

AI-Based Smart Waste Classification and Segregation System

EXTENSIVE PROJECT REPORT

Event: IBM SkillsBuild | CSRBOX | AI Innovation Challenge 2026

Theme: Sustainable Living & Environment

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1. Introduction

Waste management has become one of the most pressing challenges faced by modern society. Rapid urbanization, population growth, and changing consumption patterns have led to a significant increase in solid waste generation. In India, a major contributor to inefficient waste management is the lack of proper segregation at the source. When waste is not segregated, recyclable and biodegradable materials get mixed, resulting in increased landfill usage, environmental pollution, and health hazards. This project focuses on leveraging Artificial Intelligence and embedded systems to automate waste segregation at the point of disposal.

2. Problem Statement

Despite government initiatives and public awareness campaigns, waste segregation at the source remains poor. Manual segregation is inconsistent, labor-intensive, and highly dependent on human behavior. Mixed waste reduces recycling efficiency and increases environmental pollution. Sanitation workers are also exposed to severe health risks. Therefore, there is a strong need for an intelligent, automated, and scalable waste segregation solution.

3. Objectives

- To design an AI-based system capable of classifying waste into wet, dry, plastic, and metal categories.
- To automate waste segregation at the source using embedded hardware.
- To reduce landfill waste and improve recycling efficiency.
- To support sustainable living and smart city initiatives.

4. Literature Review

Traditional waste segregation systems rely on manual labor or basic sensors such as moisture and metal detectors. While these methods provide limited segregation, they fail to accurately classify complex waste types. Recent studies show that computer vision and deep learning models, particularly Convolutional Neural Networks (CNNs), offer high accuracy in image-based waste classification. However, cloud-based solutions suffer from latency and internet dependency. Edge AI provides a reliable alternative by enabling offline, real-time processing.

5. Proposed Solution

The proposed solution is an AI-based smart waste classification and segregation system. A Raspberry Pi equipped with a camera module captures images of waste placed on an input tray. A CNN-based AI model classifies the waste into wet, dry, plastic, and metal categories. Based on the classification result, servo motors automatically guide the waste into the appropriate bin. The system operates offline using Edge AI, ensuring low latency and reliability.



6. System Architecture

The system architecture consists of four main modules: input, processing, decision-making, and output. The input module includes the waste tray and camera module. The processing module is the Raspberry Pi running the AI model. The decision-making module interprets the AI output, and the output module includes servo motors and multiple waste bins.

7. Block Diagram Description

Waste is placed on the input tray and captured by the camera. The Raspberry Pi processes the image using a CNN model. Based on the classification output, the corresponding servo motor is activated, allowing the waste to fall into the appropriate bin through gravity.

8. Artificial Intelligence Methodology

A Convolutional Neural Network (CNN) is trained using a combination of the TrashNet dataset and custom-collected Indian waste images. The trained model is optimized using TensorFlow Lite to reduce model size and improve inference speed. This allows real-time, offline execution on Raspberry Pi.

9. System Flowchart

Start → Waste Placed on Tray → Image Capture → Image Preprocessing → AI Classification → Decision Logic → Servo Motor Activation → Waste Segregated into Bin → End.

10. Algorithm

Step 1: Start the system.
Step 2: Capture waste image using camera.
Step 3: Preprocess the image.
Step 4: Perform AI-based classification.
Step 5: Identify waste category.
Step 6: Activate corresponding servo motor.
Step 7: Segregate waste into bin.
Step 8: Reset system for next input.

11. Arduino Working Prototype

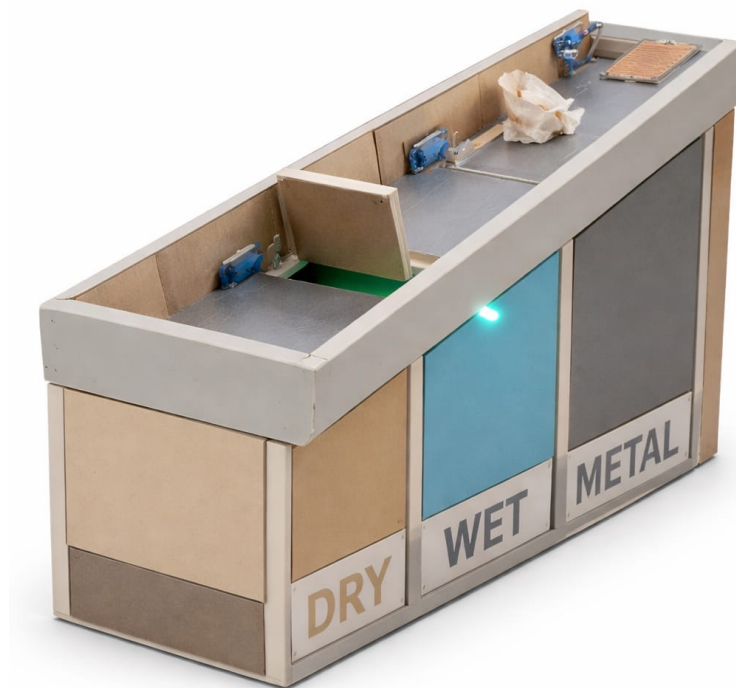
For hackathon demonstration, a sensor-based Arduino prototype is developed. This prototype uses a moisture sensor and an inductive metal sensor to identify waste type. Based on sensor readings, a servo motor performs segregation. Although simpler than the AI-based system, it validates the mechanical and control logic.

12. Hardware Components

- Raspberry Pi
- Camera Module
- Servo Motors
- Inductive Metal Sensor
- Moisture Sensor
- Mechanical Frame

13. Software Components

- Python
- TensorFlow Lite
- OpenCV
- Arduino IDE



14. Impact and Benefits

The system significantly reduces mixed waste generation and improves recycling efficiency. It minimizes human intervention, reduces health risks for sanitation workers, and promotes cleanliness. The solution supports environmental sustainability and smart city initiatives.

15. Scalability

The system can be scaled for deployment in residential complexes, educational institutions, public places, railway stations, and smart city infrastructure.

16. Future Scope

Future enhancements include cloud-based monitoring dashboards, mobile applications, improved AI accuracy through continuous learning, and integration with municipal waste management systems.

17. Conclusion

The AI-based smart waste classification and segregation system demonstrates a practical, scalable, and sustainable solution to modern waste management challenges. By combining Artificial Intelligence with embedded systems, the project addresses a critical environmental problem effectively.

18. References

1. TrashNet Dataset
2. TensorFlow Lite Documentation
3. Research papers on AI-based waste management