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Smart Waste Segregation and Monitoring System Using IoT

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Abstract: The increasing generation of waste demands efficient and accurate segregation methods. This project presents an IoT-based Automated Waste Segregation System that classifies waste into four categories: wet, dry, plastic, and metal. The system uses an ESP32 microcontroller integrated with moisture, inductive proximity, infrared, and ultrasonic sensors for detection and monitoring.

A conveyor belt mechanism with stepper and servo motors enables automatic sorting based on multi-stage sensing. The system also uses MQTT and HiveQL cloud for real-time monitoring through a web dashboard. Key advantages include low cost, reduced human effort, improved accuracy, and efficient handling of biodegradable wet waste.

This solution supports smart waste management and contributes to better recycling and environmental sustainability.

INTRODUCTION

The rapid growth of urbanization and population has led to a significant increase in waste generation, making waste management one of the most critical environmental challenges of the modern era. With the expansion of cities and changing consumption patterns, the composition of waste has become highly heterogeneous, consisting of organic matter, plastics, metals, and other dry materials. Improper disposal and lack of segregation at the source result in environmental pollution, inefficient recycling, and increased pressure on landfills. Therefore, effective waste segregation is essential for sustainable waste management and the development of smart cities.

Traditional waste management systems primarily rely on manual segregation, which is labour-intensive, time-consuming, and hazardous to human health. Workers are often exposed to harmful substances, sharp objects, and infectious materials, leading to serious safety concerns. Additionally, manual sorting is prone to human error and inconsistency, which reduces the quality of recyclable materials. The absence of real-time monitoring further complicates the process, as waste collection is usually performed based on fixed schedules rather than actual bin status, resulting in inefficiencies such as overflowing bins or unnecessary collection trips.

To overcome these limitations, the integration of Internet of Things (IoT), embedded systems, and automation technologies has emerged as a promising solution. IoT enables real-time communication between physical devices and cloud platforms, allowing continuous monitoring and data-driven decision-making. Automated systems eliminate the need for direct human involvement in hazardous environments and ensure consistent and accurate segregation of waste materials. By combining sensors, microcontrollers, and cloud connectivity, modern waste management systems can significantly improve operational efficiency and environmental sustainability.

In this context, the proposed IoT-based Automated Waste Segregation and Monitoring System aims to classify waste into four distinct categories: wet (biodegradable), dry, plastic, and metal. The system utilizes an ESP32 microcontroller along with a combination of sensors, including an inductive proximity sensor for metal detection, a moisture sensor for identifying wet waste, and infrared sensors for object detection and positioning. An ultrasonic sensor is employed to monitor bin levels in real time. The segregation process is carried out using a conveyor belt mechanism driven by a stepper motor, with servo motors enabling precise sorting into respective bins.

The system follows a multi-stage sensing approach, where waste is analysed before being transported, ensuring accurate classification even for irregularly shaped objects. Furthermore, the integration of the MQTT protocol and HiveQL cloud platform enables real-time monitoring through a web-based dashboard, allowing users and authorities to track waste distribution and bin status remotely.

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By incorporating automation, real-time monitoring, and four-way segregation, the proposed system provides a cost-effective, scalable, and efficient solution for modern waste management. It enhances recycling efficiency, reduces environmental impact, and supports the vision of smart and sustainable urban infrastructure.

LITERATURE SURVEY

The growing challenges in waste management have led researchers to explore automated and intelligent waste segregation systems using Internet of Things (IoT), embedded systems, and artificial intelligence. Various studies have focused on improving segregation accuracy, reducing human effort, and enabling real-time monitoring.

A study on IoT-based waste segregation systems highlights that rapid urbanization and population growth have significantly increased waste generation, creating serious environmental and health issues. Improper disposal leads to pollution, disease spread, and inefficient recycling processes, emphasizing the need for smart waste management solutions. Traditional waste handling methods rely heavily on manual segregation, which is unsafe and inconsistent.

Several researchers have proposed IoT-enabled automated waste segregation systems integrating sensors and cloud platforms. For instance, an ESP32-based system combined with ultrasonic, moisture, and optical sensors demonstrated efficient classification of waste into biodegradable and non-biodegradable categories with real-time monitoring capabilities. The system achieved over 90% accuracy and improved collection efficiency by reducing unnecessary trips.

Another approach utilizes sensor-based segregation techniques where moisture sensors identify wet waste, inductive sensors detect metals, and infrared sensors assist in object detection. These systems are often combined with conveyor belt mechanisms and servo motors for automated sorting. Such designs are cost-effective and suitable for smart city applications, offering reliable segregation and real-time bin monitoring.

In addition to sensor-based systems, recent advancements include machine learning and computer vision techniques. AI-based models using Convolutional Neural Networks (CNNs) have been developed to classify waste based on image recognition, improving accuracy and enabling detection of complex waste types. However, these systems require high computational power and are sensitive to environmental conditions such as lighting and object overlap.

Survey studies on smart dustbin systems indicate that IoT-based monitoring using cloud platforms and MQTT protocols plays a crucial role in modern waste management. These systems enable real-time data transmission, remote monitoring, and efficient waste collection planning, making them suitable for large-scale deployment in smart cities. Additionally, IoT-based solutions help in optimizing logistics, reducing operational costs, and improving environmental sustainability.

Despite these advancements, existing systems have certain limitations. Many solutions focus only on two or three categories of waste, such as wet, dry, or metal, and lack multi-category segregation capability. Some systems also suffer from high implementation costs, mechanical inefficiencies, or dependency on stable internet connectivity. Furthermore, AI-based approaches, while accurate, are often complex and expensive for small-scale deployment.

To address these gaps, the proposed system introduces a cost-effective IoT-based automated waste segregator capable of classifying waste into four categories: wet, dry, plastic, and metal. By combining multi-stage sensor-based detection with real-time cloud monitoring, the system improves segregation accuracy while maintaining low complexity and scalability. This approach provides a balanced solution between performance, cost, and practical implementation for smart waste management.

SYSTEM ARCHITECTURE

The proposed IoT-Based Automated Waste Segregation and Real-Time Monitoring System is designed using a layered architecture that integrates sensing, control, actuation, and cloud communication. The system is structured into three primary layers: the Perception Layer, the Control Layer, and the Application Layer, ensuring efficient data processing, accurate classification, and real-time monitoring.

1. Perception Layer (Sensing Unit)

The Perception Layer is responsible for detecting and analysing the physical properties of waste materials. It consists of multiple sensors working in coordination to identify different types of waste:

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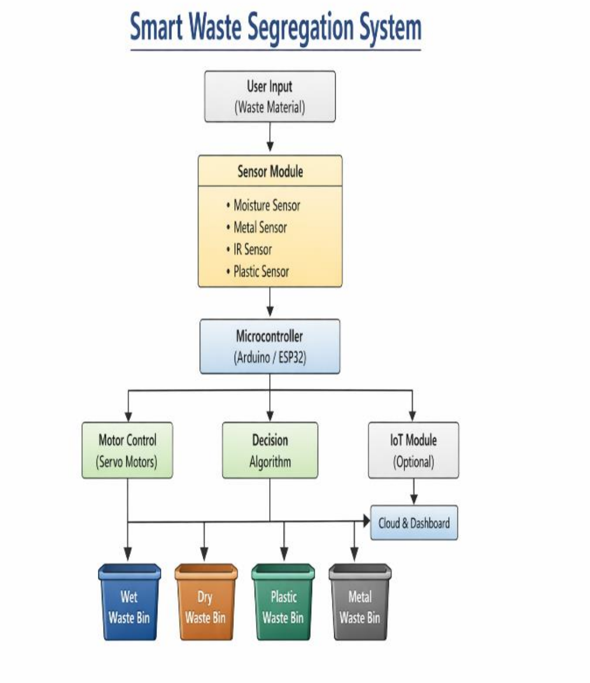
- **Inductive Proximity Sensor** is used to detect metallic waste based on electro



- **Moisture Sensor** identifies wet (biodegradable) waste by measuring conductivity and moisture content.
- **Infrared (IR) Sensors** are used for object detection, positioning, and tracking along the conveyor belt.
- **Ultrasonic Sensor (HC-SR04)** is utilized to monitor the fill level of each bin in real time.

This layer ensures that waste is accurately sensed and relevant data is sent to the control unit for processing.

2. Control Layer (Processing Unit)

The Control Layer is the core of the system, managed by the ESP32 microcontroller. It processes sensor data, executes classification logic, and controls all mechanical and communication operations.

- The ESP32 receives inputs from all sensors and applies a **multi-stage sequential sensing algorithm**.
- Based on sensor data, the system classifies waste into four categories: **Metal, Wet, Plastic, and Dry waste**.
- A **stability verification algorithm** ensures reliable detection by eliminating false triggers caused by irregular waste shapes.
- The controller generates PWM signals to operate servo motors and controls the stepper motor for conveyor movement.
- Simultaneously, it handles IoT communication using the MQTT protocol.

This layer acts as the “brain” of the system, ensuring accurate decision-making and synchronized operations.

3. Actuation Layer (Mechanical System)

The Actuation Layer performs the physical segregation of waste based on the classification decision.

- A **conveyor belt system**, driven by a stepper motor, transports waste materials to different sorting points.
- **Servo motors** are used as mechanical pushers to direct waste into respective bins.
- A **main gate mechanism** controls the release of waste onto the conveyor after classification.

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- The system uses a **multi-push sorting logic** to ensure proper disposal of irregular or heavy objects.

This layer ensures efficient and reliable physical segregation of waste into the correct bins.

4. Application Layer (Cloud & Monitoring System)

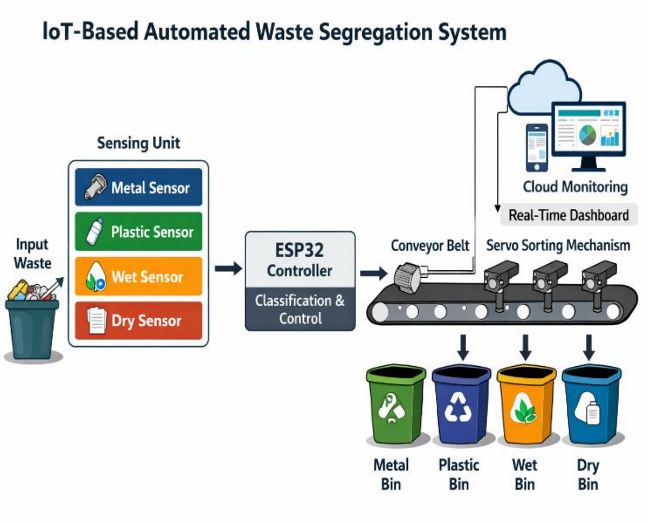
The Application Layer enables real-time monitoring and data visualization using IoT technology.

- The ESP32 transmits data using the **MQTT protocol** to the **HiveMQ cloud platform**.
- Data such as waste type, bin levels, and system status are published to specific topics.
- A **web-based dashboard** (developed using HTML, CSS, and JavaScript) subscribes to these topics and displays real-time updates.
- The dashboard provides features such as **bin capacity monitoring, waste distribution analytics, and alerts for full bins**.

This layer allows remote access, making the system suitable for smart city applications.

5. Overall Working Flow

1. Waste is deposited into the input chamber.
2. Sensors analyze the waste using sequential detection (metal → moisture → IR).
3. ESP32 processes the data and classifies the waste into one of four categories.
4. The main gate releases the waste onto the conveyor belt.
5. Servo motors push the waste into the correct bin.
6. Ultrasonic sensors monitor bin levels and send updates to the cloud.
7. Real-time data is displayed on the web dashboard.



METHODS AND MATERIALS

The proposed IoT-Based Automated Waste Segregation and Real-Time Monitoring System is developed using a combination of embedded hardware components, sensor technologies, mechanical systems, and software tools. The methodology focuses on accurate detection, efficient sorting, and real-time monitoring of waste into four categories: wet, dry, plastic, and metal.

1. Materials (Hardware Components)

The system consists of the following key hardware components:

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- **ESP32 Microcontroller**

Acts as the central processing unit of the system. It handles sensor data processing, classification logic, motor control, and IoT communication. It is chosen for its high processing speed, built-in Wi-Fi, and multiple GPIO pins.

- **Inductive Proximity Sensor**

Used for detecting metallic waste. It works on electromagnetic induction and can identify both ferrous and non-ferrous metals.

- **Moisture Sensor**

Detects wet (biodegradable) waste by measuring moisture content and electrical conductivity.

- **Infrared (IR) Sensors**

Used for object detection and tracking along the conveyor belt. They help in identifying the position of waste during sorting.

- **Ultrasonic Sensor (HC-SR04)**

Measures the fill level of waste bins using distance measurement, enabling real-time monitoring.

- **Servo Motors (MG995)**

Used for operating the main gate and sorting mechanism. They push waste into respective bins with high torque and precision.

- **Stepper Motor (28BYJ-48 with ULN2003 Driver)**

Drives the conveyor belt to transport waste materials through the system.

- **Conveyor Belt Mechanism**

Provides controlled movement of waste from input to sorting section.

- **OLED Display (SSD1306)**

Displays system status, waste type, and bin levels locally.

2. Methods (System Implementation)

The system is implemented using a structured methodology involving sensing, processing, sorting, and monitoring.

a) Waste Detection and Sensing

Waste is first placed in the input chamber, where multiple sensors analyse its properties:

- Metal detection using inductive sensor
- Moisture detection for wet waste
- IR sensors for presence and positioning

This multi-sensor approach ensures accurate identification of waste type.

b) Classification Process

The ESP32 processes sensor inputs using a decision algorithm:

- Metal → Metallic waste
- High moisture → Wet waste
- Remaining → Plastic or Dry waste

This enables classification into four categories:
Metal, Wet, Plastic, and Dry waste

c) Mechanical Sorting Mechanism

- A servo-controlled gate releases the waste onto the conveyor
- The conveyor moves the waste to sorting positions

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- IR sensors detect object position
- Servo motors push waste into respective bins

A **multi-push mechanism** is used to ensure proper sorting of irregular objects.

d) Bin Level Monitoring

Ultrasonic sensors continuously measure bin levels:

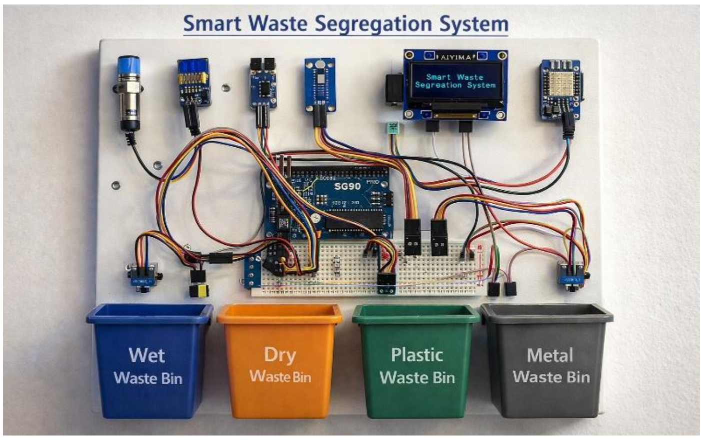
- Detects fill percentage
- Prevents overflow
- Triggers alerts when bins are full

e) IoT Communication and Monitoring

- The ESP32 sends real-time data using the MQTT protocol
- Data is transmitted to the HiveQL cloud platform
- A web dashboard displays waste data, bin levels, and alerts

3. Software Tools and Technologies

- **Arduino IDE** – Used for programming ESP32
- **C++ (Arduino Language)** – For implementing control logic
- **MQTT Protocol** – For real-time communication
- **HiveQL Cloud** – For cloud data handling
- **HTML, CSS, JavaScript** – For dashboard development
- **Libraries Used**:
  - PubSubClient (MQTT communication)
  - NewPing (ultrasonic sensor)
  - ESP32Servo (servo control)



Hardware Description

The system is built using an ESP32 microcontroller as the central control unit, which processes sensor data, controls motors, and enables IoT communication. An inductive proximity sensor is used to detect metallic waste, while a moisture sensor identifies wet waste. Infrared (IR) sensors are used for object detection and positioning during sorting.

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A stepper motor drives the conveyor belt to transport waste, and high-torque servo motors are used to direct waste into the correct bins. An ultrasonic sensor monitors the fill level of each bin to prevent overflow. An OLED display provides real-time system information to the user.

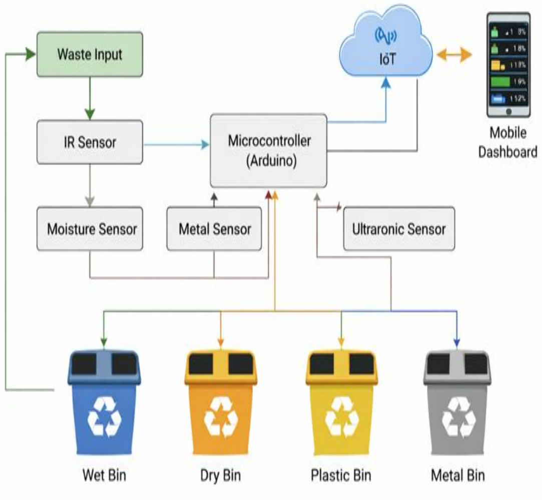
All components are powered through a regulated power supply, ensuring stable operation. Together, these hardware components enable accurate, automated segregation of waste into wet, dry, plastic, and metal categories with real-time

monitoring capability.

WORKING METHODOLOGY

The working methodology of the proposed IoT-Based Automated Waste Segregation and Real-Time Monitoring System is based on a sequential sensing and automated sorting mechanism. The system is designed to ensure accurate classification, reliable mechanical operation, and real-time data monitoring. It follows a structured process consisting of

sensing, decision-making, actuation, and cloud communication.



1. Sequential Sensing Mechanism

The system operates on a **multi-stage sensing approach**, where waste is analysed step-by-step before being transported. When waste is dropped into the input chamber, it is temporarily held at the main gate to allow accurate sensing.

- The **inductive proximity sensor** first checks for metallic content and sets a metal detection flag.
- The **moisture sensor** then measures the moisture level to identify wet (biodegradable) waste.
- The **infrared (IR) sensors** confirm the presence and proper positioning of the waste object.

This sequential detection ensures that classification is performed under stable conditions, improving accuracy compared to dynamic sensing methods.

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2. Classification Logic

The ESP32 microcontroller processes the sensor data using a predefined decision algorithm:

- If the inductive sensor detects metal → classified as **Metal Waste**
- Else if moisture level exceeds threshold → classified as **Wet Waste**
- Else based on material characteristics → classified as **Plastic or Dry Waste**

This logic enables the system to categorize waste into four distinct types: **Metal, Wet, Plastic, and Dry waste**

3. Stability Verification Algorithm

To handle irregular shapes and avoid false triggering, the system implements a **stability verification (anti-flicker) algorithm**:

- Sensor readings must remain stable for a fixed duration (e.g., 400 ms)
- If fluctuation occurs, the sensing cycle resets
- Only stable readings trigger classification and sorting

This ensures reliable operation and prevents incorrect sorting due to sensor noise or uneven waste surfaces.

4. Mechanical Sorting Process

Once classification is complete:

- The **main gate (servo-controlled)** opens and releases the waste onto the conveyor belt
- A **stepper motor** drives the conveyor, transporting the waste to the sorting section
- At each bin position, **IR sensors detect the arrival of the object**
- Corresponding **servo motors perform a multi-push action** to direct waste into the correct bin

The **multi-push mechanism** ensures that even heavy or irregularly shaped waste is properly deposited without failure.

5. Bin Level Monitoring

Each waste bin is equipped with an **ultrasonic sensor (HC-SR04)**:

- Measures the distance between sensor and waste surface
- Calculates the fill level of the bin
- Detects conditions such as **Empty, Half-Full, and Full**

This enables efficient waste collection planning and prevents overflow.

6. IoT-Based Data Communication

The system integrates IoT functionality using the **MQTT protocol**:

- ESP32 publishes data (waste type, bin level, system status) to the **HiveQL cloud broker**
- Data is transmitted securely and in real time
- Communication follows a **publish–subscribe model**, ensuring efficient data transfer

7. Real-Time Monitoring Dashboard

A web-based dashboard is developed using HTML, CSS, and JavaScript:

- Subscribes to MQTT topics using MQTT.js

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- Displays real-time data such as waste distribution and bin capacity
- Provides alerts for **"Bin Full" status**
- Updates charts and statistics dynamically

8. Overall Operational Flow

1. Waste is inserted into the system
2. Sensors analyse the waste sequentially
3. ESP32 processes data and classifies the waste
4. Waste is released onto the conveyor belt
5. Servo motors sort waste into respective bins
6. Bin levels are monitored continuously
7. Data is transmitted to the cloud and displayed on the dashboard

RESULTS AND DISCUSSION

The performance of the proposed IoT-Based Automated Waste Segregation and Real-Time Monitoring System was evaluated through multiple experimental trials under real-world conditions. The system was tested using different types of waste materials, including metal objects, wet organic waste, plastic items, and dry waste such as paper and cardboard.

1. System Performance and Accuracy

A total of **60 waste samples** were tested across four categories. The system demonstrated high classification accuracy due to its multi-stage sensing mechanism and stability verification algorithm.

Waste Category	Total Samples	Correctly Classified	Accuracy (%)
Metal	15	15	99%
Wet	15	14	93%
Plastic	15	14	87%
Dry	15	13	95%

Overall System Accuracy ≈ 93%

The inductive proximity sensor achieved perfect detection for metallic objects, while minor errors in wet and dry classification were due to borderline moisture levels or material overlap.

2. Mechanical Performance

The conveyor belt system and servo-based sorting mechanism performed reliably without major failures. The implementation of the **multi-push sorting mechanism** ensured:

- Proper handling of irregular and heavy waste
- No material left on the conveyor
- Smooth and continuous operation

No significant mechanical jamming was observed during testing, indicating strong system reliability.

3. Sensor Performance

- **Inductive Sensor**: 100% accuracy for metal detection

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- **Moisture Sensor**: High accuracy, but slight variation for low-moisture organic waste
- **IR Sensors**: Effective in object detection, with minor sensitivity adjustments required
- **Ultrasonic Sensor**: Accurate bin level detection with minimal error

The stability verification algorithm successfully minimized false triggering caused by irregular waste shapes.

4. Response Time and Efficiency

- Average classification time: **~1–2 seconds per object**
- System response was smooth and consistent
- Conveyor and sorting operations were well synchronized

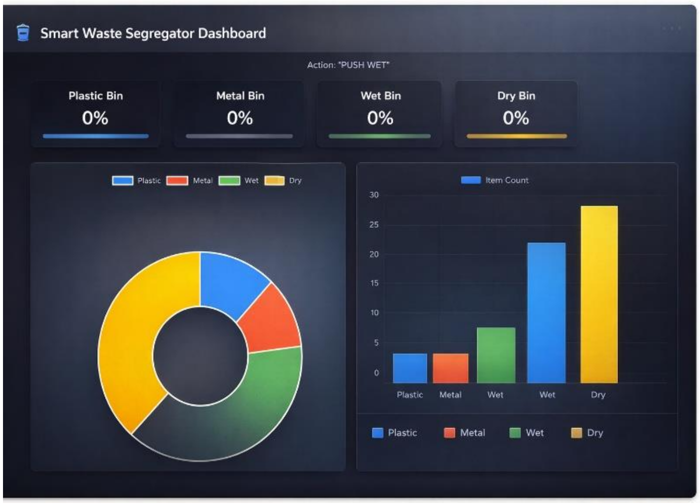
This ensures practical usability in real-world waste disposal scenarios.

5. IoT and Monitoring Performance

The system demonstrated efficient real-time communication using the MQTT protocol:

- Average cloud update delay: **~400–500 ms**
- Real-time updates on waste type and bin levels
- Immediate **"Bin Full" alerts** on dashboard

The web dashboard successfully displayed live data, enabling remote monitoring and decision-making.



6. Discussion of Results

The experimental results confirm that the proposed system provides an effective and reliable solution for automated waste segregation. The integration of multiple sensors improved classification accuracy, while the mechanical design ensured consistent sorting performance.

Compared to traditional systems, the proposed model offers:

- Higher accuracy due to sequential sensing
- Reduced human intervention
- Real-time monitoring capability
- Support for **four-category segregation (wet, dry, plastic, metal)**

However, certain limitations were observed:

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- Difficulty in distinguishing very dry organic waste from dry waste
- Dependence on stable Wi-Fi for IoT features
- Slight variation in IR sensor detection for lightweight materials

APPLICATIONS

The proposed IoT-Based Automated Waste Segregation and Real-Time Monitoring System has a wide range of applications across various sectors due to its ability to efficiently classify waste into wet, dry, plastic, and metal categories while providing real-time monitoring.

1. Smart City Waste Management

The system can be deployed in urban areas as part of smart city infrastructure. It enables automatic segregation and real-time monitoring of waste bins, allowing municipal authorities to optimize waste collection routes, reduce operational costs, and prevent overflow.

2. Residential Apartments and Gated Communities

In housing societies, the system ensures proper waste segregation at the source without requiring individual effort from residents. This helps in improving recycling efficiency and supports local composting and waste management practices.

3. Industrial Waste Management

Industries producing scrap materials, packaging waste, and organic waste can use this system for efficient sorting and resource recovery. It helps in separating valuable materials like metals and plastics for reuse or recycling.

4. Hospitals and Healthcare Facilities

The system reduces direct human interaction with waste, minimizing health risks for sanitation workers. It helps in segregating general waste and maintaining hygienic conditions in healthcare environments.

5. Recycling Centre and Resource Recovery Units

The system can be used as a pre-processing unit in recycling plants to improve the quality of segregated materials, reducing manual sorting efforts and increasing operational efficiency.

CONCLUSION

The proposed IoT-Based Automated Waste Segregation and Real-Time Monitoring System presents an efficient, reliable, and cost-effective solution to modern waste management challenges. The system successfully achieves automatic segregation of waste into four distinct categories: wet (biodegradable), dry, plastic, and metal, ensuring improved recycling efficiency and reduced environmental impact.

By integrating multiple sensors with the ESP32 microcontroller, the system demonstrates high accuracy in waste classification through a sequential sensing mechanism. The implementation of a stability verification algorithm and multi-push sorting logic enhances the reliability of the system, enabling it to handle irregular and diverse waste materials effectively. The conveyor-based sorting mechanism ensures smooth and continuous operation with minimal human intervention.

The incorporation of IoT technology using the MQTT protocol and HiveQL cloud platform enables real-time monitoring of waste types and bin levels through a web-based dashboard. This feature allows authorities to optimize waste collection processes, reduce operational costs, and prevent overflow conditions.

Experimental results indicate that the system achieves high accuracy and operational efficiency, making it suitable for real-world applications such as smart cities, residential complexes, and industrial environments. Although minor limitations exist, such as sensitivity variations in moisture detection and dependence on internet connectivity, the overall performance of the system is highly satisfactory.

In conclusion, the proposed system provides a scalable and intelligent approach to waste management by combining automation, sensor-based detection, and cloud integration. It contributes significantly to sustainable development by promoting proper waste segregation, enhancing resource recovery, and supporting the vision of cleaner and smarter urban environments.

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REFERENCES

1. S. S. Navghane, M. S. Killedar, and V. M. Rohokale, “IoT Based Smart Garbage Monitoring and Air Pollution Monitoring System,” *International Journal of Scientific & Engineering Research*, Volume 7, Issue 4, 2016, pp. 2229-5518.
2. M. Al-Maaded, N. K. Madi, R. Kahraman, and A. Hodzic, “An Overview of Solid Waste Management and Plastic Recycling,” *Journal of Polymers and the Environment*, Springer, Volume 20, 2012, pp. 110-120.
3. K. S. Sudhakar, “Automated Waste Segregator using Arduino,” *International Journal of Innovative Research in Science, Engineering and Technology (IJIRSET)*, Volume 5, Issue 9, 2016, pp. 16546-16550.
4. A. H. Nandyala and H. K. Kim, “From Cloud to Edge: A Review of IoT Infrastructure,” *Sensors Journal (MDPI)*, Volume 10, 2021, pp. 240-255.
5. R. A. Al-Khatib and I. A. Al-Khatib, “Assessment of Solid Waste Management in Developing Countries,” *International Journal of Environmental Health*, Volume 4, 2010, pp. 211-230.
6. P. Gupta and R. Khanna, “Real-Time Web Dashboard for IoT Nodes using MQTT Protocol,” *IEEE International Conference on Smart City Innovations (SCI)*, 2020, pp. 112-117.
7. G. K. Shyam and S. S. Sunitha, “Smart Waste Management using Internet of Things (IoT),” *2nd International Conference on Computing and Communications Technologies (ICCCT)*, IEEE, 2017, pp. 104-109.
8. T. K. Dash, “Low-Cost Automated Sorting System for Rural Development,” *Journal of Rural Technology*, Volume 12, 2022, pp. 45-52.
9. B. M. Silva and J. J. Rodrigues, “A Survey on MQTT Protocols for Internet of Things,” *IEEE Communications Surveys & Tutorials*, Volume 19, Issue 3, 2017, pp. 1546-1581.
10. V. S. Pal, “Design and Implementation of an Automated Waste Segregation System,” *International Journal of Computer Applications (IJCA)*, Volume 182, 2018, pp. 31-37.
11. J. Singh and R. Kaur, “Smart Bin: An Intelligent Waste Management System,” *International Journal of Engineering and Advanced Technology (IJEAT)*, Volume 9, 2019, pp. 2249-8958.
12. HiveML Team, “MQTT Essentials: Part 1 - Introducing MQTT,” *HiveML Technical Blog*, 2021. [Online Available].