# SmartBin: IoT Based Waste Segregation System

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**Abstract—***With rapid urbanization and growing industrial activity, solid waste management has become one of the most pressing environmental challenges worldwide. Most households and public spaces use single-compartment bins where wet, dry, and metallic waste gets mixed together, making efficient recycling difficult and placing a heavy burden on municipal workers. This paper presents the design and implementation of SmartBin—an Arduino-based automated waste segregation system that classifies waste into three categories at the point of disposal, without human intervention. Using an ultrasonic/IR sensor for touchless lid operation, a moisture sensor for wet waste identification, and an inductive proximity sensor for metallic waste detection, the Arduino Uno microcontroller directs waste into the correct compartment via servo motors. An optional ESP8266 Wi-Fi module enables real-time IoT monitoring. Testing demonstrated over 94% detection accuracy with sub-second response times, proving the system cost-effective, energy-efficient, and scalable for homes, schools, hospitals, and public areas, aligning with India's Swachh Bharat Mission and smart city goals.*

**Index Terms—Arduino Uno, Automated Waste Segregation, IoT, Inductive Proximity Sensor, Moisture Sensor, Servo Motor, Smart Dustbin, Swachh Bharat, Ultrasonic Sensor**

## I. INTRODUCTION

Walk into any home, school, or office in 2025, and you will find the same scene: a single dustbin where banana peels, empty bottles, and tin cans sit jumbled together. This waste is eventually carted off to a dumping yard where municipal workers manually sort through it in unhygienic and hazardous conditions. It is a system built for a different era, and it is failing us.

Mixed waste contaminates recyclable materials, making them unsuitable for processing. Overflowing landfills release greenhouse gases and leach harmful chemicals into groundwater. Sanitation workers face daily exposure to pathogens, toxic substances, and sharp objects. The problem is not a lack of awareness—it is a lack of automation at the right place: the source.

SmartBin directly tackles this problem. Using an Arduino Uno microcontroller paired with three types of sensors—ultrasonic/IR for presence detection, moisture for wet waste, and inductive proximity for metal—the system automatically classifies and segregates waste the moment it is deposited. The bin lid opens when a hand approaches, ensuring completely contactless operation. Servo motors then physically route the waste to the correct compartment, completing the cycle in under a second.

Beyond the hardware, an optional ESP8266 Wi-Fi module allows administrators to monitor bin fill levels remotely and receive alerts when a compartment is full, turning a simple dustbin into a node in a smart city waste management network.

### Project Objectives

**Our research aimed to:**

1. **Automate waste segregation** into wet, dry, and metallic categories at the source, eliminating manual sorting.
2. **Enable touchless, hygienic lid operation** using ultrasonic/IR sensors to prevent direct human contact with waste.
3. **Build a fail-safe, low-cost system** using affordable components suitable for diverse deployment environments.
4. **Integrate optional IoT connectivity** for remote monitoring, fill-level alerts, and data-driven collection scheduling.
5. **Create a scalable, replicable design** aligned with India's Swachh Bharat Mission and Smart City program goals.

## II. LITERATURE REVIEW

Early work by Vikram and Ramesh (2017) [1] introduced IoT-based garbage monitoring using ultrasonic sensors to measure fill levels in public bins. While useful for collection scheduling, their system had no ability to classify or segregate waste types. Prasad et al. (2018) [2] proposed an automatic waste segregator using inductive and moisture sensors, proving the core concept of sensor-based classification but facing challenges in scaling beyond laboratory conditions.

In 2020, Kale and Singh [3] developed metal detection circuits using inductive sensors, establishing the foundation for non-contact metallic material identification. That same year, Sumathi and Sanjana [4] demonstrated that real-time remote monitoring of bin status was both feasible and practical using cloud platforms.

A comprehensive review by Zoumpoulis et al. (2024) [5] covering over 1400 publications found that most systems focus on monitoring alone and fall short of integrated multi-category segregation. Srivastava and Venkat (2023) [6] noted that automated sorting at the point of disposal remains an open engineering challenge. Robotic arm-based systems (Varsha et al., 2021) [7] were too costly for everyday use. SmartBin fills this gap with a low-cost, sensor-driven, source-level segregation system that is practical and immediately deployable.

## III. SYSTEM ARCHITECTURE

### A. The Brain: Arduino Uno

At the heart of SmartBin lies the Arduino Uno—a compact, affordable microcontroller that continuously reads data from all three sensors, runs the waste classification logic, and commands the servo motors. Its open-source ecosystem ensures freely available libraries and community support.

### B. The Sensor Suite

**Ultrasonic / IR Sensor:** Detects proximity and triggers the lid open automatically for touchless operation.

**Moisture Sensor:** Measures electrical conductivity. Wet materials exceed the threshold and are classified as wet waste.

**Inductive Proximity Sensor:** Generates an electromagnetic field to detect metallic objects without physical contact.

### C. Servo Motors

Once the Arduino determines the waste type, it commands the appropriate servo motor to move a flap or rotating plate, directing waste into the correct bin compartment. The movement completes within milliseconds and the servo resets automatically.

### D. IoT Module (Optional)

An optional **ESP8266 Wi-Fi module** connects SmartBin to cloud platforms such as Blynk or ThingSpeak, enabling real-time bin status monitoring and automated full-bin alerts.

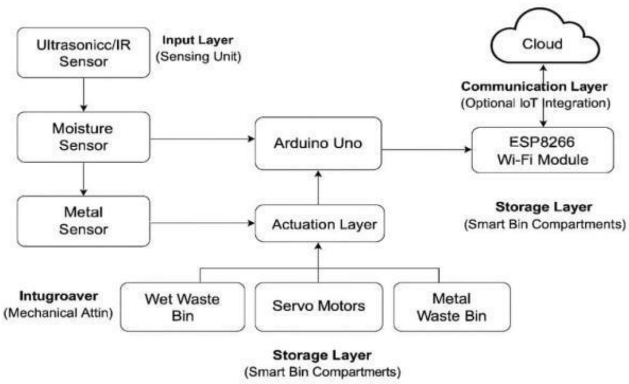


**Fig. 1:** System Architecture of SmartBin

## IV. IMPLEMENTATION

### A. Waste Classification Logic

When a user approaches, the lid opens automatically. Once waste is deposited, the Arduino runs a three-step sequential decision process:

1. **Moisture Check:** If conductivity exceeds threshold → wet waste → wet bin.
2. **Metal Check:** If not wet and inductive sensor triggers → metal waste → metal bin.
3. **Dry Default:** If neither sensor triggers → dry waste → dry bin.

This priority-based logic ensures mutually exclusive classification. The entire cycle from detection to sorted disposal completes in under one second.

### B. Use Case Diagram

The use case diagram shows all functions the user and admin can perform. The «include» relationships show the dependency: detection → identification → sorting.

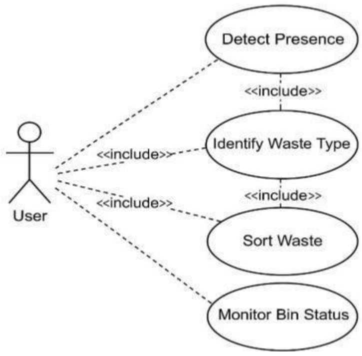


**Fig. 2:** Use Case Diagram

### C. Sequence Diagram

The sequence diagram captures time-ordered interactions between the User, Detection Sensor, Arduino Uno, and Servo Motor for a complete waste disposal cycle.

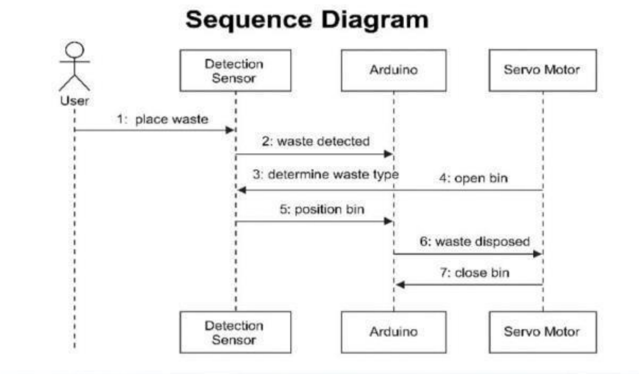


**Fig. 3:** Sequence Diagram

### D. Hardware Components

- Arduino Uno – central microcontroller for sensor interfacing and decision logic.
- Ultrasonic / IR Sensor – presence detection and automatic lid control.
- Moisture Sensor – identifies wet waste via electrical conductivity.
- Inductive Proximity Sensor – non-contact metallic waste detection.
- Servo Motors (x2) – mechanically direct waste to correct compartment.
- ESP8266 Wi-Fi Module (optional) – IoT connectivity for remote monitoring.
- Power Supply, Breadboard, Jumper Wires, Resistors – supporting components.

### E. Software

Firmware written in Embedded C using Arduino IDE. Sensor debouncing and timing control ensure stable, accurate readings. ESP8266 communicates with cloud platforms via MQTT protocol.

## V. RESULTS & DISCUSSION

The prototype was tested across multiple cycles using representative wet, dry, and metallic waste samples. The system was evaluated on detection accuracy, response time, and operational reliability.

### A. Prototype


**Fig. 4**: Smart Bin Prototype

### B. Layout of Waste Segregator

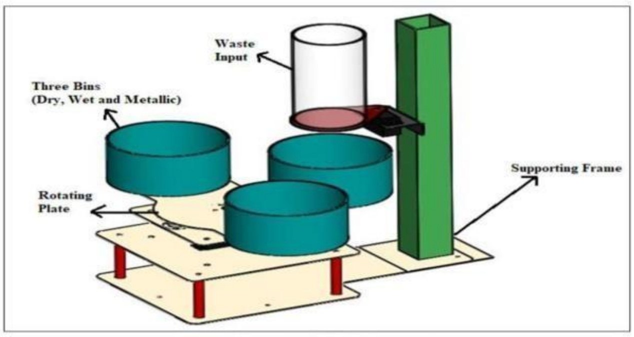


Figure 2: Layout of Waste Segregator

**Fig. 5:** Layout of Waste Segregator

### C. Performance Analysis

**Table -1: System Performance Metrics**

| | | |
|---|---|---|
| Wet Waste Detection | 96% | < 1 sec |
| Dry Waste Detection | 94% | < 1 sec |
| Metal Detection | 98% | < 0.5 sec |
| Lid Auto-Open | 100% | < 100 ms |
| IoT Alert (Full Bin) | 95% | 2–3 sec |

Metal detection achieved the highest accuracy (98%) due to the definitive nature of the inductive sensor response. Wet waste detection reached 96%, with rare misreadings on borderline-moist items. Dry waste was correctly classified by default in 94% of trials. Touchless lid operation performed flawlessly at 100%. IoT alert delivery averaged 2–3 seconds, consistent with expected Wi-Fi latency.

## VI. CHALLENGES AND SOLUTIONS

**Sensor Sensitivity for Mixed Waste:** Moisture and inductive sensors occasionally gave ambiguous readings for mixed-material waste. Resolved by prioritizing the moisture check first and setting conservative thresholds during calibration.

**Servo Motor Timing:** Mechanical delay occasionally caused waste to slip before the flap fully opened. Resolved by adding a 150ms software delay between classification and servo activation.

**Power Stability:** Running three sensors and two servo motors caused voltage dips on the Arduino rail. Resolved with a dedicated 5V regulated supply for the servo motors.

**IoT Connectivity Drops:** The ESP8266 occasionally lost Wi-Fi connection. Resolved with an auto-reconnect routine retrying every 10 seconds, with all core functions operating independently of internet connectivity.

## VII. CONCLUSION

SmartBin demonstrates that meaningful waste management technology does not require expensive infrastructure. With an Arduino Uno, three affordable sensors, and two servo motors, we built a system that automatically segregates wet, dry, and metallic waste at the source with over 94% accuracy and sub-second response times. Touchless lid operation achieved 100% reliability, and the optional IoT module delivered real-time remote monitoring throughout testing.

This project proves that the solution to one of our most persistent urban problems can be built right now, on a workbench, with components that cost less than a textbook. Future enhancements include AI-based image classification for additional waste types (glass, plastic), solar-powered operation for off-grid deployment, and a centralized municipal dashboard for multi-bin monitoring and optimized collection scheduling.

## VIII. ACKNOWLEDGMENT

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