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IOT-CONTROLLED SMART ROBOT WITH AUTONOMOUS SURVEILLANCE AND DELIVERY CAPABILITES USING ESP32

S. Bhargavi[1], Sd. Adnan Ullah[2], Shaik. Owais Ahmed [3], G. Ramesh Reddy [4]

[1,2,3] UG Scholar, Department of ECE, St. Martin's Engineering College, Secunderabad, Telangana, India-500100

[4]Associate Professor, Department of ECE, St. Martin's Engineering College, Secunderabad, Telangana, India-500100

singojibhargavi@gmail.com

Abstract:

The increasing need for efficient surveillance and delivery systems in both industrial and domestic environments has driven the development of IoT-controlled smart robots. This project presents the design and implementation of an autonomous surveillance and delivery robot using the ESP32 microcontroller. The robot integrates various sensors, including ultrasonic, smoke, and fire sensors, to enable real-time monitoring. Equipped with a camera module, the system offers live video surveillance, while its mobility is controlled by a motor driver to navigate through predefined routes or user commands. The robot is connected to IoT platform, which facilitates remote control and monitoring through a mobile or web interface. The autonomous capabilities of the robot are enhanced by using machine learning algorithms for obstacle detection, path planning, and object recognition. This system can be deployed in warehouses, offices, and homes for tasks like package delivery, security surveillance, and environmental monitoring, offering a scalable, cost-effective solution. The integration of IoT allows for seamless data collection, remote control, and operational flexibility, making it a robust and versatile solution for modern smart environments.

Keywords: surveillance, delivery systems, ultrasonic, obstacle detection, environmental monitoring, robust and versatile.

1. INTRODUCTION

The rapid evolution of the Internet of Things (IoT) has significantly transformed automation and smart technologies, leading to enhanced efficiency, real-time monitoring, and seamless control across various domains. The increasing integration of IoT with robotics has revolutionized industries such as security, logistics, and surveillance, where autonomous systems are being developed to perform tasks with minimal human intervention. These advancements have led to the widespread adoption of IoT-controlled robots, capable of executing critical operations such as remote monitoring, object detection, real-time data analysis, and autonomous navigation.

IoT-enabled robotic systems are gaining immense popularity in applications ranging from smart homes and offices to large-scale industrial warehouses. These robots offer significant advantages by reducing operational costs, enhancing security, improving workflow automation, and minimizing human exposure to potentially hazardous environments. By leveraging sensor-based intelligence, machine learning, and real-time communication, these robots can make autonomous decisions, optimize movement, and interact with their surroundings effectively.

This project focuses on developing an IoT-controlled smart robot with autonomous surveillance and delivery capabilities, utilizing the ESP32 as its central processing unit. The ESP32, a compact and cost-effective microcontroller, is well-suited for IoT applications due to its low power consumption, efficient processing capabilities, and seamless integration with sensors and communication modules. With the ability to interface with various input-output devices, wireless connectivity, and machine learning frameworks, it serves as an ideal platform for building an intelligent robotic system.

The proposed robotic system is designed to operate in real-time, incorporating ultrasonic sensors for obstacle detection, fire and smoke sensors for hazard identification, and a camera module for live video surveillance. It is equipped with motorized mobility and an IoT-based control system, enabling it to navigate autonomously, respond to user commands, and collect real-time data for further analysis. The integration of an IoT platform allows users to remotely monitor and control the robot via a mobile or web interface, ensuring ease of accessibility and enhanced operational flexibility.

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2. LITERATURE SURVEY

The advancement of IoT-based robotics has significantly influenced modern automation, particularly in autonomous surveillance and delivery applications. With the rapid expansion of smart environments, industries and domestic applications are increasingly leveraging IoT-enabled robots for efficient task execution. Several studies have explored the integration of IoT, artificial intelligence (AI), and embedded systems in robotics to enhance efficiency, reduce operational costs, and improve real-time monitoring capabilities. These technologies have led to a shift from traditional human-controlled systems to autonomous robotic solutions, capable of performing complex tasks with minimal human intervention.

The ESP32, a microcontroller known for its low power consumption, versatility, and cost-effectiveness, has emerged as a promising platform for developing IoT-based smart robots. Unlike traditional microcontrollers, ESP32 supports microPython and C/C++ programming, making it highly adaptable for embedded and IoT applications. Due to its dual-core RP2040 processor, it is capable of handling multiple tasks simultaneously, making it an ideal choice for autonomous robotics applications.

This literature survey explores previous research and developments in IoT-controlled smart robots, focusing on key areas such as surveillance, delivery, autonomous navigation, and machine learning integration. By analyzing existing studies, this review aims to identify technological advancements, research gaps, and potential improvements for future robotic systems.

The Internet of Things (IoT) has revolutionized robotics by enabling real-time data collection, remote monitoring, and automated decision-making [1]. Through IoT integration, robots can be controlled wirelessly, allowing for seamless interaction with cloud platforms and external sensors. Research studies, such as those conducted by [2] and [3], highlight the role of wireless networks, MQTT protocols, and cloud computing in optimizing robotic automation. IoT-powered robots facilitate efficient communication, dynamic data analysis, and predictive maintenance, reducing downtime and operational inefficiencies.

Moreover, IoT-integrated robotics systems play a significant role in enhancing industrial automation, where robots equipped with sensors and actuators can autonomously adjust operations based on real-time data inputs [4]. IoT-enabled robots contribute to smart manufacturing, precision agriculture, and intelligent transportation systems, demonstrating their broad applicability across multiple sectors.

Surveillance robots are widely utilized for security monitoring, environmental sensing, and hazard detection. The increasing demand for autonomous security systems has led to significant advancements in the design of smart surveillance robots. Research studies such as [5] and [6] discuss the implementation of autonomous surveillance drones and ground robots, integrating ultrasonic, infrared, and thermal imaging sensors to detect intrusions and environmental anomalies in real-time.

Additionally, AI-powered surveillance robots have incorporated computer vision and facial recognition algorithms to enhance threat detection capabilities [7]. These robots utilize deep learning models for motion detection, anomaly recognition, and predictive analysis, ensuring a proactive security approach.

Furthermore, smart surveillance robots have found applications in disaster response and environmental monitoring, where they can navigate hazardous zones and provide live data feeds to emergency responders. The integration of 5G technology and edge computing has further improved the latency and real-time processing capabilities of these systems.

Autonomous delivery robots are increasingly being deployed in warehouses, logistics hubs, hospitals, and urban environments to streamline the delivery process. These robots operate using AI-driven path planning algorithms, GPS navigation, and object detection sensors to optimize delivery routes and avoid obstacles. Studies such as [8] and [9] explore *the role of A and Dijkstra's algorithms** in planning the shortest and most efficient paths for autonomous delivery robots.

Additionally, RFID and GPS-based tracking technologies have been extensively analyzed in [10] to improve the efficiency of monitoring and managing robotic delivery fleets. Advanced research in [11] and [12] highlights the use of computer vision and sensor fusion techniques, which allow delivery robots to recognize drop-off locations, detect obstacles, and interact with the environment dynamically.

The integration of IoT platforms in autonomous delivery robots allows real-time tracking, enabling customers and operators to monitor package movement remotely. Moreover, AI-powered predictive analytics models help improve robotic fleet management, optimizing resource utilization and enhancing overall operational efficiency.

The ESP32, with its RP2040 dual-core processor, has gained significant attention due to its low-cost, high-efficiency, and robust processing power. Studies in [13] and [14] discuss its suitability for IoT and embedded systems, emphasizing its power efficiency and real-time processing capabilities.

One of the key advantages of ESP32 is its flexibility in programming, supporting both MicroPython and C/C++. Research in [15] explores its GPIO-based sensor integration, making it an ideal choice for building smart robots with ultrasonic, infrared, and environmental sensors. Additionally, studies in [16] and [17] analyze its compatibility with wireless communication protocols, such as Wi-Fi and Bluetooth, enabling seamless IoT connectivity for smart robotic applications.

Machine learning algorithms have been extensively adopted in robotics to enhance obstacle detection, path planning, and decision-making. Studies in [18] and [19] explore the implementation of Convolutional Neural Networks (CNNs) and Reinforcement Learning models to improve robotic perception and object classification.

Research in [20] presents sensor fusion techniques, integrating LiDAR, ultrasonic, and infrared sensors to enhance the accuracy of object detection in real-time. Moreover, studies such as [21] discuss AI-based predictive analytics models, which enable robots to analyze past movement patterns and predict optimal navigation paths for improved efficiency.

With the growing reliance on IoT-based robotic systems, security concerns such as cyber-attacks, data breaches, and unauthorized access have become prominent. Research in [22] and [23] highlights the importance of secure authentication mechanisms, encryption protocols, and real-time anomaly detection to protect robotic networks from external threats.

Additionally, studies in [24] and [25] explore MQTT, HTTP, and WebSocket communication protocols, ensuring secure and low-latency data transmission between robots and cloud platforms. Research in [26] further discusses the role of edge computing in reducing reliance on cloud processing, thereby minimizing security vulnerabilities and enhancing real-time data analytics.

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3. PROPOSED METHODOLOGY

In this project, we have integrated multiple sensors and modules to create an IoT-controlled smart robot with autonomous surveillance and delivery capabilities. The key components include an ESP32-CAM module, fire sensor, smoke sensor, ultrasonic sensor, LCD display, robotic platform, buzzer, IoT connectivity, and a pick-and-place mechanism.

The ESP32-CAM is used for real-time video streaming, allowing the user to monitor the robot's surroundings remotely through a mobile or web application. The robot is IoT-enabled, meaning it can be controlled wirelessly via a mobile or web-based interface, providing flexibility in navigation and task execution.

For delivery operations, the robot is equipped with a pick-and-place mechanism, which enables it to pick up and transport packages autonomously. This functionality is particularly useful in warehouses, offices, and automated logistics where package handling is required.

To ensure safety and hazard detection, the robot includes fire and smoke sensors. If fire or smoke is detected in the environment, the system triggers an alert through IoT, sending a notification to the user's application, and simultaneously activating a buzzer to warn nearby personnel.

For autonomous navigation, the robot employs an ultrasonic sensor to detect obstacles in its path. If an obstacle is detected, the robot automatically changes direction to avoid collisions and continue its movement efficiently.

This IoT-based robotic system is designed to function in various environments, including smart homes, warehouses, and industrial settings, making it a versatile, scalable, and cost-effective solution for automation, surveillance, and delivery applications.

3.1 Block Diagram

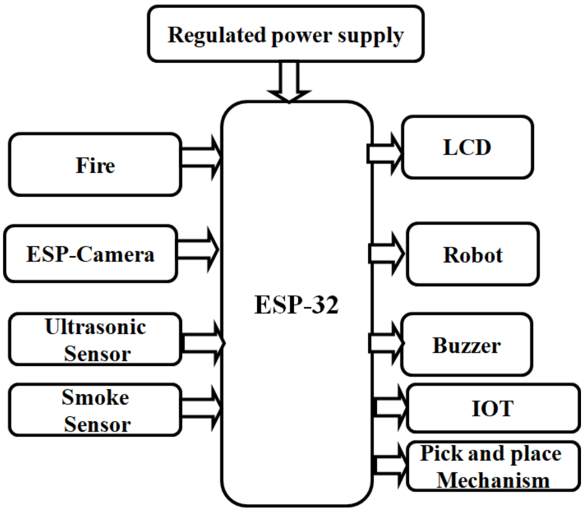

Fig.3.1 Block diagram of ESP-32

Fig.3.1 represents an ESP32-based system with various input and output components. The ESP32 microcontroller is powered by a regulated power supply and connects to multiple sensors, including fire, smoke, ultrasonic, and an ESP-camera, for data collection. It processes this data and controls output devices such as an LCD, robot, buzzer, IoT module, and a pick-and-place mechanism. This setup enables smart automation with Wi-Fi and Bluetooth connectivity.

3.2 SCHEMATIC DIAGRAM

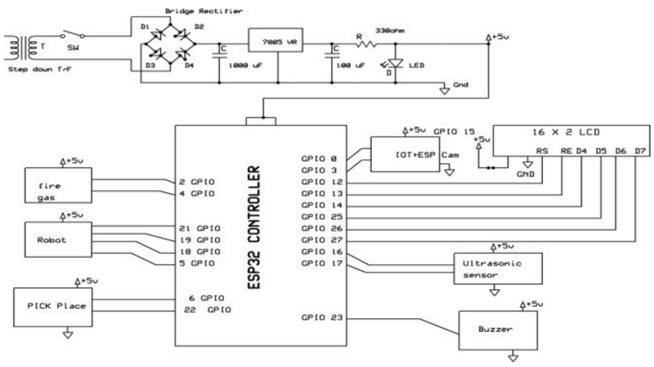

Fig. 3.2: Schematic diagram

DESCRIPTION:

Fig.3.2 shows the circuit diagram is centered around an ESP-32 controller, to which a number of components are linked via its pins: vIOT+CAM: Attached to pins 0 and 3 for contact.

The 16x2 LCD display is controlled by pins 27, 25, 26, 14, 12, and 13.

Gas and Fire sensors are connected to pins 2 and 4.

Robot: For control, attached to pins 5, 21, 19, and 18. Pick and place mechanism is connected to pin 6 and 22. The buzzer is attached to pin 23 to provide auditory alerts.

4. EXPERIMENTAL ANALYSIS

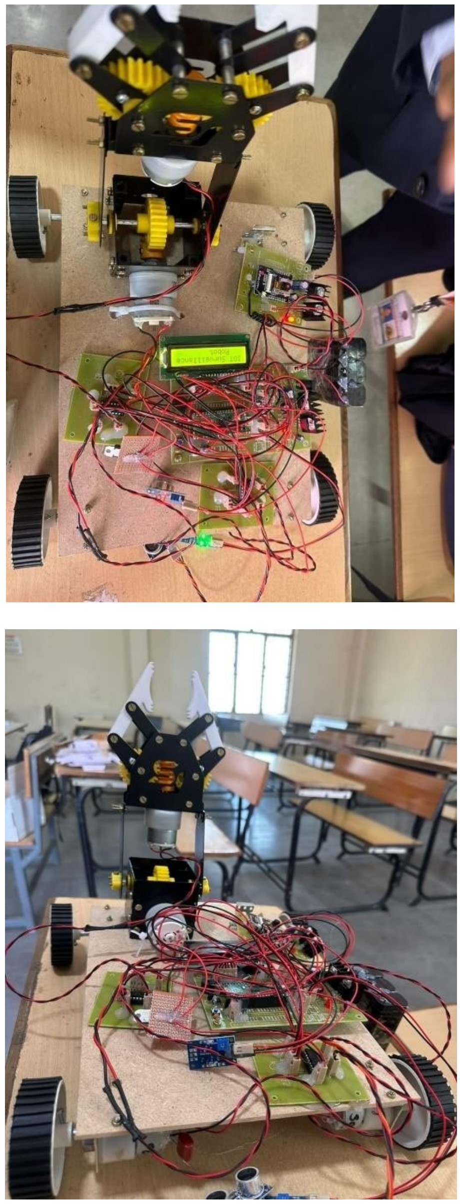

Fig 4.1 Autonomous Robot

Fig.4.1 shows IoT-controlled smart robot , the design and implementation of an autonomous surveillance and delivery robot using the ESP32 microcontroller. The robot integrates various sensors, including ultrasonic, smoke, and fire sensors, to enable real-time monitoring. Equipped with a camera module, the system offers live video surveillance, while its mobility is controlled by a motor driver to navigate through predefined routes or user commands.

5. CONCLUSION

We designed and implemented Industrial Assist Robot for security sensor and live video stream camera. The robot should improve patient experiences by offering services such as bomb squad, gas and fire safety, and live surveillance streaming while also delivering pertinent information. The main objective of this project is to create a robot that can observe human activity in industrial locations.Armed with vital intelligence to evaluate and protect regions before to deployment, industrial personnel can take advantage of real-time video footage from the wireless camera that is controlled via a IoT app. Its ability to detect intruders, possible fire events, explosive devices, and hazardous gasses is improved by the addition of sensors like, smoke, flame, and gas detectors. This robot will use ARM which will control the objects pick and palce. Using this robot to conduct reconnaissance and surveillance in dangerous areas is proving to be quite beneficial for the industrial. The significance of robotic systems in guaranteeing the safety and security of military operations is expected to increase with the advancement of technology

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