Central Training & Placement Cell, AKTU in association with ERA Foundation presents

KALAM PRAGATI

Empowering Engineers with Skills for Success

MakeX Internship

AUTONOMOUS ROBOTICS INTERNSHIP

REPORT - 2025

INDEX

Project Title	Campus Delivery Bot		
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Problem Identified	IInefficient, costly, and delayed last-mile deliveries within large university campuses		
Solution proposed	A fully autonomous delivery robot that can avoid obstacles, and safely deliver packages and maintains the verification of the recipient		

Link to the ideapitch presentation	https://www.canva.com/design/DAGw47--USQ/62Gnx0XGJHk8A_mStJpM9g/edit?utm_content=DAGw47--USQ&utm_campaign=designshare&utm_medium=link2&utm_source=sharebutton
Link to photos drive	https://drive.google.com/drive/folders/1ulG5RDBxI3LVUON8uNQn30OiiC_qH5TI?usp=sharing

1. Project Overview

1.1 Abstract

The Line Follower Campus Delivery Bot is an innovative robotic system developed to automate and enhance the process of material delivery within a campus environment. With the increasing need for efficiency, safety, and convenience in everyday logistics, the integration of robotics into campus delivery systems provides a sustainable and modern solution. This project focuses on the design and implementation of a low-cost, autonomous mobile robot that can follow predefined paths, detect obstacles, and deliver items such as books, documents, food, and stationery to designated locations across a campus.

The working principle of the bot is based on the concept of a line follower robot, which uses infrared (IR) sensors to detect and follow lines laid on the ground. The path is created using black or white strips that serve as guiding tracks for navigation. The bot employs a Raspberry Pi 5 as its central controller, connected to motor drivers, DC motors, servo motors, and ultrasonic sensors. The IR sensors continuously capture signals from the surface and provide feedback to ensure the bot remains aligned with the line. In addition, ultrasonic sensors are used for obstacle detection and collision avoidance, allowing the robot to stop or reroute when an obstacle is encountered. The Raspberry Pi also connects with a camera module, enabling visual recognition and potential real-time monitoring of the delivery process.

Power for the system is supplied through a combination of rechargeable batteries and a power bank, ensuring mobility and sustainability. Two motor drivers are used to control the four-wheel configuration, offering better stability and smoother movement. The design includes additional features such as LED indicators for signaling and a compact compartment to securely carry items during delivery.

One of the primary objectives of this project is to reduce manual effort and time spent in transporting small items across campuses such as universities, offices, or hospitals. Traditional methods require human involvement, which may lead to inefficiency, delays, or increased costs. The proposed delivery bot addresses these issues by functioning autonomously, minimizing human intervention, and ensuring reliable and timely delivery.

1.2 Introduction

Automation and robotics are transforming industries, campuses, and daily life by providing efficient and intelligent solutions to routine problems. Among the simplest yet most impactful robotic projects is the Line Follower Bot, which is designed to autonomously follow a predefined path. Traditionally, such bots rely on infrared (IR) sensors to detect contrasting lines on the floor. However, our approach upgrades this concept by integrating an ultrasonic sensor and a camera module for smarter navigation and obstacle avoidance.

The ultrasonic sensor enables the bot to measure distances and detect obstacles in real time, ensuring smooth movement without collisions. Meanwhile, the camera module enhances accuracy by identifying the line visually, allowing the robot to adapt to more complex paths, curves, and lighting conditions where IR sensors are less effective. By combining these technologies, the bot not only follows the intended path but also responds dynamically to its surroundings, making it more versatile.

This project demonstrates the practical application of sensor fusion, computer vision, and embedded systems. The Line Follower Bot serves as a foundation for more advanced robotics in fields such as autonomous vehicles, industrial automation, and smart campus logistics, where safety, precision, and adaptability are essential.

1.3 Proposed Solution

"Build a self-driving bot that rolls through campus, dodges people. Food or packages, goes straight to the delivery spot, and alerts the receiver when it arrives – all without needing a human courier."

This solution will:

- Cut delivery time by avoiding delays.
- Lower costs by reducing dependency on human couriers.
- Increase reliability with consistent, automated service.
- Work safely in pedestrian-heavy areas and different weather conditions.

2. Problem Statement

2.1 Problem Statement

The primary problem is the inefficiency and high cost of last-mile deliveries on a large campus. Manual delivery can be slow and inconsistent, leading to frustration for customers and high operational costs for businesses. Deliveries can be delayed by factors such as class schedules, crowded pathways, and traffic. The problem is to design a campus delivery bot that can autonomously navigate pedestrian-heavy areas, safely transport items to a specific location, and notify the recipient upon arrival. This would streamline the delivery process, reduce wait times, and lower the costs associated with employing human delivery staff

In large university campuses, students and staff frequently need to transport small items such as books, documents, lab equipment, and parcels between departments, hostels, and libraries. Currently, this delivery process is either manual—requiring individuals to physically carry items across long distances—or dependent on limited manpower, which is inefficient, time-consuming, and prone to delays.

2.2 What is the problem?

“Human couriers waste time wandering across campus struggling to find exact locations, get stuck in crowds or traffic, and end up delaying deliveries while driving up costs.”

The goal is to create a bot that moves on its own, avoids people, carries packages safely, goes straight to the right spot, and alerts the receiver when it arrives.

2.3 Why is it a problem?

“Manual delivery teams waste energy walking around campus, miss deadlines because of crowds or traffic, and force businesses to spend extra money – all while making people wait too long for their stuff.”

Hence, the customer is suffering a lot because they wait too long for their packages.

2.4 Who is facing the problem?

Students and staff wait around for their food or packages getting frustrated by delays, while delivery companies burn money paying workers to wander across campus and fight through crowds. Hence, the customer is suffering a lot because they wait too long and businesses suffer because of money.

2.5 When and Where does the problem occur?

“The delays hit during busy class hours on crowded walkways, in bad weather, or whenever couriers try to reach far– off spots on campus.”

So, it occurs mainly in pedestrian heavy areas at peak times, making both students and staff wait longer.

2.6 What are the existing solutions?

“Right now, people walk or ride bikes around campus, carrying food packages, or mail to the hostels”

These services try to deliver by sending human couriers, but they:

- Waste time finding location in large computers.
- Get delayed by crowds, traffic, or weather.
- Cost more because of salaries and inconsistent efficiency.
- That’s exactly why the proposed autonomous bot is needed.

2.7 Complaints about existing solution?

1 **Inefficiency in Last-Mile Delivery:** Manual delivery on large campuses is often slow and inconsistent. Delivery personnel may take longer routes or struggle to find exact locations.

2.High Operational Costs: Hiring and maintaining human delivery staff increases expenses for businesses. Overtime costs rise during peak hours (e.g., lunch breaks, exam periods).

3.Frustration for Customers: Students and staff face delays in receiving food, packages, and mail. Unreliable timing leads to dissatisfaction and poor user experience.

4. Scalability Issues: Human couriers cannot easily scale up with growing campus populations or demand spikes. Limited workforce availability leads to bottlenecks.

5. Navigation and Location Errors: Manual couriers may have trouble locating specific hostels, classrooms, or labs. Wrong deliveries or missed deliveries are common.

3. Solution

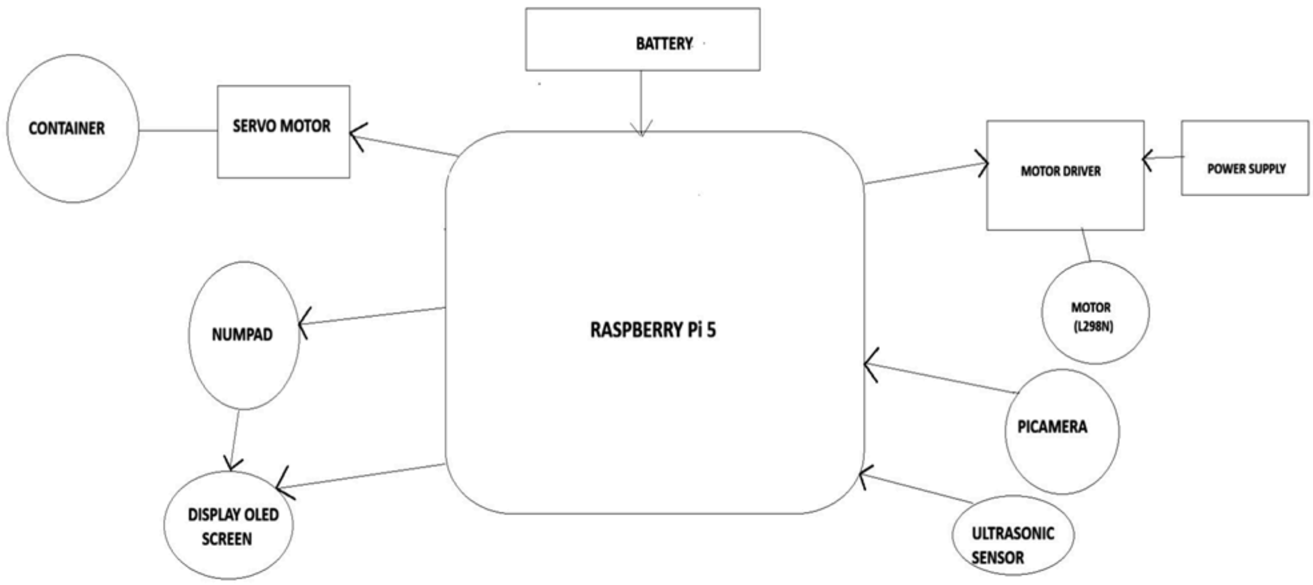
3.1 Ideation:

In large campuses, warehouses, and industrial environments, the need for efficient and automated movement of goods is increasing rapidly. Traditional delivery and transport rely heavily on human effort, which often leads to delays, higher costs, and inconsistency. During brainstorming sessions, our team identified that a smart autonomous robot could solve these issues by navigating along predefined routes with minimal human intervention.

Initially, we considered the conventional IR-based line follower bot, but we realized it had limitations in real-world scenarios, such as poor performance under varying light conditions and difficulty in handling complex routes. To overcome these drawbacks, we decided to explore advanced technologies like ultrasonic sensors for obstacle detection and a camera module for real-time line tracking.

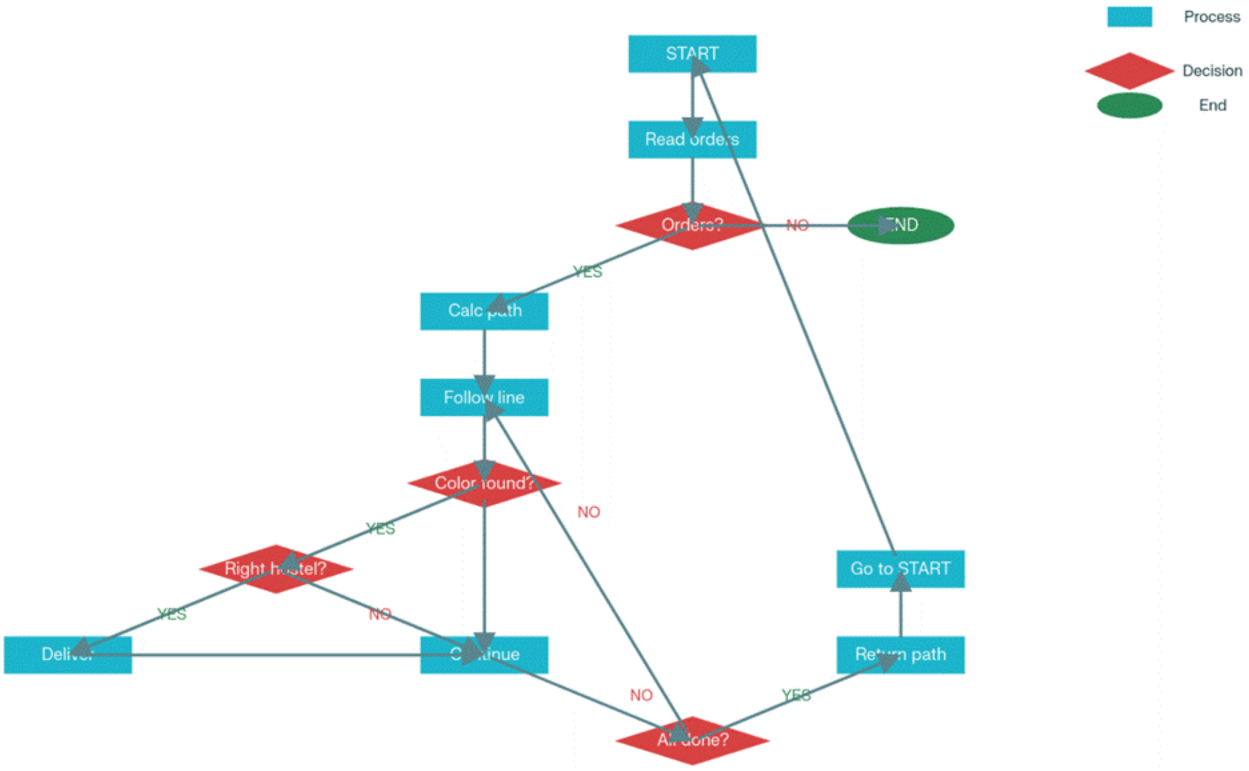
This ideation process led us to the concept of an intelligent line follower bot that not only follows a path but also adapts to its environment.

3.2 Block diagram of circuit



Block Diagram for campus delivery bot

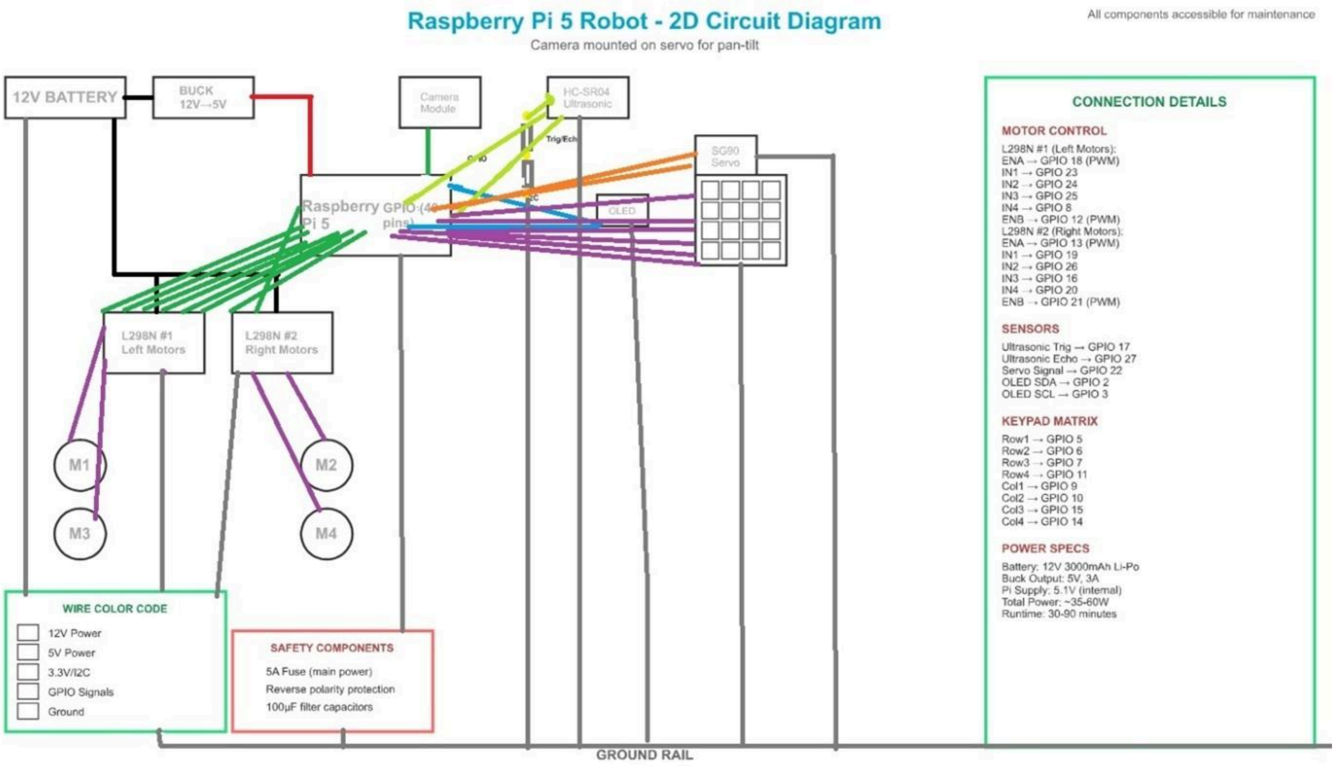
3.3 Flowchart



Flowchart for campus delivery bot

4. Prototype

4.1 Hardware Design



4.2 Software implementation

Software Implementation (Raspberry Pi 5)

The software implementation of the Line Follower Bot was carried out on Raspberry Pi 5, which served as the central processing unit for sensor data acquisition, image processing, decision-making, and motor control. Python was chosen as the primary programming language due to its compatibility with Raspberry Pi, OpenCV, and GPIO libraries.

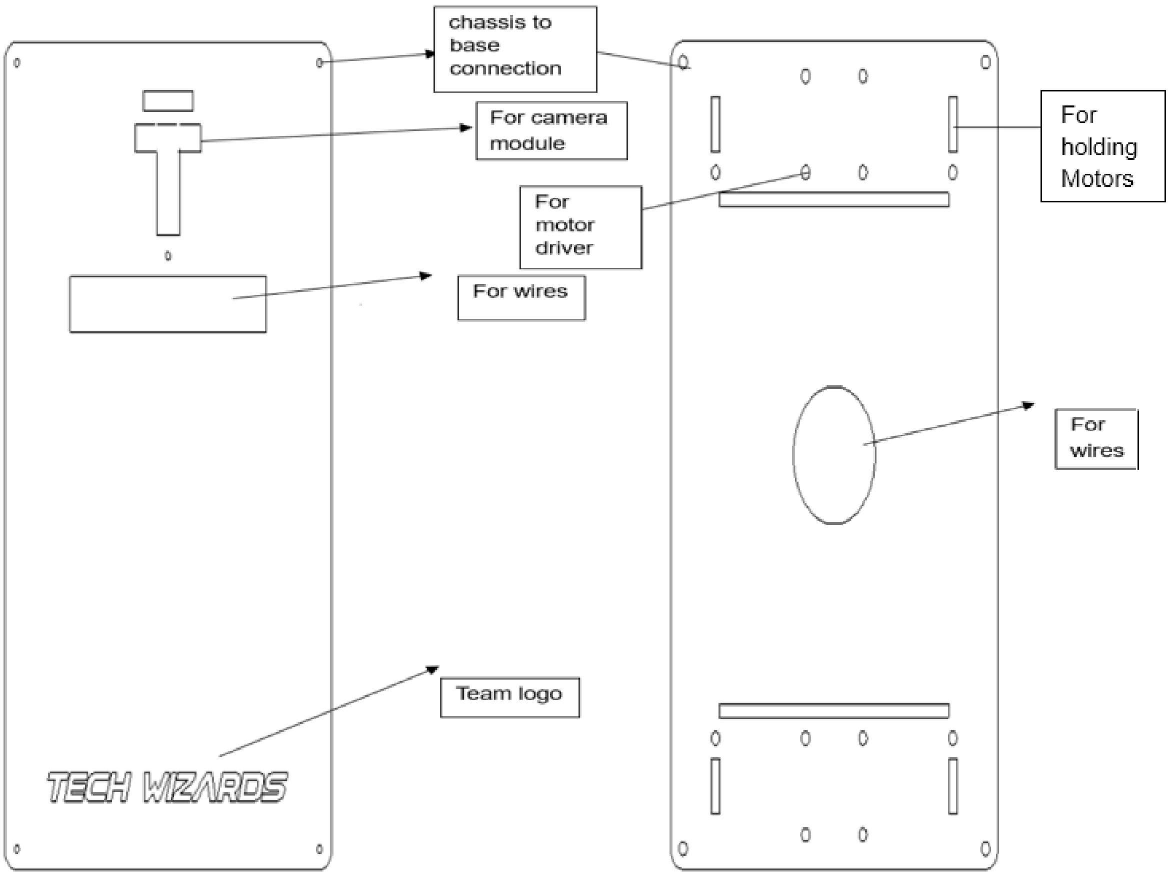
1. Working Principle: The Line Follower Campus Delivery Bot operates on the principle of line detection and path navigation, combined with a predefined campus map for accurate delivery. The campus is represented as a map with line-marked paths (black lines on the ground). Each path segment corresponds to routes leading to different buildings, departments, or delivery points. The motors are controlled through a motor driver that manages forward, left, and right movement. If the bot drifts from the line, speed adjustments are applied to correct its path. An ultrasonic sensor continuously checks for obstacles ahead. If an obstacle is detected within a 20cm distance, the bot halts, waits until the path is clear.

The bot carries items in a delivery compartment and, upon reaching the destination, notifies the user via a buzzer. An OTP verification is required to collect the package from the delivery box with an option of 5 wrong attempts, after which the user has to contact the customer care for help.. After successful verification, the compartment automatically opens for next 10 seconds using a servo motor. After completing delivery, the bot returns to its base by retracing the route.

2. Line Detection (Camera + OpenCV): The Bot captures the frames from the Pi Camera. Convert frames to grayscale and apply thresholding to detect the black/white line. Use edge detection and contours to determine the line's position relative to the bot. Implement a PID control algorithm to adjust motor speed and direction to keep the bot aligned.

3. Motor Control: Based on processed data (line position + obstacle detection), send PWM signals to the motor driver. Adjust wheel speeds for forward motion, turns, or stopping.

4.3 Mechanical Assembly (Chassis & Structure):



4.4 Technical pages

4.4.1 Sensor Interfacing Result

- **Ultrasonic sensors (HC-SR04):** An ultrasonic sensor is an electronic device that uses high frequency sound and detects objects by calculating the time of flight of these waves. In our bot ultrasonic sensor detects the obstacle for our bot which helps to move our bot precisely.

4.4.2 Motor Control & Calibration

- **DC motors:** DC motors are operated by 2 L298N motor driver used to move our bot when camera module detects the path.
- **Servo motors:** Servo motors attached in Bot to open the lid of the container attached on the bot for delivery purposes.

4.4.3 Computer Vision & Image Processing

The camera can detect the path/line more accurately and ensures that the bot stays on the track and navigates basic routes on the map. With the help of a camera, we can detect the different colors of the hostel as mapped on the map. Helps in autonomous decisions like "turn left" etc.

5. Source Code:

https://docs.google.com/document/d/1Gq5X15Pz2gK6UXIFCp4Dvp9IvfvXYV18N489GVNzBLs/edit?usp=sharing

6. Conclusion

6.1 Learning

Working on this project provided our team with valuable technical and practical knowledge across multiple domains of robotics and embedded systems:

1. Hardware Interfacing: We learned how to connect and calibrate sensors, motor drivers, and HSV values for the Raspberry Pi 5, ensuring smooth integration between components.

2. Computer Vision Basics: By using image processing techniques such as thresholding, contour detection, and centroid tracking, we explored how robots can perceive and interpret their environment. Also, through Python, we developed skills in GPIO handling, PWM motor control, and computer vision.

4. Problem-Solving & Debugging: The project taught us how to troubleshoot issues like inaccurate sensor readings, uneven motor speeds, and lighting effects on the camera.

5. System Design & Teamwork – We gained experience in designing a complete system by combining mechanical structure, electronics, and software, while also learning to work collaboratively and distribute tasks effectively.

6. Real-World Applications – The project enhanced our understanding of how simple robotics concepts can be scaled into real-world solutions such as autonomous delivery, warehouse management, and smart campus logistics.

6.2 Future scope

The Line Follower Bot developed in this project serves as a foundation for more advanced autonomous robotic systems. Although the prototype successfully demonstrated line following and obstacle detection, there are several possibilities for future enhancement:

1. AI-Based Navigation – Integrating deep learning models with the camera feed can enable advanced path planning, object recognition, and intelligent decision-making.

2. GPS & Mapping – Adding GPS modules and SLAM (Simultaneous Localization and Mapping) techniques can allow the robot to operate beyond predefined lines and cover large, dynamic range.

3. Energy Efficiency – Solar panels or improved battery management systems can be introduced to extend operational time and make the bot eco-friendly

4. Enhanced Sensors – Advanced LiDAR, stereo cameras, or depth sensors can replace basic ultrasonic sensors for more accurate obstacle detection and path planning.

7. References

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