Smart AI + IoT + Robotics-Based Waste Classification and Monitoring System

Submitted by:

Sahyadri Thombare
Date: 6 August 2025

---

1. Abstract

In urban environments, efficient waste segregation and disposal are critical for sustainable living. This project presents a smart bin system that combines **Artificial Intelligence (AI)**, **Internet of Things (IoT)**, and **Robotics** to detect, classify, and manage waste intelligently. It automates waste classification into plastic, metal, and organic categories using AI-powered image recognition and monitors fill levels and temperature using simulated sensors.

---

2. System Overview

The smart bin consists of three main modules:

1. **AI Waste Classification**: Classifies images of waste into plastic, organic, or metal using a Convolutional Neural Network (CNN).
2. **IoT Sensor Simulation**: Simulates ultrasonic sensors for bin fill level and temperature sensors for internal bin temperature.
3. **Robotic Arm Logic**: Based on AI classification, the bin simulates a robotic arm directing waste to the correct compartment.

This integration represents a prototype for future smart cities and automated waste collection systems.

---

3. Architecture Diagram

(See attached image: Smart Bin System Architecture)

---

4. Technologies Used

- **Python** (Google Colab)
- **TensorFlow/Keras** – CNN for AI classification
- **NumPy** – Array operations

- **Matplotlib** – Visual outputs (optional)
- **Canva** – Architecture design
- **Servo Motor Logic (Simulated)** – Python logic for motor rotation
- **IoT Simulation** – Python code simulating real-world sensor inputs

---

5. Dataset & AI Training

- The image dataset was organized into:
    - /plastic/
    - /organic/
    - /metal/
- Images were resized to **128x128** and normalized.
- Model:

```
Sequential([
  Conv2D(32, (3, 3), activation='relu'),
  MaxPooling2D(2, 2),
  Conv2D(64, (3, 3), activation='relu'),
  MaxPooling2D(2, 2),
  Flatten(),
  Dense(64, activation='relu'),
  Dense(3, activation='softmax')
])
```

- Trained for 5 epochs with ~3 images/class for testing.

---

6. Sensor Simulation

Python code was used to simulate:

- **Ultrasonic sensor**: Random distance (bin fill) values from 5 to 40 cm
- **Temperature sensor**: Random temperature between 20°C and 35°C

Bin Status:

- <10 cm: ⚠️ Almost Full

- <25 cm: 🟡 Half Full
- >25 cm: 🟢 Empty

---

7. Robotic Arm Decision Logic

Based on predicted waste type:

```
def control_robotic_arm(waste_type):
    if waste_type == "plastic":
        print("Rotate servo to 0°")
    elif waste_type == "organic":
        print("Rotate to 90°")
    elif waste_type == "metal":
        print("Rotate to 180°")
```

This logic will guide an actual servo motor in the real hardware prototype.

---

8. Results & Output Snapshots

- **AI Prediction**: Successfully identified uploaded images (e.g., banana peel → organic)
- **Sensor Simulation**: Accurately displayed 10 readings of bin fill and temperature
- **Robotic Logic**: Output rotated to correct bin angle based on AI prediction

---

9. Future Scope

- Replace simulation with real hardware: Ultrasonic sensor (HC-SR04), DHT11/DHT22 sensor, Servo motor
- Deploy trained AI model into a microcontroller using TensorFlow Lite
- Build live dashboard using Streamlit/Firebase
- Enable cloud-based alert system to municipal corporations

---

10. Conclusion

This prototype represents a **complete integration of AI, IoT, and Robotics** in a real-world use case. The smart bin can intelligently detect waste types, monitor internal status, and

respond with automated action, making it a scalable and valuable solution for **smart cities and cleaner environments**.

---

11. About the Developer

Name: Sahyadri Thombare
Specialization: MCA (Management), MIT-WPU
Skills: AI, Python, Data Analytics, IoT Simulation, Robotics Logic
LinkedIn: linkedin.com/in/sahyadri-thombare
GitHub: https://github.com/Sahyadri18/smart-bin-ai-iot-robotics