Design of an Arduino-Based Robot Car Metal Detector Using Design Thinking Approach

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DOI: https://dx.doi.org/10.47772/IJRISS.2025.924ILEIID0092

Received: 23 September 2025; Accepted: 30 September 2025; Published: 01 November 2025

ABSTRACT

This paper presents the design and development of an Arduino-based metal-detecting robot controlled via a smartphone for Electrical Engineering student's Final Year Project (FYP). The development used the design thinking approach. The project aimed to create a low-cost and user-friendly robotic system that helps minimizing human exposure to hazardous metal detection procedure. Following the design thinking framework, the process began with empathizing with the user needs in dangerous environments and defining the challenges of creating a safe metal detection system. Ideation led to the integration of key components including an Arduino microcontroller, Bluetooth module, motor driver, and metal detector to build a functional prototype. Prototyping and iterative testing enabled refinement of the robot's capabilities and limitation, such as real-time feedback through a buzzer upon detecting metal objects within certain range. The study uncovered limitations in detection range, battery life, and obstacle avoidance, leading to further adjustment focused on enhancing functionality and adaptability. This human-driven approach emphasized the importance of continuous innovation based on user feedback and technical constraints. The findings demonstrate the potential of design thinking in robotics development, encouraging solutions tailored for practical implementation in industrial safety and education, with future improvements in mind to increase versatility and performance reliability.

Keywords: (metal detector, Arduino, Bluetooth, microcontroller)

INTRODUCTION

Technological advancements in robotics and automation have enabled the creation of innovative systems capable of performing tasks with high efficiency, safety, and accuracy. Within this field, metal-detecting robots present exciting potential for multiple applications for example in security and industrial operations, archaeological exploration, rescue mission and many more. This project utilized a design thinking approach to develop a cost-effective using Arduino-based robot as its foundation, starts with empathizing with end-users who require safe inspection of hazardous environments and defining the core problem as the need for a reliable, remote-controlled detection system. The ideation phase explored various component configurations, leading to a prototype that integrates an Arduino microcontroller, an HC-05 Bluetooth module for wireless smartphone control, an L298N motor driver for mobility, and a metal detector sensor. The prototyping and testing phases were done step by step with focusing on optimizing both function reliability and real-time user notification upon detection.

The project is motivated by the growing need for automated solutions that can operate in hazardous environments that contribute to minimizing human risk. The final design offers a cost effective and adaptable platform suitable for educational, industrial, and personal use. This paper discusses the system's design process, hardware implementation, and performance evaluation

LITERATURE REVIEW

This literature review focuses on current research related with the application of the Design Thinking approach in higher education and engineering contexts.

Deng (2024) conducted a comprehensive systematic literature review on the integration of design thinking in

higher engineering education with focus on the UK. The study highlights that design thinking promotes creativity, interdisciplinary problem solving, and integral engineering skills such as critical thinking and innovation. It encourages a shift from knowledge to skill development and help nurtured self-driven learners.

Berglund (2024) offers a critical examination of how design thinking functions as a transformative force in education systems which includes engineering programs. The paper explores design thinking as a human-centered, collaborative approach that promotes innovative mindsets. The paper highlights pedagogical models that prepare students for dynamic problem-solving and design challenges. The model also promotes leadership, creativity, and social responsibility in engineering contexts.

Fitriyah (2025) analyzed design thinking research trends over the past decade and emphasize on its growth in engineering education globally. The review identifies design thinking as a driving force for interdisciplinarity, creativity, and applied innovation among students. It supports for design thinking in education that cultivates skills in problem framing and solving, ideation, prototyping, and testing, is crucial for engineering graduates that are bound to face technological and social challenges

These papers collectively highlight the design thinking's important role in transforming engineering education by promoting creativity, collaboration, and problem-solving abilities that is essential for future engineers.

RESULTS AND DISCUSSION

The metal-detecting robot car was built around an Arduino controller integrated with a Bluetooth module and motor driver. During the designing process and microcontroller implementation, bugged free program was embedded into the Arduino microcontroller to ensure smooth operation. Troubleshooting for hardware and software was continuously applied during development step to achieve precise control over its movements. The testing for the metal detection sensor was also done. The system successfully performed its basic functions: the robot car accurately responded to commands for forward, backward, left, and right motion, while the metal detector reliably identified objects and triggered a buzzer alert when object is detected within range.

However, several limitations were identified. The operational range of the robot car was constrained to only 20 meters due to the Bluetooth connection. Beyond this range, the robot car would disconnect from the phone. The metal detector's sensitivity, while functional, was susceptible to environmental factors such as distance and minimal interference. The range of metal detection is short with only in the range of 1-2.5 cm. Furthermore, the operational time was limited to approximately 20 minutes due to the 6V power supply used. The robot operated effectively on hard surfaces with smooth movement and performing its detection function seamlessly but struggle to detect accurately when tested on a grassy or sandy surface. Further improvements can be made as the prototype is functioning well and with potential for upgrade.

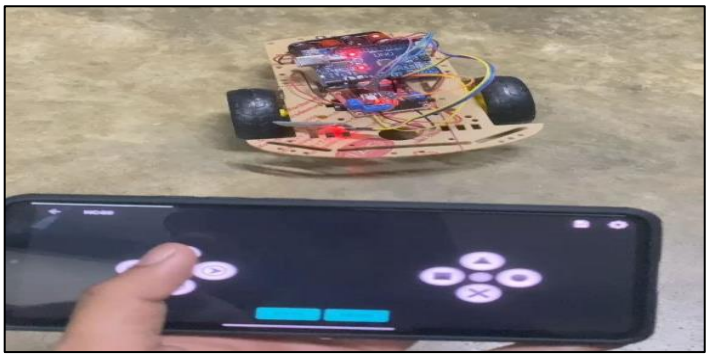

Figure 1 The robot car being controlled by smartphone using Bluetooth connection.

Table 1 Testing result range of metal detector function

Test	Material	Distance metal sensor from the ground (cm)	Output (Buzzer On/Off)
1	Aluminium	1	On
2	Zinc	2	On
3	Aluminium	3	Off

Table 1 shows the testing done to confirm the range of the metal detector. The metal detector module only able to detect object when it is in the sensor range, which is between 1cm to 2.5 cm.

CONCLUSION

This project was motivated by the need to solve the challenge of locating lost metallic objects while minimizing human involvement that can decreases the potential for fatality. Following the principles of design thinking, the development process focused on empathy with users' needs, ideation of simple and reliable solutions, and prototyping using affordable and available components. This approach ensured the built is a cost-effective robotic system with diverse applications.

Through a user-centered design process, the system focuses in detect metals with range accuracy, providing real-time alerts via a buzzer to enhance usability in practical scenarios such as finding lost items, promising safety by detecting hazardous metals with minimal contact, or supporting educational demonstrations of robotics.

However, the design thinking cycle also exposed its limitations, such as a relatively short detection range and limited operational time due to battery usage. These insights present opportunities for future improvement to enhance functionality, including extending sensing distance and improving power longevity.

ACKNOWLEDGEMENTS

I would like to express my gratitude and appreciation to all those who have supported and help throughout the process of completing this paper. Many thanks to all writers and colleagues.

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