IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

Smart Waste Segregation and Recycling System: An IoT-Driven Approach for Sustainable Waste Management

[1]Raj Satish Sutar, [2]Aditya Nagesh Kesharkha, [3]Anushka Pradip Chaudhari, [4]Prathamesh Bhaskar Pawar, [5]Dr. Vijay D. Chaudhari, [6]Dr. Hemant T. Ingale

[1,2,3,4]UG students, [5,6] Asso. Prof. E&TC Engg. Dept. GF's Godavari College of Engg., Jalgaon, M.S. India, 425001

Abstract *- Waste management has become a major global challenge due to rapid urbanization and increasing population. Improper segregation of waste at the source leads to environmental pollution, inefficient recycling, and health hazards. This paper proposes a Smart Waste Segregation and Recycling System using Internet of Things (IoT) technologies. The system utilizes multiple sensors such as moisture sensors, metal sensors, and IR proximity sensors to automatically classify waste into biodegradable, recyclable, and non-biodegradable categories. A motor-driven mechanism ensures proper segregation into designated compartments. Additionally, ultrasonic sensors monitor bin fill levels and send real-time alerts using IoT modules. The system also incorporates a data-driven reward mechanism to encourage public participation. The proposed solution enhances waste management efficiency, reduces manual labor, and promotes sustainable environmental practices.*

Keywords: *IoT, Waste Segregation, Smart Bin, Sensors, Recycling, Automation.*

1. INTRODUCTION

Waste management is one of the most pressing challenges in modern society, driven by rapid urbanization and population growth. Improper disposal and lack of segregation at the source result in environmental pollution, increased landfill usage, and inefficient recycling processes. Traditional waste segregation methods rely heavily on manual labor, which is time-consuming, inefficient, and exposes workers to hazardous conditions. Moreover, mixed waste reduces the quality of recyclable materials, making recycling processes less effective. To address these challenges, an automated system is required that can segregate waste at the source. The proposed Smart Waste Segregation and Recycling System leverages IoT and sensor-based technologies to classify and separate waste automatically while enabling real-time monitoring.

2. LITERATURE REVIEW

The application of Internet of Things (IoT) technologies in waste management has gained significant attention due to its ability to enable real-time monitoring and automation. Smart waste management systems using IoT have been developed to optimize waste collection by monitoring bin fill levels using ultrasonic sensors and transmitting data to cloud platforms for analysis [1]. These systems improve operational efficiency but do not address waste segregation at the source.

To overcome this limitation, researchers have explored intelligent waste classification techniques. Deep learning approaches, particularly Convolutional Neural Networks (CNNs), have demonstrated high accuracy in classifying different types of waste materials. Studies show that AI-based models significantly improve segregation efficiency compared to traditional methods [2].

In addition, automated waste sorting systems using image processing and robotic mechanisms have been proposed. These systems utilize sensors and cameras to identify waste types and physically separate them, improving recycling efficiency [3]. However, such systems are often expensive and require high computational resources.

Sensor-based approaches provide a cost-effective alternative for waste segregation. Systems using moisture sensors, metal detectors, and proximity sensors can classify waste based on physical properties with reasonable accuracy and low processing requirements [4]. These systems are suitable for real-time applications and are easier to implement in residential and public environments.

Furthermore, global studies highlight the urgent need for improved waste management systems due to increasing waste generation and environmental concerns. Reports indicate that improper waste handling leads to pollution, health hazards, and inefficient recycling processes, emphasizing the importance of smart and automated solutions [5].

3. PROBLEM STATEMENT

The lack of proper waste segregation at the source leads to contamination of recyclable materials, environmental pollution, and inefficient waste management processes. Manual segregation is labor-intensive, time-consuming, and exposes workers to health risks.

Additionally, mixed waste contributes to landfill overflow, greenhouse gas emissions, and groundwater contamination. Existing systems either focus only on monitoring or are too expensive for large-scale implementation.

Hence, there is a need for an automated, cost-effective, and scalable system that can accurately segregate waste at the source while providing real-time monitoring and encouraging public participation.

4. PROPOSED SYSTEM

The proposed system consists of a smart waste bin integrated with sensors, a microcontroller, and IoT connectivity. When waste is inserted, an IR sensor detects its presence and initiates the classification process.

A moisture sensor identifies whether the waste is wet or dry, while a metal sensor detects metallic components. Based on sensor data, the system classifies waste into biodegradable, recyclable, or non-biodegradable categories.

A motor-driven mechanism directs the waste into the appropriate compartment. Ultrasonic sensors monitor the fill level of each compartment and send alerts through IoT modules when the bin is full. The system also enables real-time monitoring using cloud platforms.

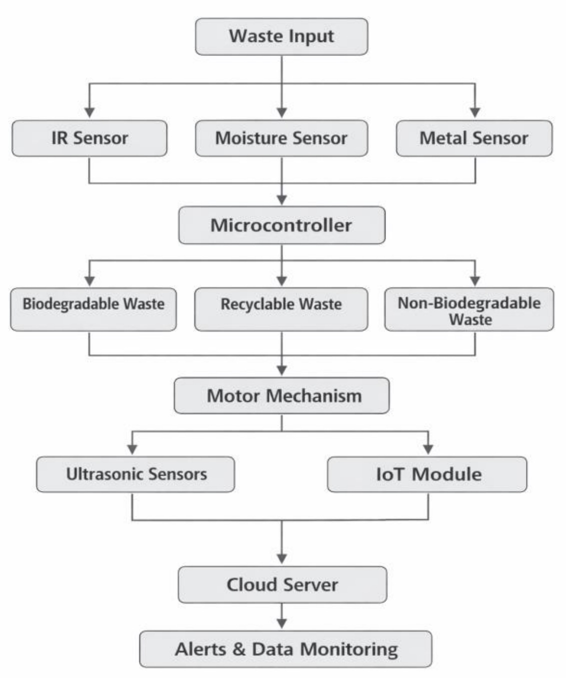


Fig. 1 Block diagram of the system

5. METHODOLOGY

The proposed system follows a systematic approach for automatic waste detection, classification, and segregation. Initially, waste is deposited into the smart bin, where an IR sensor detects its presence and activates the system.

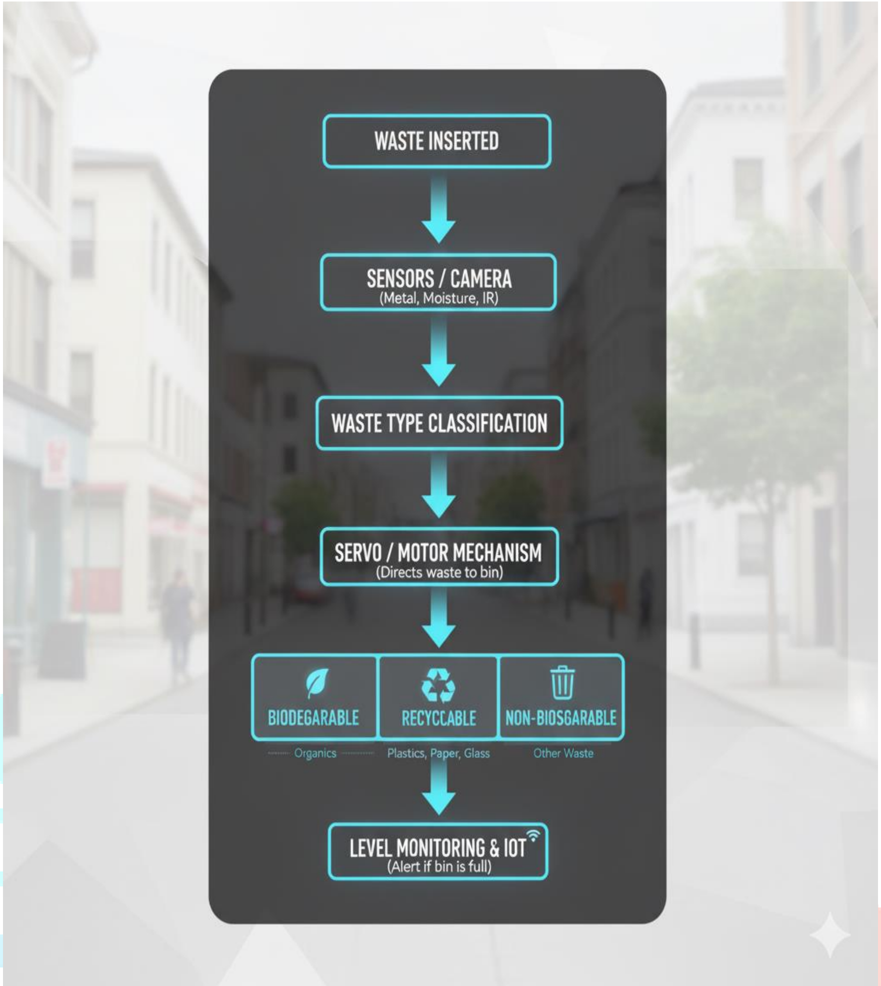
The waste then undergoes classification using multiple sensors. A moisture sensor determines whether the waste is wet or dry, while a metal sensor identifies metallic components. The sensor data is processed by the microcontroller, which compares the values with predefined conditions to classify the waste into biodegradable, recyclable, or non-biodegradable categories.

Based on the classification, the controller activates a motor-driven mechanism that directs the waste into the appropriate compartment. Each compartment is equipped with an ultrasonic sensor to monitor its fill level.

When the bin reaches a predefined threshold, the IoT module sends real-time alerts to the concerned authority or user. Simultaneously, the system logs data to a cloud platform for monitoring and analysis.

This methodology ensures efficient waste segregation, reduces manual effort, and enables real-time waste management.

Flowchart



6. HARDWARE AND SOFTWARE REQUIREMENT

Hardware component

- Raspberry Pi 4
- pH Sensor
- Turbidity Sensor
- Solenoid Valve
- Relay Module
- Power Supply
- Water Tanks

Software component

- Python programming language
- Cloud platform ThingSpeak
- Raspberry Pi OS

7. EXPECTED RESULT

The system is expected to achieve accurate waste segregation, reduce contamination, and improve recycling efficiency. Automation minimizes manual labor and enhances safety. Real-time monitoring optimizes waste collection and reduces operational costs. The system is scalable and suitable for smart city applications.

8. CONCLUSION & FUTURE SCOPE

8.1. Conclusion

The Smart Waste Segregation and Recycling System presents an effective and practical solution to the growing challenges of waste management. By integrating sensor-based classification with IoT-enabled monitoring, the system successfully automates the segregation process at the source. The use of moisture, metal, and proximity sensors ensures reliable identification of waste types, while the motor-driven mechanism enables accurate and efficient physical separation.

The implementation of real-time monitoring through IoT enhances operational efficiency by enabling timely waste collection and reducing unnecessary manual intervention. Additionally, the proposed reward-based concept promotes public participation and encourages responsible waste disposal practices.

Overall, the system improves recycling efficiency, reduces environmental pollution, and provides a scalable and cost-effective framework for modern waste management systems in both urban and rural environments.

8.2. Future scope

The proposed system can be further enhanced by integrating advanced technologies to improve accuracy and scalability. The inclusion of machine learning and computer vision techniques can enable more precise classification of complex waste types such as plastics, glass, and paper.

Additional sensors can be incorporated to detect parameters such as weight, gas emissions, or material composition for more detailed analysis. The system can also be integrated with mobile or web applications to provide real-time monitoring, user notifications, and data analytics dashboards.

Furthermore, the system can be expanded for large-scale deployment in smart cities, where multiple bins are interconnected through a centralized cloud platform for optimized waste collection and management. Integration with GPS-based tracking and route optimization can further enhance efficiency.

Future developments may also focus on improving energy efficiency through solar-powered systems and enhancing user engagement through incentive-based smart city initiatives.

9 REFERENCES

[1] M. Folianto, Y. S. Low, and W. L. Yeow, "Smartbin: Smart Waste Management System," 2015 IEEE Tenth International Conference on Intelligent Sensors, Sensor Networks and Information Processing (ISSNIP), Singapore, 2015.

[2] O. Adedeji and Z. Wang, "Intelligent Waste Classification using Deep Convolutional Neural Networks," Journal of Cleaner Production, vol. 247, 2020.

[3] Y. Wang, Q. Li, and R. Li, "An Automated Waste Sorting System based on Image Processing and Robotic Technology," Sensors, vol. 19, no. 21, 2019.

[4] H. Rathore, V. Sangwan, and R. Singh, "Smart Waste Segregation and Management System using Sensors and Microcontrollers," International Journal of Environmental Technology and Management, vol. 25, no. 3/4, pp. 312–325, 2022.

[5] S. Kaza, L. Yao, P. Bhada-Tata, and F. Van Woerden, "What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050," World Bank, 2018.