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Wi-Fi Enabled Arduino Rover Utilising Metal Detector for Landmine Detection

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***Abstract*— This project presents the development of a versatile and cost-effective Landmine Detection Rover, created to detect landmines effectively and safely in dangerous regions. The rover is equipped with key components such as an Arduino UNO microcontroller, a metal detector, and a NodeMCU ESP 8266 for communication. The prime objective is to develop a reliable robotic system that can safely identify landmines from a distance while ensuring operator safety.**

The Arduino UNO microcontroller serves as the central processing unit, providing the intelligence necessary for the rover's mobility and functionality. It interfaces with a metal detector, which employs Faraday's law of electromagnetic induction to detect buried metallic landmines. The metal detector notifies the Arduino UNO for processing when a landmine is detected.

To enable remote operation and communication, the NodeMCU ESP 8266 module is integrated into the system. This module establishes wireless communication that allows operators to send instructions to the rover, thereby controlling its mobility and actions. This capability significantly enhances the safety of the operator, as they can remotely navigate the rover in hazardous terrains. The development of this Landmine Detection Rover aligns with the critical need to address the global landmine problem and the rover provides an innovative solution for efficient and secure landmine detection. Moreover, this project emphasizes the cost-effectiveness and versatility of the system, which can be adapted for various applications, including military and humanitarian purposes. Future enhancements may include the incorporation of additional sensors, such as cameras, GPS and ground penetrating radar to further enhance the rover's capabilities and expand its potential applications in landmine detection and clearance operations.

***Index Terms*— Landmine detection, Arduino UNO microcontroller, metal detector, NodeMCU ESP 8266 and wireless communication.**

I. INTRODUCTION

Landmines persistently pose significant threats to lives, economies, and the environment in various regions around the world. Traditional landmine clearance methods, often involving human operators, are not only time-consuming but also risky. Consequently, there is an increasing interest in leveraging technological advancements to improve landmine detection and clearance processes.

This research is driven by the urgent need to create a novel, self-sufficient, and effective landmine detection system. Addressing the urgent problems associated with landmine removal in conflict areas and post-conflict areas

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is the aim. The project's goal is to build a reliable, automated landmine detecting rover that can traverse difficult terrain, locate hidden landmines, and send real-time data for prompt and safe neutralization. This project is motivated by the need to expedite rehabilitation, guarantee the protection of civilians in impacted areas, and drastically decrease human dangers associated with manual clearing by utilizing cutting-edge technology and flexible design.

Ref. [1], introduces a rover with a rocker bogie suspension system initially designed for celestial exploration. This system is extended to landmine detection, employing a metal detector synchronized with the rocker bogie mechanism. The integration includes GPS and mobile applications for real-time reporting, emphasizing cost-effectiveness and enhanced efficiency in landmine detection.

Notably, [2] introduces a robot controlled via Dual-tone Multi-frequency (DTMF) technology. It incorporates wireless camera surveillance, microcontrollers, and GPS for obstacle detection and location reporting. In a similar vein, [3] and [8] feature a Wi-Fi-controlled land rover, combining a metal detector with GSM technology for swift transmission of detected landmine information. Ref. [8] also has future work aimed at enhancing its design and incorporating advanced features like cameras, improved power systems with solar panels, and the addition of a robotic arm for safe mine diffusion.

Another group of studies, including [4], demonstrates the integration of metal detection, ultrasonic obstacle detection, and Bluetooth communication. These systems effectively navigate challenging terrains and identify landmines using sophisticated motion control and ultrasonic sensors. Ref. [6] emphasizes the use of ultra-wideband (UWB) positioning to achieve sub-centimeter accuracy in tracking sensor heads of metal detectors. This technology provides high precision and accuracy, enabling reliable target discrimination, especially for low-metallic content landmines. Similarly, the study in [10] highlights the fusion of multiple sensors—metal detectors, ultrasonic sensors, and flame detectors—to improve precision in detection. The adoption of wireless communication facilitates remote control, enhancing adaptability in diverse environments. Experimental results confirm the effectiveness of the multi-sensor fusion approach in reducing false alarm rates and enhancing the precision of minefield identification.

Among innovative technological solutions, studies such as [5] showcase the use of an Electromagnetic Band Gap (EBG) antenna to minimize interference, enhancing landmine detection capabilities. Additionally, [11] employs digital image processing and artificial neural networks for successful classification of landmines. Ref. [7] introduces path planning via image processing and user-friendly interfaces. Ref. [9] emphasizes the importance of control system conversion into wireless systems for adaptability across various terrains.

These research papers collectively underscore the urgency of adopting advanced technologies to address the persistent problem of landmines. From lightweight robots to autonomous systems with multi-sensor fusion capabilities, these innovative approaches hold the promise of making landmine detection safer, more accurate, and more efficient. By exploring various methodologies, including image processing, sensor fusion, and wireless communication, these studies pave the way for further advancements in the field of landmine detection and clearance.

The proposed methodology comprises a multi-tiered approach to address the complexities of landmine detection. It outlines the system architecture, emphasizing hardware components, sensor integration, mobility, and communication. The strategy incorporates the use of Arduino Uno as the primary microcontroller to oversee data processing and rover control, while the Node MCU enables wireless communication for remote operation and data transmission.

Critical to the methodology is the incorporation of a metal detection system, calibrated and optimized to identify buried landmines within a 60 mm range. Furthermore, the methodology details the establishment of a user interface for remote operation, data visualization, and real-time reporting.

The depth at which the rover can reliably identify hidden landmines is determined by the metal detector's range, which is of utmost importance. The ability to detect concealed dangers at a significant depth is ensured by a 60 mm range, which is a crucial benefit when it comes to locating landmines hidden below the surface. Moreover, the Node MCU-enabled Wi-Fi connectivity of the rover permits effective and seamless communication over a range of distances. Wi-Fi connectivity's wide coverage is essential for remote operation since it allows users to operate the rover and get real-time data updates from a distance, which improves the rover's usability and adaptability to various operating settings.

The robustness of the proposed rover involves an integrated approach to mobility, sensor fusion, and efficient communication. This methodology serves as a foundation for further enhancements, including obstacle avoidance mechanisms, power optimization, and the integration of advanced features for enhanced detection and safety.

II. METHODOLOGY

The theme of the project on a landmine detection rover is centered on control systems and robotics. The project aims to design, build, and test a landmine detection rover that uses the principle of eddy currents to detect landmines. The landmine detection rover was developed using a methodology that combines several essential elements, with a focus on efficient landmine detection using a metal detector with a 60 mm range, Wi-Fi communication between the Arduino Uno and NodeMCU, and a sturdy hardware configuration shown in a block diagram.

A. Metal Detector

A specific metal detector module with a detection range of 60 mm is included as part of the project's basic technique. This rover's system-integrated detection module uses electromagnetic induction to detect metallic objects, with a particular emphasis on landmines that have been buried. It works with the Arduino Uno to detect anomalies with metal, and then it sounds an alarm.

A metal detector works on the principle of electromagnetic induction, detecting the presence of metallic objects by generating electromagnetic fields and then sensing disruptions in these fields caused by nearby metals.

Equation (1) governs the inductance (L) of a coil in a metal detector.

$$L = \frac{\mu N^2 A}{l} \tag{1}$$

Where:

L = Inductance of the coil

μ = Permeability of the core material

N = Number of turns in the coil

A = Cross-sectional area of the coil

l = Length of the coil

The inductance is directly proportional to the square of the number of turns in the coil. As the number of turns increases, the inductance of the coil increases proportionally. This is essential because it influences the sensitivity and detection range of the metal detector. A higher inductance generally leads to better detection of metallic objects.

The range of the metal detector depends on several factors:

1. *Coil Size and Shape*: The diameter, shape, and number of turns in the coil directly impact the detection range. Larger coils generally have a greater detection range due to increased electromagnetic field coverage.
2. *Operating Frequency*: Different frequencies can impact the detection range. Lower frequencies tend to penetrate deeper but might lack sensitivity to smaller objects, while higher frequencies might detect smaller objects but have a shallower penetration depth.
3. *Metal Composition and Size:* Larger or more conductive metal objects are easier to detect at greater distances. The detection range varies based on the size, composition, and orientation of the metal object concerning the coil.
4. *Signal Strength and Electronics:* The sensitivity and processing capabilities of the metal detector's electronics and the strength of the signal generated play a crucial role in determining the detection range.

B. Node MCU ESP8266

The Node MCU is used to create the communication infrastructure, which permits wireless connectivity and rover control from a distance. This part acts as a conduit for data and commands to be sent and received between the external controlling systems and the main Arduino Uno unit. Real-time communication is made possible by the Node MCU's built-in Wi-Fi technology using the 2400-2484 MHz band in the IEEE 802.11 b/g/n standard, which also enables data transmission and remote operation.

Fig. 1 shows the hardware configuration of the rover system and how different parts are connected to one another and interact. It depicts the connections between the Arduino Uno, the battery-powered power supply, Node MCU that enables Wi-Fi connectivity, the metal detector module that detects landmines, and the motor driver L298N that drives the DC motors that move the rover.

Arduino Uno serves as the rover's central control unit, coordinating all its functions, such as deciphering metal detector signals, processing commands obtained via the Node MCU, and directing the motor driver to steer the vehicle across different terrains. Fig. 2 shows the circuit diagram of the proposed prototype. An I2C Bi-directional logic level converter is used to connect the receiver and transmitter pins of Arduino UNO and NodeMCU. 5 V pin of Arduino UNO and 3.3 V pin of NodeMCU are used as reference.

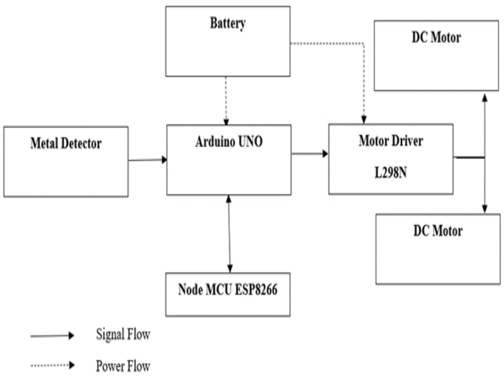

Figure 1. Block Diagram

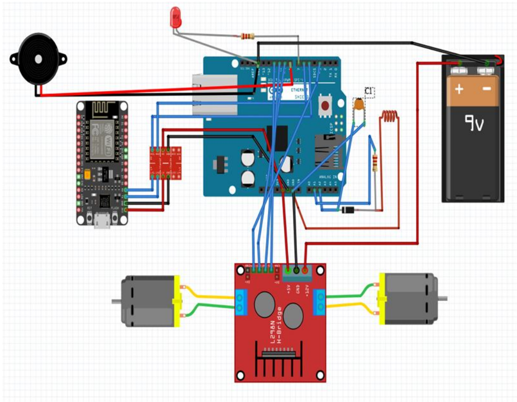

Figure 2. Circuit Diagram

III. RESULTS

We measured Received Signal Strength Indicator (RSSI) values at various distances to determine the distance at which the Node MCU WiFi module's range is optimal. This is reported in Table I and depicted as a graph in Fig. 3. Evidently, there is a decrease in the RSSI values as distance from Node MCU is increased. We also measured the range of metal detector module in various soil conditions, which is reported in Table II.

TABLE I. NODEMCU ESP8266 WI-FI RANGE

Sr. No.	Range (m)	Average Power (dBm)
1	1	-70.96
2	2	-73.91
3	3	-78.86
4	4	-80.96
5	5	-83.01
6	6	-84.08
7	7	-85.27
8	8	-86.02
9	9	-86.98
10	10	-88.21

TABLE II. METAL DETECTOR RANGE

Sr. No.	Testing Environment	Effective Range of Detection (cm)
1	Free Space	5.8
2	Clay	3.2
3	Red soil	4.1
4	Sand	3.8
5	Silt	4.7

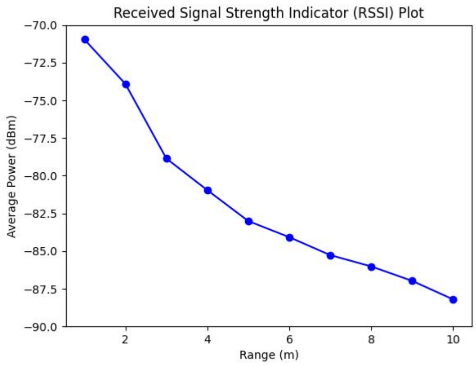

Figure 3. Average Power received from NodeMCU ESP 8266

A control application to control the robot’s motion is an Android app and has been created using MIT App Inventor. As shown in Fig. 4, MIT App Inventor is a free, cloud-based tool that allows users to create mobile applications for Android devices without any prior programming experience. The user interface (UI) of the app uses five buttons: forward, back, left, right, along with a slider for speed control. When the user presses a button, the corresponding code block is executed. For example, when the user presses the forward button, the app sends the character 'F' to the NodeMCU through the Wi-Fi server. Similarly, when the backward button is pressed, the app sends the character 'B' to the NodeMCU. The left and right buttons send the characters 'L' and 'R', respectively.

When no button is pressed, 'S' is the default state. The slider button is used to control the speed of the rover and sends the corresponding values to NodeMCU.

On the NodeMCU side, as shown in Fig. 5, the program listens for incoming messages and prints it on the Serial Monitor and Arduino UNO executes the corresponding command to move the rover. By sending different characters over Wi-Fi, the user can control the motion of the rover in different directions.

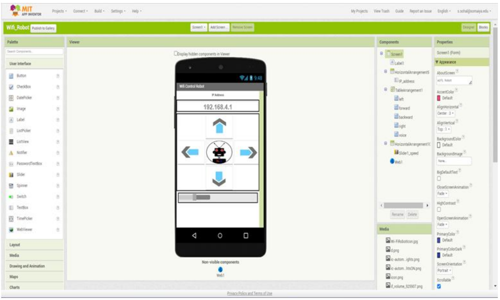

Figure 4. MIT App Inventor

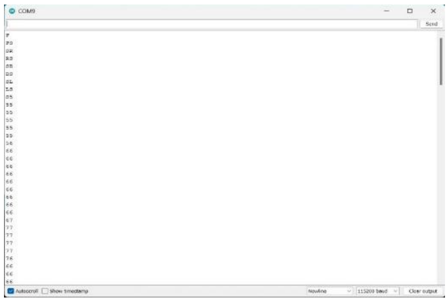

Figure 5. Characters received by NodeMCU ESP 8266 over Wi-Fi

Fig. 6 shows the Landmine Detection Rover prototype integrating the software and the hardware. Arduino UNO microcontroller, the rover's central processing unit, coordinates its motions and functions. The rover is controlled using the MIT application, which connects to NodeMCU over Wi-Fi, and serially communicates the data to Arduino. There is a slight delay when the data is being sent from the app to Arduino throughout this process. The delay is increased with increasing distance between the mobile device and the rover. The motion of the rover is controlled in this manner and the metal detector module detects any metal in its vicinity. Metal detection is limited by the range of this module.

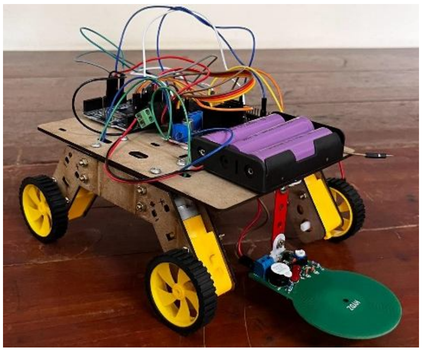

Figure 6. Landmine Detection Rover prototype

IV. Discussion

An understanding of wireless communication reliability—which is essential for operational safety—can be gained from the examination of RSSI values over Wi-Fi with increasing distance. Furthermore, rover performance in a variety of terrains is informed by the evaluation of metal detector detection range across various soil types, which is crucial for optimizing landmine detection efforts. The range and sensitivity of the metal detector is limited. The successful Wi-Fi control demonstration using a customized Android app accentuate the rover's capacity to operate remotely, improving operator freedom and safety. The data transfer from the mobile application to the Arduino, however, has a latency that grows as the distance between the mobile device and the rover increases. These tests demonstrate the rover's potential for safe and effective landmine identification, highlighting the significance of utilizing such technologies to successfully address global issues.

V. Conclusion

This project involved designing and building a landmine detector rover. We tested the rover on several soil types and determined the depth at which the metal detector module functions optimally. We also observed the RSSI readings for the specified distance to determine the rover's range and demonstrated the working of rover motion control over Wi-Fi, which worked successfully but with some delay in its operation.

In the future, we intend to use computer vision, image processing, and a Global Positioning System to make the rover autonomous and explore alternate methods to detect landmines, such as the use of ground penetrating radar which will be more accurate in detection of landmines and provide better range of detection. We also strive to improve upon the range of operation of the motion control and reduction of delay to improve user safety.

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