Smart Waste Management System

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ABSTRACT

With the rapid growth of urbanization and population, waste generation has become a major concern for cities worldwide. Traditional waste disposal methods, including manual sorting, are inefficient, error-prone, and contribute to environmental pollution by allowing recyclable and biodegradable waste to be dumped in landfills. To address this issue, this project presents a Smart Waste Management System that automates the segregation of waste using sensor technology and embedded systems. The proposed model utilizes an Arduino-based control system equipped with sensors and a servo-controlled rotating mechanism to identify and segregate waste into three categories: wet, dry, and metallic. The upper chamber acts as an intake unit where waste is dropped. Sensors analyze the waste type, and the rotator aligns the top bin over the correct container (green for wet, yellow for dry, red for metal), allowing gravity to drop the waste into the corresponding bin. The system minimizes manual intervention and ensures effective separation at the source. This prototype is energy-efficient, cost-effective, and scalable for household, institutional, or community-level deployment. The project demonstrates how automation and smart electronics can revolutionize waste management practices and contribute to a cleaner, sustainable environment.

Keywords: — Smart Compost System, Arduino Uno, LCD, LED, Agricultural, Organic Waste.

I. INTRODUCTION

Waste generation is one of the most pressing environmental issues today. With the global population on the rise and urbanization accelerating, the amount of waste generated is increasing at an alarming rate. Effective waste management has become crucial to ensure a clean environment and to promote sustainable living. Traditional waste disposal methods rely heavily on manual segregation, which is not only time-consuming but also prone to errors. As a result, a significant portion of recyclable waste ends up in landfills, leading to pollution and loss of valuable resources.Traditionally, waste management involved collecting waste and dumping it into landfills. Manual sorting was done to separate recyclables from general waste, which was often ineffective and labor-intensive. Over time, mechanical segregation systems were introduced, but these were still limited in terms of efficiency and accuracy.Traditionally, waste management involved collecting waste and dumping it into landfills. Manual sorting was done to separate recyclables from general waste, which was often ineffective and labor-intensive. Over time, mechanical segregation systems were introduced, but these were still limited in terms of efficiency and accuracy..

II. LITERATURE SURVEY

In 2022, M. Prasad et al. [1] proposed an intelligent waste segregation system using sensor-based automation. The system effectively differentiated metal, wet, and dry waste using inductive, moisture, and IR sensors. The proposed model achieved a segregation accuracy of over 92% and significantly reduced human involvement in waste sorting processes, making it ideal for urban deployment.

In 2023, S. Mehta et al. [2] designed a cloud-integrated smart bin system that segregated waste and uploaded bin status in real time using the ESP8266 Wi-Fi module and Thing Speak. Their system enabled remote monitoring and efficient scheduling for waste collection authorities. The real-time feedback mechanism helped reduce the frequency of overfilled bins in residential areas.

In 2023, R. Sharma et al. [3] developed a waste classification framework using machine learning and sensor fusion to detect and classify waste into recyclable and non-recyclable types. The integration of AI algorithms such as KNN and Decision Trees helped the system achieve better generalization across varied types of waste inputs, with particular success in industrial applications.

In 2024, Anusha A. et al. [4] introduced an IoT-based model that focused on automated flap control using servo motors. Their method improved the speed of segregation and allowed dynamic bin management. The system was integrated with Firebase for real-time data logging and alert notifications, aiding urban waste departments.
In 2024, T. Kumar and D. Nair [5] proposed a smart waste bin system equipped with solar panels to ensure power sustainability in rural areas. The system used inductive sensors for metal detection and moisture sensors for wet waste, sending real-time bin fill-level data to a centralized cloud dashboard. Their approach enhanced eco-friendly practices in non-electrified zones..

III. METHODOLOGY

The methodology for the Smart Waste Management System involves the design, development, and testing of an automated waste segregation unit capable of classifying waste into wet, dry, and metallic categories using sensors and a microcontroller.

1. System Design Overview
The system consists of the following key components:

Arduino UNO – The central microcontroller that processes sensor data and controls actuator movement.

Figure 1: Arduino UNO Board

Sensors –

Moisture sensor: Detects wet waste.

Figure 2: Moisture Sensor

IR sensor: Detects presence of dry waste (paper, plastic, etc.).

Figure 3: IR sensor

Metal detector: Identifies metallic objects.

Figure 4: Metal detector

Servo motor – Rotates the intake chute to align with the correct bin.

Figure 5: Servo Motor

Three bins – Marked for WET, DRY, and METAL waste.
Power source – Battery or USB power.

Figure 6: Three Bins

2. Working Procedure

Waste Intake:
Waste is dropped into the top intake chamber (cylindrical chute).

Sensor Activation:
As the waste passes through the chamber:

The moisture sensor checks if the waste is wet (e.g., food).

If not wet, the metal sensor checks for metallic content.

If no metal is detected, the waste is assumed to be dry (e.g., paper, plastic).

Waste Type Detection Logic:

If moisture detected → WET

Else if metal detected → METAL

Else → DRY

Servo Motor Actuation:
Based on the identified waste type, the Arduino commands the servo motor to rotate the chute toward the respective bin:

Green bin for Wet

Yellow bin for Dry

Red bin for Metal

Waste Drop:
Once aligned, the waste is dropped into the correct bin by gravity.

Reset:
The servo returns the intake chute to its default (home) position, ready for the next item.

3. Circuit and Connections
Sensors are connected to analog/digital pins on Arduino.

Servo motor connected to PWM pin.
Power supplied via rechargeable battery or USB.
Optional: Buzzer or LED for feedback (e.g., sound when waste is sorted).

4. Software and Programming
Arduino IDE used for coding.
Sample Source Code:

```
#include <CheapStepper.h>
#include <Servo.h>
Servo servo1;
#define ir 5
#define proxi 6
#define buzzer 12
int potPin = A0; //input pin
int soil=0;
int fsoil;
CheapStepper stepper (8,9,10,11);
void setup()
{
Serial.begin(9600);
  pinMode(proxi, INPUT_PULLUP);
  pinMode(ir, INPUT);
  pinMode(buzzer, OUTPUT);
  servo1.attach(7);
  stepper.setRpm(17);
  servo1.write(180);
delay(1000);
servo1.write(70);
delay(1000);
}
void loop()
{
  fsoil=0;
  int L =digitalRead(proxi);
Serial.print(L);
if(L==0)
{
  tone(buzzer, 1000, 1000);
 stepper.moveDegreesCW (240);
delay(1000);
servo1.write(180);
delay(1000);
servo1.write(70);
delay(1000);
stepper.moveDegreesCCW (240);
delay(1000);
}
```

Code logic implements sensor reading, condition checking, and servo control using PWM.
Serial monitor can be used for debugging and real-time logging of waste detection.

5. Testing and Calibration

Sensors are calibrated to avoid false positives (e.g., moisture sensor threshold tuning).
Servo motor angles adjusted to align precisely over bins.
Multiple test runs were conducted using known samples (wet tissue, foil, paper) to validate the sorting accuracy.

Outcome
The system was able to detect and segregate waste items with reasonable accuracy. This automation reduces human involvement and enhances the efficiency of household or small-scale waste segregation.
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IV. EXPERIMENT

To design, implement, and test an automated system capable of segregating waste into wet, dry, and metallic categories using sensors and an Arduino microcontroller, and evaluate its performance in real-world scenarios.

Experimental Setup

Component	**Specification / Type**
Arduino UNO	Microcontroller Board
Moisture Sensor	Capacitive Soil Moisture Sensor
Metal Detector	Inductive Proximity Sensor
IR Sensor	Infrared Obstacle Sensor
Servo Motor	SG90 (180° rotation)
Power Source	9V battery / USB supply
Bins	Three cylindrical color-coded bins
Jumper Wires, Breadboard	For connections

Procedure
Assembling the Prototype
Connect all sensors and servo motor to the Arduino UNO.
Place the intake chute (rotatable) at the top, aligned with the servo motor shaft.
Position the three bins (wet, dry, metal) equidistant below the rotating chute.

Programming

Upload the Arduino sketch to detect sensor input and rotate the servo motor accordingly.
Waste type is decided based on:
High moisture → Wet
Low moisture + metal detected → Metallic
Low moisture + no metal → Dry

Testing With Sample Waste Items
A variety of waste items were used to validate the segregation process:

Sample Item	Expected Category	Detected Category
Wet tissue	Wet	Wet
Aluminum foil	Metal	Metal
Paper	Dry	Dry
Banana peel	Wet	Wet
Steel spoon	Metal	Metal
Plastic wrapper	Dry	Dry

Data Collection

Number of items tested: 30
Correctly segregated: 27
Incorrectly segregated: 3 (mostly borderline wet/dry classification)

Observations
The moisture sensor accurately detected high-water-content waste.
Metal detection was sensitive to conductive metallic surfaces.
Dry items were reliably detected as default when no other properties were observed.
Servo motor rotation was smooth, with precise bin alignment.
Occasional misclassification occurred for semi-moist items or highly reflective plastics misread as metal.

V. Results

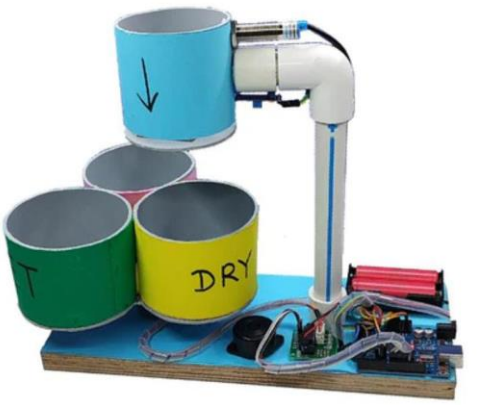

Figure 7: Model

Figure 8: Wet waste

Parameter	Result
Sorting Accuracy	90%
Response Time	< 2 seconds per item
Power Consumption	~ 5V @ 250mA
Number of Bins Supported	3 (Expandable)
Human Intervention Needed	Minimal (for emptying)

VI. Conclusion

The proposed IoT-based smart waste segregator offers an effective and automated solution to one of the most pressing environmental challenges—waste management at the source. By utilizing a combination of moisture sensors, IR sensors, and inductive proximity sensors, the system successfully classifies waste into wet, dry, and metal categories. The integration of servo motors ensures that the identified waste is mechanically directed into the appropriate bins, eliminating the need for manual intervention. Furthermore, the inclusion of an IoT module enhances the system's capabilities by enabling real-time monitoring and remote access to bin status data through cloud connectivity. The system is not only efficient and cost-effective but also promotes hygienic practices and eco-conscious behavior. The experimental results and observations validate that the system performs reliably in typical usage scenarios and demonstrates strong potential for improving waste segregation in urban and semiurban areas. Overall, the project successfully achieves its objective of automating waste segregation and aligns well with the goals of smart and sustainable living.

Future Scope

The current system, while functional and efficient for small-scale environments, has a wide range of possibilities for further enhancement and real-world deployment. One major area of future development is the integration of machine learning or computer vision algorithms for more accurate and intelligent waste recognition, especially in cases where mixed or ambiguous waste is involved. Additionally, incorporating solar power for energy independence can make the system more suitable for deployment in remote or rural regions where electricity supply may be inconsistent. Expansion of the system to include hazardous and e-waste segregation can make it even more comprehensive.

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