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Dual-Mode Hand Gesture and Line-Following Controlled Robotic Car

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Abstract

In recent years, the rapid advancement of automation and robotics has led to the development of intelligent systems capable of performing tasks with minimal human intervention. This paper presents a Dual-Mode Hand Gesture and Line-Following Controlled Robotic Car that integrates both autonomous navigation and intuitive manual control into a single platform. The robot operates in two distinct modes: line-following mode using infrared (IR) sensors for automated path tracking, and hand-gesture control mode using an MPU6050 motion sensor, NodeMCU, and RF communication for wireless directional commands (forward, backward, left, right). An ultrasonic sensor provides real-time obstacle avoidance for enhanced safety. The system is built around an Arduino Uno receiver and supports seamless mode switching. Testing demonstrates reliable line tracking, accurate gesture response with minimal delay, effective obstacle detection within 15 cm, and stable operation. The low-cost prototype (≈ ₹3,500) offers a versatile, educational, and practical solution for industrial automation, assistive robotics, and human-machine interaction.

Keywords: Robotics, Dual-Mode Control, Hand Gesture Recognition, Line Following, MPU6050, RF Communication, Arduino, Obstacle Avoidance, Embedded Systems

I. Introduction

Automation and robotics have become integral to modern industries, healthcare, and education. Traditional robotic systems often operate in a single mode — either fully autonomous or manually controlled — limiting their flexibility in dynamic environments. This project addresses the need for a

versatile robotic platform by designing a dual-mode smart robotic car capable of autonomous line following and intuitive hand-gesture control.

The system enables the robot to follow a predefined black line using IR sensors in autonomous mode, making it suitable for material handling and automated guided vehicles. In gesture-control mode, hand movements captured by an MPU6050 sensor are processed and transmitted wirelessly via RF modules, allowing natural human-machine interaction. An ultrasonic sensor ensures safety by detecting obstacles and halting the robot automatically.This dual-mode approach enhances usability, adaptability, and safety while serving as an excellent educational platform for embedded systems and robotics.

II. Literature Survey

Several studies have explored line-following robots and gesture-controlled systems. Early line-following robots relied on simple threshold-based IR sensor logic, while recent works incorporate PID control for smoother path tracking. Gesture-controlled robots commonly use accelerometers and gyroscopes (such as MPU6050) with wireless modules (Bluetooth, RF, or Wi-Fi) for intuitive control. Hybrid/dual-mode systems that combine autonomous and manual operation have gained attention for their flexibility in real-world applications.

Research gap: Most existing systems operate in only one mode and lack seamless switching between autonomous line following and wireless gesture control with built-in obstacle avoidance. This project bridges the gap by integrating both modes with reliable RF communication and ultrasonic safety features in a low-cost, compact platform.

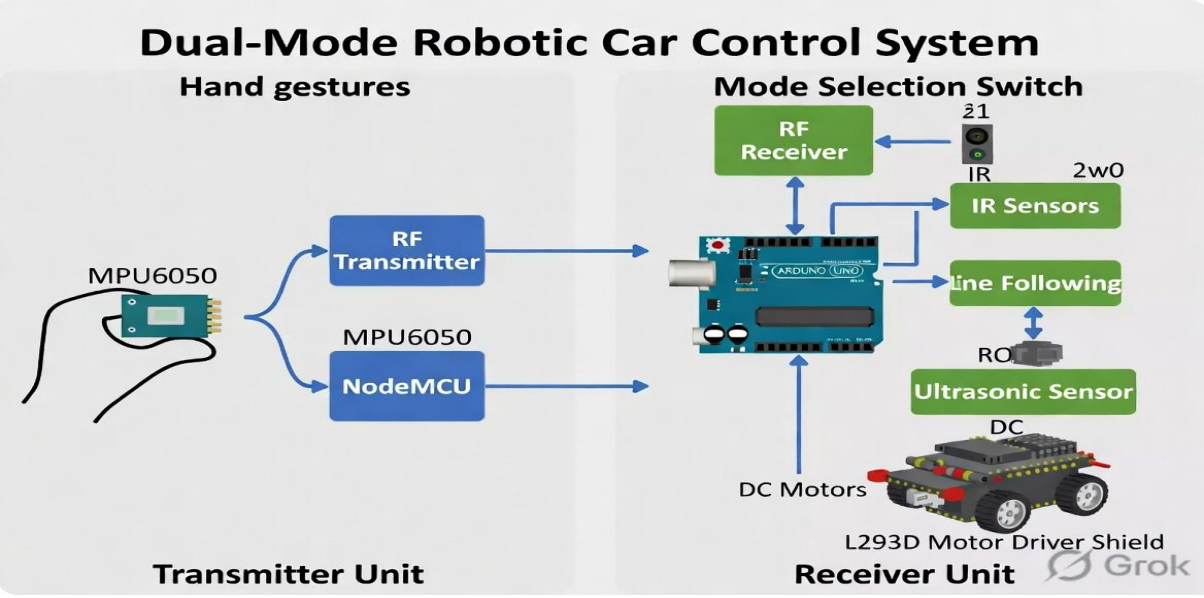
III. Methodology

III-A. System Architecture

The system follows a modular dual-unit architecture consisting of a Transmitter Unit and a Receiver Unit connected via RF wireless communication.

The Transmitter Unit comprises an MPU6050 motion sensor and NodeMCU that detects hand gestures and transmits directional commands.

The Receiver Unit uses an Arduino Uno to process inputs from IR sensors (line following), RF receiver (gesture commands), ultrasonic sensor (obstacle detection), and controls four DC motors through an L293D motor driver. A mode-selection switch allows seamless switching between the two operating modes.



III-B. Working Principle / Algorithm

Algorithm: Dual-Mode Robotic Car Operation

Step 1: System Initialization — Arduino Uno and NodeMCU initialize sensors and RF modules.

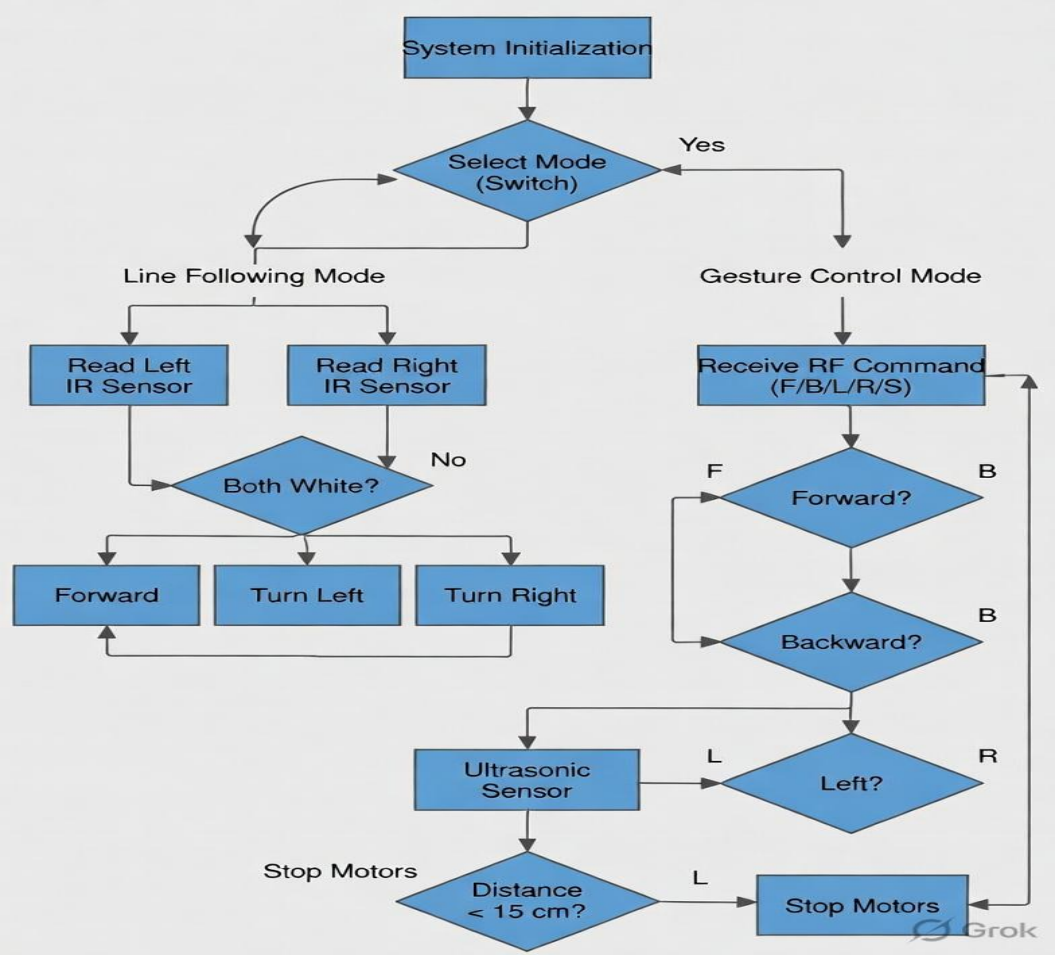
Step 2: Mode Selection — User selects line-following or gesture-control mode via switch.

Step 3: Line-Following Mode — IR sensors read surface contrast; Arduino adjusts motor speeds (forward, left turn, right turn) to stay on the black line.

Step 4: Gesture-Control Mode — MPU6050 reads acceleration/tilt; NodeMCU converts data into commands (“F”, “B”, “L”, “R”, “S”) and transmits via RF. Arduino receives and executes motor actions.

Step 5: Obstacle Avoidance — Ultrasonic sensor continuously measures distance; if < 15 cm, motors stop immediately (applies to both modes).

Step 6: Continuous Loop — System repeats sensor reading, decision making, and motor control in real time.



III-C. Hardware and Software Components

Hardware: Arduino Uno (main receiver controller), NodeMCU (transmitter), MPU6050 (motion sensor), L293D Motor Driver Shield, 4 DC motors with chassis, 2 IR sensors, HC-SR04 Ultrasonic sensor, 433 MHz RF transmitter-receiver pair, 9V/12V battery pack.

Software: Arduino IDE with C++ programming, MPU6050 and RadioHead (RF) libraries, custom logic for mode switching, motor control, and sensor fusion.

IV. Results and Discussion

TABLE I: SYSTEM PERFORMANCE EVALUATION

Parameter	Reference / Target	System Result
Line-Following Accuracy	Straight & curved paths	Reliable tracking
Gesture Response Time	—	< 300 ms
Obstacle Detection Range	—	15 cm (accurate)
RF Communication Range	—	Up to 10–15 m

Parameter	Reference / Target	System Result
Battery Life (continuous)	2+ hours	3.5+ hours
Mode Switching Time	—	< 1 second
Prototype Cost	—	≈ ₹3,500

The system was extensively tested on straight, curved, and interrupted paths. Line-following mode performed accurately under normal lighting. Gesture control responded reliably with minimal delay. The ultrasonic sensor successfully prevented collisions. Overall, the dual-mode robot demonstrated high reliability, intuitive operation, and practical performance suitable for educational and industrial use.

V. Conclusion and Future Work

This paper presented the design and implementation of a low-cost Dual-Mode Hand Gesture and Line-Following Controlled Robotic Car achieving reliable autonomous navigation and intuitive wireless gesture control with built-in obstacle avoidance. The system successfully integrates embedded hardware, wireless communication, and sensor technologies while maintaining simplicity and affordability.

Future work includes adding IoT-based remote monitoring via Wi-Fi/Bluetooth, integrating camera-based computer vision for advanced navigation, implementing voice control, and developing a mobile application for enhanced user interaction. Clinical or industrial trials can further validate the system's real-world impact.

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