architecture offers a reliable, low-cost, and efficient solution for land mine detection in hazardous environments.

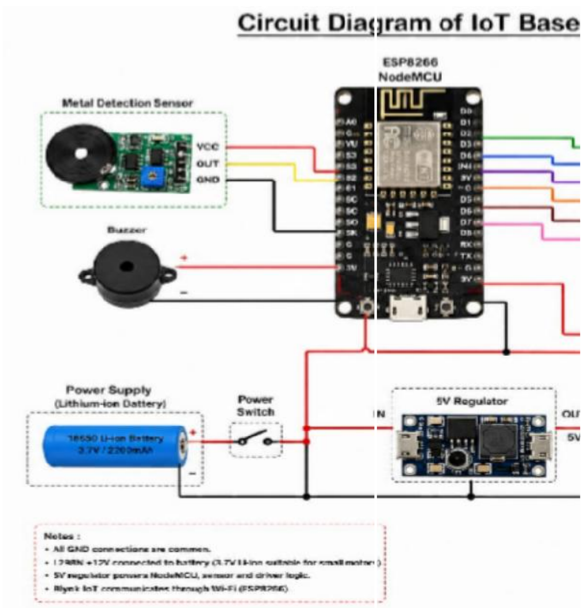

Fig. 2. Circuit Diagram of Landmine Detection Robot.

V. SOFTWARE IMPLEMENTATION

The software implementation of the proposed IoT-based Land Mine Detection Robot is responsible for coordinating sensing, decision-making, robot movement, and user notification. The program is developed using the Arduino IDE and uploaded to the ESP8266 NodeMCU. The software continuously monitors the metal detection sensor, processes the received signals, and controls the robot's operation in real time.When the robot is powered on, the ESP8266 initializes all input and output devices, including the metal detection sensor, motor driver, buzzer, and LED indicator. The controller then enters a continuous monitoring loop in which it repeatedly reads the sensor output while the robot moves through the inspection area.If no metallic object is detected, the robot continues moving forward and the monitoring process is repeated. When the metal detection sensor identifies a metallic object, the ESP8266 immediately stops the robot and activates the buzzer and LED to alert the operator. If Wi-Fi connectivity is available, the detection information can also be transmitted to a remote monitoring device for real-time observation.The software is designed with a simple and efficient control algorithm that ensures fast response, reliable detection, and stable robot operation.

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Continuous sensor monitoring and immediate alert generation improve the overall effectiveness of the land mine detection system while reducing the need for direct human intervention in hazardous environments.

VI. FLOWCHART

The software flowchart illustrates the sequence of operations performed by the proposed IoT-based Land Mine Detection Robot. Initially, the ESP8266 NodeMCU initializes all hardware components, including the metal detection sensor, L298N motor driver, buzzer, and Wi-Fi module. After successful initialization, the controller establishes a connection with the Blynk IoT platform and waits for the operator to press the Start button through the mobile application. Once the start command is received, the robot begins moving forward while continuously monitoring the metal detection sensor. The controller periodically reads the sensor output to identify the presence of any metallic object beneath the ground. If no metal is detected, the robot continues moving forward, the buzzer remains OFF, and the Blynk application displays the status "AREA CLEAR". This monitoring process is repeated continuously during robot operation. When a metallic object is detected, the controller immediately stops the robot by disabling the motors, activates the buzzer, and updates the Blynk application with the message "METAL OBJECT DETECTED". An IoT event notification is also generated to alert the operator. After detection, the Start button is reset, and the robot waits for the operator to restart the system before continuing the scanning process.

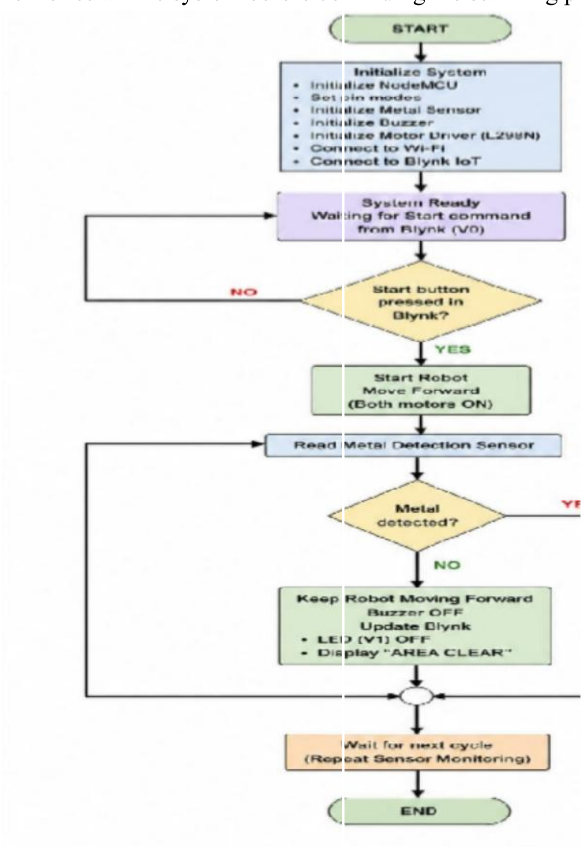

Fig. 3. Software Flowchart of the Proposed IoT-Based Land Mine Detection Robot.

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VII. WORKING PRINCIPLE

The proposed IoT-Based Land Mine Detection Robot is designed to detect metallic objects while minimizing human exposure to hazardous environments. The system integrates an ESP8266 NodeMCU, a metal detection sensor, an L298N motor driver, DC motors, a buzzer, and the Blynk IoT platform to provide autonomous operation and real-time monitoring. When the robot is powered on, the ESP8266 NodeMCU initializes all hardware components, including the metal detection sensor, motor driver, buzzer, and Wi-Fi module. The controller then establishes a connection with the Blynk IoT platform, enabling wireless communication between the robot and the mobile application.

The robot remains in standby mode until the operator presses the Start button in the Blynk application. After receiving the command, the ESP8266 controls the L298N motor driver to operate the DC motors, allowing the robot to move forward while continuously scanning the ground surface.

The metal detection sensor monitors the presence of metallic objects throughout the robot's movement. If no metal is detected, the robot continues moving forward, the buzzer remains OFF, and the Blynk application displays the status "AREA CLEAR".

When a metallic object is detected, the sensor sends a detection signal to the ESP8266 NodeMCU. The controller immediately stops the robot by disabling the motors, activates the buzzer to provide an audible warning, and updates the Blynk application with the message "METAL OBJECT DETECTED". Simultaneously, an IoT event notification is sent to alert the operator in real time. The system then waits for the operator to restart the robot before continuing the scanning process.

This working principle enables continuous monitoring, rapid detection, and immediate notification, making the proposed system an efficient, low-cost, and safer solution for detecting metallic land mines in hazardous environments.

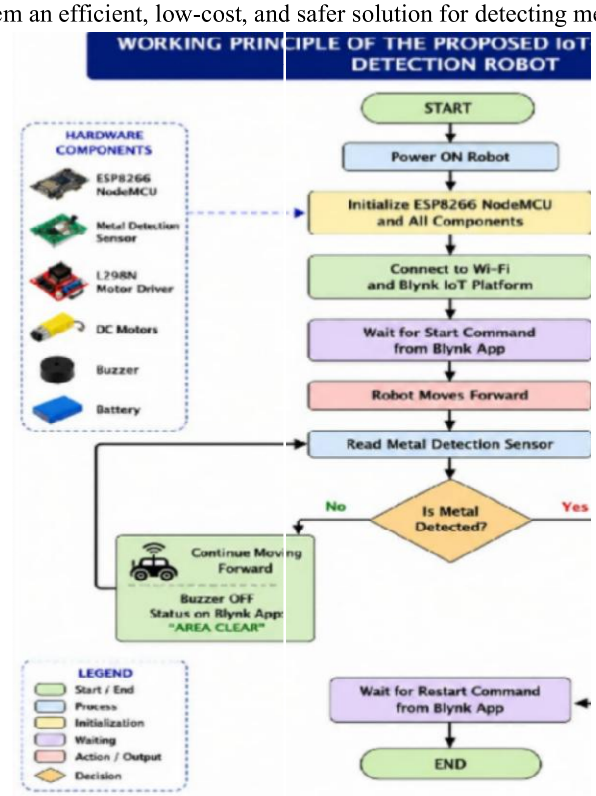

Fig. 4. Working Principle of the Proposed IoT-Based Land Mine Detection Robot.

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VIII. EXPERIMENTAL RESULT

The proposed IoT-Based Land Mine Detection Robot was developed and tested under controlled laboratory conditions to evaluate its performance in detecting metallic objects and providing real-time alerts. The robot successfully integrated the ESP8266 NodeMCU, metal detection sensor, L298N motor driver, DC motors, buzzer, and the Blynk IoT platform.

During the experiment, the robot moved continuously over the test surface while the metal detection sensor scanned for metallic objects. In the absence of metal, the robot maintained forward movement, the buzzer remained OFF, and the Blynk application displayed the status "AREA CLEAR". When a metallic object was placed within the sensing range, the sensor detected it successfully. The ESP8266 immediately stopped the robot, activated the buzzer, updated the Blynk application with the message "METAL OBJECT DETECTED", and generated an IoT notification to alert the operator.

The experimental observations confirmed that the proposed system provides reliable metal detection, immediate response, and wireless monitoring. The integration of IoT technology enables the operator to monitor the robot remotely, thereby reducing direct human exposure to hazardous areas.

Table 1 Experimental Results

Test Scenario	Expected Result	Observed Result	Status
System Power ON	Hardware initializes successfully	Successful	Pass
Wi-Fi & Blynk Connection	Robot connects to IoT platform	Connected successfully	Pass
Start Command	Robot moves forward	Working correctly	Pass
No Metal Present	Robot continues moving	Area scanned continuously	Pass
Metal Detected	Robot stops automatically	Detection successful	Pass
Buzzer Alert	Audible alarm activated	Working correctly	Pass
Blynk Notification	Alert sent to operator	Notification received	Pass
Restart Operation	Robot resumes after restart	Working correctly	Pass

Result Summary

The experimental evaluation demonstrates that the proposed IoT-Based Land Mine Detection Robot operates reliably under

IX. CONCLUSION

The proposed IoT-Based Land Mine Detection Robot provides a simple, cost-effective, and reliable solution for detecting metallic land mines while minimizing the risk to human operators. The system combines an ESP8266 NodeMCU, a metal detection sensor, an L298N motor driver, DC motors, a buzzer, and the Blynk IoT platform to achieve real-time monitoring and remote operation.Experimental testing demonstrated that the robot successfully detected metallic objects, stopped automatically upon detection, generated audible alerts, and transmitted instant notifications through the Blynk application. The integration of IoT technology enables remote supervision, enhancing operator safety and improving the efficiency of detection tasks.The developed prototype demonstrates the feasibility of using embedded systems and wireless communication for hazardous area inspection. Although the current system is intended for detecting metallic objects, it provides a strong foundation for future enhancements, such as GPS-based location tracking, autonomous navigation, artificial intelligence, and advanced sensing technologies. Overall, the proposed robot offers an effective and practical approach for improving safety in land mine detection operations

X. FUTURE SCOPE

The proposed IoT-Based Land Mine Detection Robot demonstrates the feasibility of using embedded systems and IoT technology for safe metal detection. However, the system can be further improved by incorporating advanced technologies to enhance its performance and applicability. Future developments may include: Integration of a GPS

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module to record and transmit the exact location of detected land mines. Implementation of autonomous navigation using obstacle avoidance and path-planning algorithms. Addition of a camera module for real-time video monitoring and remote surveillance.Application of Artificial Intelligence (AI) and Machine Learning (ML) techniques to distinguish land mines from other metallic objects and reduce false detections. Development of a solar-powered energy system to increase operational time in remote locations. Integration of cloud-based data storage for maintaining detection records and generating analysis reports. Use of high-sensitivity sensors, such as Ground Penetrating Radar (GPR), to improve detection accuracy and identify non-metallic land mines. Design of a more rugged and all-terrain robotic platform capable of operating in challenging environmental conditions.These improvements can significantly enhance the efficiency, accuracy, and reliability of the proposed system, making it more suitable for real-world humanitarian demining and defense applications.

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