Design and Implementation of a Bluetooth-Controlled Metal Detection System Using Arduino

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Abstract—
The detection of metallic objects is crucial in applications ranging from security inspections and industrial automation to archaeological explorations. Traditional handheld metal detectors, while effective, lack automation, mobility, and remote operability. This paper presents the design and implementation of a low-cost, Arduino-based mobile robotic system that integrates metal detection with Bluetooth-enabled wireless control. The core of the system is the Arduino Uno R3 microcontroller, which coordinates inputs from a non-contact metal detector module and controls outputs to a buzzer for alerts and an L298N motor driver to maneuver two DC motors. The HC-05 Bluetooth module facilitates communication with a Smartphone, allowing users to navigate the robot remotely using simple commands. When a metallic object is detected within a short range (approximately 10 mm), the metal sensor triggers an audible beep, alerting the user in real time. The robotic platform is powered by a compact battery pack, ensuring portability and ease of deployment in various terrains. The proposed system demonstrates reliability, modularity, and cost-efficiency, making it ideal for small-scale applications such as school and college-level robotics projects, initial-stage security systems, localized industrial monitoring, and hobbyist innovations. Moreover, the architecture supports future enhancements, including the addition of graphical user interfaces (GUIs), GPS for location tagging, obstacle avoidance systems, and high-sensitivity sensors for deeper or more precise detection. Through this project, we establish a foundation for developing intelligent, remotely-operated metal detection systems that are both accessible and scalable.

Keywords— Arduino Uno, HC-05 Bluetooth module, L298N motor driver, metal detector sensor, robotic vehicle, wireless control, embedded systems, automation.

I. Introduction

In the past, metal detection systems were primarily limited to handheld, manually-operated devices. These were extensively used in fields such as treasure hunting, security screening at entry points, archaeological excavations, and industrial safety inspections. Although functional and widely deployed, such traditional systems lacked automation, user convenience, and remote accessibility—requiring human presence in potentially hazardous or inaccessible locations.

In the present day, advancements in embedded systems, microcontrollers, and wireless technologies have revolutionized automation and control applications. The integration of the platforms like Arduino, Bluetooth communication modules, and motor drivers has enabled the development of compact, mobile, and remotely controllable systems. Contemporary solutions are increasingly focused on low-cost, modular designs to promote wide accessibility in educational institutions and prototyping environments. This project embodies such a development—a Bluetooth-controlled robotic car embedded with a basic metal detector. The system uses an Arduino Uno R3 microcontroller as its core controller, interfaced with the HC-05 Bluetooth module for wireless communication and the L298N motor driver to operate dual DC motors for mobility. The user can navigate the robot wirelessly via a Smartphone application while monitoring for the presence of nearby metallic objects.

Looking toward the latest and future trends**,** metal detection systems are being enhanced with artificial intelligence (AI), machine learning, cloud connectivity, and sensor fusion techniques. These emerging systems aim to offer real-time data analysis, high-resolution object differentiation, and autonomous navigation for large-scale deployment in industries like defense, mining, and disaster recovery. The current project, while basic, lays the groundwork for future expansion. By integrating more advanced sensors, mobile apps, and data logging capabilities, this system can evolve into a scalable platform for smart detection and mapping of metallic objects in complex environments.

II. LITERATURE REVIEW

Horowitz and Hill [1] provided foundational insights into analog circuit design, which are instrumental in understanding oscillator-based metal detector modules. Floyd [2] also discussed digital logic principles essential for programming motor drivers and interpreting sensor outputs.

R. S. Khandpur [3] contributed to PCB design theory relevant to constructing the physical detector unit. Mazidi et al. [4] and Ayala [5] contributed significantly to microcontroller programming knowledge, particularly in C and assembly languages, which laid the groundwork for implementing control logic in embedded platforms like Arduino.

Patranabis [6] detailed sensor principles that explain how inductive proximity sensors and coil-based detectors respond to metallic objects. These theories support the working principle of the metal detector module used in this project.

Mukhopadhyay and Suryadevara [7] demonstrated the use of sensor-based monitoring for remote systems, suggesting its relevance to real-time detection tasks.

Kennedy and Patterson [8] developed a miniature robotic vehicle for landmine detection using metal detector sensors.

Gaikwad and Kakade [9] presented a simplified version of a metal detector robot using Arduino.

Roy and Ghosh [10] introduced a Bluetooth-controlled robotic car with obstacle detection capabilities.

Abirami and Kumar [11] designed a smart metal detector based on Arduino.

Kumar and Sahani [12] proposed an Arduino-based robotic car with fundamental motion control features. urther innovations have emerged in the last few years. Gana *et al.* [13] built an obstacle-avoidance, goal-based autonomous vehicle using Arduino Uno with infrared and ultrasonic sensors. Rakshith *et al.* [14] combined obstacle avoidance, Bluetooth, and voice control in a robot car, improving user interaction. Gundlapalle *et al.* [15] developed a metal detecting robot for terrestrial applications using an Arduino development board. Hemalatha *et al.* [16] proposed a robotic vehicle with metal detection capabilities for security and industrial uses.

Unpublished reports like *Obstacle Avoiding Robot using Arduino* [17] highlight practical student-level applications. A review by IJRASET [18] summarizes advanced obstacle avoidance techniques for Arduino-based intelligent vehicles. Bui *et al.* [19] introduced *CarGameAR*, an augmented reality car game authoring interface for Arduino-programmed cars, showing the versatility of Arduino beyond industrial applications. Kamal [20] presented an Arduino-controlled spy robo car with live-streaming capabilities for surveillance.

III. System overview

A. Hardware Components

1. **Arduino Uno R3**: Acts as the central control unit, handling sensor data processing and motor control.
2. **HC-05 Bluetooth Module**: Enables wireless serial communication with a Smartphone.
3. **L298N Motor Driver Module**: Interfaces between the Arduino and two DC motors, controlling speed and direction.
4. **DC Motors**: Drive the robot's movement.
5. **Metal Detector Module**: Detects metallic objects and signals presence via a piezo buzzer.

B. Power Supply

The system operates on a 6V battery pack (4x1.5V AA cells), powering both the motors and metal detector. The onboard 78M05 regulator in the L298N module supplies 5V to the Arduino.

IV. Design & Implementation

A. Motor Driver Integration The L298N module is interfaced with Arduino pins (ENA, ENB, and IN1–IN4) to control direction and speed of two DC motors. The enable pins are connected to PWM-capable pins for variable speed control. The motors respond to logic signals for directional control (e.g., HIGH/LOW for forward or reverse motion).

B. Bluetooth Communication Using the HC-05 module, the system communicates with a Smartphone app. ASCII characters ('F', 'B', 'L', 'R', 'S') are sent via Bluetooth to control movement. A voltage divider protects the RX pin of the Bluetooth module from the 5V Arduino TX signal.

C. Metal Detector Module The sensor consists of a printed rectangular coil, oscillators, and a piezo buzzer. On detection of metal within 10 mm, signal frequency changes, triggering a sound alert. The oscillator operates around 300 kHz and shows poor sensitivity for small objects, making it suitable for surface or large object detection.

V. Results & Discussion

The metal detecting car successfully responded to Bluetooth commands and detected metallic objects within ~10 mm. The speed control and directional responses were consistent. However, the metal detector's range was limited and sensitive to power fluctuations, requiring periodic trimpot adjustments. Overall, the system was effective for short-range detection and remote-controlled navigation.

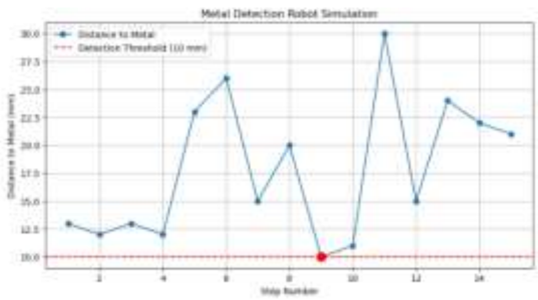

Fig1 graph of metal detection Robot simulation

VI. Conclusion

In this project, a Bluetooth-controlled metal detecting robotic car was successfully conceptualized, designed, and implemented using cost-effective and readily available components such as the Arduino Uno R3 microcontroller, HC-05 Bluetooth module, L298N motor driver, DC motors, and a non-contact metal detector module. The integration of these hardware elements was carefully executed to achieve a fully functional mobile platform capable of detecting metal objects and transmitting user commands wirelessly through a Smartphone interface.

The system not only demonstrates a practical use of embedded system programming and robotics but also highlights the effectiveness of combining wireless communication with sensor-based automation. The car is capable of real-time metal detection within a limited range and provides audible alerts upon detection, making it useful for small-scale applications such as educational demonstrations, localized industrial inspections, and entry-level security systems.

Although the detection range is modest (~10 mm), the design offers a strong foundation for future enhancements. Potential improvements include integrating high-sensitivity metal detectors to increase the detection range, adding a graphical user interface (GUI)-based mobile application for more intuitive control and data visualization, and implementing power optimization techniques such as smart power management modules to increase operational time.

Moreover, the system's modularity allows for scalability—additional sensors (e.g., GPS, ultrasonic, IR) and AI-driven modules (for obstacle avoidance or pattern recognition) can be incorporated to expand its functionality in complex environments. Overall, the project successfully demonstrates the practical viability of a low-cost robotic system for targeted metal detection and remote operation, aligning with the growing demand for intelligent, automated systems in diverse sectors such as defense, archaeology, industrial maintenance, and education.

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