INDUSTRIAL ORIENTED MINI PROJECT
Report

On

IOT-DRIVEN SMART WASTE SEGREGATION

Submitted in partial fulfilment of the requirements for the award of the degree of

BACHELOR OF TECHNOLOGY

In

INFORMATION TECHNOLOGY

By

Tanneru Joshnavi - 22261A1255

Pothepaka Prasanna -22261A1248

Under the guidance of

Mrs.Ch. Lakshmi Kumari

Assistant Professor, Department of IT

DEPARTMENT OF INFORMATION TECHNOLOGY

MAHATMA GANDHI INSTITUTE OF TECHNOLOGY

(AUTONOMOUS)

(Affiliated to JNTU, Hyderabad; Eight UG Programs Accredited by NBA; Accredited by NAAC with 'A++' Grade)

Gandipet, Hyderabad, Telangana, Chaitanya Bharati (P.O), RangaReddy District, Hyderabad– 500075, Telangana

2024-2025

CERTIFICATE

This is to certify that the **Industrial Oriented Mini Project** entitled **IOT-DRIVEN SMART WASTE SEGREGATION** submitted by **Tanneru Joshnavi (22261A1255), Pothepaka Prasanna (22261A1248)** in partial fulfillment of the requirements for the Award of the Degree of Bachelor of Technology in Information Technology as specialization is a record of the bona fide work carried out under the supervision of **Mrs. Ch. Lakshmi Kumari**, and this has not been submitted to any other University or Institute for the award of any degree or diploma.

Internal Supervisor:	**IOMP Supervisor:**
Mrs.Ch. Lakshmi Kumari	**Dr.U.Chaitanya**
Assistant Professor	Assistant Professor
Dept. of IT	Dept. of IT

EXTERNAL EXAMINER	**Dr. D. VijayaLakshmi**
	Professor and HOD
	Dept. of IT

..

DECLARATION

We hear by declare that the **Industrial Oriented Mini Project** entitled **IOT-DRIVEN SMART WASTE SEGREGATION** is an original and bona fide work carried out by us as a part of fulfilment of Bachelor of Technology in Information Technology, Mahatma Gandhi Institute of Technology, Hyderabad, under the guidance of **Mrs.Ch. Lakshmi Kumari, Assistant Professor**, Department of IT, MGIT.

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Tanneru Joshnavi - 22261A1255

Pothepaka Prasanna - 22261A1248

ACKNOWLEDGEMENT

The satisfaction that accompanies the successful completion of any task would be incomplete without introducing the people who made it possible and whose constant guidance and encouragement crowns all efforts with success. They have been a guiding light and source of inspiration towards the completion of the **Industrial Oriented Mini Project**.

We would like to express our sincere gratitude and indebtedness to our Internal supervisor **Mrs. Ch. Lakshmi Kumari, Assistant Professor**, Dept. of IT, who has supported us throughout our project with immense patience and expertise.

We are also thankful to our honourable Principal of MGIT **Prof. G. Chandramohan Reddy** and **Dr. D. Vijaya Lakshmi**, Professor and HOD, Department of IT, for providing excellent infrastructure and a conducive atmosphere for completing this **Industrial Oriented Mini Project** successfully.

We are also extremely thankful to our IOMP supervisor **Dr. U. Chaitanya**, Assistant Professor, Department of IT, and senior faculty **Mrs. B. Meenakshi**, Assistant Professor, Department of IT for their valuable suggestions and guidance throughout the course of this project.

We convey our heartfelt thanks to the lab staff for allowing us to use the required equipment whenever needed.

Finally, we would like to take this opportunity to thank our families for their support all through the work. We sincerely acknowledge and thank all those who gave directly or indirectly their support for completion of this work.

Tanneru Joshnavi - 22261A1255

Pothepaka Prasanna -22261A1248

ABSTRACT

Efficient and sustainable waste management is a growing need in both urban and rural environments due to increasing environmental concerns and rapid waste generation. Traditional waste segregation methods are often manual, time-consuming, and inefficient, leading to poor recycling practices and increased landfill waste. To address these challenges, this project proposes an Automated Waste Segregation System that classifies waste into dry, wet, and metallic categories using an Arduino-controlled setup equipped with multiple sensors and motorized mechanisms.

The system integrates an Infrared (IR) sensor, a rain drop sensor, and a proximity switch to intelligently identify and categorize different types of waste. The proximity sensor detects the presence of waste material approaching the input section. Once detected, the IR sensor helps distinguish solid dry waste from liquids or metallic objects based on reflectivity, while the rain drop sensor identifies the moisture content, determining if the waste is wet or organic in nature.

For mechanical control, the system employs a combination of a servo motor and a stepper motor. The servo motor controls the opening and closing of the waste flap or lid, while the stepper motor accurately rotates or shifts the waste container to direct the waste into the corresponding bin—dry, wet, or metal. An integrated buzzer provides audio alerts for specific system actions or user feedback, such as waste detection or bin full notification.

The entire system is powered by rechargeable 18650 Li-ion batteries, ensuring portability, low power consumption, and suitability for deployment in areas without a stable power

supply. This makes the setup ideal not only for homes but also for offices, schools, industries, and public spaces.

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1.INTRODUCTION

1.1 MOTIVATION

Increased urbanization and population growth have led to a significant surge in waste generation, posing serious environmental and health hazards. Traditional waste management systems rely heavily on manual segregation, which is often inefficient, time-consuming, and unhygienic. Improper segregation leads to reduced effectiveness of recycling processes and contributes to land, water, and air pollution.

With the advancement of IoT and automation technologies, there is a strong opportunity to build intelligent systems that minimize human involvement and ensure accurate, real-time waste categorization. This project is driven by the need to develop an automated, portable, and energy-efficient waste segregation system that can sort waste into dry, wet, and metal categories using a combination of sensors and microcontroller-based logic.

The motivation stems from the vision to improve public health, promote sustainable practices, and support smart city initiatives by integrating simple hardware components with intelligent control for enhanced waste management.

1.2 PROBLEM STATEMENT

Conventional waste segregation methods are predominantly manual, leading to inefficient sorting, increased labor costs, and significant health risks due to direct contact with waste. These traditional systems often fail to accurately distinguish between different types of waste such as dry, wet, and metallic, resulting in improper disposal and reduced effectiveness of recycling efforts.

Furthermore, existing smart bins primarily focus on monitoring fill levels and lack the capability to perform real-time, automated waste classification and segregation. This gap limits the scalability and practical utility of such systems in real-world applications like households, offices, and urban infrastructure.

Hence, there is a pressing need for a fully automated, energy-efficient, and intelligent system that can accurately detect, classify, and sort different types of waste with minimal human intervention. This project aims to design and implement a sensor-based waste segregation system using Arduino, capable of improving hygiene, enhancing recycling, and supporting sustainable waste management practices.

1.3 EXISTING SYSTEM

Existing waste segregation systems are largely manual or semi-automated, relying on human labor for the identification and sorting of waste materials. This traditional approach is time-consuming, unhygienic, and prone to errors, leading to ineffective recycling and improper waste disposal. Manual segregation also increases the risk of exposure to hazardous materials, particularly in medical and industrial environments.

Some systems make use of basic IoT-enabled smart bins, which are capable of tracking waste levels and sending alerts when bins are full. However, these systems lack the ability to classify waste types such as dry, wet, and metallic. Additionally, many of these models are not portable and require a continuous power supply, limiting their usability in various settings like remote areas or outdoor environments.

Although a few research efforts have explored AI-based waste detection and deep learning for image-based classification, such solutions are often expensive, computationally intensive, and not easily deployable in low-resource settings.

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1.3.1 LIMITATIONS

- **Manual Effort**: Traditional waste segregation methods rely heavily on human involvement, making the process labor-intensive and prone to human error.
- **Health Hazards**: Manual sorting exposes workers to unhygienic and potentially hazardous waste, increasing the risk of infections and injuries.
- **No Categorization Ability**: Existing smart bins may monitor fill levels but lack the intelligence to differentiate between dry, wet, and metallic waste.

1.4 PROPOSED SYSTEM

The proposed system aims to develop an **automated smart waste management system** that efficiently segregates and disposes of different types of waste using sensor-based technology and actuators. The system integrates multiple sensors such as IR sensors, soil moisture sensors, and proximity sensors to detect the type of waste being disposed. Based on sensor inputs, a microcontroller controls the opening of specific compartments in the smart dustbin by rotating the lid at predefined angles suitable for different waste types.

This system will automate the segregation process, minimizing human intervention and improving waste management efficiency. It is designed to be user-friendly, hygienic, and capable of reducing contamination between wet and dry waste. Additionally, the system can provide real-time feedback on waste disposal patterns and help municipal authorities optimize collection schedules.

Key features of the proposed system include:

- **Sensor-based waste detection:** IR sensors detect dry waste, soil moisture sensors identify wet waste, and proximity sensors manage the lid operation.
- **Automated lid control:** Servo motors rotate the lid to specific angles based on detected waste type (e.g., 120° for dry waste, 180° for wet waste).
- **Real-time monitoring:** Potential integration of IoT for remote monitoring and data analytics.
- **Improved hygiene:** Minimizes human contact with waste, reducing health hazards.

This system is an innovative approach towards smart city initiatives and promotes environmental sustainability by enhancing waste segregation at the source.

1.4.1 ADVANTAGES

- **Efficient Waste Segregation**: Automatically separates wet and dry waste, improving recycling and disposal processes.

- **Hygienic and User-Friendly**: Minimizes direct contact with waste, reducing the risk of contamination and health hazards.

- **Time-Saving**: Automates the waste sorting process, saving time and effort compared to manual segregation.
- **Environmentally Friendly**: Encourages proper waste disposal, contributing to cleaner surroundings and reducing landfill load.
- **Promotes Smart City Initiatives**: Integrates technology to improve urban living standards and resource management.

1.5 OBJECTIVES

- To develop an automated smart waste bin that can classify and segregate waste based on its type (wet or dry) using sensor technology.
- To implement real-time waste detection using Infrared (IR), soil moisture, and proximity sensors to ensure accurate identification and handling of waste.
- To automate the dustbin lid operation using a servo motor and control the rotation of waste compartments using a stepper motor based on the type of waste detected.
- To provide an interactive feedback mechanism (via buzzer and serial monitor) to inform users about system status and detected waste type**.**

1.6 HARDWARE AND SOFTWARE REQUIREMENTS

1.6.1 SOFTWARE REQUIREMENTS

- Software Development Platform:

  The system is developed using the Arduino IDE, a lightweight and efficient environment for writing, compiling, and uploading embedded C/C++ code to the Arduino Uno microcontroller. It allows real-time monitoring through its built-in Serial Monitor, making it ideal for debugging and sensor output validation.
- Primary Language:

  The project is primarily developed using C/C++, which is optimal for microcontroller-based systems. This language is used to interface with hardware components like sensors, servo and stepper motors, and the buzzer. Key Arduino libraries such as Servo.h and CheapStepper.h are included to streamline actuator control.

- Sensor Integration and Logic Control:
  The Arduino code handles sensor data interpretation and decision-making logic for detecting dry, wet, or approaching objects. Real-time conditions from IR, proximity, and moisture sensors are used to control motor actions precisely.
- Data Output & Debugging:
  Serial communication is implemented for real-time data visualization, including sensor readings and operational logs, enhancing system transparency and reliability during development and testing phases.
- Platform Compatibility:
  The system is compatible with Windows, macOS, and Linux platforms, offering flexibility in choosing a development machine.

1.6.2 HARDWARE REQUIREMENTS

- Operating System:
  The development tools and Arduino IDE are compatible with both Windows and macOS operating systems, ensuring a smooth setup process for the developers.
- Processor:
  A processor with at least an Intel i3 or i5 (or equivalent) is recommended to efficiently compile code, upload to Arduino, and monitor real-time sensor outputs. This ensures the system can handle IDE operations and serial communication without lag.
- RAM:
  A minimum of 4GB RAM is recommended to run the Arduino IDE smoothly along with browser-based resources (for documentation, datasheets, etc.). For an improved experience, especially when using simulation tools or multiple serial monitors, 8GB or more is ideal.
- Microcontroller Unit:
  The Arduino Uno serves as the central processing unit, handling all input from sensors and providing output to actuators based on programmed logic.
- Sensors and Actuators:

- IR Sensor – For detecting dry/metal waste.
- Soil Moisture Sensor – For detecting wet/organic waste.
- Proximity Sensor – For sensing user presence.
- Servo Motor – To open and close the dustbin lid.
- Stepper Motor – To rotate the waste bin section for segregation.
- Buzzer – To provide audio alerts on sensor triggers or system actions.

- Power Supply:
  A regulated 5V–12V DC adapter or battery is required to power the Arduino and associated motors reliably during operation.
- Supporting Components:
  Jumper wires, breadboards or PCBs, resistors, and enclosures are used to complete the circuit and assemble the dustbin structure. A laptop or desktop computer is needed for code upload, serial monitoring, and system control.

2.LITERATURE SURVEY

M. P. Arthur et al. (2024) conducted a comprehensive survey on IoT-based smart dustbins integrated with deep learning, focusing on improving real-time waste monitoring accuracy. Their work demonstrates the potential of combining sensor data with machine learning for dynamic waste classification. However, the study highlights a lack of scalability and practical applicability in large-scale deployments, pointing to the need for cost-effective and robust models in real-world environments.

N. H. Mohamed et al. (2024) proposed a system under the concept of Waste 4.0 that integrates AI with IoT for managing medical waste. Their framework emphasizes automation and digital tracking to handle biohazardous materials effectively. Despite its innovation, the study acknowledges high implementation costs and the necessity for privacy-preserving digital infrastructures, which present significant deployment barriers in urban waste management.

B. Fang et al. (2023) reviewed the use of AI techniques—including machine learning, computer vision, and optimization—in developing intelligent waste management systems. The study supports AI-based strategies for smart cities, suggesting that such models improve accuracy and efficiency. However, a notable gap is the lack of real-world validation; the models discussed are mostly theoretical or lab-scale, with limited field deployment evidence.

S. K. Singh et al. (2023) introduced an IoT-enabled smart bin equipped with fill-level sensors and classification modules. Their system automates the waste collection process by signaling authorities when bins are nearly full, thus optimizing collection routes. While the design enhances efficiency and reduces overflow, the authors identify potential issues with sensor inaccuracies and emphasize the need for adaptive systems that incorporate error-handling capabilities.

M. S. Sivakumar et al. (2022) explored a computer vision-based approach to waste segregation, integrated with IoT frameworks. Their method delivers high accuracy in classifying different waste types using image recognition. Nonetheless, the study mentions the dependency on high-quality images and stable infrastructure as a limitation, calling for more resilient and generalized models suitable for a variety of environments and waste materials.

Table 2.1 Literature Survey of Smart Waste Segregation

Ref	Author & year of publication	Journal/ Conference	Method/ Approach	Merits	Limitations	Research Gap
[1]	M. P. Arthur et al., 2024	*Artificial Intelligence Review*, Springer	Survey of IoT-based smart dustbins with deep learning	Combines IoT and deep learning for accurate real-time waste monitoring	Limited coverage on large-scale deployment issues	Need for cost-effective, scalable models
[2]	N. H. Mohamed et al., 2024	*Discover Sustainability*, Springer Nature	Waste 4.0 with AI-based medical waste segregation and digital tracking	Addresses healthcare waste challenges using AI and automation	High implementation cost and regulatory concerns	Integration of secure systems with privacy safeguards
[3]	*B. Fang et al., 2023*	*Environmental Chemistry Letters*, Springer	Review of AI in waste management using ML, computer vision, and optimization techniques	Offers solutions comprehensive AI-based strategies for smart city waste	Lacks practical implementation details	Need for real-world case studies to validate AI models
[4]	S. K. Singh et al., 2023	*Neural Computing and*	IoT-based smart bin with	Improves collection efficiency and	Sensor failures may cause	Need for adaptive systems

		Applications, Springer	fill-level sensors and classification	reduces overflow	incorrect readings	with error-handling
[5]	M. S. Sivakumar et al., 2022	*Environmental Science and Pollution Research*, Springer	Computer vision-based waste classification with IoT integration	High accuracy in automated waste segregation	Requires high-quality images and infrastructure	More robust models needed for diverse waste types

3.ANALYSIS AND DESIGN

The field of urban waste management faces significant challenges, particularly in efficient segregation, handling, and disposal of various waste types. Manual segregation not only poses health risks but also leads to operational inefficiencies and poor recycling outcomes. This project aims to develop an IoT-Driven Smart Waste Segregation System, designed to tackle these challenges by automating the waste classification process using low-cost sensors, actuators, and embedded programming. The system integrates sensors and motors with microcontrollers to provide intelligent waste disposal in public and domestic environments.

At the core of the system is its ability to detect and differentiate between wet, dry, and metallic waste using a combination of infrared (IR) sensors, a soil moisture sensor, and a proximity sensor. These sensors are interfaced with an Arduino Uno microcontroller, which acts as the decision-making unit. Based on sensor inputs, the system dynamically activates a servo motor to open the bin lid and a stepper motor to rotate the platform and dispose of the waste into the correct compartment.

The proximity sensor detects the presence of a person near the dustbin and automatically opens the lid using the servo motor, enhancing hygiene and ease of use. If the IR sensor detects the object, it categorizes it as dry or metallic waste, triggering the stepper motor to rotate the disposal tray to 120°. Conversely, if the moisture sensor reads a value below the threshold (indicating wet waste), the tray rotates to 180° for proper disposal. Each action is accompanied by buzzer feedback to provide status confirmation.

This rule-based automation ensures contactless operation, accurate waste classification, and reduced human involvement. The embedded logic in the Arduino handles real-time sensor input processing and motor control, making the system efficient and responsive. The modular nature of the system also allows it to be adapted for larger-scale implementations by integrating with cloud platforms or GSM modules for fill-level tracking, status updates, or remote monitoring in future enhancements.

In summary, the system's design offers a cost-effective, energy-efficient, and automated waste segregation mechanism, ensuring cleaner surroundings and promoting environmental sustainability through proper disposal practices. The integration of sensor-based automation with simple electromechanical components makes it suitable for smart city applications, public infrastructure, and even domestic waste management.

3.1 MODULES

The IoT-Driven Smart Waste Segregation System is structured into several functional modules that work in coordination to achieve efficient and automated waste classification. Each module is designed to perform specific tasks to ensure accurate segregation with minimal human intervention.

1. Waste Detection Module

This module is responsible for sensing the presence of waste and identifying its physical characteristics. It comprises:

- An IR sensor or raindrop sensor to differentiate between solid (dry) and liquid (wet) waste.
- A proximity sensor to detect the presence of metallic objects.

  Upon detection, this module activates the classification process and sends the relevant data to the processing unit.

2. Waste Segregation Module

This mechanical module performs the physical segregation of waste into appropriate bins. It includes:

- A stepper motor to rotate and align the disposal opening with the correct bin depending on waste type (dry, wet, or metal).
- A servo motor to operate the flap mechanism, allowing smooth and controlled release of the waste into the respective compartment.

3. Notification and Feedback Module

This module provides real-time feedback to users and aids in system monitoring by:

- Using a buzzer to indicate successful waste detection and sorting operations.
- Displaying sensor readings and system status on the Serial Monitor during the testing phase for debugging and performance monitoring.

These modules collectively enable automated, precise, and user-friendly waste segregation, improving efficiency and hygiene in waste management.

3.2 CIRCUIT DIAGRAM

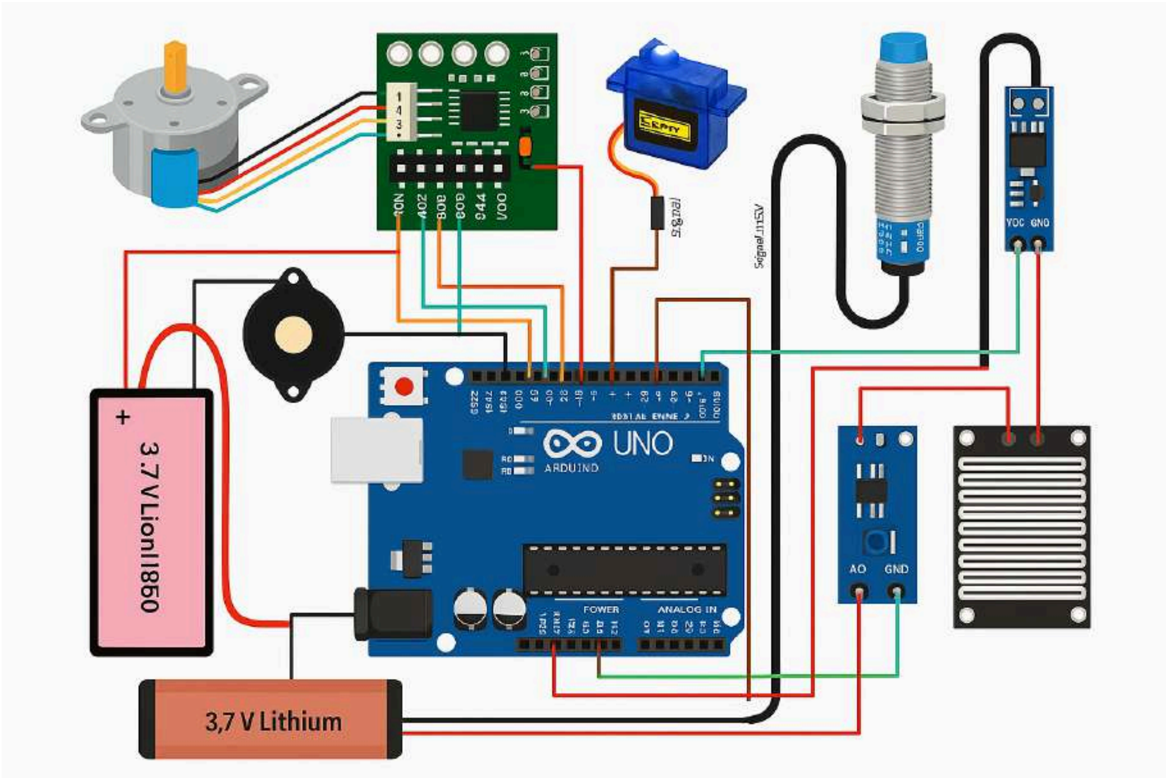

Fig. 6.2.1 Circuit Diagram of Automated Waste Segregation System

The architecture of the system, as shown in Fig. 6.2.1, illustrates the electronic connections used for automated waste segregation. The system is powered by an Arduino UNO, which coordinates the operation of all sensors and actuators. Waste detection is performed using three key sensors: an IR sensor for dry waste, a rain/moisture sensor for wet waste, and an inductive proximity sensor for metal waste.

Once a waste item is identified, control signals are sent to a servo motor to open the lid, and to a stepper motor (via the ULN2003 driver) to rotate the bin to the appropriate compartment—90° for dry, 120° for wet, and 0° for metal. The buzzer provides audible feedback upon detection. The entire system is powered using a pair of 18650 Li-ion batteries, ensuring portability and energy efficiency.

This circuit design enables efficient, automated waste handling, offering a contactless and environmentally conscious solution for everyday waste disposal.

3.3 UML DIAGRAMS

3.3.1 USE CASE DIAGRAMS

A use case diagram is a visual representation that depicts the interactions between various actors and a system, capturing how users or external entities interact with the system to achieve specific goals. It is a fundamental tool in system analysis and design, widely used in software engineering and system development. In a use case diagram, actors represent entities external to the system that interact with it, while use cases represent specific functionalities or features provided by the system. These interactions are shown by lines connecting actors to use cases, illustrating the system's scope and functionalities from a high-level perspective.

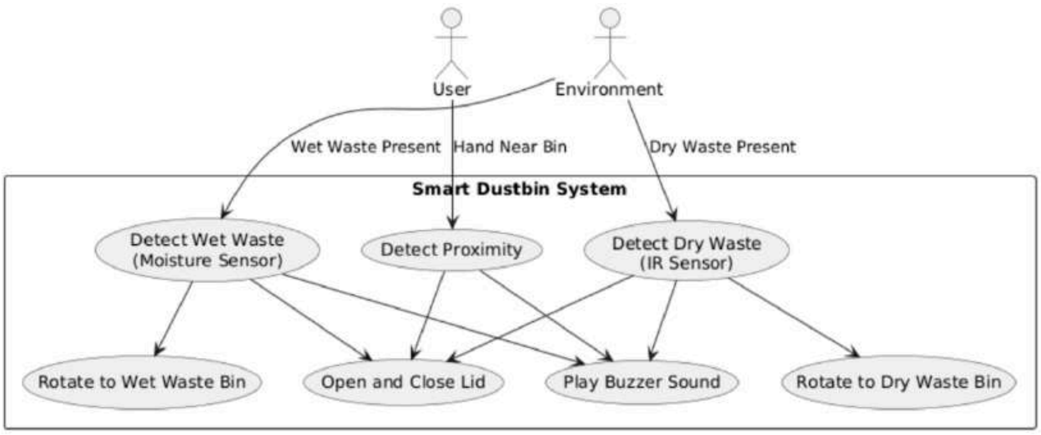

Fig. 3.3.1.1 Use Case Diagram

Actors:

1. **User:** The individual who interacts with the smart waste segregation system by disposing of waste and receiving feedback on waste classification.

2. **System:** The automated IoT-based system responsible for detecting waste type, classifying it, and managing the segregation process.

Use Cases:

1. **Detect Waste:** The system detects the presence and type of waste (dry, wet, metal) using sensors such as IR, proximity, and moisture sensors.
2. **Classify Waste:** Based on sensor input, the system classifies waste into categories for proper segregation.
3. **Segregate Waste:** The stepper and servo motors physically position and open the respective compartments to dispose of the identified waste correctly.
4. **Provide Feedback:** The system uses buzzer signals to notify the user of successful detection and segregation operations.
5. **Display System Status:** During testing, sensor readings and operational status are displayed on the Serial Monitor for debugging and monitoring.

3.3.2 CLASS DIAGRAM

A class diagram is a visual representation that models the static structure of a system, showcasing the system's classes, their attributes, methods (operations), and the relationships between them as seen in Fig. 3.3.2.1. It is a fundamental tool in object-oriented design and widely used in software engineering to define the blueprint of a system.

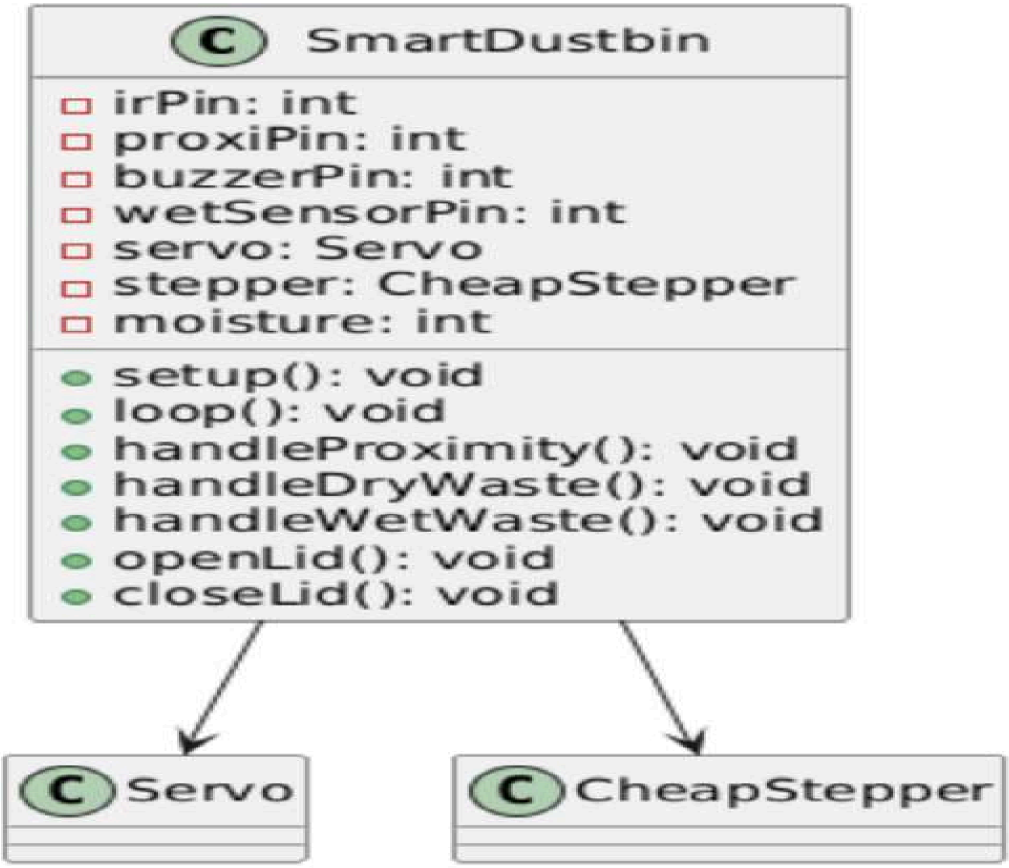

Fig. 3.3.2.1 Class Diagram

Relationships:

- **User → WasteDetectionModule:**

  The User interacts with the Waste Detection Module by disposing of waste and initiating the detection process.

  The module senses the presence and type of waste using sensors like IR, moisture, and proximity sensors.
- **WasteDetectionModule → WasteSegregationModule:**

  Upon detecting the waste type, the Waste Detection Module sends this information to the Waste Segregation Module.

  The Segregation Module controls motors (stepper and servo) to physically sort the waste into designated bins based on the classification.
- **WasteSegregationModule → NotificationModule:**

  After segregation, the Waste Segregation Module communicates with the notification Module to provide feedback.

The Notification Module activates the buzzer or visual signals to inform the user about successful sorting.

- **User → NotificationModule:**

  The User receives feedback through audio or visual alerts provided by the Notification Module during waste disposal.

System → Database (optional for logging or extended systems):

If implemented, the system can log sensor data, sorting events, and errors into a Database for monitoring or analytics.

System Flow:

1. **User Interaction:**

   The User disposes of waste, triggering the Waste Detection Module to scan and classify the waste type.
2. **Waste Detection:**

   The Waste Detection Module uses sensors to identify waste characteristics such as dry, wet, or metallic waste
3. **Waste Segregation:**

   Based on detection, the Waste Segregation Module moves the disposal flap and aligns the bin using stepper and servo motors for correct waste placement.
4. **Feedback to User:**

   The Notification Module signals the user via buzzer sounds or LED indicators about the status of detection and segregation.

3.3.3 ACTIVITY DIAGRAM FOR SMART WASTE SEGREGATION

An Activity Diagram is a type of behavioral diagram in UML used to represent the flow of control and actions in the system as seen in Fig. 3.3.3.1. It captures the sequence of operations in the waste detection, classification, and segregation workflow, illustrating how the system automates smart waste disposal.

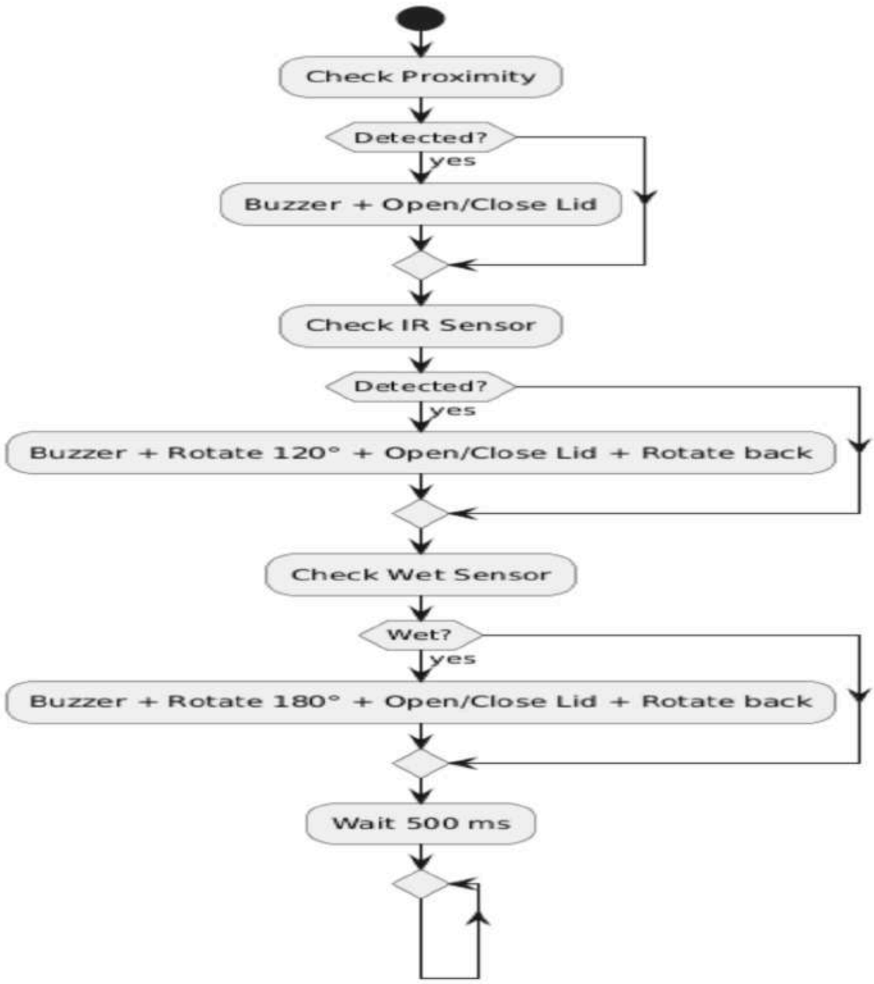

Fig. 3.3.3.1 Activity Diagram

Flow Explanation:

1. **Start System**

   The system is powered on or activated, initializing sensors and motors.

2. **User Approaches Waste Bin**

   The user brings waste near the bin's disposal area.

3. **Detect Waste Presence**

   Sensors (IR, proximity, rain drop) detect the presence of waste and start data acquisition.

4. **Classify Waste Type**

   The system processes sensor data to classify the waste as dry, wet, or metallic.

5. **Waste Detected?**
6. If waste is detected, proceed to waste segregation.
7. If no waste is detected, continue monitoring.
8. **Segregate Waste**

   Stepper motor rotates to align the disposal opening with the appropriate bin according to the waste type.

   Servo motor opens the flap to release the waste into the selected bin.

9. **Provide Feedback**

   The buzzer sounds and/or LEDs light up to indicate successful waste detection and segregation.

10. **Ready for Next Waste**

    System resets sensors and motors, ready to detect the next waste item.

11. **End of Cycle**

    User can dispose of more waste or walk away.

3.3.4 SEQUENCE DIAGRAM

A sequence diagram illustrates the flow of interactions between actors and system components over time, as seen in **Fig. 3.3.4.1**, emphasizing the sequence of messages exchanged to accomplish specific system functionalities. In this diagram, the **User** and **Sensors/Motors** represent key components of the IoT-based system, and their interactions demonstrate how smart waste segregation is achieved dynamically and in real-time.

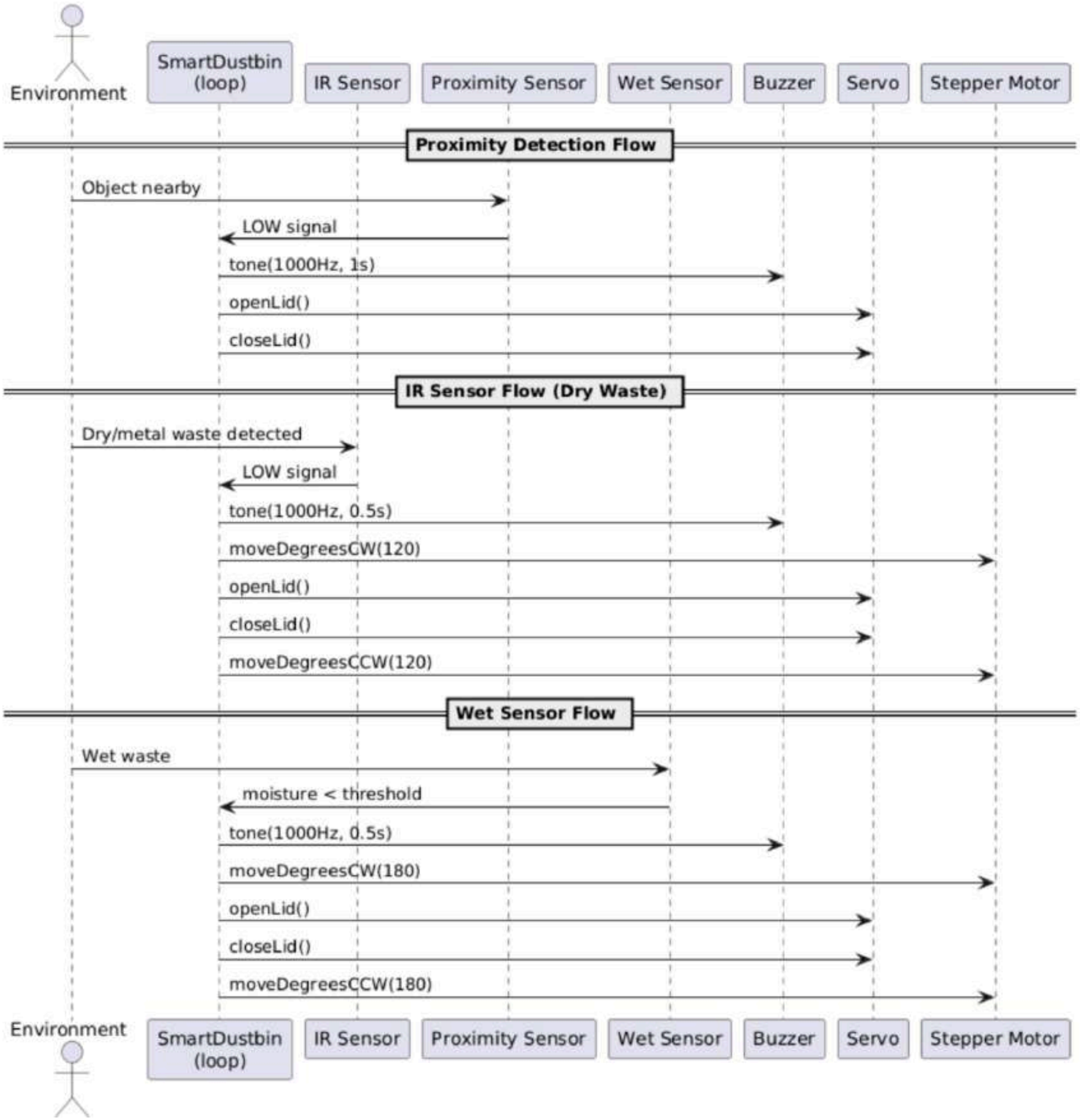

Fig. 3.3.4.1 Sequence Diagram

Key Interactions and Relationships

User and Waste Detection Module:

- **Waste Disposal Attempt**: The user drops or brings waste near the dustbin.

- **Sensor Activation**: The IR sensor, rain drop sensor, and proximity sensor are triggered to detect the presence and type of waste (wet, dry, or metallic).

Waste Detection Module and Processing Unit (Microcontroller):

- **Send Sensor Data**: The sensor data (e.g., moisture level, object distance) is sent to the processing unit.

- **Classify Waste**: The microcontroller processes the data and classifies the waste as wet, dry, or metal based on predefined logic.

Processing Unit and Waste Segregation Module:

- **Activate Motors**: Based on the classification, the processing unit commands the **stepper motor** to rotate the platform and the **servo motor** to open the flap for releasing waste into the appropriate bin.

Processing Unit and Feedback Module:

- **Trigger Feedback**: The **buzzer** is activated to notify the user that the waste has been successfully detected and segregated.

System and Serial Monitor (for Debugging):

- **Display Sensor Readings**: During development/testing, the microcontroller sends sensor values and motor actions to the serial monitor to help monitor internal system status.

System Reset:

Once segregation is complete, the system resets sensor states and motor positions, readying itself for the next waste input.

3.3.5 COMPONENT DIAGRAM

A Component Diagram is a structural diagram that depicts the organization and dependencies among major components in the IoT-Driven Smart Waste Segregation System, as illustrated in **Fig. 3.3.5.1**. Each component encapsulates specific functionalities and interacts with others to realize the automated waste classification process.

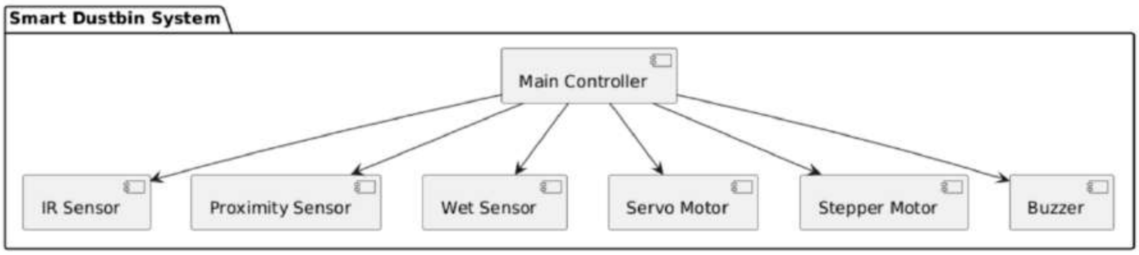

Fig. 3.3.5.1 Component Diagram

Main Components:

User Interface Module:

- Description: The physical interface where users interact with the smart dustbin system. This includes waste disposal actions and receiving visual or audio feedback via LEDs, buzzers, or displays.

Sensor Module:

- Description: Comprises various sensors such as IR sensors, rain drop sensors, and proximity sensors that detect waste presence and type (dry, wet, metallic). It collects raw data for classification.

Processing Unit (Microcontroller):

- Description: The core component that receives sensor data, processes it using embedded logic or algorithms, and coordinates waste classification by controlling motors and feedback mechanisms.

Waste Segregation Module:

- Description: Contains the mechanical parts like the stepper motor and servo motor. Responsible for physically sorting waste by rotating the dustbin and operating flaps to direct waste into appropriate compartments.

Feedback Module:

- Description: Provides real-time audible and visual feedback to the user through buzzers and LEDs, indicating successful waste detection and segregation.

Communication Interface:

- Description: Facilitates debugging and monitoring during development through serial communication, sending sensor readings and status updates to a connected monitor or PC.

Power Management Module:

- Description: Supplies and manages power to all electronic and mechanical components, ensuring stable operation of sensors, motors, and feedback devices.

3.3.6 DEPLOYMENT DIAGRAM

The Deployment Diagram illustrates the physical distribution of hardware and software components in the IoT-Driven Smart Waste Segregation System. It highlights how the system’s sensors, actuators, microcontroller, and user feedback devices interact in a real-world deployment scenario.

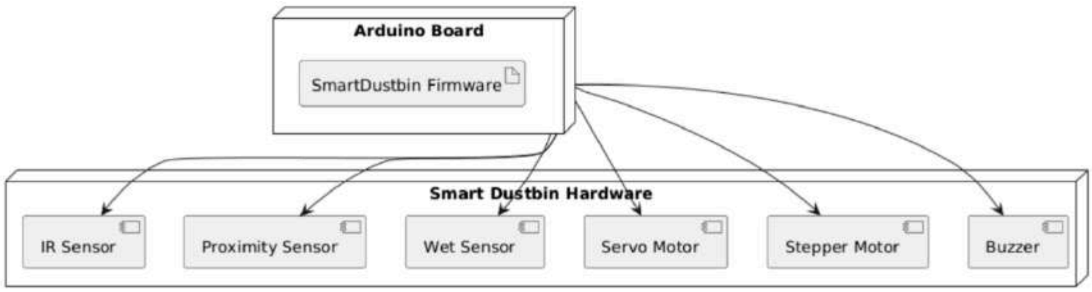

Fig. 3.3.6.1 Deployment Diagram

The deployment diagram shows the system components distributed across the following hardware nodes:

User Interface Node:

- Physical waste disposal interface where the user places waste near the sensor area.
- Includes indicators such as LEDs or buzzer for providing feedback to the user.

Sensor Node:

- Contains IR sensors, rain drop sensor, and proximity sensors to detect the presence and type of waste (dry, wet, metallic).

- These sensors continuously send data to the microcontroller for processing.

Microcontroller Node (Processing Unit):

- The main controller (e.g., Arduino or similar) that receives sensor input.
- Processes sensor data to classify the waste.
- Controls the stepper motor and servo motor to segregate the waste physically.
- Sends commands to the feedback devices to notify the user.
- Manages communication between all hardware components in real-time.

Power Supply Node:

- Provides electrical power to sensors, microcontroller, motors, and feedback modules.
- Ensures uninterrupted operation of the system components.

3.4 METHODOLOGY

Data Acquisition

Sensor Data Collection:

The system continuously collects real-time data from multiple sensors attached to the waste bin interface:

- **IR Sensor and Raindrop Sensor:** Detects and differentiates between solid (dry) and liquid (wet) waste.
- **Proximity Sensor:** Detects metallic objects or presence of waste near the bin opening.

Purpose:

This live sensor data is essential for initiating the waste classification process and deciding the correct disposal mechanism. Data accuracy ensures precise segregation and minimal human intervention.

System Processing Steps

Waste Detection:

The sensors capture the physical and environmental characteristics of the waste (dry, wet, or metallic). Sensor signals are filtered and pre-processed to reduce noise and false detection.

Classification Logic:

Based on sensor inputs, the microcontroller applies pre-defined decision rules:

- IR/Raindrop sensor triggered → classify as wet waste.

- Proximity sensor triggered with metal detected → classify as metallic waste.

- Otherwise, classify it as dry waste.

Actuation and Segregation:
Using the classification result, the system controls:

- Stepper Motor: Rotates the disposal chute to align with the correct waste bin.

- Servo Motor: Opens the flap to release waste into the corresponding compartment.

User Feedback:
Once segregation is complete, feedback is provided via:

- Buzzer: Audible signal indicating successful operation.

- LED indicators: Visual confirmation of detected waste type and segregation status.

4. CODE AND IMPLEMENTATION

4.1 CODE

SmartDustbinWasteSegregation.ino

```
#include <CheapStepper.h>
#include <Servo.h>

#define ir 5
#define proxi 6
#define buzzer 12
#define wetSensorPin A0

Servo servo1;
CheapStepper stepper(8, 9, 10, 11);

void setup() {
  Serial.begin(9600); // Start Serial Monitor
  pinMode(proxi, INPUT_PULLUP);
  pinMode(ir, INPUT);
  pinMode(buzzer, OUTPUT);

  servo1.attach(7);
  stepper.setRpm(17);

  // Initialize lid to closed
  servo1.write(180);
  delay(1000);
  servo1.write(70);
  delay(1000);
}

void loop() {
  // Proximity Sensor Logic (just open/close lid)
```

```
  if (digitalRead(proxi) == LOW) {
    Serial.println("Proximity Detected!");  // Print when proximity sensor detects
    tone(buzzer, 1000, 1000);
    servo1.write(180); delay(1000);  // Open
    servo1.write(70);  delay(1000);  // Close
  }

  // IR Sensor (Dry Waste or Metal Waste)
  if (digitalRead(ir) == LOW) {
    Serial.println("Dry Waste Detected!");  // Print when IR sensor detects dry waste or
metal
    tone(buzzer, 1000, 500);
    delay(1000);
    stepper.moveDegreesCW(120); delay(1000);
    servo1.write(180); delay(1000);
    servo1.write(70);  delay(1000);
    stepper.moveDegreesCCW(120); delay(1000);
  }

  // Wet Sensor (Soil Moisture)
  int moisture = analogRead(wetSensorPin);
  Serial.print("Moisture: ");
  Serial.println(moisture);

  if (moisture < 600) { // Wet detected
    Serial.println("Wet Waste Detected!");  // Print when wet waste is detected
    tone(buzzer, 1000, 500);
    delay(1000);

    stepper.moveDegreesCW(180); delay(1000);
    servo1.write(180); delay(1000);
    servo1.write(70);  delay(1000);
    stepper.moveDegreesCCW(180); delay(1000);
```

```
  }

  delay(500); // Small pause between checks
}
```

4.2 IMPLEMENTATION

Installing Required Tools and Libraries

- **Arduino IDE:** Download and install from https://www.arduino.cc/en/software

- **Arduino Libraries:** Install the following libraries via Library Manager or manually:

    - CheapStepper (for stepper motor control)

    - Servo (for servo motor control)

Uploading Arduino Code

- Open WasteSegregation.ino in Arduino IDE.
- Connect your Arduino board via USB.
- Select the correct board and port under Tools.
- Upload the sketch to the board.

The code handles sensor readings from IR, proximity, and wet sensors and controls motors accordingly.

Sample Arduino Code Overview

- **Sensor Pins:**

    - IR sensor: pin 5
    - Proximity sensor: pin 6
    - Wet sensor (soil moisture): analog pin A0

- **Motors:**
    - Stepper motor pins: 8, 9, 10, 11
    - Servo motor pin: 7

Buzzer: pin 12

The Arduino code reads sensors and performs:

- Lid open/close using servo motor on proximity detection
- Stepper motor rotation 120° for dry waste (IR sensor detection)
- Stepper motor rotation 180° for wet waste (wet sensor detection)
- Buzzer alerts when waste is detected

5. TESTING

5.1 INTRODUCTION TO TESTING

Testing is a critical phase in IoT project development that ensures the integrated hardware and software components function correctly and reliably. For an IoT-Driven Waste Segregation System, testing validates sensor accuracy, actuator responses, timing coordination, and alert mechanisms under different environmental conditions. This phase helps identify sensor malfunctions, motor control errors, or logical flaws in waste classification to ensure consistent performance.

In this project, testing was vital to confirm that the system accurately detects waste types (dry, wet, proximity), triggers appropriate motor actions (stepper motor rotation and servo lid operation), and provides audible feedback through the buzzer. The testing also verified the overall synchronization and stability of the system for real-time waste segregation.

Test cases were designed to verify:

- Correct sensor readings (IR, proximity, wet sensors) and threshold detection
- Accurate motor movements and lid operations per sensor input
- Proper buzzer activation on waste detection
- System behavior under no input or multiple simultaneous inputs
- Stability and responsiveness over continuous operation

5.2 TEST CASES:

Table 5.1 Test Cases of waste segregation system

Test Case ID	Test Case Name	Test Description	Expected Output	Actual Output	Remarks
TC_01	Proximity Sensor	Place object near proximity sensor	Lid servo opens and closes with buzzer alert	Lid servo opened/closed and buzzer sounded	Success
TC_02	IR Sensor Detection	Detect dry waste using IR sensor	Stepper motor rotates 120° clockwise and counterclockwise; buzzer sounds	Stepper rotated 120° CW & CCW, buzzer sounded	Success
TC_03	Wet Sensor Detection	Simulate wet waste with moisture level < threshold	Stepper motor rotates 180° clockwise and counterclockwise; buzzer sounds	Stepper rotated 180° CW & CCW, buzzer sounded	Success
TC_04	No Waste Detection	No waste present; sensors return no detection	No motor or buzzer activity	No motor/buzzer activity	Success
TC_05	Buzzer Functionality	Waste detected by any sensor	Buzzer rings for specified duration	Buzzer rang correctly	Success

TC_06	Motor Reset Position	After operation, motors return to starting position	Stepper motor rotates back to initial position; servo lid closed	Motors reset properly	Success
TC_07	Power Cycling	Restart the system with sensors active	System initializes, motors at rest, sensors ready	System initialized correctly	Success
TC_08	Continuous Operation	Run system continuously for 1 hour	No motor jams, sensor misreads, or system crashes	System stable and responsive	Success

6. RESULTS

Fig 6.1 Waste Segregation System

Fig 6.1 shows the model of the system, where the upper cup is used to throw the waste, and the three cups below represent the segregation of waste into three categories: metal, wet, and dry. The system detects the type of waste using IR (dry), moisture (wet), and metal sensors. Once identified, the bin rotates to the correct section using a stepper motor, and the lid opens via a servo motor. A buzzer beeps to confirm successful segregation, ensuring efficient and contactless waste disposal.

Fig 6.2 Throwing Metal Waste

From Fig 6.2, the waste material is thrown into the upper cup, where sensors first detect its type—dry, wet, or metal. Based on the sensor data, the system initiates appropriate rotation and lid opening for proper segregation.

Fig 6.3 Detected Metal Waste

From Fig 6.3, it is observed that when the detected waste is metal, the system does not rotate the bin. Instead, it directly opens the lid and disposes the waste into the designated metal compartment.

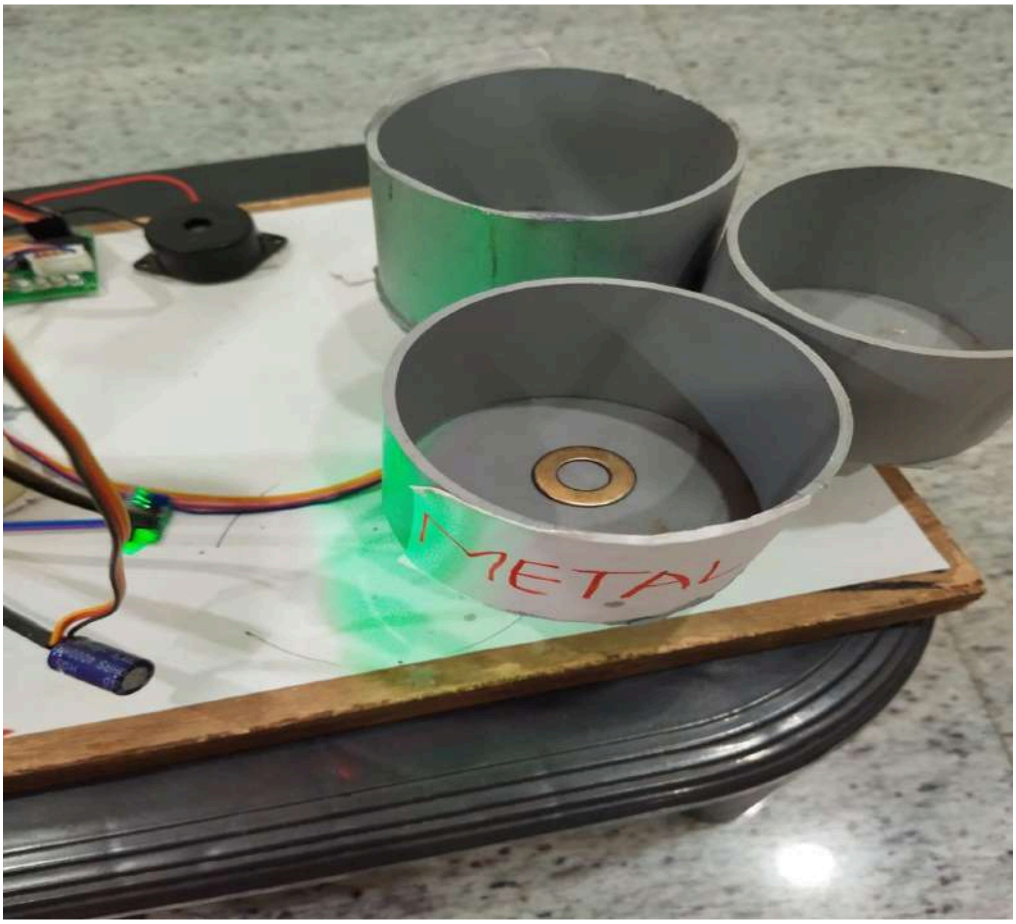

Fig 6.4 After Detection of Metal Waste

From Fig 6.4, after the waste is detected as metal, the lid opens and the waste is disposed into the metal compartment. Since no rotation is required, the system returns to its original state, ready for the next input.

Fig 6.5 Throwing Dry Waste

From Fig 6.5, the waste material is thrown into the upper cup, where sensors first detect its type—dry, wet, or metal. Based on the sensor data, the system initiates appropriate rotation and lid opening for proper segregation.

Fig 6.6 Detected Dry Waste

From Fig 6.6, it is observed that when the detected waste is dry, the system rotates the bin to the dry compartment. Then, the lid opens, and the waste is disposed of properly before the bin returns to its original position.

Fig 6.7 After Detection of Dry Waste

From Fig 6.7, after the waste is detected as dry, the system rotates the bin 90 degrees to align with the dry waste compartment. The lid then opens for disposal, and once the waste is dropped, the bin returns to its original position, ready for the next cycle.

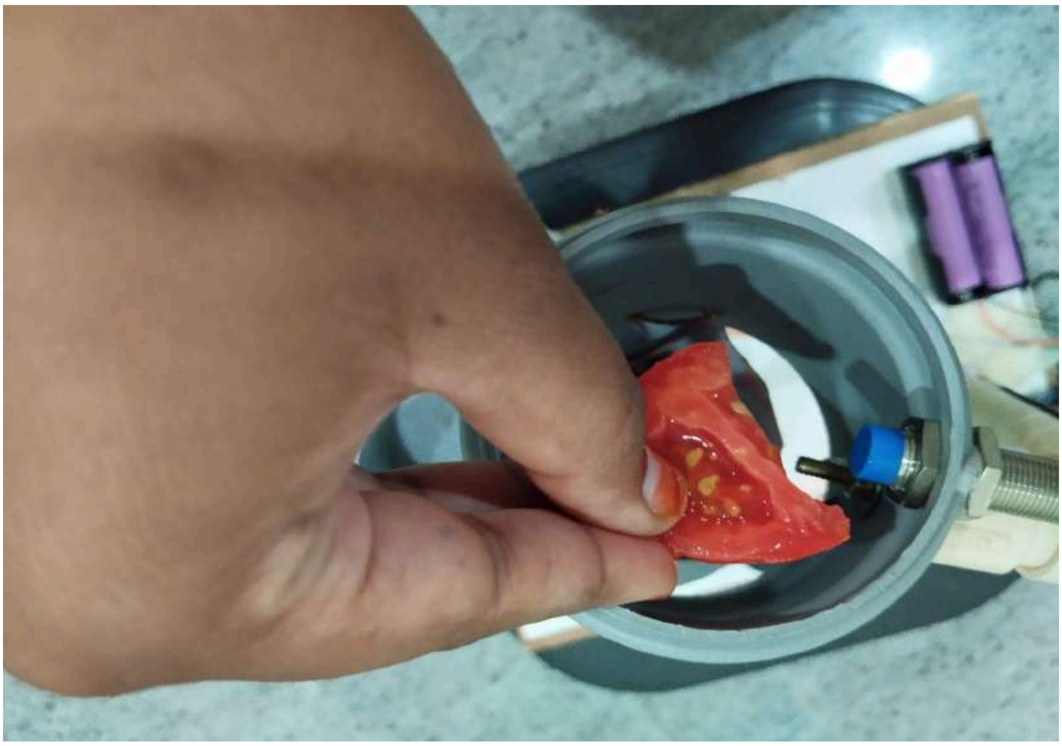

Fig 6.8 Throwing Wet Waste

From Fig 6.8, the waste material is thrown into the upper cup, where sensors first detect its type—dry, wet, or metal. Based on the sensor data, the system initiates appropriate rotation and lid opening for proper segregation.

Fig 6.9 Detected Wet Waste

From Fig 6.9, it is observed that when the detected waste is wet, the system rotates the bin 120 degrees to align with the wet waste compartment. Then, the lid opens, and the waste is disposed of properly before the bin returns to its original position.

Fig 6.10 After Detection of Wet Waste

From Fig 6.10, after the waste is detected as wet, the system rotates the bin 120 degrees to align with the wet waste compartment. The lid then opens for disposal, and once the waste is dropped, the bin returns to its original position, ready for the next cycle.

Fig 6.11 After 3-categories segregation

From Fig 6.11,After detection and classification, the system successfully segregates the waste into three distinct compartments: dry, wet, and metal. Each type is directed to its designated section through controlled rotation and lid operation. This ensures clean, efficient, and automated waste management

7. CONCLUSION AND FUTURE ENHANCEMENTS

7.1 CONCLUSION

The IoT-Driven Waste Segregation System successfully demonstrates the effective integration of sensor technologies, microcontroller-based control, and actuator mechanisms to automate waste classification and disposal. By utilizing IR, proximity, and moisture sensors, the system accurately identifies different types of waste—dry, wet, and recyclable—and responds with precise motor movements and lid operations to segregate the waste appropriately.

A key achievement of this project is its real-time responsiveness and reliability in diverse environmental conditions, ensuring seamless waste segregation with minimal human intervention. The use of a buzzer as auditory feedback further enhances user awareness during waste disposal, improving the overall user experience.

This automated solution not only promotes better waste management practices but also supports sustainability by encouraging correct waste segregation at the source. Its modular and scalable design enables future enhancements, such as integration with cloud platforms for data analytics or adding more sensor types for advanced waste categorization.

Overall, the system is practical, cost-effective, and user-friendly, making it a promising tool for smart waste management in homes, offices, and public spaces where efficient and hygienic disposal is critical.

7.2 FUTURE ENHANCEMENTS

While the current IoT-Driven Waste Segregation System effectively automates waste classification, several enhancements can further improve its functionality, scalability, and user experience:

- **Cloud Connectivity and Data Analytics:** Integrate IoT cloud platforms (such as AWS IoT or Azure IoT) to collect real-time data on waste segregation patterns, enabling advanced analytics and reporting for households or municipalities.

- **Mobile App Integration:** Develop a mobile application that notifies users about waste disposal schedules, system status, and maintenance alerts, improving user interaction and system monitoring remotely.
- **Expanded Sensor Suite:** Incorporate additional sensors like gas sensors for detecting hazardous or compostable waste, or weight sensors to measure waste quantity, enhancing the accuracy and scope of segregation.
- **Machine Learning for Waste Classification:** Use image processing and machine learning algorithms with cameras to improve identification of waste types beyond basic sensor detection, enabling smarter segregation.
- **Solar-Powered Operation:** Add solar panels or energy harvesting techniques to make the system more sustainable and suitable for outdoor or remote locations without frequent power supply.

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