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Smart Waste Sorter-Automatic Waste Segregation System

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Abstract—Today, the rapid increase in the population and the urban development has led to an increase in the level of solid wastes in India. Managing this waste efficiently has now become a major challenge for the modern societies. One of the main problem in waste management is the lack of segregation at the source. This leads to environmental pollution, health risks and inefficient recycling process. To overcome such issues, this project presents an Automated Waste classification and monitoring system powered by IoT. It automatically separates waste into 3 categories that is wet, dry and metallic waste. The system uses ESP32 microcontroller with sensors such as IR sensor, Raindrop sensor, Proximity sensor. A stepper motor is used to move the position of the bins, while a servo motor is used to control the waste inlet flap. This automated system reduces the manual effort required for segregation and improves waste management efficiency, making it suitable for homes, campuses as well in public areas.

Keywords—IoT, Waste Segregation, ESP32, Servo motor, Stepper motor

I. INTRODUCTION

Waste Management has become a major issue in modern cities due to rapid population growth and increasing urbanization. Every day, large amounts of solid waste come from households, industries, institutions and public areas. Improper and handling of these waste can cause environmental pollution, health risks and poor recycling processes. One key problem in traditional waste management systems is the lack of proper sorting of waste at the source. In many areas, waste such as organic materials, recyclables and metal objects are mixed in the same bin. This makes recycling harder and increases the amount of waste that goes into the landfills. Sorting waste by hand takes a lot of time, requires many workers, and can be unsafe for sanitation workers who may come into contact with harmful materials. Therefore, a need exists for an automated system that can sort different type of waste without requiring human involvement. Recent advancements in Internet Of Things (IoT) technology and embedded systems have opened the door to smart solutions for waste management. IoT systems use sensors, microcontrollers, and networks to collect send data in real time. By integrating sensors and automated mechanisms, waste can be detected, classified and monitored effectively. The proposed project introduces a smart waste sorting and monitoring system that automatically divides waste into categories such as dry, wet and Metallic waste. The sensors are connected to Arduino the Arduino is connected to ESP32 microcontroller. The motor mechanism directs the waste into correct bin, ensuring proper sorting. The system allows for real-time monitoring through an IoT platform. This improves the waste collection efficiency. By combining automation, sensors and IoT technology, the proposed system seek to enhance waste sorting, lessen manual work, and promote sustainable waste management practices for smart cities and modern communities.

II. LITERATURE SURVEY

Waste management is getting really tough these days because cities are growing so fast and people are producing trash all the time. It is not about just about throwing stuff away anymore, its about sorting it properly to recycle and all that. Researchers have been trying out different ways with tech like sensors and automation to make segregation easier, cutting down on the manual work that takes forever. Islam et al. (2026) proposed a smart waste segregation and monitoring system that integrates multiple sensors

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with an ESP32 microcontroller. Their system used infrared, moisture, metal detection, and ultrasonic sensors to identify different waste materials and monitor bin levels. Mechanical components such as stepper and servo motors were used to direct waste into separate containers. The system also included IoT connectivity that allowed users to monitor waste levels remotely through an online platform. A study published in IJERT (2025) presented an automated waste segregation system that utilized sensor technology to classify waste materials. In this system, moisture sensors and metal detectors were used to analyze the properties of waste. A microcontroller processed the sensor data and controlled a motorized mechanism that directed the waste to appropriate bins. The researchers highlighted that such automated solutions can improve recycling efficiency and reduce the need for manual sorting. A study published in the International Journal of Advanced Computer Science and Applications (2025) focused on the use of IoT - based technologies for waste segregation in smart city environments. The system combined sensor-based detection with cloud connectivity to monitor waste collection processes. Data from the sensors was transmitted to a remote platform where authorities could monitor waste levels and optimize waste management operations. Megalan Leo et al. (2022) presented an automated waste segregation and monitoring system that utilized sensors along with IoT-based alert mechanisms. The developed prototype was able to separate waste effectively and provide remote monitoring capabilities. However, the system encountered certain limitations such as issues with mechanical alignment, difficulties in scaling the system for larger applications, and higher costs associated with actuation components. Pires et al. (2025) came up with this IoT setup in 2025, basically for keeping an eye on city trash bins in real time. They used sensors and stuff like that to check how full the bins get. It sends the details up to a cloud so the city can plan better pickups, you know, to make waste collection not such a mess. Kadalagere Lingaraju et al. (2023) came up with this IoT system for sorting waste. It had GPS to track locations, and it also kept an eye on air quality somehow. That part seems pretty useful for bigger setups. The proposed framework was designed to support smart city infrastructure by enabling environmental monitoring and waste management through connected technologies. However, the system mainly focused on centralized monitoring and was not specifically intended for compact and cost-effective waste segregation at the source level. From the review of existing studies, it can be observed that many previously developed systems tend to concentrate on either keeping an eye on waste or sorting it. Very few manage to do both in a small, affordable setup right where the waste is generated. While using cameras can make waste identification more accurate, it usually makes the system pricier and more complicated. Systems that only monitor how full bins are helpful for tracking, but they don't automatically separate different types of waste. To address these issues, our system combines sensor-based waste sorting with IoT monitoring in one package. It can sort waste into categories like dry, wet, and metallic using various sensors. The detected sensor data is sent to the IoT/cloud platform, where the waste type—wet, dry, or metallic—is identified and monitored in real time.

TABLE II

Existing Systems	Limitations Identified	Improvisation in Our Project
Use of IR and Ultrasonic sensors for waste detection.	Cannot accurately differentiate between all waste types.	Integration of IR, proximity, moisture, and metal sensors for better classification.
IoT-based monitoring using MQTT.	Power consumption and connectivity issues.	Optimized MQTT communication with stable power supply.
Basic mechanical sorting mechanisms.	Servo misalignment and inaccurate bin positioning.	Improved servo alignment and precise positioning mechanism.
Simple bin-level monitoring systems.	Only detects bin fill level, not waste type.	Multi-level detection with waste-type classification.

III. METHODOLOGY

1. CIRCUIT DIAGRAM

The circuit design of the proposed system is shown below:-

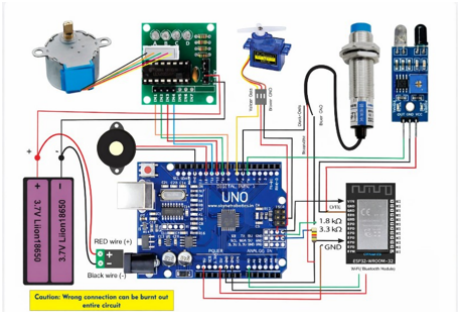

Fig. 1. Circuit Diagram

1. FLOW CHART

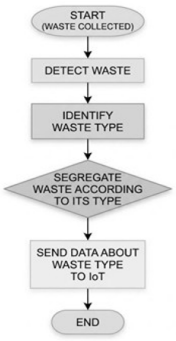

Fig. 2. Flowchart

1. BLOCK DIAGRAM

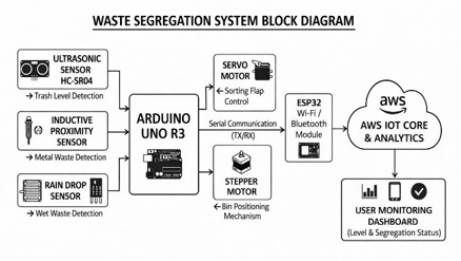

Fig. 3. Block Diagram

1. HARDWARE COMPONENTS

The below shown hardware components are the major components used in the project along with their roles explained in Smart Waste Sorter- Automatic Waste Segregation System. A. Arduino Uno Board

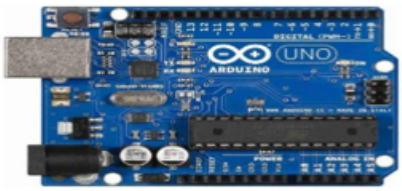

Fig. 4. Arduino Uno Board

In our system, the acts as the main regulator of the system and processes the data received from different sensors. It helps to analyze the sensor inputs to determine the type of waste such as wet, dry, or metallic. Grounded on this information, the Arduino controls the motors and other components to direct the waste into the appropriate bin.

B. ESP32 Microcontroller

Fig. 5. ESP32 Microcontroller

The acts as the main processing and communication unit of the system. It grabs input data from the sensors and processes it to determine the type of waste such as wet, dry, or metallic. The processed information is then transmitted to the IoT/cloud platform through the ESP32 using it's built-in Wi-Fi for real-time monitoring.

C. Raindrop Sensor

Fig. 6. Raindrop Sensor

The is used to detect the presence of moisture in the waste. In the system, it helps identify wet waste by sensing water content on the waste surface. When moisture is detected, the signal is sent to the controller to classify the waste as wet waste and direct it to the appropriate bin. It has analogue output and operates at 5v DC Voltage.

D. IR Sensor

Fig. 7. IR Sensor

The is used to detect the presence of waste in the system. When an object is placed near the sensor, it senses the reflected infrared light and sends a signal to the controller. This helps the system identify when waste is inserted, so that the segregation process can begin. The range of this sensor is 0-10 cm, and operates at 5v DC Voltage.

E. Proximity Sensor

Fig. 8. Proximity Sensor

The is used to detect the presence of metallic waste in the system. It identifies metal objects without direct contact by sensing changes in the electromagnetic field. Once the metal is detected, the sensor sends a signal to the controller, which then directs the waste to the metal waste bin This sensor works best when objects are between 3 and 9 millimetres away, and it runs on a DC voltage range of 7 to 37 volts.

F. Stepper Motor (28BYJ-48) with ULN2003 Deiver

Fig. 9. Stepper Motor

The is used to rotate the waste sorting mechanism in the system. It moves in precise steps to position the waste towards the correct bin based on the sensor detection. This controlled movement helps ensure accurate segregation of dry, wet, and metallic waste. It has Step Angle about 5.6°, approximately 2000–2050 steps per revolution, with a rotational speed close to 10 rpm.

G. Servo Motor

Fig. 10. Servo Motor

The Servo Motor is used to control the opening and closing of the waste inlet flap in the system. It rotates to a specific angle based on the signal from the controller. This controlled movement helps guide the waste towards the appropriate sorting mechanism for proper segregation. Its operating dc voltage is 4-6 V and Rotates from 0°-180°.

1. SOFTWARE COMPONENTS

The software tools that we have used in this project that are essential for monitoring, programming and testing the system. A. AWS IOT MQTT TEST CLIENT OUTPUT

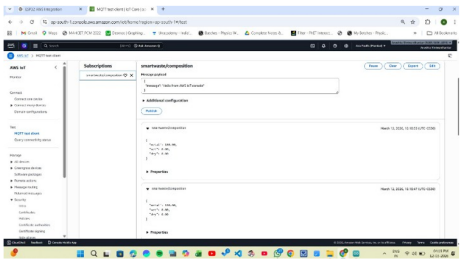

Fig. 11. AWS Output

B. OUTPUT RECORDED WHILE TESTING

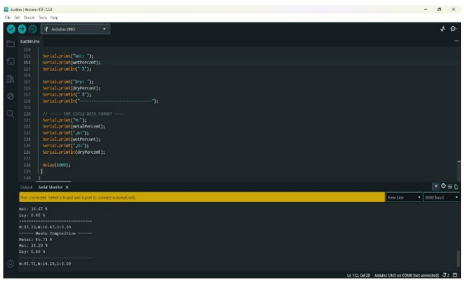

Fig. 13. Output on Serial Monitor

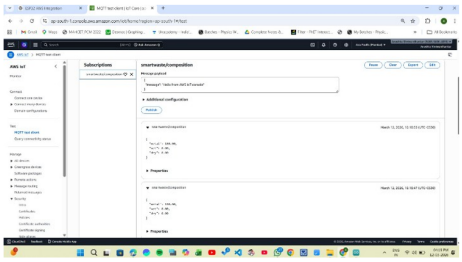

Fig. 12. AWS Output

IV. FINAL DESIGN

Fig. 14. Prototype of Waste Segregation System

V. EXPERIMENTAL SETUP

The project prototype Smart Waste Sorter-Automatic waste segregation system is built using sensors, motors, arduino uno and ESP32 microcontroller.This system sorts your trash on its own.You drop in your waste, and it figures out what kind it is, the drops on its own into the correct bin. At the same time, it sends updates to an IoT platform, so everything's tracked. Here's how it works:

- Main Controller

The acts as the central control unit of the system. It receives input signals from all the sensors, processes the data, and controls the motors used for waste segregation. The ESP32 also enables wireless communication by transmitting waste information and bin status to the IoT cloud platform through Wi-Fi.

- Waste Detection Section

At the top of the prototype, a waste inlet section is provided where users can dispose of waste materials. Several sensors are placed near this inlet to detect the characteristics of the waste. An detects the presence of waste when an object is inserted into the system. A identifies wet waste by detecting the presence of moisture. A proximity sensor is used to detect metallic objects. Based on the sensor data, the system classifies the waste into dry, wet, or metallic categories.

- Sorting Mechanism

After identifying the waste type, the controller activates the sorting mechanism. A servo motor controls the opening and closing of the inlet flap to guide the waste towards the sorting section. A stepper motor rotates the bin platform so that the appropriate bin is positioned under the waste inlet. The precise step movement of the stepper motor ensures accurate alignment of the bins.

- Waste Collection Bins

The prototype consists of three separate bins designed to collect different categories of waste: dry waste, wet waste, and metallic waste. Once the correct bin is positioned under the inlet, the waste is automatically dropped into the corresponding bin.

- IoT Monitoring System

The sensors used in the system are connected to the Arduino board, which collects and processes the sensor data. The Arduino then communicates this information to the ESP32 microcontroller, which acts as the IoT communication module. The ESP32 transmits the processed data to the IoT/cloud platform through Wi-Fi, where the dashboard displays the type of waste detected, bin fill levels, and alerts when a bin becomes full.

- Prototype Testing

The prototype was tested using different types of waste materials such as paper, plastic, vegetable waste, and metal objects. Multiple tests were performed to verify sensor detection accuracy, motor operation, bin alignment, and successful data transmission to the IoT dashboard.

VI. RESULTS

The developed Smart Waste Sorter- Automatic Waste Segregation prototype was experimentally tested using different types of waste materials such as dry waste (paper and plastic), wet waste (organic or vegetable waste), and metallic objects. The system successfully detected the type of waste using sensors and automatically directed it to the appropriate bin. The IoT dashboard also displayed the detected waste category based on the rotation and positioning of the bins during the segregation process. The experimental results show that the prototype was able to perform automatic waste segregation effectively.

VII. IOT MONITORING

Real-time bin level data were successfully transmitted to the IoT / cloud allowing users to monitor the system status remotely. The IoT dashboard displayed whether the waste is dry, wet or metallic waste. In addition to the IoT display, a buzzer was used as a local alert mechanism to indicate important system notifications. The delay in data transmission was minimal, ensuring stable and reliable

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IoT communication for monitoring purposes.

VIII. FUTURE ENHANCEMENTS

In future, this system can be further improved to enhance accuracy, scalability, and overall efficiency. The Ultrasonic sensors can be integrated with each waste bin to continuously monitor and track the bin fill levels, allowing better waste management and timely collection. Advanced AI-based image processing techniques may be added in future to improve waste classification, especially for mixed or complex waste types. In addition, mobile notifications and alert systems can be implemented to inform users or authorities when bins reach their capacity. The system can also be connected to centralised municipal dashboards to support smart city waste management and optimise waste collection routes. Finally, improvements such as weather-resistant enclosures and automated cleaning mechanisms can enhance the durability and hygiene of the system.

IX. CONCLUSION

This research presented the design and implementation of a Smart Waste Sorter – Automatic Waste Segregation Prototype that automatically classifies waste into dry, wet, and metallic categories using multiple sensors. The system integrates Arduino, ESP32 microcontroller, IR sensor, moisture sensor, proximity sensor, ultrasonic sensor, stepper motor, and servo motor to perform automatic waste detection and segregation. The experimental results demonstrated that the prototype was able to successfully identify different types of waste and direct them to the appropriate bins through a motorized sorting mechanism. A buzzer alert mechanism was also incorporated to notify users when required. Overall, the developed prototype provides a simple, cost-effective, and efficient solution for improving waste segregation at the source level. By combining sensor-based detection with IoT monitoring, the system supports better waste management practices and contributes toward cleaner and smarter environments.

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