Eco-Friendly Smart Waste Segregation

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Abstract - *The goal of this project is to create an environmentally sustainable and effective smart waste segregation system. The system is constructed with an STM32 Blue Pill microcontroller, an IR sensor, a moisture sensor, a servo motor, and a 16x2 LCD display in order to automate waste segregation. The moisture sensor measures the amount of moisture in the waste, while the infrared sensor detects waste. After analyzing the sensor data, the STM32 microcontroller instructs the servo motor to deposit the waste in the appropriate collection bin. The LCD display provides real-time information about the type of waste and system status. The proposed system reduces the amount of manual labor, improves segregation accuracy, promotes proper recycling practices, and helps maintain cleanliness. By providing an economical, dependable, and eco-friendly solution for residences, workplaces, educational institutions, and public areas through the automation of waste classification and disposal, the project advances sustainable waste management and environmental preservation.*

Key Words: Eco-Friendly Technology, STM32, Sensor Based Automation, Segregation, Waste Management.

1. INTRODUCTION

The Waste Management System is a modern waste management solution that allows wet and dry waste to be automatically separated at the source. Fast urbanization and population growth have resulted in a sharp increase in waste production, making recycling and proper waste disposal more important than ever. But waste is often disposed of carelessly, contaminating the environment and making recycling difficult.

This system uses sensors, a microcontroller, and an automated mechanism to identify the type of waste and route it into the appropriate compartment. By automatically separating waste, the system lowers the possibility of contamination between various waste types, improves recycling efficiency, and minimizes manual labor. The Smart Waste Segregation System supports sustainable waste management practices, promotes cleaner environments, and protects the environment.

Homes, workplaces, schools, and public areas can all use it when efficient waste management is required. Despite the fact that waste segregation is an essential step in effective waste management, wet and dry waste are often disposed of together. This increases environmental contamination, complicates recycling and waste processing, and adds to the workload of sanitation personnel. Given the daily increase in waste production, manual segregation is labor-intensive, time-consuming, and often ineffective.

To address these issues, an automatic waste segregation dustbin is recommended. The system automatically separates dry waste from wet waste using sensors and a control mechanism. By separating waste at the source, the dustbin reduces human labor, boosts recycling efficiency, and encourages proper waste disposal practices. This strategy aims to enhance hygiene, reduce its detrimental effects on the environment, and promote a more sustainable waste management system.

The following are the goals of the eco-friendly smart waste segregation solution.

- To use an infrared sensor to automatically detect the presence of waste and start the segregation process.
- To accurately separate waste by using a moisture sensor to determine and categorize waste as wet or dry.
- To use an automated sorting system to increase waste management efficiency and decrease manual labor.
- To encourage recycling and environmental cleanliness by making sure waste is properly disposed of and separated at the source.

2. LITERATURE SURVEY

Zhou et al. (2020) proposed an Intelligent Sorting Trash Dustbin Based on STM32 for automatic waste segregation. The system employs an STM32 microcontroller, ultrasonic sensors, speech recognition, and servo mechanisms to classify and dispose of waste automatically. The study demonstrated that the STM32-based embedded system provides reliable real-time operation, reduces manual intervention, and improves waste management efficiency. The authors concluded that intelligent embedded systems can significantly contribute to sustainable waste management practices [1].

White et al. (2020) introduced WasteNet, a deep learning-based waste classification system for smart bins. The proposed model utilizes convolutional neural network

(CNNs) deployed on edge devices to classify waste into computing. The experimental results achieved approximately 97% classification accuracy, demonstrating the feasibility of edge AI for real-time waste segregation [2].

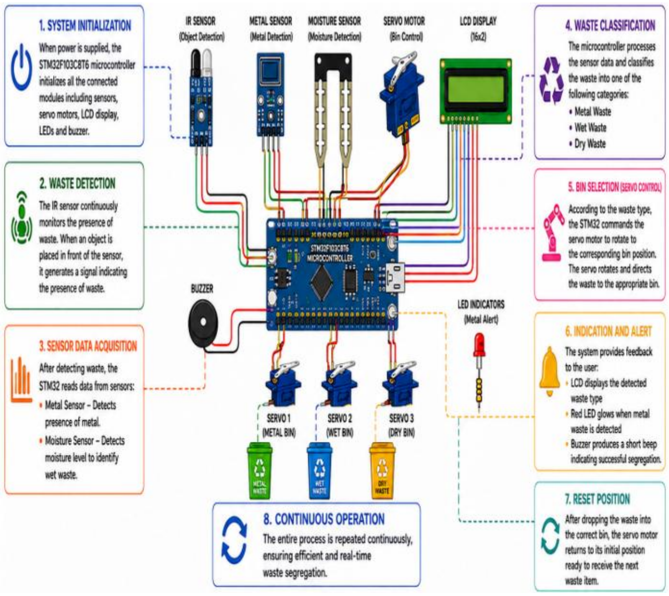

Fig -1: Block Diagram for Smart Waste Segregation System

Mohammed Aarif et al. (2022) developed a Smart Bin using Deep Learning and IoT for sustainable smart cities. The proposed system integrates image processing, IoT communication, and intelligent waste classification to automate segregation and monitor waste collection. The study concluded that combining deep learning with IoT significantly enhances segregation accuracy and supports efficient municipal waste management [3].

Shenoy et al. (2022) proposed a Smart Waste Segregation System using Convolutional Neural Networks. The system employs a Pi camera, CNN algorithm, robotic arm, and ultrasonic sensor to classify waste into different categories automatically. Experimental results indicated that image-based classification improves segregation accuracy compared with conventional sensor-only systems [4].

Bakar et al. (2023) presented a Low-Cost IoT-Based Garbage Segregation and Monitoring System using Raspberry Pi and multiple sensors. The proposed prototype automatically segregates waste while monitoring the fill level of bins and providing remote notifications. The authors reported that the low-cost IoT approach improves waste
Lingaraju et al. (2023) proposed an IoT-Based Waste Segregation with Location Tracking and Air Quality Monitoring for smart cities. Their system integrates waste segregation with environmental monitoring and cloud communication. The study demonstrated that IoT-based monitoring enables real-time waste management, reduces collection delays, and improves urban sanitation [6].

Bhowmick et al. (2024) developed a Smart Waste Segregation System using CNN and Arduino. The proposed system captures waste images using a camera and classifies them with the EfficientNetB0 deep learning model before directing waste into the corresponding bin. The authors reported improved classification accuracy and contactless waste disposal suitable for public environments [7].

Bhuiyan et al. (2026) proposed an STM32-Based SmartWaste Bin for Hygienic Disposal Using Embedded Sensing and Automated Control. The system integrates an STM32 microcontroller, ultrasonic sensors, servo motor, and OLED display to provide contactless waste disposal and real-time waste-level monitoring. Experimental evaluation showed fast response time, stable sensing performance, and reliable operation in public and household environments [8].

Recent studies on intelligent waste management emphasize that integrating embedded controllers, sensors, IoT, and artificial intelligence can significantly improve waste segregation accuracy, reduce manual labour, and enhance recycling efficiency. Although AI-based methods provide higher classification accuracy, sensor-based embedded systems remain a cost-effective and practical solution for educational institutions, homes, and small-scale applications due to their simplicity and low implementation cost [9].

3. METHODOLOGY

The Eco-Friendly Smart Waste Segregation Solution uses a microcontroller and sensors to automatically identify and categorize waste. When waste is added to the system, the infrared sensor detects its presence and starts the process. The moisture sensor then measures the moisture content of the waste to determine whether it is wet or dry. After receiving and processing the sensor data, the STM32 Blue Pill microcontroller identifies the type of waste. Based on the classification outcome, the microcontroller controls the servo motor to direct waste into the appropriate collection bin. During this process, LED indicators provide visual feedback while the 16x2 LCD display shows the detected waste type

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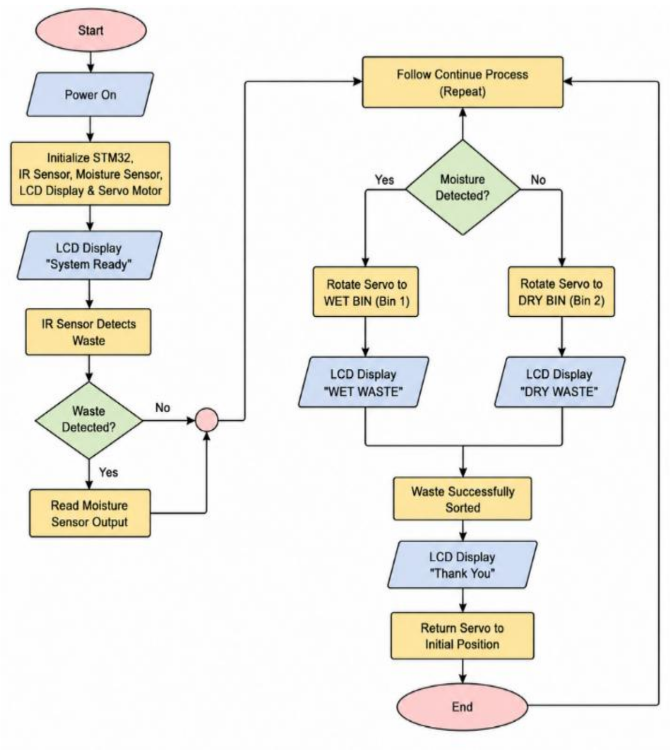

Fig -2: Flow of process for Smart Waste Segregation System

and system status. This automated approach promotes efficient and ecologically friendly waste management, reduces manual labor, and improves waste segregation accuracy.

3.1 Flowchart

Turning on the system and initializing the STM32 microcontroller, IR sensor, moisture sensor, LCD display, and servo motor are the first steps in the Eco-Friendly Smart Waste Segregation Solution flowchart illustrated in Fig 2. The IR sensor keeps an eye out for waste all the time. The LCD shows "WASTE DETECTED" when waste is found, and the moisture sensor begins to examine the waste. The LCD shows "ANALYSING" while this is going on.

The STM32 microcontroller receives the sensor data and uses the moisture level to determine whether the waste is wet or dry. The LCD shows "WET WASTE" and the servo motor turns in the direction of the wet waste bin if the waste is determined to be wet. When the waste is determined to be dry, the LCD shows "DRY WASTE" and the servo motor rotates in the direction of the dry waste bin. The servo motor returns to its starting position and the system are prepared to handle the next waste item once the waste has been placed into the proper bin. Continuous repetition of this cycle guarantees effective and automated waste segregation.

3.2 Software Implementation

The software for the Automatic Waste Segregation System was developed in Embedded C and implemented on the STM32F103C8T6 microcontroller. The system was simulated in Proteus, where Logic Toggle switches were used to emulate the outputs of the IR sensor, metal sensor, and moisture sensor. The microcontroller continuously reads the logic states of these inputs and executes a classification algorithm to identify the waste type. Based on the combination of input signals, the waste is categorized as metal, wet, or dry. The classification result is displayed on a 16×2 LCD, while a buzzer and LED indicators provide visual and audible feedback. The use of Logic Toggles in Proteus enables easy testing of different sensor conditions and verification of the control logic before implementing the system with actual hardware sensors. The Software implementation is shown in Fig.3.

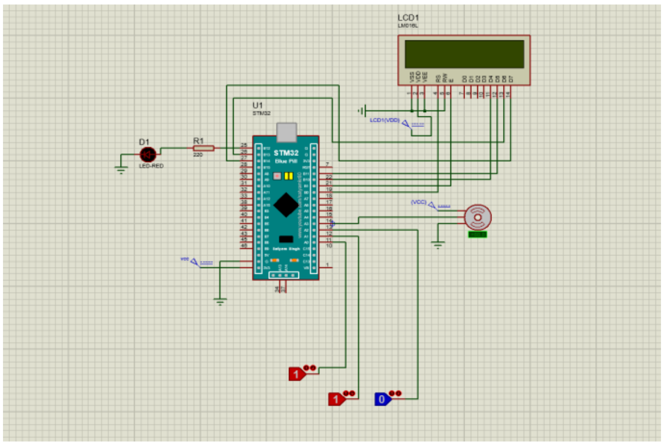

Fig -3: Software Implementation of Smart Waste Segregation System

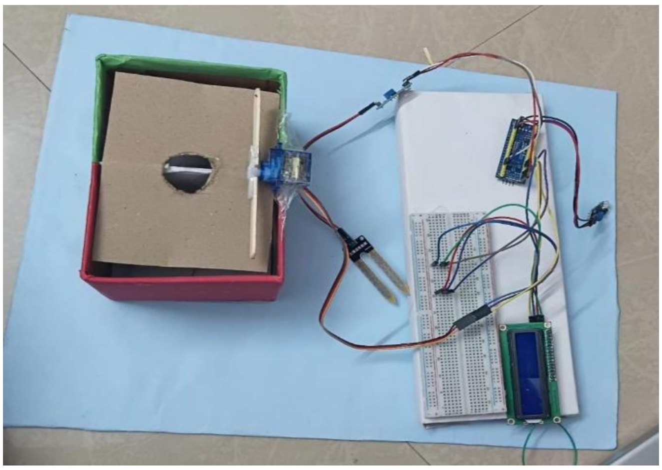

Fig -4: Hardware Implementation of Smart Waste Segregation System

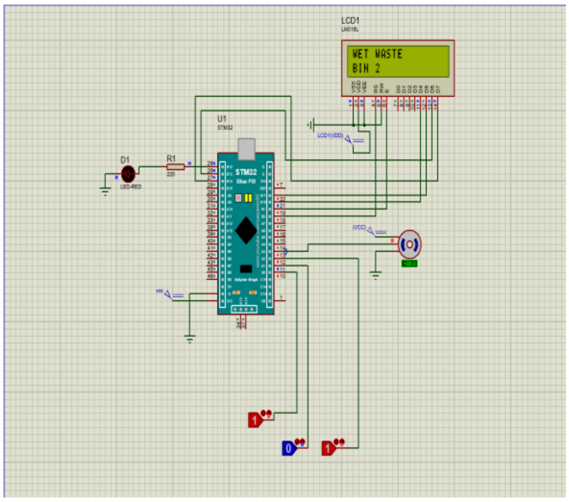

Fig -5: Software Implementation output

3.3 Hardware Implementation

An STM32 Blue Pill microcontroller, an IR sensor, a moisture sensor, a servo motor, a 16x2 LCD display, and an LED indicator are used to implement the Eco-Friendly Smart Waste Segregation Solution. Waste is detected by the infrared sensor, and its moisture content is determined by the moisture sensor. The STM32 processes the sensor data and drives the servo motor to direct the waste into the appropriate bin. "WASTE DETECTED" and "ANALYSING" are among the messages displayed on the LCD. "DRY WASTE" or "WET WASTE" to illustrate the system's condition. After segregation, the servo motor returns to its initial position, setting the system up for the next waste item.

This implementation offers an automated and effective waste segregation solution. Figure 1 depicts the Eco-Friendly Smart Waste Segregation Solution's hardware implementation. includes an IR sensor, moisture sensor, servo motor, 16x2 LCD display, LED, STM32 Blue Pill microcontroller, and auxiliary parts like a 220 Ω resistor, breadboard, and power supply. As the primary controller, the STM32 communicates with every peripheral. When waste is detected, the infrared sensor signals the microcontroller. The STM32 receives the corresponding input from the moisture sensor, which determines the moisture content of the waste it detects. The servo motor rotates and directs waste into the proper bin under the microcontroller's control based on sensor data. System messages like "WASTE DETECTED" and

"ANALYSING" are displayed on the 16x2 LCD. "WET WASTE" and "DRY WASTE," while the LED shows the system's operational state. Waste segregation is made effective and automatic by connecting all parts in accordance with the circuit design and using a regulated supply. The Hardware implementation is shown in Fig.4.

4. RESULTS OF SOFTWARE AND HARDWARE

The embedded program created for the STM32 microcontroller creates the software output. The software continuously monitors sensor inputs, processes the information, and modifies the servo motor. "SYSTEM READY," "WASTE DETECTED," and "ANALYSING" are among the messages displayed on the LCD during operation. "WET WASTE" and "DRY WASTE," ensuring proper waste segregation and providing the user with quick feedback.

The hardware output of the Eco-Friendly Smart Waste Segregation Solution is produced by a combination of the STM32 microcontroller, sensors, servo motor, LCD display, and LED indicator. After the IR sensor detects the waste and the moisture sensor determines its moisture content, the STM32 analyzes the data to determine whether the waste is wet or dry. The waste's type and status are displayed on the LCD, and depending on the result, the servo motor rotates to direct the waste into the appropriate bin. In Fig. 5 and Fig. 6, the software and hardware output are displayed respectively.

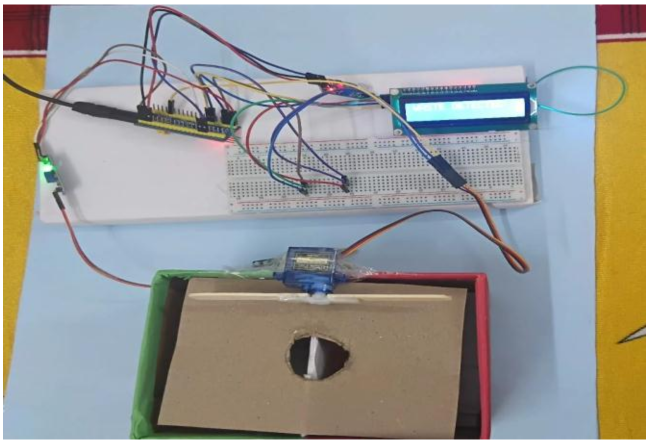

Fig -6:: Hardware Implementation output

5. CONCLUSION

By automating the waste segregation process, the Eco-Friendly Smart Waste Segregation Solution was successfully developed to improve waste management effectiveness. The system recognizes, classifies, and separates waste into wet and dry categories using an infrared sensor, moisture sensor, servo motor, LCD display, LED indicator, and STM32 Blue Pill microcontroller. The infrared sensor detects waste, and the moisture sensor measures the amount of moisture in it. By interpreting the data from the sensor readings, the STM32 microcontroller controls the servo motor to move the waste into the appropriate bin. "WASTE DETECTED" and "ANALYSING" are examples of real-time data displayed on the LCD display. Users can easily monitor system performance with "DRY WASTE" and "WET WASTE.". By putting this system into place, manual labor is reduced, segregation accuracy is improved, recycling is efficiently supported, and environmental sustainability and cleanliness are promoted.

The project is simple to use, reliable, reasonably priced, and suitable for use in homes, offices, public areas, and educational institutions. By automating waste segregation at the source, the system encourages proper waste disposal practices, reduces environmental pollution, and makes communities cleaner, greener, and smarter.

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