

EduPorter-Autonomous Campus Assistant Robo

Guide: Dr. C. N. Bhoyar

Aditya Warkar, Dhiraj Kankuntla, Pratham Nagrare, Akash Rangari

Priyadarshini College of Engineering, Nagpur

ABSTRACT

The rapid growth of automation and service robotics has opened new opportunities for improving operational efficiency in public and institutional environments educational campuses, in particular, require frequent transportation of materials, visitor guidance, and inter-departmental coordination, which are often performed manually and are time-consuming. This paper presents the design and development of "EduPorter - Autonomous Campus Assistant Robo." A service-based autonomous robot intended to assist educational institutions in routine logistical tasks. The proposed system integrates line-following navigation, obstacle detection, wireless communication, and real-time monitoring to perform material delivery and guidance functions with minimal human intervention. An ESP32-based control system combined with IR sensors, Proximity sensors. ESP32 camera module, and motor driver circuitry, enables reliable navigation and safe operation in dynamic campus environments. The system demonstrates improved efficiency reduced manpower dependency, and enhanced user experience. The proposed robot provides a scalable and cost-effective solution for smart campus automation and lays the groundwork for future advancements in service robotics

Keywords: *Autonomous Robot, Service Robot, Campus Automation, Line Follower Robot, ESP32, Obstacle Detection, Smart Campus.*

1. INTRODUCTION

Service robots are intelligent machines designed to assist humans in personal, professional, and public environments Unlike industrial robots, which are primarily used in manufacturing and repetitive tasks, service robots focus on enhancing convenience, safety, and operational efficiency in everyday applications. With the increasing demand for automation in public spaces, educational institutions are emerging as a key area where service robots can significantly improve operational workflows. Large campuses involve continuous movement of academic materials, laboratory equipment, documents, and visitor assistance. These activities, when performed manually consume considerable time and human resources and are prone to delays and errors, especially during peak academic hours or events. Autonomous service robots provide an effective solution by performing routine tasks independently while maintaining safe interaction with people EduPorter is proposed as a campus assistant robot capable of navigating predefined paths, detecting obstacles, delivering materials, and assisting visitors.

The system is designed to operate autonomously using sensor-based navigation and wireless communication, ensuring safety and reliability in crowded environments. This research focuses on the design, working principle, and applications of Edu Porter, highlighting its role in improving efficiency and introducing smart automation in educational institutions

2. WORKING PRINCIPLE

The robot initializes from a base station where tasks are assigned the floor, allowing the robot to follow predefined paths. The ESP32 processes sensor data and controls motor movement accordingly. A proximity sensor continuously monitors the path for obstacles. If an obstacle is detected, the robot stops immediately, triggers an alert, and activates the camera for monitoring. Upon reaching the destination, the robot delivers or collects assigned items. After task completion, it either waits for further instructions or returns to the base station.

The Robot is based on the integration of sensing, control, navigation, and communication modules to perform autonomous campus assistance tasks. The system is controlled by an ESP32 microcontroller, which initializes and manages all hardware components such as infrared sensors, proximity sensors, motor drivers, wireless communication module (ESP32), and display unit. Once powered on, the robot receives task instructions and prepares itself for autonomous operation within the campus environment.

Navigation is achieved using a line-following technique with infrared sensors mounted beneath the robot. These sensors continuously detect the contrast between the predefined guiding path and the surrounding floor surface. Based on the sensor inputs, the microcontroller adjusts the speed and direction of the DC motors through the motor driver circuit, ensuring smooth and accurate movement along the designated route. This closed-loop control mechanism enables the robot to navigate efficiently without human intervention. To ensure safe operation, the system continuously monitors its surroundings using a proximity sensor for obstacle detection. When an obstacle is detected within a specified safety range, the microcontroller immediately stops the robot's movement to prevent collisions. An alert is generated, and the wireless communication module allows the user to monitor the situation remotely. This safety feature enables the robot to operate reliably in dynamic and crowded campus environments.

3. BLOCK DIAGRAM

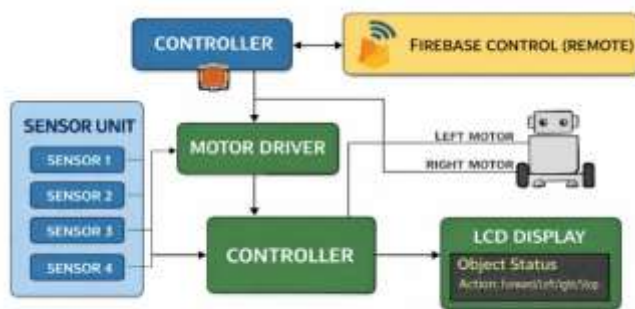


Fig. 1: Overview of the system

4. PROJECT OBJECTIVES

The main objective of this research is to design and develop an intelligent robotic system capable of performing automated indoor delivery tasks with minimal human intervention. The proposed system integrates sensing, embedded control, and monitoring technologies to ensure efficient navigation, safety, and real-time monitoring.

1. To design an autonomous delivery robot capable of transporting items within indoor environments such as educational institutions, offices, hospitals, and warehouses.
2. To implement accurate line-following navigation using a 5-Way IR Sensor Array that allows the robot to detect and follow predefined paths efficiently.
3. To develop a centralized control system using the ESP32 for processing sensor data and controlling the robot's movement.
4. To incorporate obstacle detection mechanisms using the HC-SR04 Sensor to ensure safe navigation and prevent collisions.
5. To enable real-time monitoring of the robot's environment using the ESP32-CAM, allowing remote supervision and security monitoring.
6. To provide a user-friendly interface through a 16×2 LCD Display that displays system status, operational messages, and alerts.

7. To develop an efficient power management system using rechargeable batteries and voltage regulators to ensure reliable and continuous operation.
8. To demonstrate the application of robotics and automation technologies in improving operational efficiency and reducing manual effort in routine transportation tasks.

These objectives aim to develop a reliable, efficient, and scalable robotic system that can be applied in various smart automation environments.

5. LITERATURE REVIEW

Paper [1] discusses the use of digital technologies to enhance monitoring and management of infrastructure systems. The study conducted by S. A. Argyroudis and co-authors highlights how advanced sensing technologies and digital platforms can improve inspection processes and increase operational efficiency. The research emphasizes the role of intelligent monitoring systems in improving reliability and reducing manual inspection efforts. However, the study mainly focuses on infrastructure monitoring and does not address small-scale automation systems used in robotic applications.

Paper [2] examines the growing role of robots in service environments. The study by Fiona McLeay, Verena S. Osburg, and colleagues analyses how robotic technologies influence service industries and customer experiences. The research highlights that robots can improve service efficiency and consistency while reducing operational costs. However, the study focuses mainly on service management aspects and does not address the technical design of robotic automation systems.

Paper [3] investigates customer preferences between robotic services and human services in hospitality industries during the COVID-19 pandemic. The research conducted by Seong Seop Kim and co-authors analyses how health concerns influenced the acceptance of service robots in hotels. The study found that robotic services gained higher acceptance due to reduced human contact. However, the research mainly focuses on user perception and service management rather than robotic system design.

Paper [4] presents a theoretical framework for implementing service robots in different industries. The research by Daniel Belanche and colleagues explains how robotic systems can improve efficiency, automation, and customer interaction in service environments. The authors propose a research agenda for future developments in service robotics. Despite its valuable theoretical contributions, the study does not provide practical hardware implementation details for robotic systems.

Paper [5] presents the design of a line follower robot using a microcontroller. The research conducted by Alimul Rajee and Mohammad Rifatul Islam Marof explains how sensors and microcontrollers can be used to develop an autonomous navigation system. The study demonstrates the use of line-following algorithms and sensor-based control mechanisms for robotic movement. However, the system mainly focuses on navigation and does not include additional monitoring or smart automation features.

Paper [6] introduces a sorting system based on color detection using a line follower robot. The study by Zaenur rohman and co-authors describes how sensors and control algorithms can be used to classify objects based on color properties. The research demonstrates effective sorting performance using automated robotic mechanisms. However, the system is limited to color-based sorting and does not include advanced monitoring or intelligent decision-making capabilities.

Paper [7] discusses the use of service robots for contactless services during the COVID-19 pandemic. The study conducted by Subhdeep Mukherjee and colleagues' highlights the importance of robotic technologies in reducing human interaction while maintaining service efficiency. The research emphasizes the potential of

service robots in hospitality and healthcare sectors. However, the study focuses mainly on application scenarios rather than the technical implementation of robotic systems.

6. RESEARCH METHODOLOGY

In this project, an autonomous robotic delivery system (EduPorter) is developed to transport items efficiently within indoor environments with minimal human intervention. The system continuously monitors its surroundings and performs navigation and delivery tasks in a controlled and systematic manner. When the robot is activated using a push button, the system begins the navigation and monitoring process automatically.

As the robot starts moving, the line detection mechanism plays a crucial role in guiding the robot along a predefined path. The robot uses a 5-Way IR Sensor Array to detect the contrast between black and white surfaces on the floor. These sensors continuously send signals to the ESP32, which processes the sensor data and determines the direction of movement. If the robot deviates from the line, corrective signals are sent to the motor driver to adjust the movement and bring the robot back to the correct path.

During navigation, the robot also monitors its surroundings to ensure safe operation. A Proximity Sensor is used for obstacle detection. If an obstacle is detected in front of the robot, the system immediately stops movement to prevent collisions. This safety mechanism ensures that the robot operates reliably in environments where people or objects may be present.

For monitoring and security purposes, the robot is equipped with an ESP32-CAM that captures images or video of the surrounding environment. The captured data can be transmitted wirelessly, allowing remote monitoring of the robot's activities. This feature is particularly useful in applications where supervision or security monitoring is required.

The system also includes a 16×2 LCD Display that provides real-time feedback about the robot's status. The display shows messages such as system initialization, navigation status, obstacle alerts, and delivery notifications. This improves the user interface and allows operators to easily monitor the system's operation.

The robot operates in a continuous loop. After completing one delivery cycle, it returns to its starting position and waits for the next command or task. This allows the system to perform multiple delivery operations sequentially while maintaining consistent performance.

In addition, the methodology focuses on creating a system that is compact, energy-efficient, and easy to implement. The use of embedded systems and sensor-based navigation ensures reliable operation while minimizing power consumption. Overall, this step-by-step methodology enables efficient autonomous navigation, safe obstacle detection, and effective item transportation, making the system suitable for applications in institutions, offices, hospitals, and smart buildings.

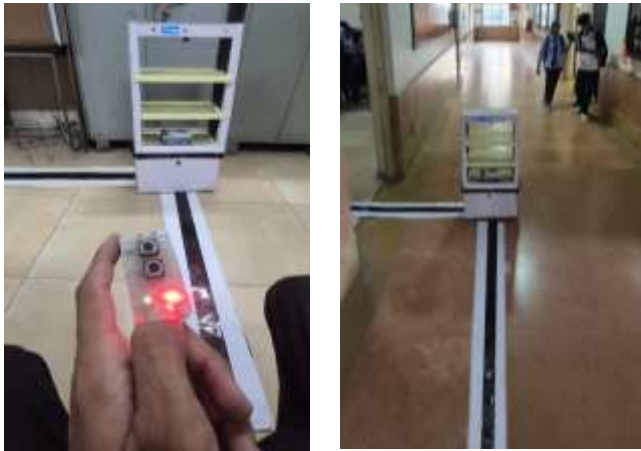
7. IMPLEMENTATION OF EDU PORTER-AUTONOMOUS CAMPUS ASSISTANT ROBO

The implementation of the proposed autonomous robotic system is carried out using a microcontroller-based architecture integrating an ESP32 controller, ESP32 communication module, IR sensors, camera module, motor driver, LCD display, and DC motors. The complete system is designed in modular form to ensure reliable navigation, monitoring, communication, and task execution.

1. System Initialization

The robot initializes at its predefined base station. Upon powering ON, the ESP32 configures all input and output peripherals including IR sensors, motor driver, LCD display, and communication interfaces. The ESP32 module

establishes wireless connectivity through Wi-Fi or Bluetooth. The user assigns a task using manual push buttons, a wireless mobile interface, or an input control panel. The selected task is stored in the controller memory, and the robot prepares for execution.



2. Line Following Navigation Implementation

The navigation system is implemented using infrared (IR) sensors placed at the bottom of the robot chassis. These sensors continuously detect the contrast between black guiding lines and white floor surfaces. The sensor outputs are fed to the ESP32, which executes a predefined control algorithm.

If Both sensors detect black → robot moves forward.

Left sensor detects white → robot turns left.

Right sensor detects white → robot turns right.

If Both detect white → stop or adjust direction.

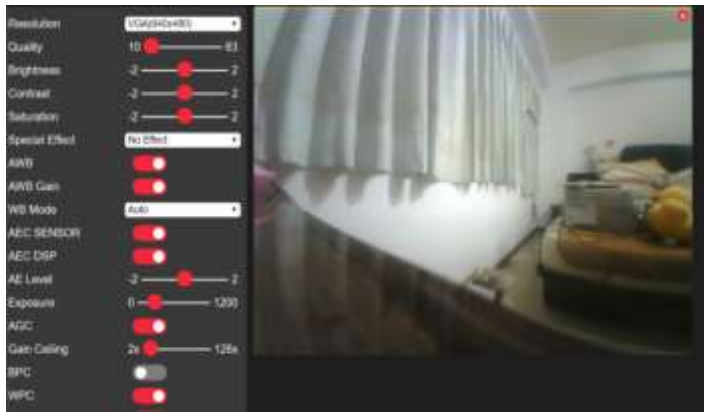
The ESP32 generates Pulse Width Modulation (PWM) signals to the motor driver module, which controls the DC motors accordingly. This ensures smooth and accurate line tracking.

3. Obstacle Detection and Monitoring Implementation

A sensor (Proximity sensor) is mounted at the front of the robot for real-time obstacle detection. The sensor continuously transmits waves and measures the echo return time to calculate distance using:

If the measured distance is less than the predefined threshold (e.g., 15 cm): The ESP32 immediately stops the motors.

An alarm or buzzer is activated. A signal is sent to the ESP32 module. The ESP32 then activates the camera module to capture an image or stream live video to the remote monitoring system. This ensures real-time obstacle monitoring and enhances safety.



4. Task Execution Mechanism

After confirming a clear path, the robot continues moving toward the designated user location using line-following guidance. The predefined path ensures that the robot reaches the correct delivery or collection point. Upon arrival: The robot stops automatically. A notification is displayed on the LCD. If configured, a servo-based mechanism can release or collect the assigned object. The system waits for confirmation before proceeding to the next instruction.

5. Communication and Display Implementation

The ESP32 module enables wireless communication between the robot and user devices. Communication can be implemented using: Wi-Fi-based web server interface, Mobile application control, IoT cloud monitoring platform, The real-time status such as: Current position Obstacle detection alerts Task status (In Progress / Completed), Battery level (if integrated) is displayed on the LCD screen mounted on the robot and simultaneously transmitted to a remote monitoring

6. Completion and Return Strategy

After task completion, the robot operates in two possible modes: Standby Mode: Waits at the user location for further commands. Auto-Return Mode: Follows the predefined return path back to the base station. The return navigation uses the same IR line-following algorithm. Once the base station is reached: Motors are stopped. System enters low-power standby state. LCD displays “Task Completed – Waiting for New Assignment”. Software Implementation The system software is developed using ESP32 IDE. The program consists of: Sensor initialization functions Line-following control algorithm Obstacle detection interrupt logic Wi-Fi communication routines (ESP32) Camera

streaming configuration LCD display update functions A structured programming approach with modular functions ensures scalability and easy debugging. Hardware Integration The hardware components are interconnected as follows:

5-way IR sensors → ESP32 digital pins

Sensor → Trigger & Echo pins

Motor driver → PWM output pins

DC motors → Motor driver output

ESP32 → Serial communication with ESP32

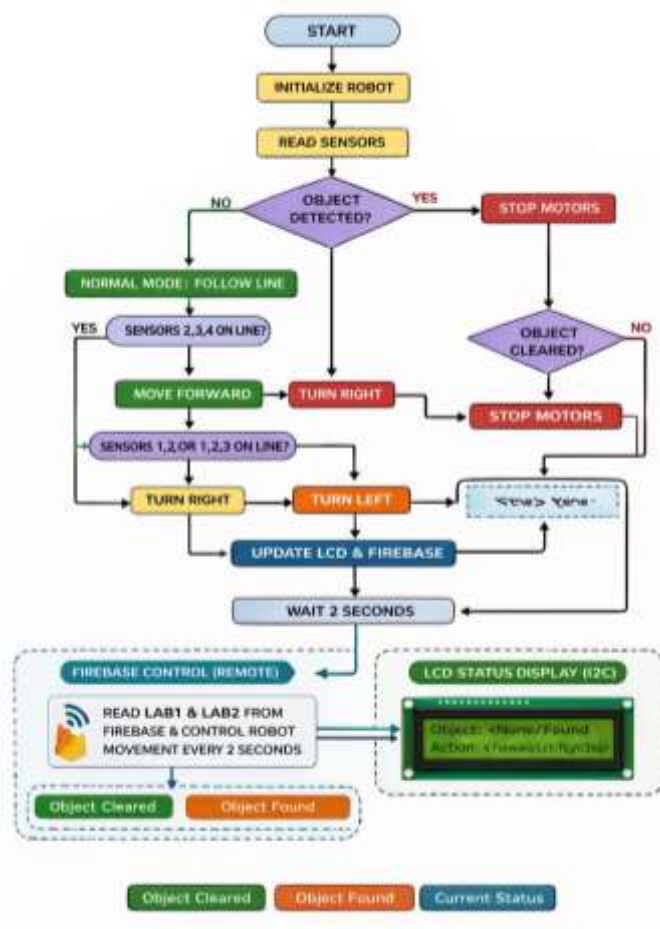
Camera module → ESP32 interface

LCD → I2C communication

Proper voltage regulation (5V/3.3V) and grounding techniques are implemented to ensure stable system performance.

8. WORKING OF THE PROPOSED SYSTEM

- 1. Initialization:** The robot initially starts from its base station. The user assigns a specific task using manual push buttons, a wireless device, or an input interface. After receiving the command, the system begins its operation.
- 2. Line Following Navigation:** The robot uses IR sensors to detect the contrast between black and white lines on the floor. The sensor data is processed by the microcontroller, which continuously adjusts the movement of the robot to ensure accurate path tracking.
- 3. Obstacle Detection and Monitoring:** A sensor is used to detect obstacles in the robot's path. If an obstacle is detected, the robot immediately stops and activates an alert system. At the same time, the camera connected through the ESP32 module captures or streams the surrounding environment for monitoring.
- 4. Task Execution:** After safely navigating the path, the robot reaches the user's location and performs the assigned task, such as delivering or collecting items.
- 5. Communication and Display:** The ESP32 module enables wireless communication between the robot and user devices. The system status and operational updates are displayed on the LCD screen and can also be monitored remotely.
- 6. Completion and Return:** Once the task is completed, the robot either waits for further instructions from the user or automatically returns to the base station and remains in standby mode until a new task is assigned.



9. PROBLEM STATEMENT

Large educational institutions often face significant operational challenges in campus navigation, inter-departmental communication, and material transportation. Students, faculty, and staff frequently encounter difficulties in locating departments, laboratories, and administrative offices within expansive campus environments. Additionally, the manual transportation of documents, laboratory equipment, and other materials between departments is time-consuming, labour-intensive, and prone to delays and human error.

Traditional delivery and assistance methods rely heavily on human involvement, leading to inefficiencies, increased workload, and inconsistent service quality. Furthermore, there is limited automation available for providing real-time guidance to visitors, offering on-demand assistance, and ensuring systematic resource distribution across campus facilities.

These limitations highlight the need for an intelligent, autonomous, and cost-effective robotic system capable of navigating complex campus environments. Such a system

should be able to perform material delivery, provide interactive guidance, and support communication processes with minimal human intervention. Developing a reliable autonomous robotic solution can significantly enhance operational efficiency, reduce labour dependency, and improve overall campus management

10. ADVANTAGES OF THE PROPOSED SYSTEM

The proposed EduPorter robotic system offers several advantages in terms of automation, efficiency, safety, and ease of operation. The integration of embedded systems, sensors, and monitoring technologies enables the system to perform delivery tasks effectively within indoor environments.

1. **Autonomous Navigation:** The system uses a 5-Way IR Sensor Array to follow predefined paths automatically. This allows the robot to navigate without manual guidance, ensuring accurate and reliable movement along the designated route.
2. **Reduced Human Effort:** By automating the item transportation process, the system minimizes the need for human involvement in routine delivery tasks. This helps reduce workload and improves operational efficiency in environments such as offices, hospitals, and educational institutions.
3. **Obstacle Detection for Safety:** The robot is equipped with a proximity Sensor to detect obstacles in its path. This feature prevents collisions and ensures safe operation in crowded environments.
4. **Real-Time Monitoring:** The inclusion of an ESP32-CAM enables real-time image or video monitoring. This allows users to remotely observe the robot's surroundings and activities, improving system supervision and security.
5. **User-Friendly Interface:** A 16×2 LCD Display is used to display system messages, navigation status, and alerts. This helps users easily understand the robot's current operation and system condition.
6. **Cost-Effective Implementation:** The system uses widely available and affordable components such as ESP32 and basic sensors. This makes the project economical and suitable for educational and small-scale applications.
7. **Compact and Energy Efficient Design:** The proposed system is designed to be compact and consumes relatively low power, making it suitable for continuous operation in indoor environments.
8. **Scalability and Flexibility:** The system can be easily upgraded with additional sensors, wireless communication modules, or advanced control algorithms to support more complex automation tasks in the future.

11. FUTURE SCOPE

The future development of the EduPorter robotic system can include several technological improvements to enhance its efficiency and intelligence. Advanced navigation techniques such as artificial intelligence and vision-based systems can be implemented using the ESP32-CAM to enable better obstacle recognition and autonomous decision-making. Additional sensors can be integrated with the proximity Sensor to improve environmental

awareness and safety. The system can also be connected to IoT platforms for remote monitoring and control. Furthermore, advanced mapping technologies can be introduced to reduce dependency on the 5-Way IR Sensor Array for navigation. These improvements would make the system more intelligent, scalable, and suitable for smart environments such as hospitals, offices, and educational institutions.

12. CONCLUSION

This research highlights the growing need for automation in large educational institutions to address challenges related to campus navigation, material transportation, and inter-departmental coordination. Traditional manual methods are inefficient, time-consuming, and prone to errors, creating operational delays and increasing the workload on staff and students.

The proposed autonomous robotic solution offers a cost-effective and reliable approach to improving campus efficiency. By integrating intelligent navigation, obstacle detection, real-time communication, and automated delivery mechanisms, the system can streamline resource distribution and provide on-demand assistance to students, faculty, and visitors.

Implementing such a robotic system not only reduces human dependency but also enhances accuracy, operational speed, and overall campus management. In the future, the system can be further improved with advanced technologies such as AI-based path optimization, IoT integration, cloud-based monitoring, and machine learning algorithms for adaptive decision-making.

Overall, the development of an autonomous campus robotic assistant represents a significant step toward smart campus infrastructure, ensuring efficiency, reliability, and technological advancement in modern educational institutions.

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