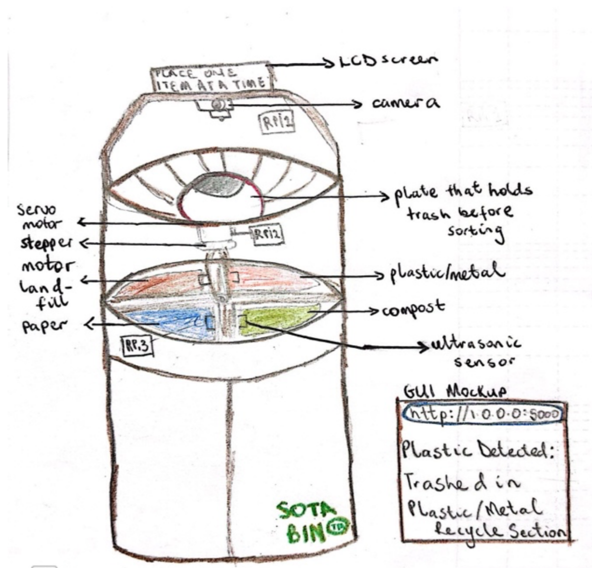
SYSC3010
Computer Systems Development Project

Sota Bin:
State-of-the-Art Sorting for a Sustainable Future

Project Proposal



Group L2-G3

Uchenna Obikwelu, 101241887
Adeyehun Folahanmi, 101237546
Dearell Tobenna Ezeoke, 101245819
Emeka Anonyei, 101209704
Tobiloba Ola, 101244412

TA: Afsoon Khodaee

February 15th, 2025

Table of Contents

1 Introduction

As an ever-growing environmental hazard, waste reduction is a significant problem, where recycling in exchange diminishes pollution, conserves natural resources, and advances maintainability. But even with the handy multi-section recycling bins appearing everywhere, meant for compost, paper/cardboard, plastic/metal and landfill in that order, many individuals still cannot decipher which waste goes into which bin correctly. This causes waste to be disposed of incorrectly, which can contaminate recyclables, decrease the amount of waste being put in landfills, and make the recycling process less efficient.

One thing that causes this reoccurring issue is that people do not receive feedback immediately when they throw away waste. Without this knowledge, users guess on how to correctly classify where waste goes, which leads to an incorrect placement of trash. Schools, businesses, and public spaces struggle to recycle as users are unsure how to sort waste or simply do not have the time to. While education and behavioural adjustment is important, traditional recycling bins offer neither interactive support nor real-time correction.

To solve this issue, we introduced Sota Bin, a waste management solution designed to optimize the recycling process with smart classification, interactive direction, and real-time feedback. Unlike emblematic recycling bins, our system uses sensors-based detection and Computer Vision to recognize waste items and send them to appropriate section (compost, plastic/metal, paper, and landfill). An integrated motorized tilting plate mechanism drives the grey waste plate to ensure that there is no obstructed waste placement, and an interactive display or mobile application provides result information in real-time, thus enforcing appropriate recycling habits.

This innovation is aimed at making the process of recycling easier for everyone, including individuals, families, schools, businesses, and public institutions. Sota Bin is aimed at the solution to a timely problem as source sorting of waste will make municipal recycling program more effective and boost sustainability programs. As the cities gradually transition into smart and environmental waste systems, our solution is a crucial link connecting technology with ecology.

This document outlines the motivation, background, objectives, system design, and implementation plan for Sota Bin, including component details, use cases, milestones, and required hardware.

1.1 Background

The continuous growth of global waste production has driven cities to adopt modern recycling systems for sustainability purposes and environmental protection. A large quantity of recyclable materials continues to enter landfills because people make mistakes when they dispose of them. Contamination at the waste origination continues to be a main problem because recycling plants primarily focus on bulk material sorting operations.

Basic multi-compartment recycling bins exist as current solutions, yet their effectiveness depends completely on user decisions while also being susceptible to human mistakes. The use of RFID-tagged waste tracking systems in modern approaches proves expensive while being impractical for widespread public application. The functionality for real-time waste classification remains absent in automated trash compactors and IoT-enabled waste monitoring systems because they do not achieve effective individual waste sorting.

Sota Bin solves this problem through an automated system which enhances waste identification from the beginning. A camera module captures an image of the waste item placed on the bin plate, and using OpenCV, the system applies color and shape detection to classify waste—paper is identified as flat, rectangular shapes in white or brown, plastic/metal is detected via smooth, reflective surfaces through color and brightness analysis, compost is recognized based on color and texture (e.g., green or brown with irregular textures), while unclassified items like Styrofoam, chip bags, and coffee cups default to landfill. The metal sensor identifies aluminum cans from plastic materials while surface texture and moisture level analysis by IR and ultrasonic sensors enhances material classification especially for compostable items. The ultrasonic sensors used in the system identify when any section reaches its maximum capacity and automatically send alerts to users. The automated sorting mechanism uses servo and stepper motors that rotate and tilt the bin plate for proper waste placement. Users can access real time feedback about proper recycling practices through an LCD display and web interface and receive notifications of the classification result.

The system enables educational facilities and municipal and office spaces to enhance waste management practices while lowering contamination rates in recycling systems and achieving environmental cleanliness.

Motivation

Waste sorting mistakes produce contamination which degrades recycling plants' efficiency while enlarging the amount of waste sent to landfills. Most people desire proper recycling, yet they struggle to perform it appropriately. Public institutions together with offices and schools show inadequate compliance with waste management guidelines because these guidelines remain hard to understand and difficult to follow.

This project is driven by the need to:

- Reduce human error in waste sorting by automating classification.
- Encourage proper recycling habits through real-time feedback.
- Make recycling more accessible and engaging for individuals, schools, and businesses.
- Support local and municipal waste management efforts with data-driven insights on waste disposal trends.

The target audience for this system consists of environmentally minded individuals together with their families and educational institutions. Small businesses along with local governments and offices form the secondary user group which requires smart waste management systems.

1.2 Project Objective

The purpose of this document is to provide an explanation of our motivation, background research The project aims to create a Sota Bin - a smart recycling bin that utilizes computer vision and sensor information for waste classification, automatic sorting, and real-time feedback to enhance waste disposal practices. Our Intelligent Recycling solution aims to build a smarter recycling system using computer vision, and a mechanical sorting mechanism that makes recycling accurate, easy, and meaningful.

By doing so, the system will educate people, improve recycling quality, and reduce waste contamination, all riding on the back of a growing circular economy.

1.3 Specific Goals

- Computer Vision and Sensor-Based Waste Classification**:** Develop a rule-based computer vision system combined with sensors to identify and categorize waste items (compost, paper, plastic/metal, landfill) based on color, shape, and texture analysis.
- Automated Sorting System: Integrate a motorized tilting plate to direct waste into the correct compartment.
- Real-Time User Feedback: Provide instant feedback through a mobile app or display screen, notifying users of correct or incorrect disposal.
- Data Collection & Analysis: Track disposal patterns and generate insights for schools, offices, or municipalities on recycling efficiency.
- Modular and Scalable Design: Allow for easy expansion or modification of the bin to accommodate different recycling needs.

Functional requirements

- The camera shall capture an image when an item is placed on the bin plate.
- The system shall sort waste according to the four categories in the bin compost, recycling landfill and cardboard.
- The system shall flash red led when bin section is full.
- The systems GUI shall display classification result to users in real-time.
- The system shall store the classification result in a local SQLite database for data logging.

Non-functional requirements for the Sota Bin

- The system shall classify and sort waste withing 5 seconds after the user places an item on the bin plate.
- Bin full detection system shall update the web server and notify the user within 2 seconds of detecting a full bin.
- System components be modular, allowing easy replacement or upgrades of parts.
- Hardware components should be easily replaceable without major rewiring or reprograming.
- The bin system shall operate on low power consumption
- Data transmissions between the Raspberry Pis and the cloud database must be encrypted.

- The interface must be intuitive, providing real-time feedback within a second of waste disposal.

2 System Design

2.1 System Overview Diagram

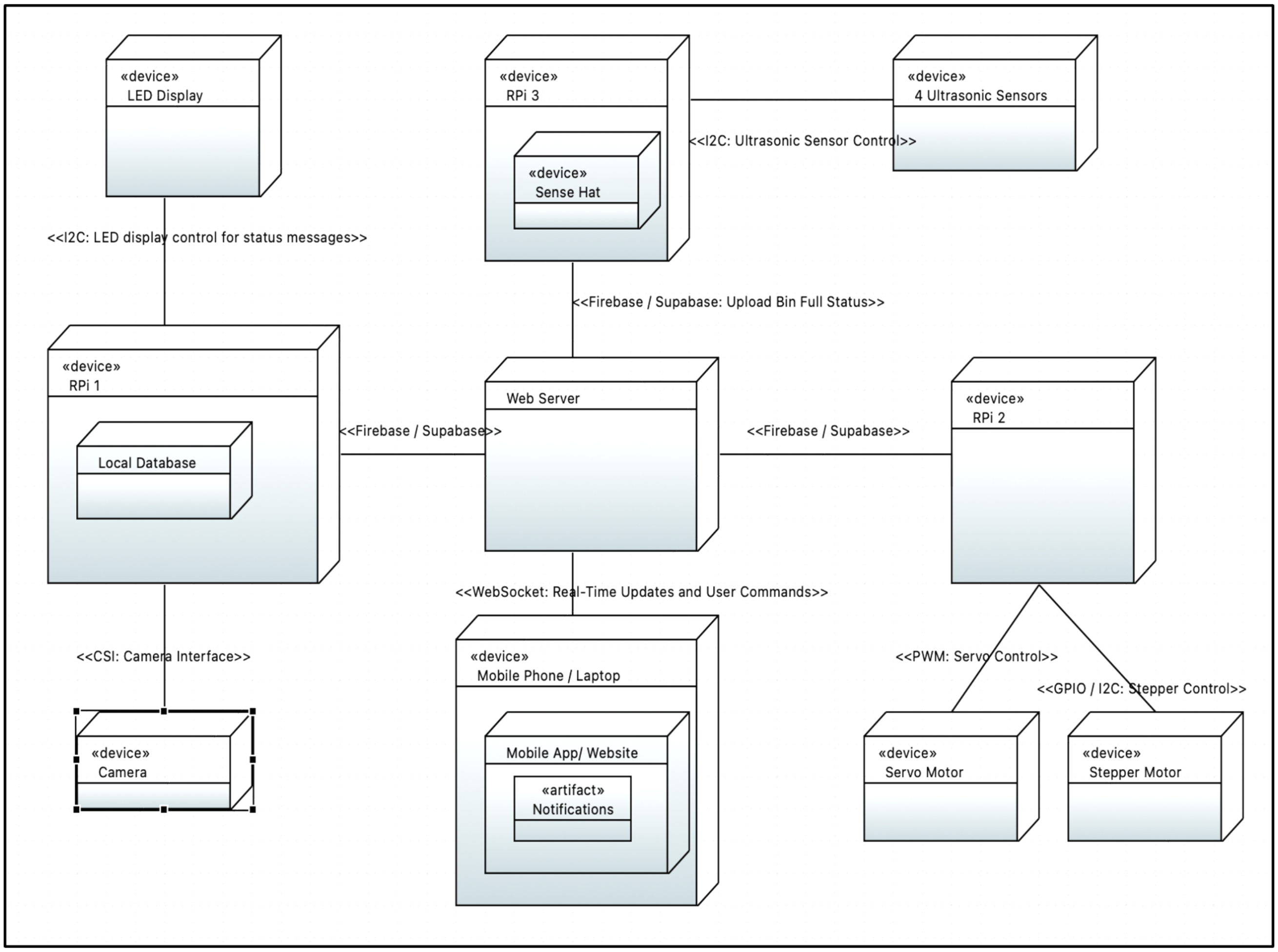


Figure 1: Deployment diagram

Figure 1 illustrates the high-level architecture of Sota Bin. The system diagram consists of 10 nodes, which can be grouped into 5 major components: 3 Raspberry Pis and their connected hardware devices, the Web Server, and the Website.

- RPi1 controls the camera for object detection and an LED display visible to users for bin status updates.
- RPi2 controls the two motors that direct waste materials into their appropriate sections.
- RPi3 controls the ultrasonic sensors to detect when a section of the smart bin is full.

The Website displays classification results to the user, notifying them which section the item was sorted into. Additionally, it updates the manager when a bin section is full and sends email and SMS notifications to the manager.

Our system has been designed with modularity and scalability in mind to ensure there is no cluttering or overload. This design also enables efficient teamwork. For example, instead of using just one Raspberry Pi to control both the motors and ultrasonic sensors, we extended the system to use three Raspberry Pis. This separation allows for modular testing, future reuse, and expansion.

2.1.1 Communication Protocols

This section outlines the communication protocols used between the Raspberry Pis nodes and hardware devices in the SotaBin system. A combination of GPIO, serial protocols, and IoT communication tools are used to interact with hardware devices. Below are the specific protocols used.

Communication Between Hardware Devices and Raspberry Pis

1) ***GPIO (General Purpose Input/Output):***
   - GPIO pins are used for direct communication with hardware components including the motors and sensors.
   - Implementation:
     a) Stepper Motor: Controlled via GPIO pins using a motor driver. GPIO pins send step and direction signals to rotate the bin plate.
     b) Servo Motor: Controlled via PWM (Pulse Width Modulation) signals generated by GPIO pins to tilt the bin plate.
     c) Ultrasonic Sensors: GPIO pins are used to trigger the sensors and read echo signals for distance measurement.
2) ***I2C (Inter-Integrated Circuit) Protocol:***
   - I2C is used for communication with devices that require a simple, two-wire interface.
   - Implementation:
     a) LED Display: RPi1 communicates with the LED display using I2C to show real-time feedback (e.g., "Place One Item at a Time" or classification results).
     b) Sense HAT: RPi3 uses I2C to display bin status (e.g., Green: empty, Red: full) on the Sense HAT.
3) ***CSI (Camera Serial Interface) Protocol:***

- CSI is used for high-speed communication between the Raspberry Pi Camera and RPi1.
- Implementation:
    a) The camera captures images of waste items and sends them to RPi1 for processing via the CSI interface.

4) UART (Universal Asynchronous Receiver-Transmitter):

- UART is used for serial communication between devices.
- Implementation:
    a) Used for debugging and logging data from sensors and motors.

Communication Between the Raspberry Pis (Nodes)

Sota Bin uses IoT communication tools to facilitate data exchange between the Raspberry Pis and the central Web Server. Below are the protocols used:

1. Firebase

- Firebase is used for real-time data synchronization between the Raspberry Pis and the Web Server.
- Implementation:
    a) RPi1: Uploads classification results and sensor data to the Web Server.
    b) RPi2: Fetches sorting instructions from the Web Server.
    c) RPi3: Uploads bin status data (e.g., empty, half-full, full) to the Web Server.

Communication Between the Web Server and GUI

1. WebSocket Protocol

- Enables real-time, bidirectional communication between the Web Server and the GUI.
- Implementation:
    a) The Web Server sends real-time updates (e.g., waste classification results, bin full notifications) to the GUI.

***2.* HTTP/HTTPS**

- Used for general communication between the GUI and the Web Server when real-time updates are not required
- Implementation:

a) Used for general communication between the GUI and the Web Server when real-time updates are not required.

b) The GUI sends commands (e.g., reset bin status) to the Web Server.

2.2 Component Details

2.2.1 RPi1: Object Detection and Local Database

The first component in the system is Raspberry Pi 1 (RPi1), which is responsible for object detection, classification, and managing a local database. This component interfaces with the Raspberry Pi Camera via the CSI Protocol to capture images of waste items placed on the bin plate. Using computer vision and material information from sensors, RPi1 processes the image data to classify the waste into one of four categories: compost, paper, plastic/metal, or landfill. The classification results are stored in an SQLite database hosted locally on RPi1, providing a reliable record of processed data for offline use.

In addition to classification, RPi1 connects to an LED Display via the I2C Protocol to provide real-time feedback to users. The display shows messages such as "Place One Item at a Time" and the classification result of the current waste item. This ensures users are informed about the system's status and operations. Once the classification process is complete, RPi1 uploads the data to the Web Server via Firebase/Supabase for further processing and integration with other components.

2.2.2. RPi2: Motor Control

Raspberry Pi 2 (RPi2) is the component responsible for controlling the mechanical sorting mechanism of Sota Bin. It fetches sorting instructions from the Web Server using Firebase/Supabase. Based on these instructions, RPi2 operates two motors: the Stepper Motor, which rotates the bin plate 360° to align with the correct bin section, and the Servo Motor, which tilts the plate to drop the waste into the designated section. The stepper motor is controlled via either the GPIO or I2C Protocol, depending on the specific motor driver used, while the servo motor is controlled via the PWM Protocol. The modular design of RPi2 ensures scalability by allowing additional motors or bin sections to be added without significant changes to the system. Additionally, RPi2 includes a fallback mechanism that defaults to sorting waste into a predefined section if no instructions are available from the Web Server.

2.2.3 RPi3: Bin Full Monitoring

The third component, Raspberry Pi 3 (RPi3), is dedicated to monitoring the fullness levels of each bin section. It interfaces with 4 Ultrasonic Sensors using the I2C Protocol to measure the distance between the sensors and the waste within each bin. This data is used to determine whether a bin is empty, half-full, or full. The status of each bin is displayed on the Sense HAT using a traffic light system: green indicates the bin is empty, yellow shows it is half-full, and red signals that the bin is full. RPi3 communicates bin status updates to the Web Server via Firebase/Supabase, ensuring that authorized users are notified in real time through the GUI. This modular design enables scalability by supporting additional ultrasonic sensors if more bins are added to the system.

RPi2: Web Server

The Web Server acts as the central hub for communication and data management in the system. It receives classification data from RPi1 and bin status updates from RPi3 via Firebase/Supabase. These inputs are processed to provide sorting instructions to RPi2 and to update the GUI with real-time notifications. The Web Server also uses the WebSocket Protocol to enable persistent, bidirectional communication with the GUI, ensuring low-latency updates for users.

Designed for scalability, the Web Server can handle multiple RPis and expand its functionality to support additional sensors, motors, or user interfaces. The modular nature of this component allows for seamless integration with other IoT services or data analytics platforms.

RPi2: Mobile App/Website

The GUI, accessible via a mobile app or website, serves as the primary user interface for the Sota Bin. It communicates with the Web Server using the WebSocket Protocol to receive real-time updates on system status, including waste classification results and bin full notifications. The GUI also allows users to send commands, such as overriding sorting instructions, which are processed by the Web Server and executed by the appropriate Raspberry Pi.

The design of the GUI prioritizes user accessibility and functionality. It provides a clear overview of system operations while supporting future scalability, such as the addition of advanced features like analytics dashboards or remote diagnostics. A mock-up of the GUI interface is included later in this report to illustrate its functionality and layout

2.3 Use Cases

2.3.1 Use Case 1: User drops one item on the bin plate

Table 1: Use Case Description 1

Use Case Name	User Drops One Item on the Bin Plate
Participating Actor(s)	Initiated by User Communicates with Camera, Raspberry Pi 1 (RPi1), Raspberry Pi 2 (RPi2), LED Display, Web Server, Web GUI
Entry Condition	- SotaBin is operational. - The bin plate is empty and ready to receive an item. - The camera is active for waste classification.
Flow of events	1. The user drops an item onto the bin plate. 2. The camera captures the image of the item. 3. The image is processed locally on RPi1, classifying the item into compost, paper, plastic/metal, or landfill. 4. The classification result is displayed on the LED display, informing the user where the waste is being placed. 6. The same classification result is sent to the remote web server for logging. 7. The web GUI displays the waste classification information for tracking purposes. 8. RPi2 communicates with the web server and sends sorting instructions to the servo motor and stepper motor. 9. The servo motor and stepper motor work together to move the bin plate and place the waste in the correct section.
Exit Condition	- The waste item is successfully sorted into the correct section. - The classification result is displayed to the user. - The web server logs the action.

Figure 2 illustrates the first use case, where the user drops an item on the bin plate, and the system processes and sorts the waste item.

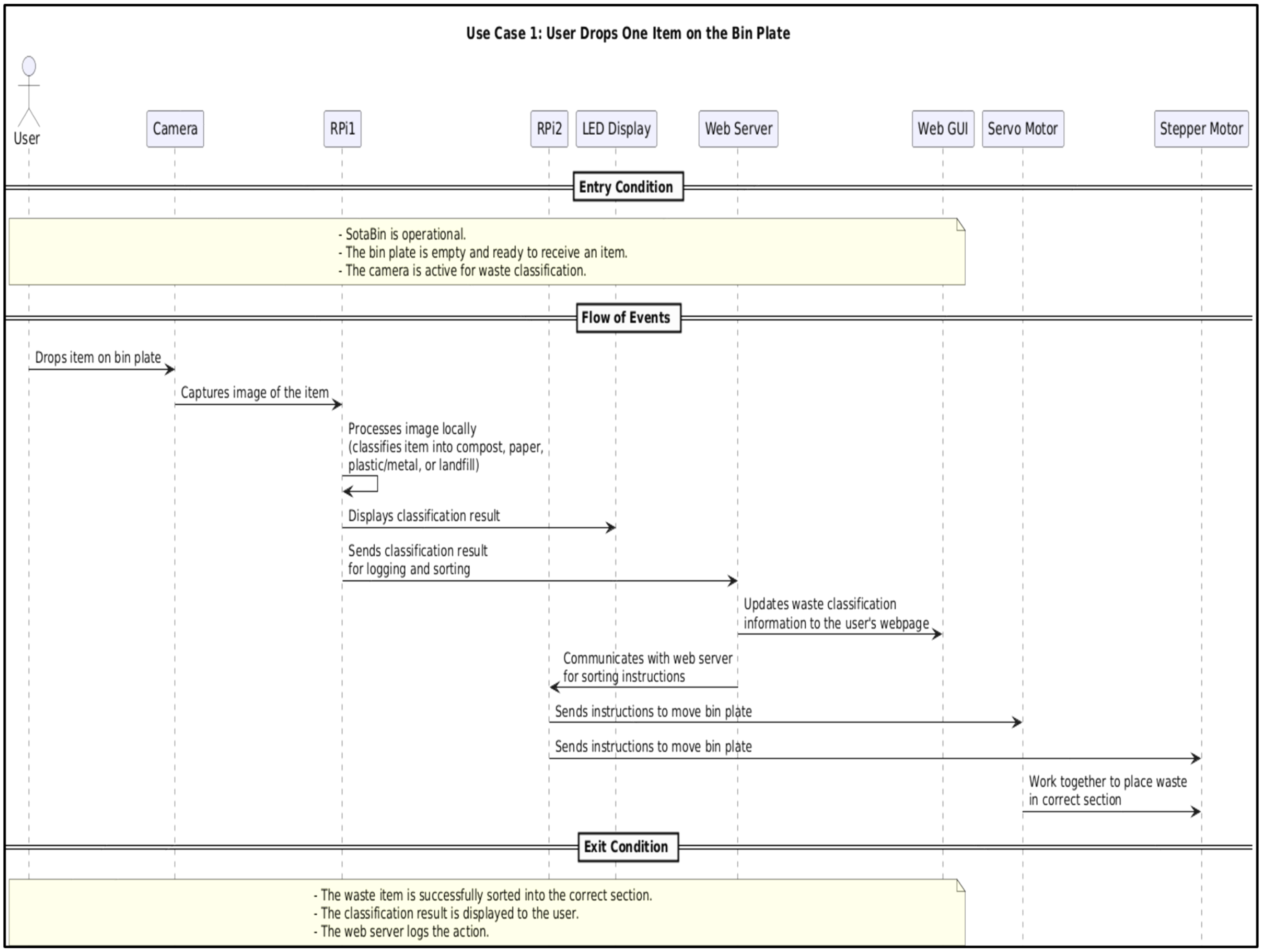


Figure 2: Sequence diagram for Use Case 1

2.3.2 Use Case 2: User Drops More Than One Item on the Bin Plate

Use Case Name	User Drops More Than One Item on the Bin Plate
Participating Actor(s)	Initiated by User Communicates with Camera, Raspberry Pi 1 (RPi1), Raspberry Pi 2 (RPi2), LED Display, Web Server, Web GUI
Entry Condition	Sota Bin is operational. The bin plate is empty and ready to receive an item. The camera is active for waste classification.
Flow of Events	1. The user drops more than one item onto the bin plate. 2. The camera captures the image, and the sorting mechanism detects multiple objects.

	3. If all items are the same, continue with the standard classification process from Use Case: User Drops One Item on the Bin Plate. 4. If the items are different, the LED display shows: "More than one item detected, remove one item." 5. A 10-second timeout starts, prompting the user to remove one item. 6. If the user removes an item within 10 seconds, the system proceeds with normal classification. 7. If the user does NOT remove an item, the system: Places all items into the landfill section and Displays the message: "Multiple items detected. Placed in landfill."
Exit Condition	• Waste is either sorted correctly or placed in landfill due to multiple items. • The LED display notifies the user of the classification decision. • The web server logs the action.

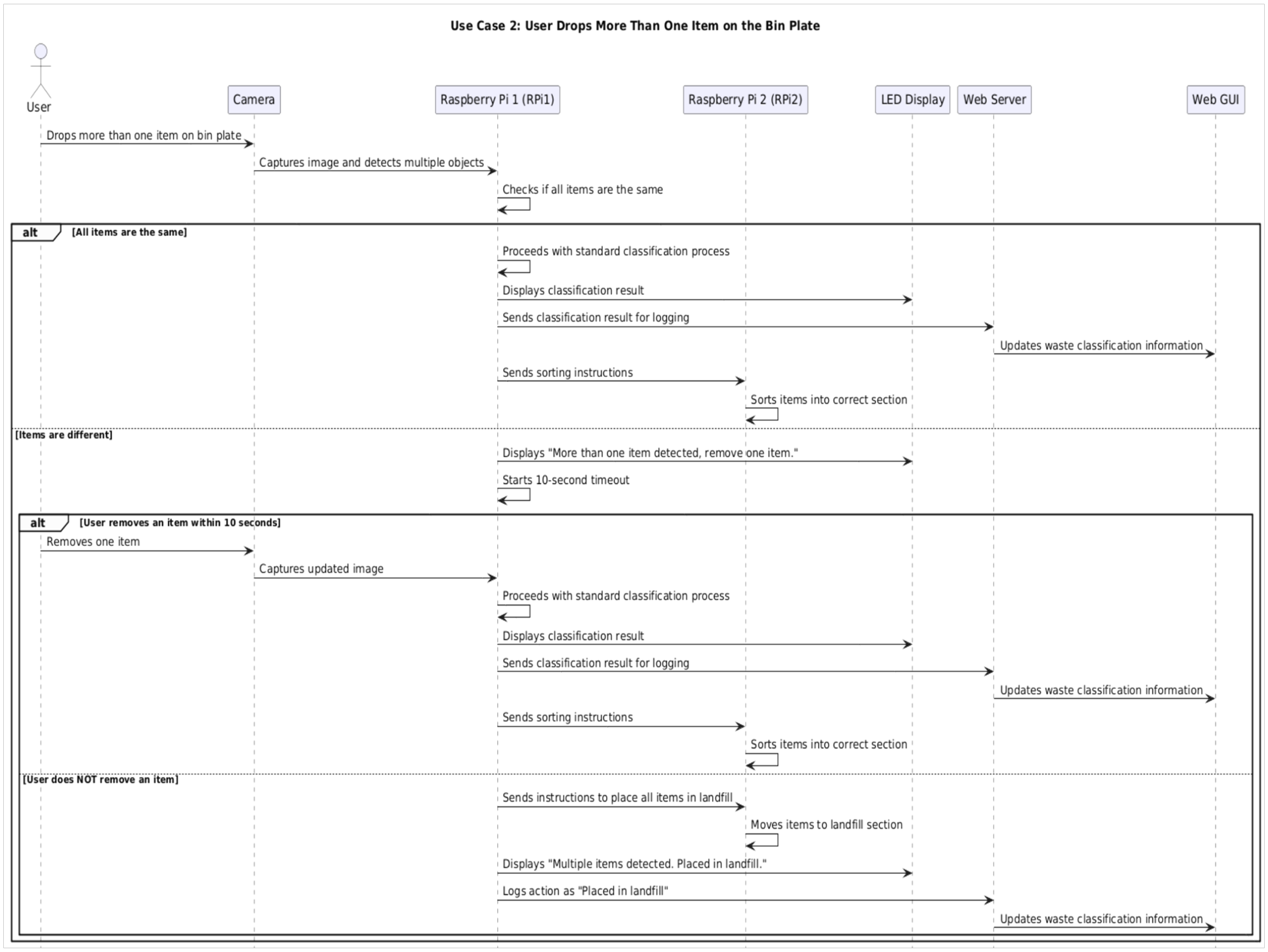


Figure 3: Sequence diagram for Use Case 2

2.3.3 Use Case 3: Bin Full Detection

Use Case Name	Bin Full Detection
Participating Actor(s)	Initiated by Ultrasonic Sensors (RPi3) Communicates with Raspberry Pi 1 (RPi1), Remote Web Server, Manager, User
Entry Condition	• Sota Bin system is operational. • One or more bin sections (Compost, Paper, Plastic/Metal, Landfill) reach full capacity.
Flow of Events	1. Ultrasonic sensors (RPi3) continuously monitor bin levels for each section. 2. When a specific bin section surpasses its full threshold, RPi3:

	• Sends a status update to the remote web server, specifying the full section. • Updates the LED display on RPi1 with: " Bin <section> Full - Needs Takeout." 3. The web server displays an alert on the manager's webpage, showing which bin section needs to be emptied. 4. The manager empties the bin and logs into the GUI (on a smartphone or web dashboard). 5. The manager manually resets the bin status via the GUI, updating the remote web server. 6. The web server sends an update to RPi3, restoring the bin section to "Available." 7. The LED display updates to remove the "Bin Full" message, and normal sorting resumes.
Exit Condition	• The bin status is restored to "Available." • The system allows sorting into the emptied bin section again. • The manager has successfully updated the system via the GUI.

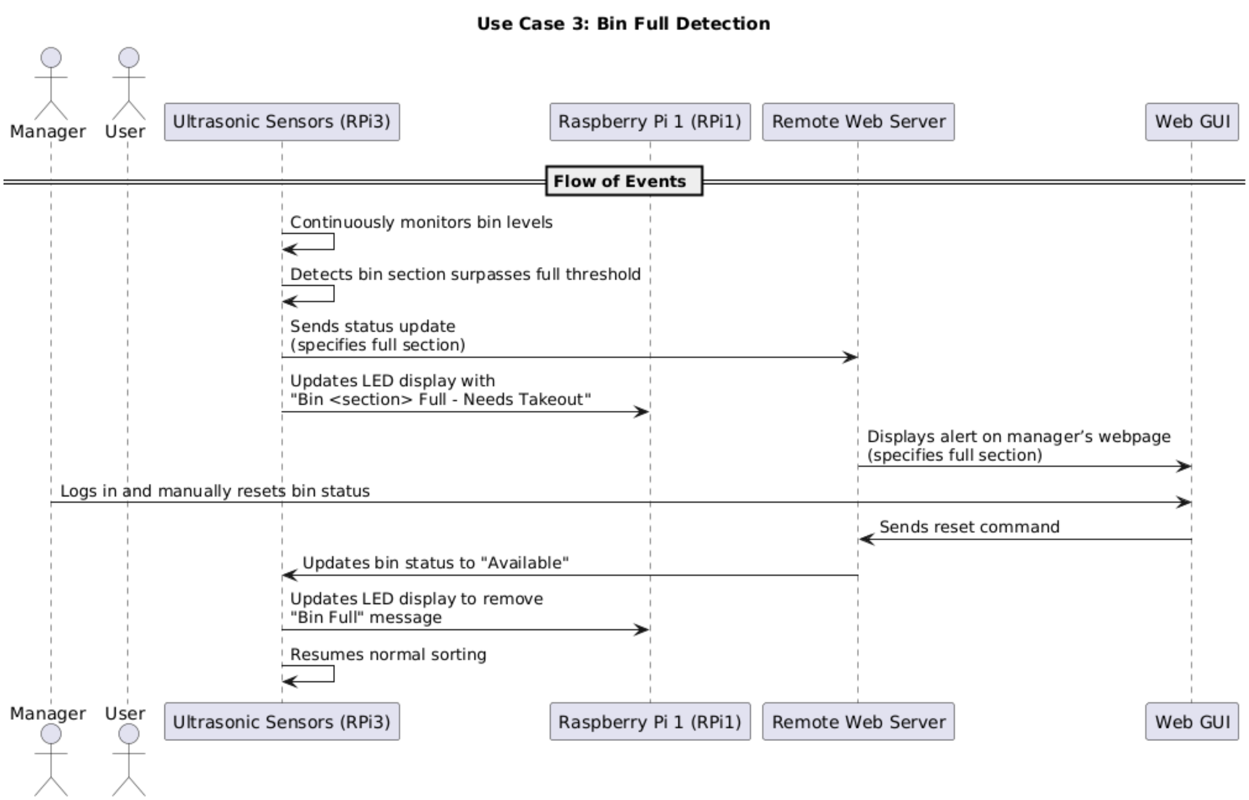


Figure 4: Sequence Diagram for Use Case 3

2.3.4 Use Case 4: User Attempts to Trash an Item in a Full Bin

Use Case Name	User Attempts to Trash an Item in a Full Bin
Participating Actor(s)	Initiated by User Communicates with Raspberry Pi 1 (RPi1), Raspberry Pi 3 (RPi3), Remote Web Server with Raspberry Pi 1 (RPi1), Remote Web Server, Manager, User
Entry Condition	• The Sota Bin system is operational. • A user places an item in the bin, and the system classifies it into a section that is already full.
Flow of Events	1. The user places an item on the bin plate. 2. The camera captures the image, and the classification process determines the correct bin section. 3. RPi3 detects that the assigned section is full. 4. The system prevents sorting into that section and displays a message on the LED screen: "Section Full. Please Find Another Bin." 5. A 10-second timeout starts. 6. If the user removes the item within 10 seconds, the system does nothing. 7. If the user leaves the item on the bin plate beyond the timeout, the system automatically places the waste in the landfill if landfill is not full. 8. If landfill is also full, the system prevents trashing altogether and displays: "All Sections Full. No Disposal Possible."
Exit Condition	The waste is either removed by the user, placed in landfill, or the system prevents disposal if all sections are full.

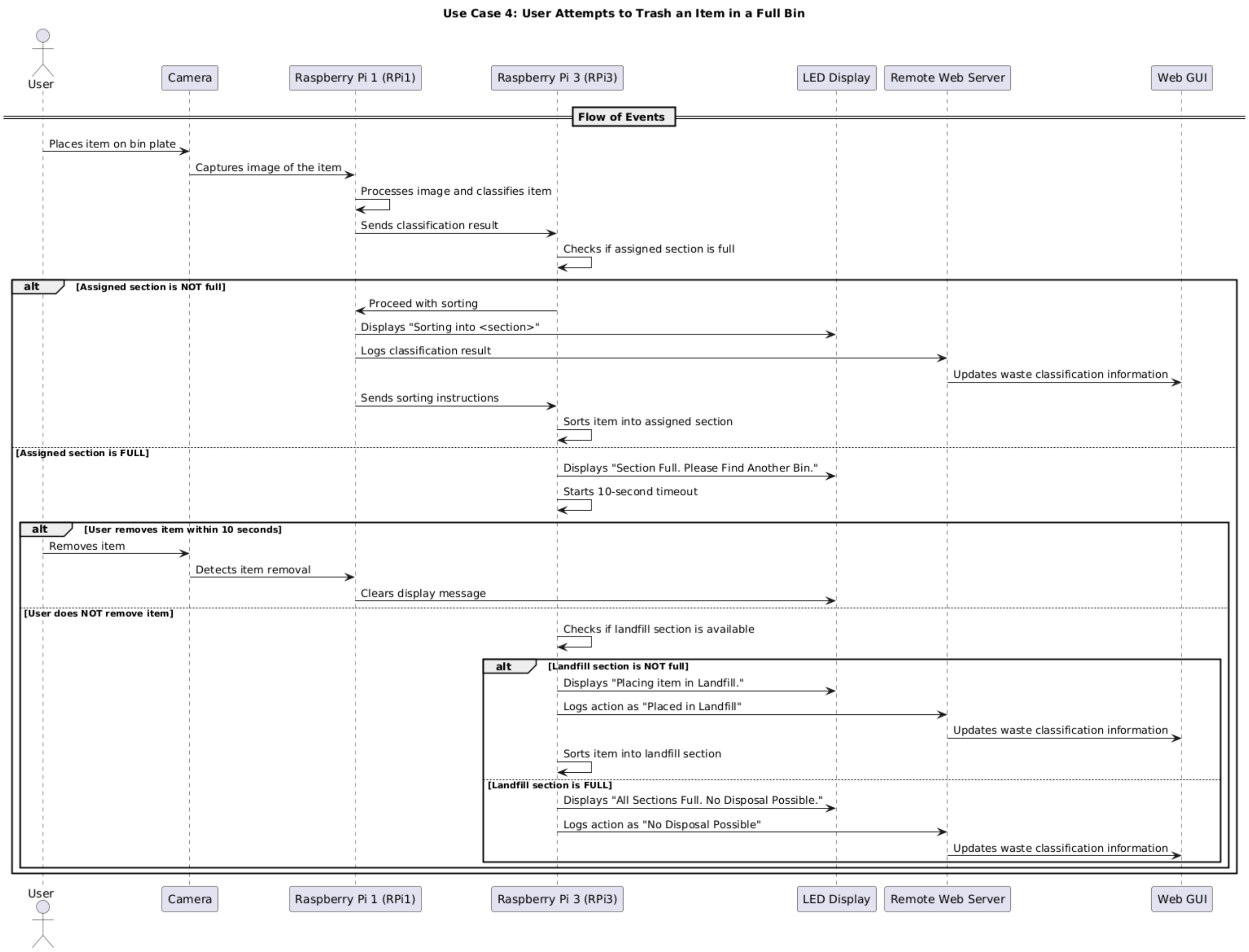


Figure 5: Sequence Diagram for Use Case 4

3 Work Plan

3.1 The Project Team

Sota Bin Team is made up of 5 group members: Uchenna Obikwelu, Adeyehun Folahanmi, Tobiloba Ola, Tobenna Ezeoke likes working with UI (User Interface), Emeka Anonyei. Folahanmi likes working with embedded systems. Uchenna enjoys working on object recognition. Tobiloba specializes in AutoCAD, and Emeka has a passion for databases.

Roles and Tasks

Tasks	Primary	secondary
Object recognition	Uchenna	Emeka
Image processing	Uchenna	Folahanmi
Sensor integration	Tobenna	Emeka
Database Management	Emeka	Folahanmi
backend	Folahanmi	
Complete frontend client interface	Tobiloba ola	Folahanmi
Designing and assembling a motorized tilting plate for sorting waste	Tobiloba ola	Tobenna
Connect all subsystems	All members	
Complete unit test	All members	

Teamwork Strategy

We will be following the Waterfall Model as our teamwork strategy. The Waterfall approach ensures a structured and sequential development process, where each phase is completed before moving on to the next. This methodology will allow us to establish clear requirements, maintain well-documented progress, and systematically verify each stage of development.

Our project workflow will be divided into distinct phases:

1. **Requirement Analysis & Planning:**
    a. The team will conduct initial meetings to define clear objectives, gather requirements, and outline the project scope.
    b. Communication during this phase will occur through scheduled in-person or virtual meetings.
2. **System & Software Design:**
    a. Based on the gathered requirements, we will create a detailed system architecture, specifying hardware and software components.
    b. Documentation and design diagrams will be shared using GitHub for version control.
3. **Implementation (Coding & Integration):**

   a. Each team member will be assigned specific tasks based on the design phase.
   b. Code will be developed in isolated modules and later integrated sequentially.
   c. GitHub will be used for source code management, with team members conducting code reviews before integration.
4. **Testing & Verification:**
   a. Once the implementation phase is complete, we will conduct rigorous testing to verify that all components function correctly.
   b. Issues found during testing will be documented and resolved systematically before proceeding to deployment.

To ensure smooth communication throughout the project, Teams for scheduled meetings, SMS for quick notifications, and GitHub for version control and code-related collaboration

What we will need to learn

To successfully develop the Sota Bin, our team must strengthen our knowledge in computer vision, hardware integration, cloud computing, and software development. This understanding image processing for waste classification, and interfacing camera modules with Raspberry Pi 1. We also need to control a servo motor with Raspberry Pi 2 and manage GPIO programming for hardware interactions.

Additionally, we must set up a cloud database for real-time synchronization, develop a web-based GUI using HTML, CSS, and JavaScript, and implement Python-based embedded systems for motor control and classification. Mechanical aspects, such as designing a motorized tilting plate and ensuring power management, are also critical to the project's success.

3.2 Project Milestones

Milestone Number	Milestone name	Description	Timeline
1	**System Foundation & Hardware Setup**	Set up Raspberry Pi 1 and Raspberry Pi 2 with necessary OS and dependencies. Connect and test the camera module on RPi-1. Connect and test servo motors for sorting on RPi-2. Design and build the circular bin structure with four sections.	February 15
2	**Waste Classification System (RPi-1)**	Collect and preprocess image datasets for different waste types.	February 20

		Use object recognition for waste classification. Deploy the model on RPi-1 and test its accuracy. Implement communication between RPi-1 and RPi-2	
3	**Sorting Mechanism & Control (RPi-2**	Develop software to control the servo motor and tilting plate. Implement logic to direct waste into the correct section based on classification results. Test the integration of RPi-1's classification with RPi-2's sorting mechanism.	February 23
4	**Web-based GUI & Local Database**	Develop a web-based GUI for real-time feedback and monitoring. Implement a local database on RPi-2 to store sorting logs and recycling metrics. Connect the GUI to the local database for real-time updates.	February 28
5	**Cloud Integration & Analytics**	Set up a cloud database to store classification data and recycling statistics. Implement synchronization between the cloud and the local database.	March 2nd

		Integrate real-time insights and analytics into the web GUI.	
6	**Testing & Optimization**	Conduct end-to-end testing of the entire system. Optimize the ML model for better accuracy and performance. Fine-tune servo motor movements for precise sorting. Identify and fix any software or hardware issues.	March 15th

3.3 Schedule of Activities

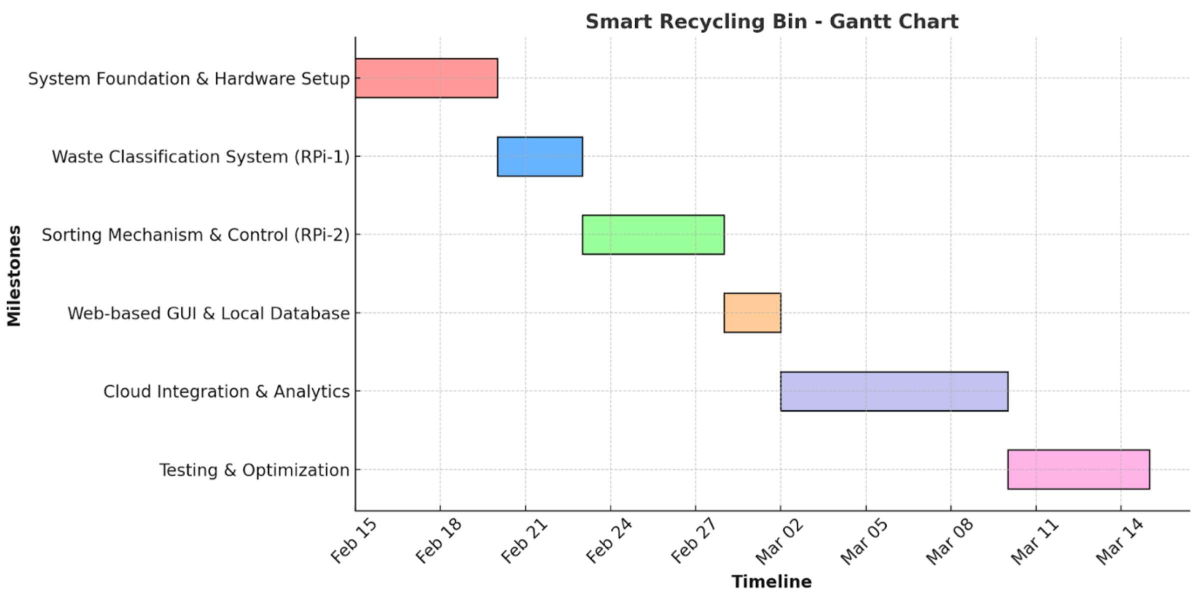


Figure 6: Milestones vs Timeline

4 Project Requirements Checklist

Category	Requirements	Fulfilment
Computer Components	Is there at least one computer per student in the group	Yes, the project includes three Raspberry Pi devices: RPi-1 for detection & classification, RPi-2 for controlling the motors, and RPi-3 which handles the bin full detection
	Is at least one Raspberry Pi (RPi) in headless mode?	Yes, the 3 Raspberry Pis work in headless mode. This allows for a clean set up.
Hardware Components	Is there at least one hardware device per student in the group with at least one actuator and one sensor?	Yes, we have 5 hardware devices incorporated into Sota Bin. A Raspberry Pi Camera, a LED display, 2 motors, and 4 ultrasonic sensors
	Is there an actuator?	Yes, Sota Bin includes two actuators: Stepper Motor which enables 360° plate rotation and the Servo Motor which tilts the plate 180° to direct the item into the bin.
	Is there a feedback loop?	Yes, RPi-1 uploads waste classification data to the web server, while RPi-2 retrieves sorting instructions to control actuators. RPi-3 sends bin full status updates, which are displayed on the bin manager's GUI. The manager can then reset the bin status to "normal" via the GUI once the trash has been emptied.
Software Components	Is there a database with at least two tables and does the computer hosting the database have other responsibilities?	Yes, we have both a local and cloud-based database. RPi1 hosts an SQLite database with two tables: Detected Object Logs and Classification Results. The cloud database contains a Classification Table (stores detected objects and categories) and a Stats Table (tracks waste metrics and user engagement). Yes, RPi1 has other responsibilities including manages the Raspberry Pi camera and controls the LED display.
	Is there a periodic timing loop?	Yes, the system includes periodic timing loops. The ultrasonic sensors (RPi3) continuously check bin fill levels, and RPi1 periodically monitors the bin plate for waste classification. Additionally, RPi2 controls motor movements in timed sequences, and the Web Server updates the GUI in real time using WebSocket's.

	Is there some processing or analysis of the IoT data read?	Yes, IoT data from ultrasonic sensors is analyzed to detect bin fullness, and waste classification data from the camera is processed to determine the correct section for disposal.
	Are notifications sent (SMS and/or email)?	Yes, users receive real-time notifications via the GUI or mobile alerts, indicating waste sorting results and recycling stats.
	Is there at least one GUI running on a computer?	Yes, the system includes a web-based GUI accessible on a computer. The user’s webpage displays real-time waste classification results, while the manager's interface provides classification history and bin full updates.

5 Additional Hardware Required

Component/Service	**Description**	**Quantity**	**Digi-Key Part Number**
Stepper Motor	Enables 360° rotation of the bin plate.	1	1528-1062-ND
Servo Motor	Tilts the plate to drop waste into the designated section.	1	1738-1300-ND
Stepper Motor Driver	Controls the stepper motor (e.g., A4988).	1	To be purchased from Amazon/ other
Ultrasonic Sensors	Measures bin fullness levels.	4	To be purchased from Amazon/ other
LED Display	Provides real-time feedback to users (16x2 I2C LCD).	1	4411-CN0296DND
Metal Sensor	Detects aluminum cans in the plastic/metal category.	1	To be purchased from Amazon/ other
Power Supply (5V, 3A+)	Provides power to the Raspberry Pis and connected components.	3	To be purchased from Amazon/ other
Jumper Wires	Connects components on the breadboard to Raspberry Pis.	1 set	To be purchased from Amazon/ other

Resistors (10kΩ)	Used for signal stabilization with sensors.	10	To be borrowed from the engineering department
Capacitors (10µF)	Used for voltage stabilization and filtering.	5	To be borrowed from the engineering department

6 References

[1] YouTube, "Ameru AI Smart Bin 5.0 Demo," *YouTube*, [Online]. Available: https://www.youtube.com/shorts/WiNRz2VhiV4. [Accessed: 15-Feb-2025].

Appendices

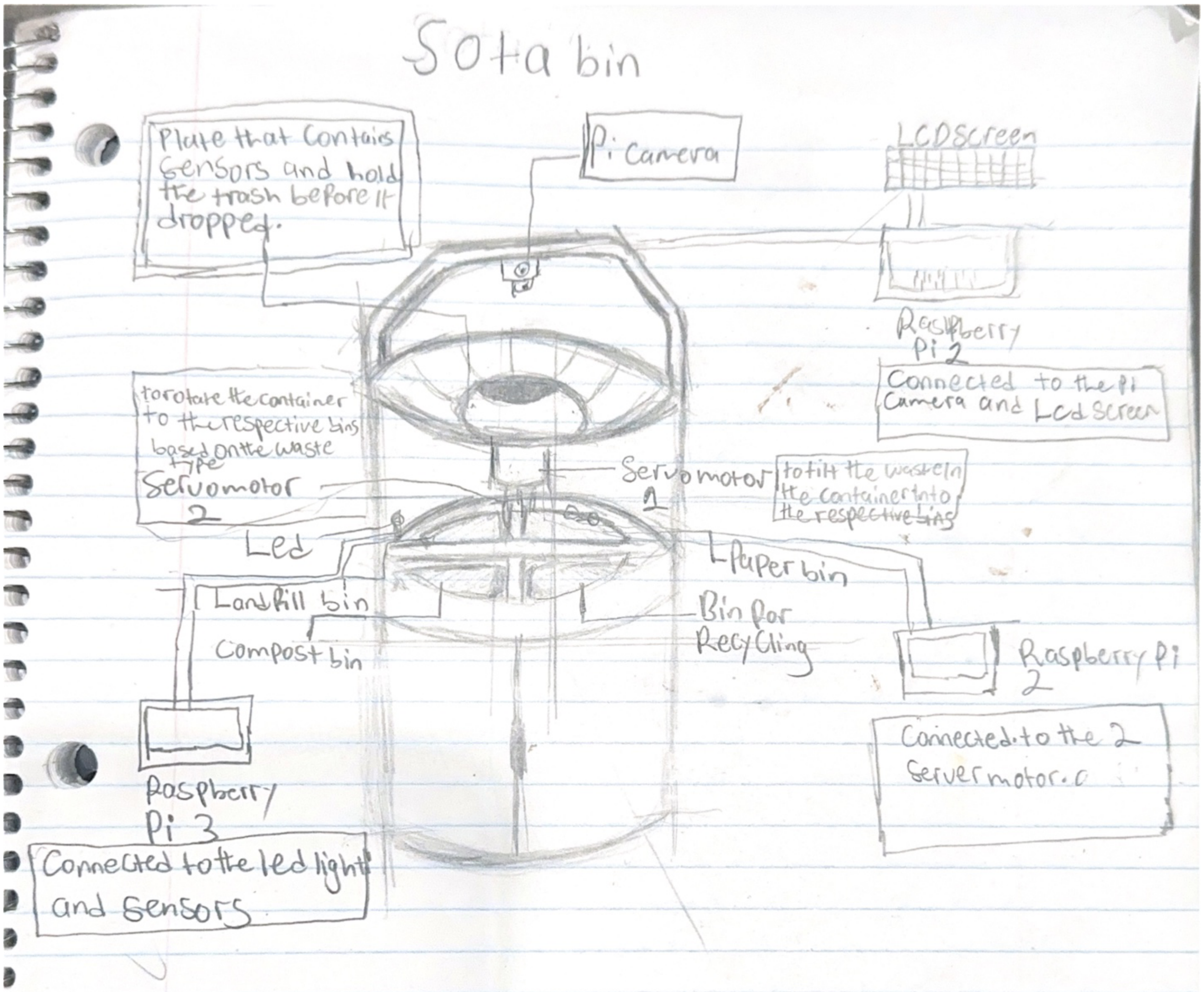


Figure 7: Sota Bin Sketch Labelled Diagram