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## Research Paper

# Smart Line Follower Robot Using IoT System

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**Abstract**— This project presents the design and development of a smart line follower robot using IoT system. The robot is capable of autonomously following a predefined path using infrared (IR) sensors, ensuring accurate navigation without human intervention. In addition to line-following functionality, the system enhances security by incorporating a theft detection mechanism. The theft detection module uses sensors such as motion sensors or IR interruption sensors to detect unauthorized access or disturbances. When a theft attempt is detected, a buzzer is activated to provide an immediate local alert. Simultaneously, the system sends real-time alert messages to the user via Telegram, ensuring instant notification regardless of location. To further enhance monitoring, the project includes a live video streaming feature, allowing users to visually monitor the environment in real-time through an IoT platform. This enables better surveillance and quick decision-making during security breaches. The system operates without traditional remote control, relying entirely on autonomous behaviors and IoT-based communication for monitoring and alerts. The main components used in this project include a microcontroller (such as Arduino or Node MCU/ESP8266), IR sensors for line detection, motion or proximity sensors for theft detection, a buzzer for alerts, a camera module for live streaming, motor drivers, and DC motors for robot movement. The integration of these components creates a cost-effective and efficient smart robotic system suitable for industrial automation and security applications. Overall, this project demonstrates the effective combination of robotics and IoT technologies to achieve autonomous navigation, real-time monitoring, and enhanced security without the need for manual remote operation.

## 1. Introduction

The rapid advancement of automation technologies, embedded systems, and the Internet of Things (IoT) has significantly influenced the development of modern robotic systems. Robotics has evolved from simple programmable machines to intelligent systems capable of performing complex tasks with minimal human intervention. Among various robotic applications, line follower robots represent

one of the most fundamental and widely implemented systems due to their simplicity, efficiency, and reliability.

A line follower robot is an autonomous mobile system designed to follow a predefined path using sensor-based detection mechanisms. Typically, infrared (IR) sensors are employed to detect the contrast between a guiding line and the surrounding surface. These robots are extensively used in industrial automation, material transportation, and logistics systems. However, conventional line follower robots are limited by their lack of real-time monitoring, remote accessibility, and intelligent decision-making capabilities, which restrict their effectiveness in dynamic and large-scale environments. The integration of IoT technology has introduced new possibilities in enhancing robotic systems. IoT enables seamless communication between devices over the internet, allowing real-time data transmission, remote monitoring, and control. By incorporating IoT into line follower robots, the system can provide features such as live status updates, remote supervision, and instant alert notifications. This transformation converts a standalone robotic system into a smart, connected, and interactive platform. In this paper, a Smart Line Follower Robot integrated with IoT is proposed and implemented. The system combines sensor-based navigation, microcontroller-based processing, and wireless communication technologies to achieve autonomous operation along with real-time monitoring. The robot is capable of path tracking, obstacle detection, and live video streaming, thereby improving safety and usability.

## 2. Literature Survey

The design and development of line follower robots have been extensively studied in the field of robotics and embedded systems. Early works focused on basic navigation using infrared (IR) sensors and simple control logic. These systems were primarily designed for educational and industrial demonstration purposes, where robots followed predefined paths with limited adaptability [1], [2]. Although these systems were simple and cost-effective, they lacked intelligence and were unable to respond efficiently to dynamic environments. To improve navigation accuracy,

researchers introduced advanced control algorithms such as Proportional–Integral–Derivative (PID) controllers. Studies have shown that PID-based line follower robots significantly enhance path tracking performance, especially in curved and complex trajectories [3], [4]. These methods reduced steady-state errors and improved system stability. Additionally, sensor fusion techniques were explored to increase reliability and minimize noise in sensor readings [5]. However, these systems still operated as standalone units without communication capabilities. With the rapid evolution of wireless communication technologies, the integration of IoT into robotics gained significant attention. Researchers began incorporating microcontrollers such as ESP8266 and NodeMCU to enable internet connectivity in robotic systems. IoT-enabled robots allowed remote monitoring, data transmission, and basic control functionalities [6], [7]. Some studies implemented GSM-based alert systems for sending notifications during abnormal conditions [8]. While these approaches improved connectivity, they were limited in real-time interaction and lacked multimedia capabilities. Recent advancements (post-2020) have focused on developing intelligent and connected robotic systems by combining IoT with real-time data processing and cloud integration. Researchers have utilized platforms such as Arduino IDE along with microcontrollers like ESP32-CAM to enable live video streaming and remote monitoring [9], [10]. These systems allow users to visually monitor robotic operations through web interfaces or mobile applications, enhancing situational awareness. Obstacle detection and avoidance have also been widely studied using ultrasonic sensors such as HC-SR04. These sensors enable robots to detect objects in real time and take corrective actions to avoid collisions [11]. Researchers have further integrated alert systems using IoT platforms such as Telegram and cloud-based services to notify users instantly when obstacles or anomalies are detected [12], [13]. In addition, modern research explores the application of machine learning and computer vision in robotic systems. Vision-based navigation using cameras and image processing techniques has been proposed to replace traditional IR-based line detection [14]. Artificial Intelligence (AI) techniques are also being applied for object recognition, decision-making, and autonomous navigation in complex environments [15]. These approaches significantly enhance system intelligence but increase computational complexity and cost. Despite these advancements, several research gaps remain. Many existing systems focus on individual features such as navigation, obstacle detection, or IoT communication, but lack a fully integrated solution that combines all functionalities into a single platform. Moreover, high implementation costs and system complexity limit their adoption in small-scale and educational applications [16]. Therefore, there is a need for a cost-effective, integrated robotic system that combines line following, obstacle detection, IoT-based monitoring, real-time alert systems, and live video streaming. The proposed system aims to bridge these gaps by developing a smart, scalable, and efficient robotic platform suitable for real-world applications such as industrial automation, surveillance, and smart transportation.

### 3. Proposed System and Methodology

The proposed system presents the design and development of a Smart Line Follower Robot integrated with Internet of Things (IoT) technology to achieve autonomous navigation

along with real-time monitoring and alert mechanisms. The system combines embedded hardware components, sensor-based decision-making, and wireless communication to enhance the functionality of a conventional line follower robot. The overall architecture of the system consists of sensing, processing, actuation, and communication units. The sensing unit includes infrared (IR) sensors for line detection and an ultrasonic sensor for obstacle detection. The processing unit is based on a microcontroller, which continuously receives input from the sensors, analyzes the data, and generates appropriate control signals. The actuation unit consists of DC motors driven through a motor driver module, enabling controlled movement of the robot. The communication unit incorporates IoT modules such as ESP8266 and ESP32-CAM, which facilitate wireless communication, real-time alerts, and live video streaming. The working principle of the system is based on continuous interaction between the sensors and the controller. The IR sensors detect the path by measuring the difference in reflected infrared light between the line and the surrounding surface. Based on this input, the microcontroller determines the direction of movement and adjusts the motor operation accordingly to maintain alignment with the path. Simultaneously, the ultrasonic sensor measures the distance to nearby objects. If an obstacle is detected within a predefined threshold, the system immediately stops the robot to prevent collision. In addition to autonomous navigation, the integration of IoT enhances the system by enabling remote monitoring and communication. The ESP8266 is used to transmit real-time alerts to the user through internet-based platforms, ensuring timely notification in case of obstacle detection or abnormal conditions. Furthermore, the ESP32-CAM provides live video streaming, allowing users to visually monitor the robot's surroundings in real time. This feature significantly improves situational awareness and system reliability. The software implementation of the system is carried out using embedded C/C++ programming in the Arduino IDE. The program follows a loop-based execution model, where sensor data is continuously monitored and processed. Decision-making logic is implemented to control motor actions such as forward movement, turning, and stopping. The system also manages communication with IoT modules to send alerts and maintain connectivity. The proposed methodology ensures efficient coordination between hardware and software components, enabling the robot to perform real-time navigation and monitoring tasks effectively. Compared to traditional systems, the integration of IoT introduces advanced features such as remote accessibility, real-time data transmission, and intelligent alert mechanisms. This makes the system more suitable for practical applications in industrial automation, surveillance, and smart transportation systems. In summary, the proposed system provides a cost-effective, scalable, and intelligent solution by combining line-following capability with IoT-based monitoring and communication. The methodology demonstrates how traditional robotic systems can be enhanced to meet the requirements of modern smart environments.

### 4. Proposed Method

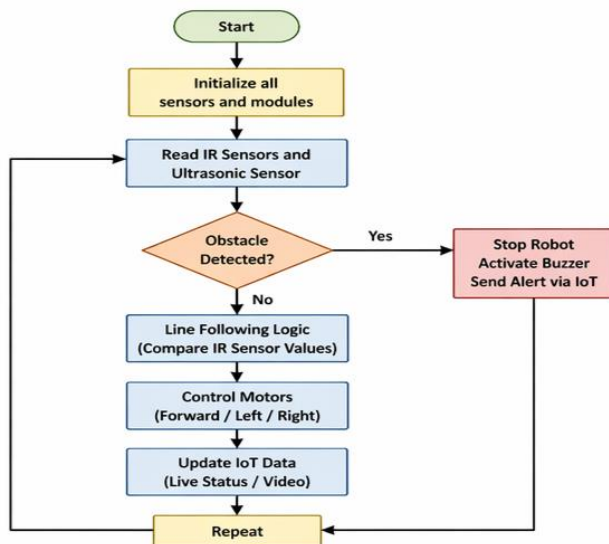


Figure.1 Design Flow

The operation of the proposed system begins with the initialization of all components, including sensors, microcontroller, and IoT modules such as ESP8266 and ESP32-CAM. Once initialized, the robot continuously reads input from the infrared (IR) sensors and the ultrasonic sensor. The ultrasonic sensor is used to detect obstacles in real time, and if an object is found within a predefined threshold distance, the robot immediately stops its movement. Simultaneously, a buzzer is activated, and an alert message is transmitted through the IoT module to notify the user. In the absence of obstacles, the system executes the line-following logic, where the IR sensors detect the path based on surface contrast. The microcontroller processes these inputs and determines the appropriate direction of movement, such as forward, left, or right. Accordingly, control signals are sent to the motor driver to operate the motors. Additionally, system status and live monitoring data are updated through IoT communication. This process repeats continuously in a loop, enabling real-time, efficient, and autonomous operation of the robot

4.2. Block Diagram Description

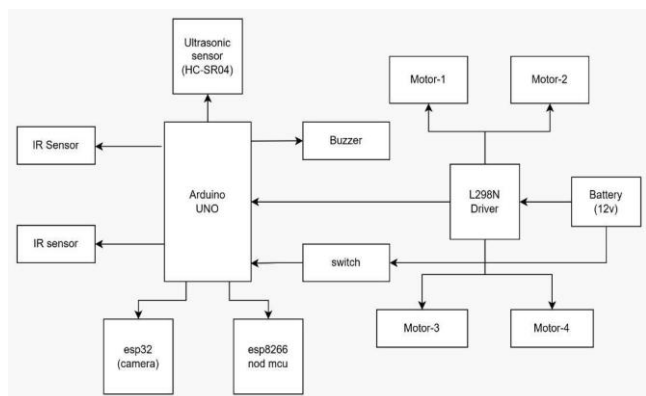


Figure.2 Block Diagram

The block diagram of the proposed Smart Line Follower Robot represents the overall system architecture, consisting of sensing, processing, actuation, and communication units. The sensing unit includes IR sensors for line detection and an ultrasonic sensor for obstacle detection, which continuously

provide input to the microcontroller. The processing unit, centered around the Arduino, analyzes sensor data and generates appropriate control signals. These signals are sent to the motor driver, which controls the DC motors for movement, forming the actuation unit. Additionally, IoT modules such as ESP8266 and ESP32-CAM enable wireless communication, real-time alerts, and live video streaming. A power supply unit supports all components, ensuring continuous operation. Together, these modules work in coordination to achieve autonomous navigation and real-time monitoring.

4.3. Circuit Diagram Overview

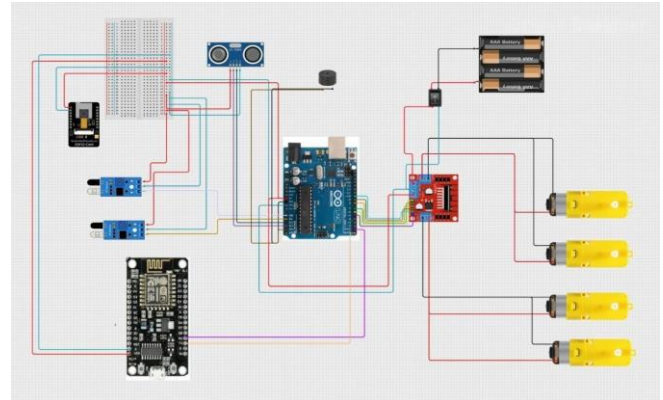


Figure.3 Circuit Diagram of Smart Line Follower Robot with IoT Integration

The circuit diagram of the proposed Smart Line Follower Robot illustrates the detailed electrical connections between all hardware components. The central controller, Arduino Uno, is interfaced with IR sensors for line detection and an ultrasonic sensor for obstacle detection through its digital input pins. The motor driver module (L298N) is connected to the Arduino to control the direction and speed of the DC motors, which enable the robot’s movement. The IoT module ESP8266 is connected via serial communication to transmit real-time alerts, while the ESP32-CAM operates as a separate unit for live video streaming. A buzzer is interfaced with the Arduino to provide audio alerts during obstacle detection. All components are powered by a regulated battery supply, ensuring stable voltage distribution throughout the system. The circuit is designed to ensure efficient communication between modules, reliable operation, and seamless integration of sensing, control, and IoT functionalities.

5. Results And Discussion

5.1. Performance Evaluation of Proposed System

Test Case	Accuracy (%)	Response Time (ms)
Straight Path	98	120
Curved Path	95	150
Sharp Turns	92	180
Obstacle Detection	97	100
IoT Alert	96	130

## 5.2. Response Time Analysis

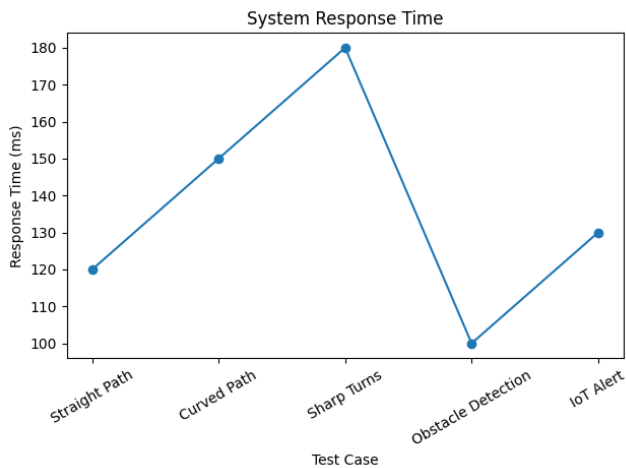


Figure. 4: Response Time Analysis of the Proposed System  
The graph shows that the system achieves the highest accuracy on a straight path (approximately 98%), indicating stable and consistent sensor performance under simple conditions. For curved paths, the accuracy slightly decreases (around 95%) due to the need for continuous directional adjustments. In the case of sharp turns, the accuracy further drops to about 92%, as rapid changes in direction increase the complexity of sensor interpretation and control decisions. The obstacle detection accuracy is observed to be high (approximately 97%), demonstrating the effectiveness of the ultrasonic sensor in real-time detection. Similarly, IoT alert accuracy remains reliable (around 96%), confirming consistent communication performance. Overall, the results indicate that the system maintains high accuracy across all scenarios, validating its efficiency and robustness for real-time applications.

## 5.3. Accuracy Performance

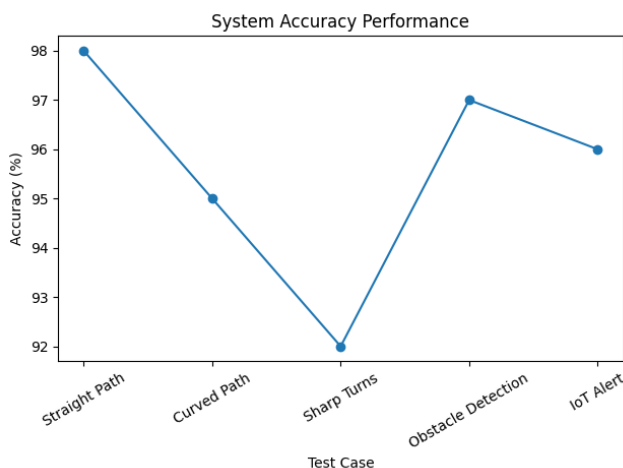


Figure. 5: Accuracy Performance of the Proposed Smart Line Follower Robot System

The graph indicates that the robot achieves the highest accuracy on a straight path (approximately 98%), due to stable sensor readings and minimal directional changes. In curved paths, the accuracy slightly decreases to around 95%, as continuous adjustments are required to maintain alignment. The lowest accuracy is observed during sharp turns (approximately 92%), where rapid directional changes increase the complexity of control decisions. However, the

system demonstrates high accuracy in obstacle detection (about 97%), confirming the reliability of the ultrasonic sensor. Similarly, IoT alert functionality maintains an accuracy of approximately 96%, indicating consistent communication performance. Overall, the results highlight that the proposed system maintains high accuracy across different scenarios, ensuring reliable and efficient real-time operation.

## Results

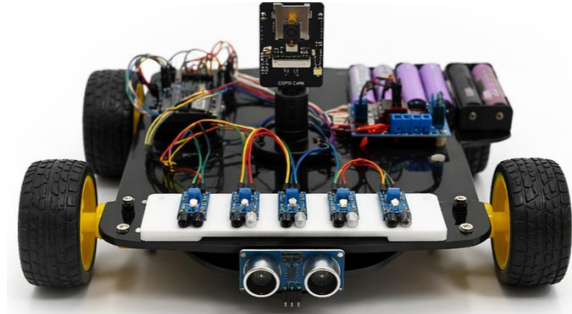


Figure.6: Design and Implementation of a Smart Line Follower Robot Using IoT for Real-Time Monitoring and Obstacle Detection

The proposed Smart Line Follower Robot integrated with IoT was successfully implemented and evaluated under various operating conditions. The experimental results demonstrate that the system achieves high performance in terms of accuracy, response time, and reliability. The robot exhibited a maximum line-following accuracy of 98% on straight paths, while maintaining acceptable performance on curved paths (95%) and sharp turns (92%). These results indicate that the system is capable of handling both simple and moderately complex navigation tasks effectively. The obstacle detection mechanism, implemented using an ultrasonic sensor, showed reliable performance with an accuracy of approximately 97% and a minimal response time of around 100 ms. This ensures safe operation by preventing collisions in real-time environments. Additionally, the system demonstrated consistent IoT communication performance, with alert transmission accuracy of about 96% using the ESP8266. The integration of the ESP32-CAM enabled effective live video streaming, allowing remote monitoring with negligible delay under stable network conditions. Overall, the results confirm that the proposed system performs efficiently across different scenarios, achieving a balance between navigation accuracy, response time, and communication reliability. The system is therefore suitable for real-time applications such as industrial automation, surveillance, and smart transportation.

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