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Gesture Controlled Metal Detector Car Using Arduino

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***Abstract:** This paper presents the design and implementation of a Gesture Controlled Metal Detector Car Using Arduino, which is an intuitive and natural solution for controlling a robot car's movement using hand gestures. The system combines multiple components, including an ultrasonic detector, Bluetooth module, flex sensor, accelerometer, metal detector, and Arduino board, to recognize hand movements and control the robot car wirelessly. Additionally, the system integrates a metal detection process using a metal detector device to identify landmines in high-tension areas, enhancing security for defense systems.*

The metal detector is mounted on the robot car and continuously scans the ground while the car moves, providing real-time alerts when metallic objects are detected. This crucial functionality aids in landmine detection, making the system practical for defense and security applications.

The motion control system uses a flex sensor to track finger movement and an accelerometer to measure hand motion. The Arduino board processes the data from these sensors and sends appropriate commands to control the robot car's motors via Bluetooth. Experimental results confirm that the system effectively responds to hand gestures and accurately detects metallic objects, demonstrating its viability in real-world applications.

This study contributes to the field of human-robot interaction by offering a hands-free, user-friendly, and wireless system for controlling robotic systems. The system's advantages include ease of use, hands-free control, wireless communication, and enhanced security through metal detection. However, it also presents limitations such as a limited range of motion and gesture recognition capabilities. Despite these challenges, this design opens the door for further exploration and improvement in gesture-based control technologies, particularly in areas such as education, accessibility for individuals with disabilities, entertainment, and defense applications.

***Keywords:** Hand Gesture, Controller, Robot Car, Metal Detector, Arduino, Ultrasonic Sensor, Bluetooth, Flex Sensor, Accelerometer, Wireless Communication, Motors, Movement Control.*

I. INTRODUCTION

Human-robot interaction has emerged as a widely researched area due to its potential in various sectors, including industrial automation, healthcare, defense, and entertainment. Among the various interaction methods, hand gesture control has attracted considerable attention because of its intuitive and user-friendly nature. This paper presents the design and implementation of a Hand Gesture Controlled Robot Car with Metal Detection Using Arduino and Sensors, which allows users to manipulate the robot car's movements using hand gestures. Additionally, the system is equipped with a metal detector to identify landmines and other metallic objects, making it highly suitable for defense applications.

Moreover, this project also incorporates the use of a mobile application to control the vehicle's movement in two ways: either manually using a virtual joystick or through gesture control. This dual control mechanism enhances flexibility and usability, allowing users to switch between manual and gesture-based control as needed.

A. System Overview

The advanced system utilizes multiple components to achieve seamless functionality:

1) *Ultrasonic Detector*: Detects obstacles in the robot car's path and ensures safe navigation.
2) *Bluetooth Module:* Facilitates wireless communication between the robot car and both the hand gesture controller and the mobile application.
3) *Flex Sensor and Accelerometer:* Capture the user's hand movements accurately and transmit data to the Arduino board.

4) *Metal Detector Devices:* Mounted on the robot car to scan the ground for metallic objects, especially landmines, in high-tension areas. The metal detector continuously monitors the terrain and provides real-time alerts upon detecting metallic substances.
5) *Buzzer Alert and Safety Mechanism:* When the metal detector identifies a metallic object, the system immediately triggers a buzzer sound to alert the user. Simultaneously, the robot car moves backward to prevent its tires from running over the potential landmine or explosive material, which usually consists of metals. Additionally, an LED light indicator flashes three times to visually signal the detection of a metallic object. This precautionary mechanism significantly reduces the risk of accidents during operations.
6) *Arduino Board:* Processes data from sensors and transmits appropriate commands to the robot car's motors via Bluetooth.
7) *Mobile Application:* Provides an alternative control mechanism, allowing users to choose between manual joystick control and gesture-based control.

B. Experimental Results

Experimental results indicate that the system efficiently controls the robot car's movements based on hand gestures and accurately detects metallic objects in its path. The dual control method using both gestures and a mobile app enhances usability and adaptability to various situations. The metal detection capability has proven effective in identifying metallic objects, and the integrated buzzer alert system successfully notifies the user of potential threats. The backward movement mechanism upon detection ensures that the robot car avoids running over explosive materials, minimizing the risk of detonation. The LED light flashing three times further aids in visual identification during critical operations.

C. Contribution

The proposed system enables users to control the robot car via hand gestures or a mobile app, eliminating the need for complex user interfaces and simplifying the learning process. The integration of metal detection, buzzer alerts, and automated backward movement significantly enhances the system's safety and practicality, particularly in defense and high-tension scenarios. This makes it a versatile and user-friendly solution. Overall, this paper contributes to the advancement of natural and intuitive human-robot interaction methods through gesture control technology while adding value through metal detection, dual control modes, and enhanced safety features.

II. LITERATURE REVIEW

This section reviews the existing literature on hand gesture control in robotics and robotic vehicles, leading to the proposed Hand Gesture Controlled Robot Car with Metal Detection using Arduino.

A. Motion Control in Robotics

Motion control has garnered significant attention in robotics research due to its potential to establish intuitive and natural interactions between humans and robots. Various methods have been explored, including machine learning algorithms, computer vision techniques, and perception-based control. These methods facilitate precise navigation and motion control in diverse robotic applications, such as bio-bots and drones.

One prominent approach involves using non-standard electrical components like bend sensors and joysticks to interpret hand movements and gestures for controlling robotic systems. Additionally, wireless communication technologies, including Bluetooth and Wi-Fi, are often employed to transmit navigation commands to robots, enhancing their responsiveness and ease of control.

B. Motion Control in Robotic Vehicles

While motion control is well-researched in general robotics, its application in robotic vehicles remains relatively underexplored. Robotic vehicles, particularly those designed for surveillance, investigation, and hazardous area monitoring, require reliable and precise motion control.

Several studies have investigated computer vision-based techniques and sensor fusion methods for achieving accurate motion control and direction recognition in robotic vehicles. However, most implementations focus on fixed-path navigation rather than dynamic human gesture interaction. The integration of hand gesture control with robotic vehicles is promising, offering a hands-free and intuitive way to navigate through complex environments.

C. Gesture Controlled Robotic Car with Metal Detection

The concept of a gesture-controlled robotic car, developed using Arduino R3, aims to provide a practical and user-friendly method for controlling robot movements through hand gestures and mobile app control. The system combines sensor-based gesture recognition, wireless communication, and metal detection to create a versatile and efficient robotic platform.

Yousif Elfatih Yousif et.al [1] demonstrated a metal detection technique by designing a metal detector circuit to study the frequencies of various metals such as aluminium, gold, and silver. The experimental results obtained from the device were compared with theoretical results, revealing that theoretical values differed from practical findings. The proposed system featured a smart robotic vehicle equipped with modern metal detection techniques, comprising Arduino, motors, and sensors to enhance detection accuracy and reliability. The designed detector proved to be simple to install, cost-effective, and efficient in detecting metals in the area surrounding the sensor. The paper also discussed the design characteristics, performance, working area, and accuracy of the device, emphasizing its practical application in low-cost metal detection solutions.

Mendes et.al [12] demonstrated about the framework of human-robot interaction for recognition of human behavior and gestures. It depends on the vision based system and 3-axis accelerometer which were used to clarify the gestures, and behaviors. They used integrate system i.e. hidden Markov's model based dynamic recognition and Artificial Neural Networks.

B.O. Omijeh [5] presented a Metal Detection System with GSM technology that detects metallic objects and sends an SMS alert to a designated security number for prompt action. The system comprises a power supply unit, metal detectors, GSM modem, GLCD, microcontroller, and multiplexer unit to select detector ports. Experimental tests demonstrated satisfactory performance, indicating that full implementation in restricted areas like banks and airports could significantly enhance security by detecting dangerous metallic objects and reducing crime rates.

Aswath S et.al [6] presented an Electromyogram (EMG)-based control system for humanoid robots, enabling precise and natural gesture recognition. The system uses EMG electrodes attached to human muscles to generate analog signals, which are then processed by a differential muscle sensor. These signals are converted to digital form using the microcontroller's ADC and transmitted to the CM-530 humanoid robot controller via a Zigbee wireless interface. The CM-530 processor directs servo motors to perform human-like actions with enhanced accuracy. This approach allows for intuitive control without the need for remote units, making it more user-friendly and efficient.

The robotic arm manipulator that was operated by limb movement and gestures was demonstrated by Li, X [9]. He used the certain types of algorithms to carry out the soma to sensory interaction. He tracked the coordinates of arm movements and gestures using the DTW template matching technique.

D. Key Features.

1) *Gesture Controllers:* The system utilizes bend sensors and ADXL335 accelerometers to detect the operator's hand movements. The captured data is processed by the Arduino R3, which interprets the movements and sends control signals to the robotic car.
2) *Wireless Communication:* The HC-05 Bluetooth module enables seamless wireless communication between the robot car and a mobile application, allowing users to operate the vehicle via manual joystick mode or gesture-based control. The system also uses an RF module (nRF24L01) for long-distance gesture signal transmission.
3) *Robot Car Configuration:* The robot car is equipped with ultrasonic sensors for obstacle detection, ensuring smooth navigation in cluttered environments. A metal detector is integrated to identify metallic objects like landmines or explosive devices. Upon detecting a metal object, the system activates a buzzer alert and moves backward to avoid the detected hazard. Additionally, the LED indicator flashes three times to visually warn the operator.
4) *Arduino Programming*: The Arduino R3 processes gesture signals, motor control instructions, and metal detection alerts. Custom code enables gesture recognition, motor speed regulation, obstacle avoidance, and buzzer control. The programming logic is designed to switch seamlessly between gesture control and joystick-based manual control through a mobile app.

III. METHODOLOGY

To construct the Hand Gesture Controlled Robot Car with Metal Detection, the following steps are undertaken:

A. Hardware Setup

1) *Assembling the Robot Car Chassis:* The initial step involves assembling the robot car chassis, which includes attaching the motors, wheels, and other mechanical components. The chassis is designed as a four-wheel-drive system with two DC motors powering the rear wheels and two servo motors controlling the steering of the front wheels.

2) *Installing the Ultrasonic Sensor:* The ultrasonic sensor, responsible for detecting obstacles ahead of the robot car and sending signals to the Arduino R3 for obstacle avoidance, is mounted on the front of the chassis. This helps prevent collisions and ensures smooth navigation.
3) *Connecting the Motor Driver:* The motor driver (L298N) is connected to both the DC motors and the Arduino R3. It manages the speed and direction of the motors based on the signals received from the control unit.
4) *Integrating the RF Module:* The RF module (nRF24L01) is used to wirelessly transmit hand gesture signals from the transmitter to the receiver section. It is connected to the Arduino R3 and allows seamless communication between the hand gesture controller and the robot car.
5) *Integrating the HC-05 Bluetooth Module:* The HC-05 Bluetooth module is used to establish wireless communication between the robot car and the mobile app. This module enables manual control via a joystick interface on the app, offering an alternative to gesture-based control. The Bluetooth module is connected to the Arduino R3, allowing users to switch between gesture mode and manual mode as needed.
6) *Connecting the ADXL335 Accelerometer:* The ADXL335 accelerometer detects hand orientation and sends corresponding signals to the Arduino R3. It is carefully mounted on a glove to capture hand movements effectively.
7) *Integrating the Metal Detector:* The metal detection unit is mounted on the underside of the robot car to scan the ground for metallic objects, particularly hazardous items like landmines or unexploded ordnance. The metal detector operates on the inductive sensor principle, where changes in inductance indicate the presence of metal.
8) *Buzzer Alert Safety Mechanism:* When the metal detector identifies a metallic object, it immediately triggers a buzzer sound to alert the user. Simultaneously, the robot car moves backward to prevent its tires from running over the detected object. An LED light indicator also flashes three times as a visual warning. This automatic backward movement helps minimize the risk of encountering dangerous materials, especially in high-tension or security-sensitive areas.

B. Software Setup

1) *Installing the Arduino IDE:* The Arduino IDE is required to program the Arduino R3. Download and install the latest version from the official website.
2) *Installing Necessary Libraries:* Several libraries are required for the project, including RF24 to handle wireless communication via the RF module, Servo to control servo motors for steering, NewPing to manage the ultrasonic sensor for obstacle detection, SoftwareSerial to establish Bluetooth communication using the HC-05 module, Tone to generate the buzzer sound upon metal detection. These libraries can be installed directly from the Arduino Library Manager.
3) *Uploading the Transmitter Code:* The transmitter code reads signals from the ADXL335 accelerometer and sends them wirelessly to the receiver section. Upload the code to the Arduino R3 in the transmitter module.
4) *Uploading the Receiver Code*: The receiver code processes the signals from the transmitter and controls the robot car's movement, including backward movement when metal is detected. The code also handles Bluetooth communication, buzzer activation, and LED flashing. Upload this code to the Arduino R3 in the receiver section.

C. Testing And Calibrations

1) *Testing the Ultrasonic Sensor:* Place obstacles at varying distances to test the ultrasonic sensor's accuracy. Verify that it transmits signals to the Arduino R3 for obstacle avoidance.
2) *Testing Hand Gesture Control:* Perform various hand gestures to ensure that the robot car responds correctly to each movement. Adjust gesture sensitivity as needed.
3) *Testing Bluetooth Control via Mobile App:* Connect the HC-05 Bluetooth module to the mobile app and test the joystick control mode. Verify smooth and accurate manual control of the robot car.
4) *Calibrating the ADXL335 Accelerometer*: Calibrate the accelerometer to ensure accurate detection of hand movements. Fine-tune it to minimize false triggers and maintain precision during control.
5) *Testing Metal Detection and Safety Mechanism:* Place metallic objects on the ground and maneuver the robot car towards them. Verify that the system correctly identifies the metal, triggers the buzzer sound, moves backward, and flashes the LED indicator three times. Ensure that the backward movement is adequate to avoid potential threats.
6) *Adjusting Motor Speed and Steering:* Fine-tune the motor speed and steering controls to ensure smooth and precise movement in response to both hand gesture signals and joystick commands from the mobile app.

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IV. RESULT AND DISCUSSION

The experimental outcomes indicate that the Hand Gesture Controlled Robot Car with Metal Detection Using Arduino and Sensors successfully responds to various hand gestures while effectively identifying metallic objects.

The system integrates multiple sensors, including a flex sensor and an accelerometer, which accurately capture hand movements. Wireless communication via the Bluetooth module ensures smooth data transmission between the controller and the robot car, while ultrasonic sensors enable obstacle detection and safe navigation.

A. Metal Detection Techniques

One of the most significant features of this robot car is its metal detection capability, which is designed to identify potential threats such as landmines and other metallic objects commonly found in high-tension areas. The metal detection system uses an inductive sensor-based technique, where the presence of metal changes the inductance of a coil, generating a signal that triggers the detection alert. Upon identifying a metallic object, the robot car immediately activates a buzzer sound to notify the operator and moves backward to avoid running over the potentially hazardous material. In addition, an LED light indicator flashes three times as a visual warning. This integrated safety protocol ensures that the robot car does not proceed over the detected object, thereby minimizing the risk of accidental detonation.

B. Performance and Evaluation

The test results confirmed that the robot car could be maneuvered efficiently using simple hand gestures, with the Arduino board processing signals and controlling the motors as expected. The dual control system, featuring both gesture-based control and mobile app-based joystick control, enhances flexibility and adaptability. The mobile app proves useful when gesture control may not be feasible or when manual override is necessary.

The real-time interaction capabilities of the system allow for intuitive, hands-free control of the robot, while the metal detection mechanism consistently identifies metallic threats and triggers appropriate safety responses. The combination of sound and visual alerts, coupled with automatic backward movement, enhances the system's practicality in security and defense applications.

C. Challenges and Limitations

Despite its promising performance, several challenges were observed. The system's reliance on RF modules restricts its range of operation, making it less suitable for long-distance applications. Additionally, the limited variety of hand gestures supported by the current configuration poses a challenge when implementing more complex commands. Periodic calibration of the accelerometer is necessary to maintain precise control, which can be cumbersome in time-sensitive situations. Furthermore, the metal detection sensitivity may vary based on the type and size of the metallic object, which requires fine-tuning for optimal performance.

D. Future Directions

To enhance the system's capabilities, future improvements could focus on expanding the gesture recognition range, improving sensor accuracy, and integrating longer-range communication modules. Additionally, enhancing the metal detection algorithm to better distinguish between hazardous and non-hazardous metals could increase operational efficiency. Addressing these aspects will make the system more reliable and robust for diverse real-world applications, particularly in defense and safety scenarios.

V. FIGURES AND TABLES

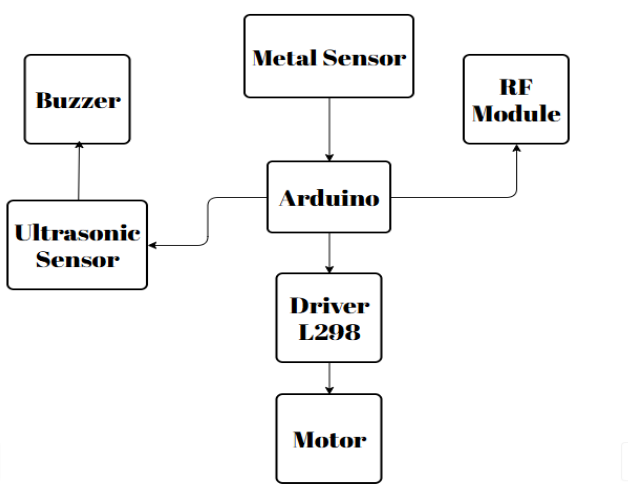

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Fig. 1 Block and circuit diagram

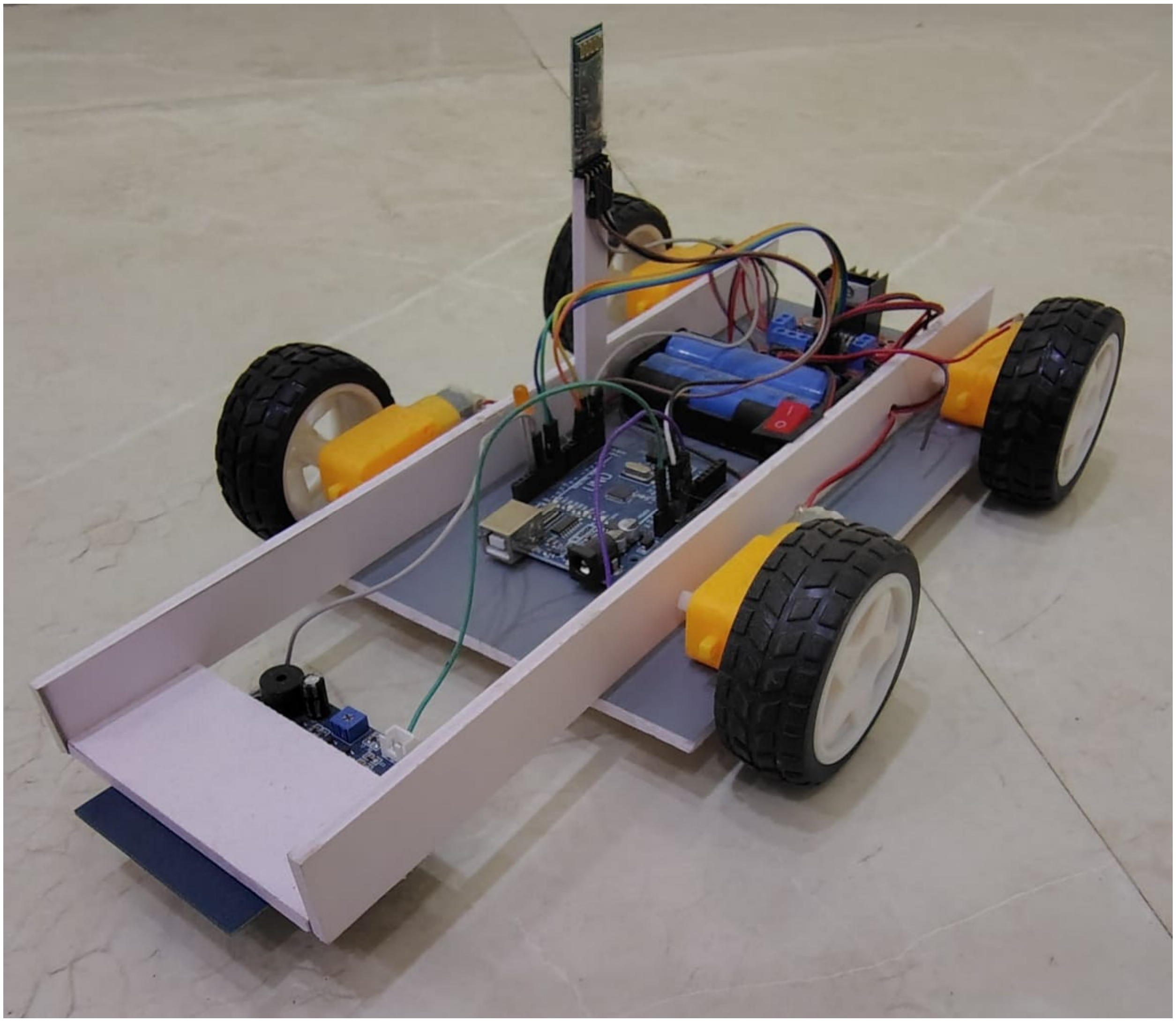

Fig. 2 Design of proposed system

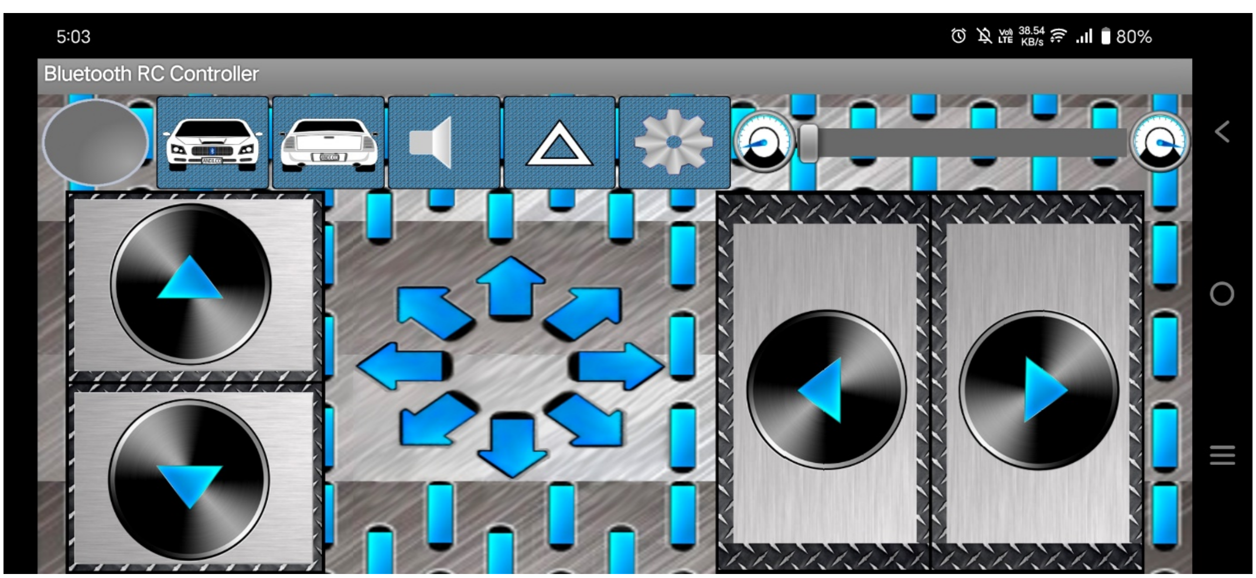

Fig. 3 Button based control

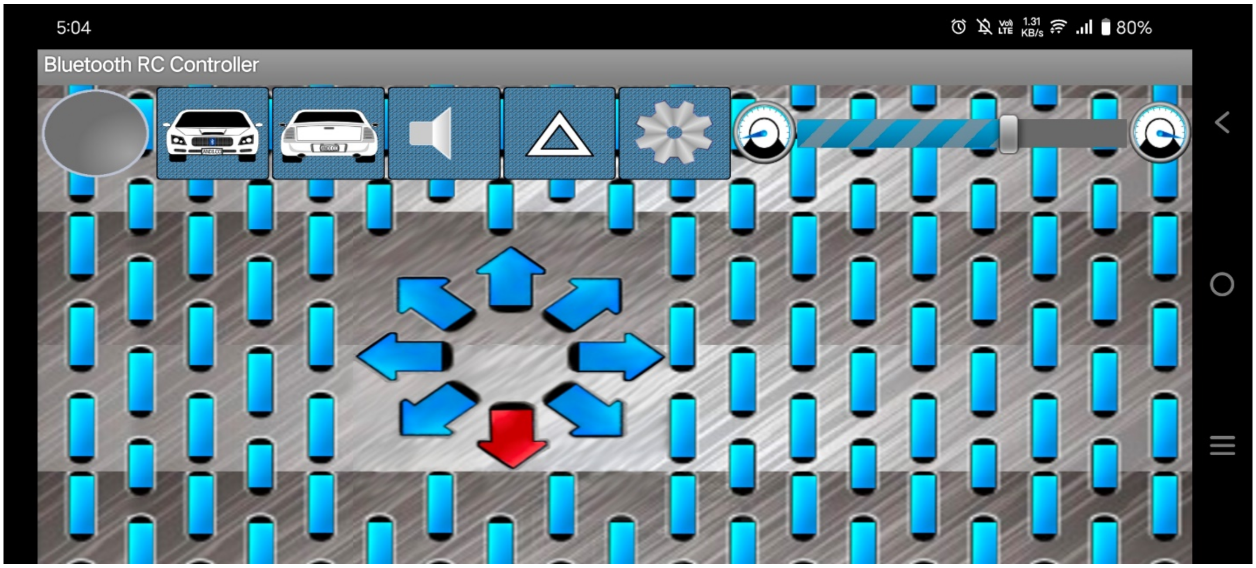

Fig. 4 Gyro / Gesture based control

VI. CONCLUSIONS

In summary, the Hand Gesture Controlled Robot Car with Metal Detection Using Arduino and Sensors offers an innovative and versatile approach to controlling a robot car's movement. The system is designed to be user-friendly and highly adaptable, utilizing both gesture-based control and a mobile application. This dual-control mechanism allows users to operate the robot car either through hand gestures or a virtual joystick on the app, enhancing flexibility and usability. The integration of a metal detection system significantly extends the application's practicality, particularly in defense and security operations where landmine detection is crucial. The system's safety features, including a buzzer alert, backward movement upon metal detection, and LED light indication, provide real-time notifications and mitigate risks associated with landmine exposure.

The wireless communication enabled by the Bluetooth module ensures smooth interaction between the controller and the robot car, while the combination of sensors—such as the ultrasonic detector, accelerometer, and flex sensor—ensures precise gesture recognition and obstacle avoidance.

Despite some limitations, such as the restricted range of movement and limited gesture recognition capabilities, the system demonstrates great potential for real-world applications. Future studies could focus on improving the range, expanding gesture options, and enhancing metal detection sensitivity. Overall, this project contributes significantly to the field of human-robot interaction by offering a robust, intuitive, and multi-functional control system suitable for a wide range of applications, including security, defense, education, and entertainment.

VII. ACKNOWLEDGMENT

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Special thanks to our project supervisor for their guidance and encouragement throughout the study. We also extend our appreciation to the open-source community for providing useful tools, libraries, and frameworks that greatly contributed to the successful implementation of this project. The integration of dual control mechanisms—both joystick-based and gesture-based—along with the safety features of metal detection and buzzer alerts, would not have been possible without the collaborative efforts and shared knowledge of the community.

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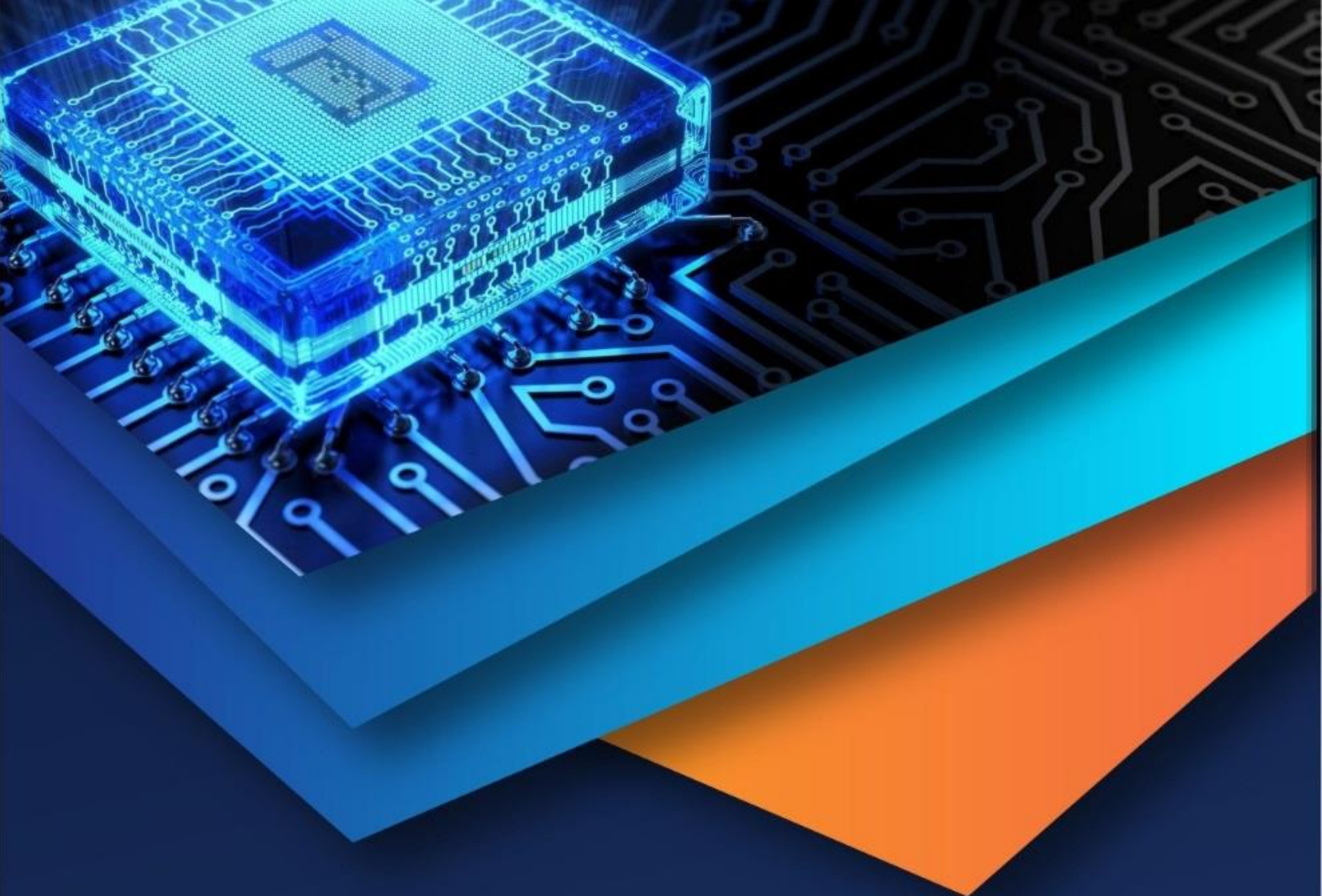

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