Grenze International Journal of Engineering and Technology, June Issue

Smart Waste Management System Design using Garbage Segregation Techniques

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***Abstract*— The main objective of this project is to segregate dry waste and wet waste into different bins using Internet of things (iot). The system is designed to detect whether the waste bin is full and send a notification to the user. It also detects if any hot material is placed in the bin and sends a notification. Additionally, the type of waste is displayed when it is placed on the sensors. In this project, two separate bins are used to store waste. The waste is placed on a moisture sensor, which detects the moisture content present in the waste. Based on the detected moisture level, the waste is segregated into the appropriate bin with the help of a servo motor. Ultrasonic sensors are placed inside each bin to monitor the level of waste and determine whether the bins are full. As a result, a working model of an IoT-based waste segregation system has been successfully developed. The system efficiently segregates waste into two different bins and accurately determines the status of each bin by identifying whether it is completely filled or not. This project can be applied in urban waste management systems, where waste generation is increasing due to rapid urbanization. Proper waste segregation helps in recycling and effective waste processing. With further development, this system can be implemented in different areas to collect waste efficiently and support recycling on a larger scale.**

***Index Terms*— Internet of things, moisture sensor, servo motor, ultrasonic sensor.**

I. INTRODUCTION

Retail shopping today is This project highlights the importance of segregating waste at the source, which is one of the most effective ways to manage increasing amounts of garbage. Mixing wet and dry waste makes recycling difficult and leads to environmental pollution. By automating the segregation process, this system minimizes human errors and ensures that waste is correctly separated from the beginning.

This not only improves recycling efficiency but also reduces health risks faced by sanitation workers who manually handle mixed waste. The use of embedded systems and sensors makes the project both cost-effective and reliable. Components such as moisture sensors, ultrasonic sensors, and servo motors work together under the control of a microcontroller to perform accurate waste detection and movement. The system operates in real time, providing quick responses when waste is placed in the bin. This demonstrates the practical application of electronics and programming concepts learned in academics, making the project educational as well as functional [1].

Grenze ID: 01.GIJET.12.2.438_24

Another important aspect of this project is its scalability and adaptability. The basic model can be expanded by adding more sensors or bins to classify waste into multiple categories such as plastic, metal, and biodegradable waste. It can also be integrated with wireless communication modules to send real-time data to municipal authorities. This would help in planning efficient waste collection routes and reducing operational costs. Overall, the automatic dry-wet waste segregation system represents a step toward smart city development. By combining automation, sensor technology, and IoT concepts, the project promotes sustainable waste management practices. With further research and development, this system can be implemented in public places, residential areas, schools, and offices to maintain cleanliness, protect the environment, and support a greener future [2].

II. Scope and Objectives of the Work

In this section, the scope & objectives of the works are presented in a nutshell.
Scope: The scope of this research and development project is to design, build, and demonstrate the functionality of an autonomous Waste Detection and Segregation
In this section, we present the main objectives of the project work that is being done as follows [3].

A. Automatic Waste Detection and Segregation

- Detect the presence of waste using appropriate sensors.
- Identify wet and dry waste based on moisture content using a moisture sensor.
- Automatically segregate waste into respective bins using a servo motor mechanism.

B. Smart Bin Monitoring and Level Detection

- Monitor the fill level of each bin using ultrasonic sensors.
- Detect whether the bin is empty, partially filled, or completely full.
- Prevent overflow by sending alerts when the bin reaches its maximum capacity.

C. Safety and Hazard Detection

- Detect the presence of hot or unsafe materials placed in the bin.
- Generate notifications or alerts to ensure system safety and prevent damage.

D. Real-Time Display and User Feedback

- Display the detected type of waste (wet or dry) on a display unit.
- Provide real-time feedback to users during waste disposal.

E. IoT-Based Notification and Communication

- Send notifications when bins are full or unsafe conditions are detected.
- Enable real-time monitoring of bin status through IoT technology.
- Support efficient waste collection planning and management.

F. Efficient and Scalable System Design

- Design a low-cost, energy-efficient waste segregation system.
- Ensure modular architecture for easy maintenance and future upgrades.

III. Proposed Methodology and Block Diagram

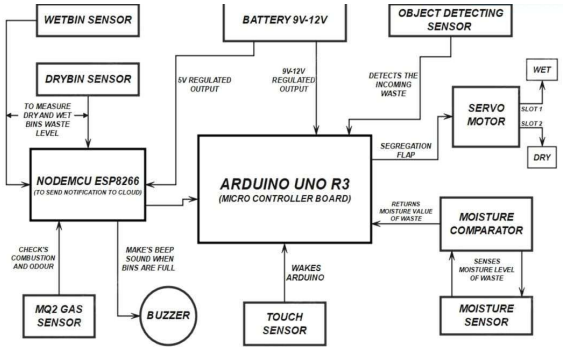

Fig. 1: Architectural flow diagram of the waste segrgation

The Fig. 1 shows a block diagram of automatic dry and wet waste segregation system in which a 9–12 V battery supplies regulated power to all components, including the Arduino UNO, NodeMCU, sensors, and servo motor. When waste is placed near the bin, the object-detecting sensor senses its presence and triggers the Arduino to start the segregation process. The moisture sensor measures the moisture content of the waste, and the moisture comparator processes this value to clearly identify whether the waste is wet or dry. Based on this information, the Arduino UNO controls the servo motor, which rotates the segregation flap and directs the waste into either the wet bin or the dry bin [4].

The diagram shows the hardware implementation of a smart waste segregation system using Arduino UNO R3 and NodeMCU ESP8266 along with multiple sensors and actuators. The battery provides power to the entire circuit, and its supply is distributed to the Arduino, NodeMCU, sensors, buzzer, and servo motor through common power and ground lines [5].

- At the center of the system, the Arduino UNO R3 acts as the main controller responsible for real-time sensing and control operations. An object detection sensor (HC-SR04 ultrasonic sensor) is connected to the Arduino to detect when waste is placed near the inlet. Once waste is detected, the Arduino activates the moisture sensing unit, which consists of a moisture sensor and a moisture comparator module. The moisture sensor measures the moisture content of the waste, and the comparator converts this analog value into a digital signal that clearly indicates whether the waste is wet or dry.
- Based on the signal received from the moisture comparator, the Arduino controls the servo motor (SG90). The servo motor acts as a mechanical flap that rotates to different angles, directing the waste into either the wet bin or the dry bin. This enables automatic physical segregation without human intervention.
- To monitor the fill level of the bins, two ultrasonic sensors (HC-SR04) are used—one for the wet bin and one for the dry bin. These sensors continuously measure the distance between the sensor and the waste level inside the bins. When the measured distance falls below a preset threshold, it indicates that the bin is nearly full.
- The NodeMCU ESP8266 is used as the IoT communication module in this system. It receives bin-level data from the wet and dry bin sensors and communicates this information to the cloud or a monitoring application through Wi-Fi. The NodeMCU also interfaces with the MQ2 gas sensor, which detects foul odour and combustible gases produced due to waste decomposition, helping to maintain hygiene and safety.
- A buzzer is connected to the system to provide an audible alert when either the wet bin or dry bin becomes full or when abnormal conditions are detected. This ensures immediate local notification even if internet connectivity is unavailable. Additionally, a touch sensor is included to wake up or activate the system when required, helping to reduce unnecessary power consumption during idle conditions.
- Overall, this circuit integrates sensing, control, mechanical actuation, and IoT communication to achieve automatic waste segregation, real-time bin monitoring, gas detection, and alert generation, making it suitable for smart waste management and smart city applications.

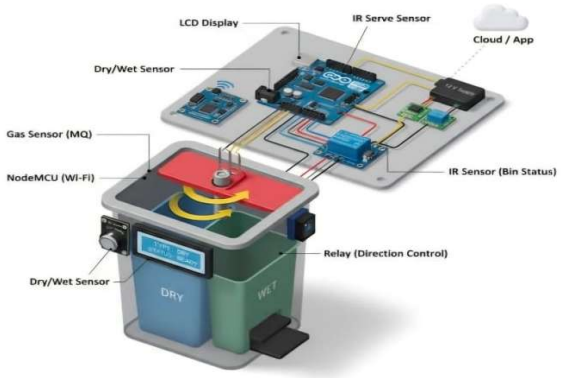

Fig. 2. Hardware design for smart waste management

The hardware design is shown in fig 2 which uses a Node MCU microcontroller with inbuilt Wi-Fi as the main controller, which takes input from all sensors, processes the data and sends the bin status to a cloud or mobile app for monitoring. Dry/wet sensors are fixed near the lid and inside the bin so the controller can detect whether the incoming waste is dry or wet and also sense the moisture level of waste already stored. An IR level sensor is mounted facing down into the bin to measure how full the bin is, while a gas sensor (such as an MQ series) is

placed inside the bin to detect harmful or foul gases produced by decomposing waste; when the readings cross a set limit, the controller can trigger alerts. A servo motor connected to the lid is driven by the Node MCU so that the lid can open or close automatically when waste is detected or when a user approaches, and a relay module is used wherever any higher-power load such as a motor or indicator lamp needs to be switched on and off safely. An LCD display on the front of the bin shows information like bin fill level, waste type and warning messages to the user, while the Wi-Fi connectivity continuously uploads sensor data to an IoT platform so that the condition of the bin can be checked remotely and notifications can be sent when it is full or unsafe for usage [6].

V. Results and Performance Analysis – Overview with Results

Working model of smart waste segregation has two bins one for dry and one for wet waste, it uses electronic components and sensors to detect and segregate the waste and a microcontroller (Arduino UNO) is used to control this setup, A Wi-fi module (Node MCU) helps in receiving information like status of bins [7]

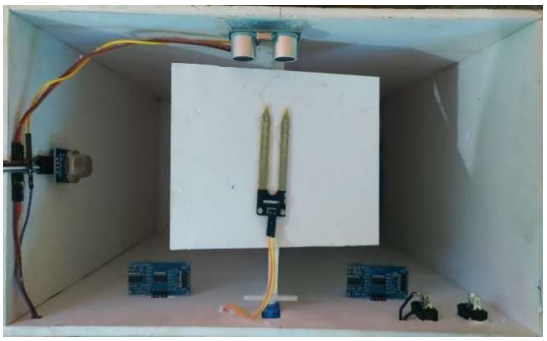

Fig. 3. working model of smart waste management system

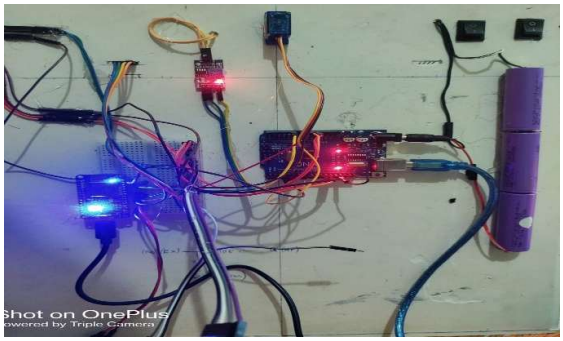

Fig. 4. Working circuit of smart waste management system

Table I: Sensor Response for Dry and Wet Waste

Sl.No	Waste Type	Sensor Used	Detection status	Analog value of moisture sensor	Bin Selected
1	Dry waste	Ultra sonic	Detected	> 600	Dry bin
2	Wet waste	Moisture sensor	Detected	< 600	Wet bin
3	No waste	—	Not detected		—

The Table 1 presents the sensor responses for different waste conditions in the waste segrigation system. The system primarily differentiates between dry and wet waste, first the ultrasonic sensor detects the weather the object is placed on the moisture sensor, the moisture sensor detects weather the waste is dry or wet. From the table, we can observed that dry waste is successfully detected using the ultrasonic sensor. When dry waste is present, the moisture sensor output shows an analog value greater than 600, indicating low moisture content. Based on this threshold, the system correctly identifies the waste as dry and directs it to the dry waste bin [8].

In the case of wet waste, the moisture sensor plays a key role. The analog value obtained is less than 600, which signifies high moisture content. This condition enables accurate detection of wet waste, and the system appropriately selects the wet waste bin for disposal. When no waste is present, neither the ultrasonic sensor nor the moisture sensor registers a valid signal. As a result, the detection status is marked as not detected, and no bin is selected. This confirms that the system avoids unnecessary actuation when waste is absent [9].

Overall, the data demonstrates that the chosen sensor thresholds effectively distinguish between dry and wet waste. The system shows reliable performance in waste identification and bin selection, validating the accuracy and efficiency of the proposed waste segregation mechanisms. In addition, the consistent sensor responses across all test conditions indicate that the system operates in a stable and predictable manner. The clear distinction between moisture values above and below the threshold ensures minimal misclassification of waste types. This improves the overall accuracy of segregation and reduces the chances of mixing wet and dry waste. The results also show that the system logic prevents false triggering when no waste is present, which enhances durability

and reduces power consumption. Furthermore, the correct bin selection in each detected case demonstrates effective coordination between sensing, processing, and actuation units. These observations confirm that the proposed system is reliable, efficient, and well-suited for practical smart waste management applications [10].

V. ADVANTAGES

- Automatically separates dry and wet waste, reducing the need for manual segregation.
- Improves cleanliness and hygiene by preventing waste mixing.
- Saves time and effort for users and waste collectors.
- Supports recycling by ensuring proper segregation at the source.
- Environment-friendly and helps reduce pollution and landfill waste.
- Cost-effective and uses easily available electronic components.
- Easy to use and suitable for homes, schools, and public places.
- Enhances learning of automation, sensors, and microcontroller applications.

V. CONCLUSIONS

In conclusion, the smart waste management system using garbage segegation project proves to be a meaningful and practical approach toward solving the problem of improper waste segregation. By automating the separation of dry and wet waste at the source, the project reduces human effort and helps maintain cleanliness and hygiene. The use of sensors, a microcontroller, and motor mechanisms shows how simple automation techniques can be applied to address real-life environmental challenges. This system encourages responsible waste disposal and makes the recycling process more efficient. In addition, the project serves as an excellent educational model for understanding the basics of electronics, automation, and environmental engineering. It helps students gain hands-on experience in working with sensors, programming, and mechanical components. The design is cost-effective and easy to understand, making it suitable for implementation in homes, schools, and small public places. Although the project has certain limitations, such as basic waste classification and dependence on sensor accuracy, it has great potential for future improvements. Features like advanced sensors, IoT connectivity, and larger capacity bins can further enhance its efficiency and usability. Overall, this project contributes to sustainable waste management practices and demonstrates how technology can be used effectively to protect the environment and promote a cleaner society.

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