



SENSORFUSIONBIN: AN IOT-ENABLED SYSTEM FOR AUTOMATED WET, DRY, AND METALLIC WASTE SEGREGATION

¹Dr.Shruthi S A,²Sumaiya Shaikh,³Shagufta Mohammadi,⁴Shaikh Muskan ,⁵Roshan Abdul Rahiman
Pathan

¹Associate Professor, ²⁻⁵Students

¹⁻⁵Computer Science & Engineering,

¹⁻⁵Sharnbasva University, Kalaburagi, Karnataka, India

Abstract: Waste segregation plays a vital role in modern waste management by enabling efficient recycling, reducing landfill accumulation, and minimizing environmental pollution. The increasing volume of municipal waste generated from urbanization and population growth has created a demand for intelligent and automated segregation solutions. This paper presents SensorFusionBin: An IoT-Enabled System for Automated Wet, Dry, and Metallic Waste Segregation, designed to classify waste materials using embedded sensing technologies and automated control mechanisms. The proposed system integrates a moisture sensor, metal detection sensor, Arduino-based controller, servo-driven segregation mechanism, and IoT-enabled monitoring framework to identify and separate different categories of waste with minimal human intervention. Moisture sensing is utilized to detect biodegradable wet waste, while metallic objects are recognized through metal detection techniques. Materials that do not satisfy either condition are categorized as dry waste. The automated segregation process improves sorting accuracy, enhances hygiene, and supports sustainable waste management practices. Experimental evaluation demonstrates reliable waste classification and effective bin allocation under controlled conditions. The system offers a cost-effective, scalable, and environmentally responsible approach for smart homes, institutions, public facilities, and future smart city applications.

Index Terms – Waste Segregation, Internet of Things (IoT), Arduino Uno, Moisture Sensor, Metal Detection Sensor, Sensor Fusion, Smart Waste Management, Embedded Systems, Automation, Sustainable Environment.

I. INTRODUCTION

Rapid urbanization, industrial expansion, and population growth have significantly increased the quantity of solid waste generated across the world. The continuous rise in waste production has created major environmental and public health concerns, making efficient waste management an essential requirement for sustainable development. Improper disposal of waste leads to land pollution, water contamination, greenhouse gas emissions, and the depletion of valuable recyclable resources. As cities continue to expand and consumption patterns increase, conventional waste handling practices are becoming inadequate for managing the growing volume and complexity of waste materials. Waste segregation is one of the most important processes in modern waste management systems because it enables the separation of waste into distinct categories for appropriate treatment, recycling, and disposal. Proper segregation improves resource recovery, enhances recycling efficiency, reduces landfill dependency, and minimizes environmental impact. However, in many locations, waste is still disposed of without classification, resulting in mixed waste

streams that are difficult and expensive to process. Traditional segregation methods primarily depend on manual sorting, which is labor-intensive, time-consuming, inconsistent, and often exposes workers to hazardous and unhygienic conditions. Recent developments in embedded systems, sensing technologies, automation, and the Internet of Things (IoT) have created opportunities for intelligent waste management solutions. Automated systems equipped with sensors and microcontrollers can identify waste characteristics and perform classification with minimal human intervention. Such systems improve operational efficiency, reduce human effort, and support cleaner and safer waste handling practices. This study presents SensorFusionBin: An IoT-Enabled System for Automated Wet, Dry, and Metallic Waste Segregation, an intelligent platform designed to automate waste classification at the source. The system integrates a moisture sensor, metal detection sensor, Arduino-based controller, servo-actuated segregation mechanism, and IoT-enabled monitoring capabilities. Moisture sensing techniques are utilized to identify wet waste, while metallic materials are detected using a dedicated metal sensing module. Waste that does not satisfy either condition is categorized as dry waste. Based on sensor outputs, the control unit activates the mechanical segregation mechanism and directs the waste into the corresponding collection compartment.

The proposed system aims to improve segregation accuracy, promote hygienic waste handling, and enhance recycling effectiveness through automated operation. Its low-cost architecture and scalable design make it suitable for residential areas, educational institutions, offices, industries, and public facilities. By combining sensor fusion, embedded intelligence, and IoT integration, the system contributes to sustainable waste management practices and supports the development of environmentally responsible smart city infrastructure.

II. RELATED WORKS

Article[1] "IoT-Enabled Solid Waste Management in Smart Cities" by S. Vishnu, A. Jino Ramson, and B. Senith Saminathan in 2021: This paper proposed an IoT-based waste management architecture for smart cities. The system utilized smart bins equipped with sensors to monitor waste levels in real time. Location tracking and centralized monitoring were incorporated to improve collection efficiency. The framework reduced unnecessary collection trips and operational costs. Data from residential and public bins were transmitted to a central server for analysis. The study emphasized scalability and efficient resource utilization. The proposed architecture improved waste collection planning and environmental sustainability. Results demonstrated better monitoring compared to traditional waste management systems.

Article[2] "IoT-based Intelligent Waste Management System" by M. M. Ahmed, M. A. Mohamed, and H. M. Hasanien in 2023: This research introduced an intelligent waste management framework using IoT sensors, actuators, and optimization techniques. Smart bins continuously monitored waste levels and transmitted information to collection centers. Missing sensor data were addressed through data completion mechanisms. The system also optimized waste collection routes to reduce fuel consumption. Real-time monitoring improved operational efficiency. The framework supported smart city applications and sustainable waste handling. Experimental results showed improved route planning and reduced waste overflow. The study demonstrated the benefits of intelligent automation in urban waste management.

Article[3] "IoT-Enabled AI Solutions for Efficient Smart City Waste Management" by R. R. Sah and S. K. Mishra in 2024: This study combined IoT and Artificial Intelligence technologies for smart waste management. Sensors collected waste-related data and transmitted it to cloud platforms. AI algorithms analyzed the information for decision making and optimization. The framework improved waste collection efficiency and resource allocation. Real-time monitoring enhanced system responsiveness. The integration of AI enabled predictive analysis and forecasting. The approach reduced operational expenses and environmental impact. The results highlighted the effectiveness of combining IoT and AI for modern waste management.

Article[4] "Smart Waste Management: A Paradigm Shift Enabled by Artificial Intelligence" by D. B. Olawade et al. in 2024: This review examined the role of Artificial Intelligence in waste collection, sorting, recycling, and monitoring. Various machine learning techniques were evaluated for waste classification. The study discussed benefits such as automation, accuracy, and reduced human intervention. Challenges including data quality and implementation costs were analyzed. AI-driven systems were found to improve waste sorting performance significantly. The review highlighted integration opportunities with IoT technologies. Future

developments in intelligent waste management were also discussed. The work emphasized sustainability and environmental protection.

Article[5] "Intelligent IoT Enabled Waste Segregation and Monitoring System" by N. S. Praveen, K. R. Harish, and M. R. Tejas in 2024: This paper proposed an automated waste segregation system using moisture, ultrasonic, inductive, and infrared sensors. The system categorized waste into dry, wet, and metallic groups. An Arduino controller coordinated sensing and segregation operations. IoT functionality enabled cloud-based monitoring of waste levels. The design reduced manual sorting requirements. Sensor-based classification improved segregation efficiency. The monitoring platform provided accessibility for municipal authorities. Experimental results validated the effectiveness of automated segregation.

Article[6] "Waste Management by Smart Bin and App System using IoT" by A. Prakash, S. Kumar, and P. Singh in 2024:

The authors developed a smart bin integrated with IoT sensors, NodeMCU, and a mobile application. The system continuously monitored garbage levels and transmitted updates to authorities. Real-time notifications improved collection scheduling. The framework minimized waste overflow situations. Mobile connectivity enhanced accessibility and user interaction. Sensor integration provided accurate monitoring. The study demonstrated improved efficiency in municipal waste handling. Results supported the use of IoT for urban cleanliness initiatives.

Article[7] "Smart Waste Management and Classification System Using IoT and Deep Learning" by A. Alourani, M. Alharbi, and S. Alshammari in 2025: This study introduced an intelligent waste management system integrating IoT and deep learning technologies. Smart bins collected waste information and communicated through mobile applications. A VGG-19 model was used for waste classification. The framework classified plastic, glass, and metallic waste with high accuracy. Real-time monitoring improved waste collection efficiency. The deep learning model achieved excellent classification performance. The system supported recycling and sustainable waste handling. Experimental outcomes demonstrated accuracy approaching 99.7%.

Article[8] "IoT-Enabled Smart Waste Management Using Renewable Energy" by S. Patel and R. Kumar in 2025: This research proposed a solar-powered smart waste management solution. IoT-enabled bins monitored fill levels and communicated with remote servers. Renewable energy reduced operational power requirements. The framework was designed for both developing and developed regions. Real-time monitoring improved waste collection planning. The use of solar energy enhanced sustainability. The system reduced maintenance costs and environmental impact. Results demonstrated feasibility for large-scale deployment.

Article[9] "Optimizing Waste Management in Smart Cities: An IoT-Based Approach" by H. Jerbi, M. Ben Salem, and A. Trabelsi in 2025: This work proposed a smart bin monitoring framework using IoT sensors and machine learning. Waste levels were categorized into different operational states. Predictive models forecasted future waste generation. The framework optimized collection routes and resource allocation. Wireless communication enabled real-time data transfer. The approach reduced overflow incidents and operational costs. Machine learning enhanced prediction accuracy. Results showed improved efficiency compared to traditional systems.

Article[10] "AI and IoT-Enabled Smart Urban Waste Management" by A. Devi, R. Sharma, and P. Verma in 2025:

The paper presented an intelligent waste management architecture combining IoT and AI technologies. Sensor networks monitored waste generation patterns continuously. AI algorithms optimized collection and segregation activities. Real-time analysis improved operational decision making. The framework enhanced sustainability and recycling performance. Cloud integration enabled remote monitoring capabilities. The proposed system supported smart city infrastructure. Experimental analysis demonstrated improved waste handling efficiency.

Article[11] "Blockchain Based Solid Waste Classification with AI and IoT Integration" by A. M. Alabdali, M. Alqahtani, and H. Alharbi in 2025: This study integrated blockchain, AI, and IoT technologies for secure waste management. Smart bins transmitted data to centralized servers. Blockchain

ensured secure and transparent data storage. Deep learning models classified waste automatically. The framework improved recycling efficiency and traceability. IoT connectivity enabled real-time monitoring. The proposed model achieved high classification accuracy. Results demonstrated reliable and secure waste management operations.

Article[12] "IoT-Based Automated Waste Segregation System for Smart Cities" by S. Gupta, R. Mishra, and A. Sharma in 2025: This paper focused on automated waste segregation using IoT technologies. Sensors identified different waste categories and directed materials into appropriate bins. Automated segregation minimized human intervention. The system improved recycling quality and waste processing efficiency. Real-time monitoring enhanced operational visibility. Smart city integration was considered for large-scale deployment. The framework reduced environmental pollution caused by mixed waste. Experimental evaluation confirmed reliable segregation performance.

III. PROBLEM STATEMENT

The rapid increase in population, urbanization, and consumer activities has led to a significant rise in solid waste generation, creating serious challenges for effective waste management. In many locations, wet, dry, and metallic waste are discarded together without proper segregation at the source. This mixing of waste reduces recycling efficiency, increases processing complexity, and contributes to environmental pollution. Conventional waste management practices primarily rely on manual sorting, which is time-consuming, labor-intensive, inconsistent, and often exposes workers to unhygienic and hazardous conditions. The absence of intelligent segregation mechanisms results in poor resource recovery and excessive landfill accumulation. Furthermore, inadequate waste classification can lead to contamination of recyclable materials and increased operational costs for waste processing facilities. The lack of automated and reliable segregation systems remains a major obstacle to sustainable waste management, environmental protection, efficient recycling operations, and long-term smart city development initiatives worldwide.

IV. OBJECTIVES

The primary objective of this study is to develop an intelligent and automated waste segregation system capable of identifying and separating wet, dry, and metallic waste materials with minimal human intervention. The study aims to improve waste management efficiency by enabling accurate classification at the source and reducing dependence on manual sorting methods. Another objective is to enhance recycling effectiveness through proper waste categorization and collection. The system is intended to promote hygienic waste handling by minimizing direct human contact with waste materials. It also seeks to reduce environmental pollution and landfill accumulation by encouraging sustainable disposal practices. Furthermore, the study focuses on integrating sensor-based detection, embedded control, and IoT capabilities to achieve reliable operation. The overall goal is to provide a cost-effective, scalable, and environmentally responsible solution suitable for smart waste management applications.

V. METHODOLOGY

1) Data Acquisition and Waste Detection: The methodology begins with the detection of waste materials placed into the system. An ultrasonic sensor continuously monitors the input area and identifies the presence of an object. Once waste is detected, the sensor transmits the corresponding information to the Arduino Uno controller. This initial detection stage ensures that the system operates only when waste is available for processing, thereby improving efficiency and reducing unnecessary power consumption.

2) Sensor-Based Waste Analysis: After waste detection, the sensing modules analyze the physical characteristics of the waste material. The moisture sensor measures the moisture content to determine whether the waste is biodegradable or wet in nature. Simultaneously, the metal detection sensor identifies the presence of metallic components. The collected sensor readings provide the required information for accurate waste classification and automated decision-making.

3) Data Processing and Classification: The Arduino Uno microcontroller acts as the central processing unit of the system. Sensor readings received from the moisture and metal sensors are continuously evaluated using predefined threshold values. Based on the processed data, the controller determines whether the waste belongs to the wet, dry, or metallic category. This classification process forms the foundation of the automated segregation mechanism.

4)Control Logic and Decision Making:Once the waste category is identified, the embedded control algorithm generates the necessary commands for mechanical actuation. The control logic prioritizes metallic waste detection, followed by wet waste identification. If neither condition is satisfied, the waste is classified as dry waste. This systematic decision-making process ensures reliable and consistent segregation performance under different operating conditions.

5)Servo Motor Actuation:The classified waste information is used to control the servo motor mechanism. The Arduino sends precise control signals to the servo motor, enabling accurate rotational movement. The actuator positions the collection pathway toward the appropriate waste compartment. Controlled actuation improves segregation accuracy and minimizes the possibility of incorrect waste disposal.

6)Waste Segregation and Collection:Following servo motor positioning, the waste is directed into the designated collection bin. Wet waste is deposited into the wet waste container, metallic waste into the metal bin, and remaining materials into the dry waste compartment. This automated segregation process eliminates the need for manual sorting and improves hygiene during waste handling operations.

7)IoT Monitoring and System Evaluation:The final stage involves IoT-enabled monitoring and performance evaluation. Sensor data and system status information can be transmitted to connected devices for remote observation. Operational testing is conducted using different waste samples to verify classification accuracy and system reliability. The evaluation process helps assess overall efficiency and supports future improvements in smart waste management applications.

VI. SYSTEM ARCHITECTURE

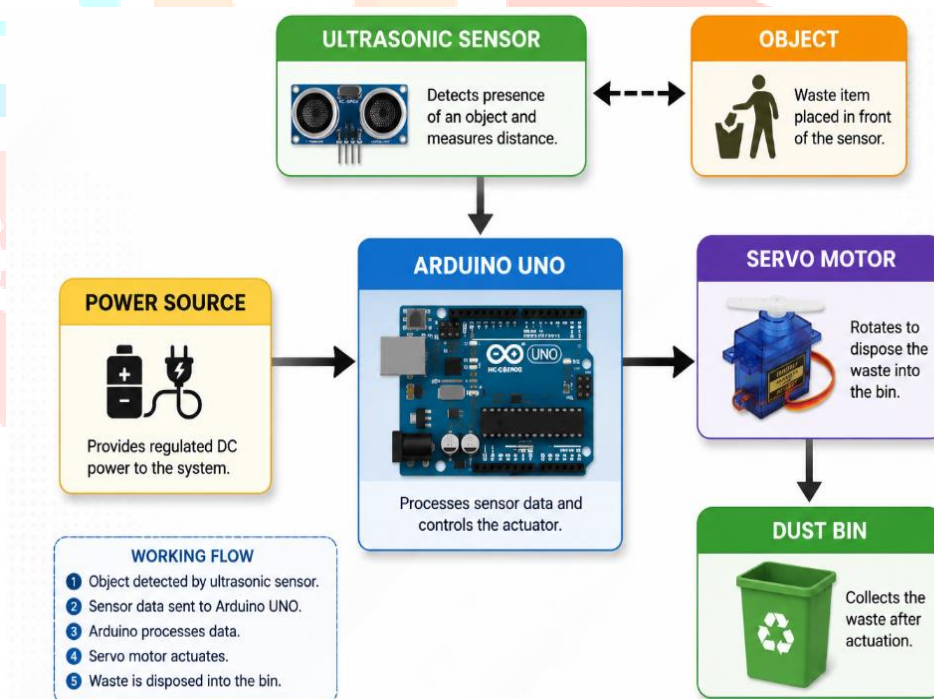


Fig 1: System Architecture of SensorFusionBin for Automated Waste Detection, Processing, and Disposal

The system architecture of SensorFusionBin is designed around an Arduino Uno microcontroller that serves as the central processing and control unit. A regulated power source supplies the necessary electrical energy to all hardware components, ensuring stable system operation. The ultrasonic sensor is positioned near the waste input section to detect the presence of an object and measure its distance from the sensing module.

Once an object is detected, the sensor transmits the corresponding data to the Arduino Uno for processing. The microcontroller analyzes the received information and determines the appropriate control action based on predefined programming logic. After processing the sensor data, the Arduino generates control signals and sends them to the servo motor. The servo motor functions as the actuator of the system and performs the required mechanical movement for waste handling or bin actuation. Through controlled rotation, the servo mechanism directs or disposes of the waste into the designated dustbin compartment. The dustbin acts as the final collection unit where the waste is stored after successful operation. This architecture enables automated sensing, processing, actuation, and disposal, resulting in efficient, reliable, and intelligent waste management with minimal human intervention.

VII. EXPERIMENTAL SETUP



Fig. 2: Hardware Prototype of SensorFusionBin for Automated Wet, Dry, and Metallic Waste Segregation

The experimental prototype integrates an Arduino Uno, moisture sensor, metal detection sensor, servo motor, and waste collection containers to perform automated waste classification and segregation. The hardware setup validates the real-time operation of the proposed system by detecting waste characteristics and directing materials into the appropriate collection compartment with minimal human intervention.

VIII. CONCLUSION AND FUTURE WORKS

In this research, SensorFusionBin successfully demonstrated an intelligent, cost-effective, and automated approach for segregating wet, dry, and metallic waste using sensor-based detection and embedded control. The system improved waste classification, reduced manual effort, enhanced hygiene, and supported efficient recycling practices through real-time automated operation. Integration of sensing technologies and IoT-enabled functionality provided a reliable framework for modern waste management applications. Future work may focus on incorporating artificial intelligence for advanced waste recognition, image-based classification, cloud analytics, smart monitoring, bin fill-level prediction, and renewable energy support. Additional improvements can include mobile application integration, robotic handling, enhanced sensor accuracy, scalable deployment, and real-time decision making to further improve sustainability, efficiency, and protection.

REFERENCES

- [1] S. Vishnu, A. Jino Ramson, and B. Senith Saminathan, "IoT-Enabled Solid Waste Management in Smart Cities," *Smart Cities*, vol. 4, no. 3, pp. 1004-1017, 2021.
- [2] M. M. Ahmed, M. A. Mohamed, and H. M. Hasaniien, "IoT-based Intelligent Waste Management System," *Neural Computing and Applications*, vol. 36, no. 2, pp. 1125-1141, 2023.
- [3] R. R. Sah and S. K. Mishra, "IoT-Enabled AI Solutions for Efficient Smart City Waste Management," *Advances in Precision Engineering and Manufacturing*, vol. 2, no. 1, pp. 1-12, 2024.

- [4] D. B. Olawade, A. O. Wada, A. A. David, and O. T. Fadare, "Smart Waste Management: A Paradigm Shift Enabled by Artificial Intelligence," *Environmental Advances*, vol. 15, pp. 100512, 2024.
- [5] N. S. Praveen, K. R. Harish, and M. R. Tejas, "Intelligent IoT Enabled Waste Segregation and Monitoring System," *Research and Reviews: Journal of Electronics and Communication Engineering*, vol. 13, no. 2, pp. 45-53, 2024.
- [6] A. Prakash, S. Kumar, and P. Singh, "Waste Management by Smart Bin and App System using IoT," *International Journal of Engineering Research & Technology (IJERT)*, vol. 13, no. 4, pp. 1-6, 2024.
- [7] A. Alourani, M. Alharbi, and S. Alshammari, "Smart Waste Management and Classification System Using IoT and Deep Learning," *Scientific Reports*, vol. 15, pp. 18452, 2025.
- [8] S. Patel and R. Kumar, "IoT-Enabled Smart Waste Management Using Renewable Energy," *Procedia Computer Science*, vol. 245, pp. 112-120, 2025.
- [9] H. Jerbi, M. Ben Salem, and A. Trabelsi, "Optimizing Waste Management in Smart Cities: An IoT-Based Approach," *Smart Cities and Society*, vol. 8, no. 1, pp. 35-48, 2025.
- [10] A. Devi, R. Sharma, and P. Verma, "AI and IoT-Enabled Smart Urban Waste Management," *E3S Web of Conferences*, vol. 612, pp. 03002, 2025.
- [11] A. M. Alabdali, M. Alqahtani, and H. Alharbi, "Blockchain Based Solid Waste Classification with AI and IoT Integration," *Scientific Reports*, vol. 15, pp. 97030, 2025.
- [12] S. Gupta, R. Mishra, and A. Sharma, "IoT-Based Automated Waste Segregation System for Smart Cities," *International Journal for Research in Applied Science and Engineering Technology (IJRASET)*, vol. 13, no. 5, pp. 221-228, 2025.

