Intelligent Automatic Waste Segregation System

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Abstract

This paper presents a smart waste segregation system leveraging IoT and sensor technologies to enhance urban sustainability. The system integrates Arduino, IR sensors, metal detectors, moisture sensors, and ultrasonic sensors to automate waste categorization into dry, wet, and metal types. A NodeMCU module enables real-time monitoring and sends notifications via Telegram when bins are full. This approach reduces manual intervention, improves hygiene, and supports data-driven waste collection strategies. By promoting efficient waste management, the proposed system contributes to cleaner and more sustainable urban environments.

I INTRODUCTION

In order to ensure efficient and sustainable waste management, national and local governments are facing an increasingly pressing challenge due to the rapid increase in the volume and types of solid and hazardous waste brought on by ongoing economic expansion, urbanisation, and industrialisation. Global municipal solid trash generation is expected to have reached 2.02 billion tonnes in 2006, a 7% yearly growth since 2003 (Global trash Management Market Report 2007). Waste must be properly separated, handled, transported, and disposed of in order to reduce hazards to the environment, public health, and patient safety. Waste is most economically valuable when it is separated. There isn't a method in place right now to separate dry, wet, and metallic garbage.

In order for waste to be routed straight for processing, this study suggests an Automated Waste Segregator (AWS), a low-cost, user-friendly alternative for a household segregation system. Its purpose is to separate the trash into three categories: dry, moist, and metallic garbage. The AWS uses capacitive sensors to differentiate between wet, dry, and metallic waste, and a parallel resonant impedance sensing system to detect metallic objects. According to experimental data, the AWS has been successfully used to separate garbage into metallic, moist, and dry categories. The rubbish in front of the smart bin is initially detected by this system's infrared sensor. Additionally, in order to reduce human intervention, we incorporate a robot system to collect the waste that will be sorted by AWS. The Robot Arm System is made up of dc motors and gear drivers that can mechanically pick up waste and place it on a platform with sensors like proximity sensors to detect metallic waste and moisture sensors to detect dry and wet waste. The slotted bin rotates to dump the waste according to colour coding.

II LITERATURE SURVEY

Effective waste management has garnered increasing attention, especially with the rise of smart city initiatives. Several studies have made an effort to automate aspects of waste monitoring and segregation, although significant limitations remain.

In [1], V. Ashwin Raju et al. proposed an IoT-based intelligent waste monitoring system that uses ZigBee communication. Their system focused primarily on detecting the fill level of waste bins and transmitting data wirelessly to central servers. While it effectively enabled remote monitoring, it lacked the ability to identify or segregate different types of waste.

Bharadwaj B. et al. in [2] implemented an automated waste management model using IoT to support the Swachh Bharat Abhiyan. Their system utilized sensors to identify bin status and alert authorities. However, like many others, it was limited to bin-level monitoring and did not perform waste classification.

A more interactive approach was seen in [3] by Abhishek Ayush et al., who introduced a voice- automated dustbin that is regulated and has a rubbish level sensor.The system could open and close the bin lid based on voice commands, and it used sensors to notify when the bin was full. Nevertheless, it did not contribute to waste segregation or environmental analytics.

Li Cao and Wei Xiang [4] explored the application of automatic trash can with a garbage level sensor and control. Clearning. Their image-based model achieved high accuracy in classifying waste types into various categories, presenting a promising direction in AI-powered segregation. But the main component of their model was software-based and did not include hardware integration for physical segregation or Sudharani A.

Ghadage and Neeta Doshi [5] conducted a comprehensive review of IoT-based garbage management systems, identifying common challenges such as delayed waste collection and ineffective utilisation of manpower. They emphasized the necessity of automation and real-time communication but noted that integration of multiple functionalities in a single system was rare.

Nyayu Latifah Husni et al. [6] proposed a garbage monitoring and warning system using sensors and microcontrollers. Their model efficiently warned users when garbage bins were full but lacked any segregation capabilities or Internet-based notification systems.

Although each of these research made a contribution, significantly towards the field, most focused on monitoring rather than segregation, or they relied on high-cost image units of processing that are nofeasible in low-income regions. Few, if any, have integrated both automated segregation and real-time IoT communication in a single, cost-effective system.

The system proposed in This study fills this gap by combining sensor-based waste classification, real- time monitoring using ultrasonic sensors, and IoT- enabled alerts via Telegram. This comprehensive solution not only automates segregation but also improves hygiene, reduces manual labor, and supports smart city infrastructure.

III METHODOLOGY

The Waste Segregation System with Intelligent Automatic Function is designed to Divide garbage into three main groups: dry, wet, and metal, and subsequently segregate them into appropriate bins using sensor inputs and motor- driven actuation. The system architecture integrates embedded hardware components, sensor modules, and IoT-based alert mechanisms.

The setup is built around an The microcontroller Arduino Uno, which serves as the central processing unit. It gathers input from multiple sensors and performs decision-making operations. The NodeMCU module is integrated for wireless communication and IoT-based updates The components include:

Arduino Uno: A microcontroller for processing and receiving sensor data.

IR Sensor: Identifies any waste materials present.

Metal Sensor: Identifies if the trash is made of metal.

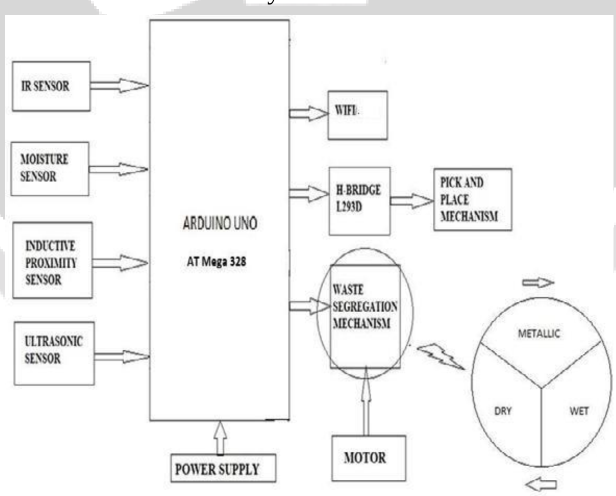
Moisture Sensor: Determines the amount of moisture in waste to distinguish between dry and wet trash.

Ultrasonic Sensor: Prevents overflow by measuring bin fill levels.

DC Motor with H-Bridge Driver: Controls the movement of a flap or rotating base to direct the waste into the correct bin.

LCD Display: Provides real-time status and bin level updates to users.

NodeMCU (ESP8266): Sends Telegram notifications when any bin is 80% or more full.



IV WORKING PROCESS

1.When an object is placed in the waste input slot, the IR sensor detects its presence.

2.The metal sensor then checks if the object contains metallic content.

3.If no metal is detected, the moisture sensor evaluates the moisture level to classify the object as wet or dry waste.

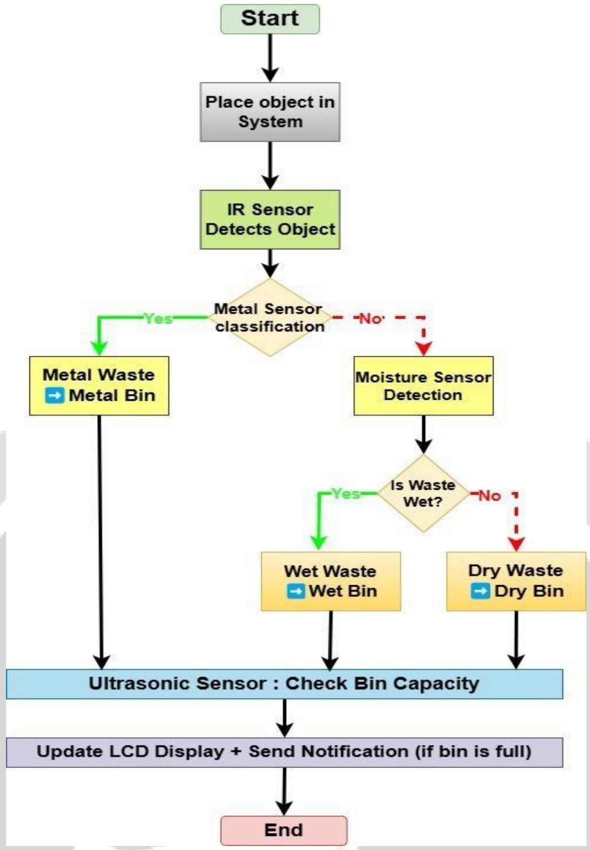
4.Based on this classification logic, the Arduino activates the DC motor to turn the flap or platform to guide the waste into the corresponding bin.

5.Meanwhile, ultrasonic sensors mounted on each bin continuously monitor fill levels.

6.Once a bin reaches 80% capacity, NodeMCU sends a notification through the Telegram app to alert waste collection authorities.

7.The LCD provides constant feedback regarding the system's operational status and bin levels.

It consists of 4 slots in dustbin for collecting different wastes like wet, dry, plastic and metallic separately.



V IMPLEMENTATION

The system was put into place utilising easily accessible hardware components and The Arduino IDE was used for programming. Each hardware module was connected and configured as per the proposed methodology.

Hardware Setup: The hardware elements including the Arduino Uno, metal detector, moisture sensor, infrared sensor, ultrasonic sensors, and DC motor were assembled on a common base. Proper insulation and wiring were maintained to ensure safety and efficiency. The LCD display was connected to show the waste type and bin status in real time. The NodeMCU was programmed with Wi-Fi credentials and linked to a Telegram bot for remote notifications. Software Development: Embedded C code was written and uploaded to the Arduino Uno using the Arduino IDE. The code interprets sensor data and controls the DC motor accordingly. For the NodeMCU, Lua scripts were used to connect with the Telegram API and trigger alert messages when bin levels exceed the set threshold.

Testing Scenarios: The system was tested with different types of waste items:

Metallic waste was correctly classified and directed to the metal

Wet waste (e.g., fruit peel) was directed to the wet bin.

Dry waste (e.g., paper, plastic) was successfully guided to the dry bin.

Additionally, ultrasonic sensors accurately tracked the fill levels and triggered notifications when bins reached 80% capacity. The response time for classification and segregation was under 2 seconds, demonstrating high efficiency.

VI OBSERVATIONS AND CHALLENGES

• Interference from ambient moisture occasionally affected moisture sensor readings.

• Metal detection was sensitive and sometimes misclassified items with small metal parts.

• Wi-Fi connectivity issues were noted in low- signal areas, affecting the consistency of Telegram alerts.

These challenges can be addressed with enhanced shielding, sensor calibration, and fallback communication options.

VI RESULT

The System for Intelligent Automatic Waste Segregation was subjected to a series of tests in a controlled environment. The following observations and outcomes were recorded:

Accuracy of Waste Classification:The system demonstrated high accuracy in classifying different types of waste:

• Metal waste: Detected with an accuracy of 95%.

• Wet waste: Correctly identified in 93% of tests.

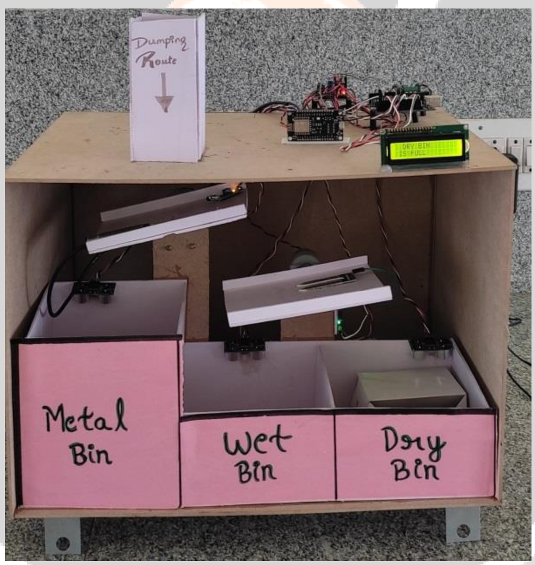
• Dry waste: Accurately classified 91% of the time. Errors mainly occurred with compositematerials (e.g., aluminum foil with food residues).

Response Time:The system responded within 1.5 to 2 seconds from object detection to classification and segregation. This quick response confirms the feasibility of using the system in real-time urban scenarios.

Bin Monitoring and Alerts: Ultrasonic sensors reliably measured bin levels. Notifications were consistently sent via Telegram when bin levels exceeded the 80% threshold. This real-time communication aids in efficient and timely waste collection.

System Reliability and Maintenance: The system operated reliably during extended tests. However, moisture sensor readings fluctuated under humid conditions, suggesting a need for periodic calibration. Additionally, power stability and network connectivity directly affected NodeMCU performance.

Discussion: The results confirm that the system can significantly lessen the participation of humans in the waste segregation process. It offers a hygienic and data-driven alternative for managing household and public waste. Despite the fact that environmental factors might influence sensor performance, the system remains adaptable and cost- effective for smart city applications.



VII APPLICATION, ADVANTAGES, LIMITATIONS

[1] Applications

• Urban waste management and recycling

• Industrial automation for sorting materials

• Security for detecting metal objects

• Vehicle detection in transport systems

• Food and pharmaceutical safety inspections

[2] Advantages

• Non-contact, hygienic detection

• Real-time monitoring and alerts

• Accurate classification of waste

• Compact and energy-efficient design

• Supports smart city infrastructure

[3] Limitations

• Limited sensor detection range

• Potential false positives due to environmental factors

VIII CONCLUSION

The Automatic Intelligent Waste Segregation System successfully demonstrates a practical, real-time, and scalable solution to the growing problem of urban waste. By automating the process of waste identification and segregation using sensor technology and IoT, the system lessens the requirement for manual assistance, minimizes health risks to waste handlers, and ensures timely waste collection.This system offers notable advantages in terms of automation, efficiency, and environmental impact. Its integration into urban infrastructure can enhance public cleanliness and support sustainable waste management practices. Additionally, the use of NodeMCU for real- time alerts demonstrates the system's compatibility with modern communication networks, enabling efficient coordination with municipal waste services.Overall, the system represents a significant step toward achieving intelligent aneco-friendly waste handling practices and can be further extended through AI, solar power, and mobile app integrations for broader utility.

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