



## SENSOR BASED AUTOMATED SMART WASTE SEGREGATION SYSTEM

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### Abstract:

Rapid urban population growth has greatly increased the amount of solid garbage produced, posing major problems for public health, environmental sustainability, and effective trash management. Traditional trash segregation techniques, which mostly rely on human sorting, are frequently ineffective, time-consuming, labor-intensive, and put workers in dangerous situations. This study suggests designing and implementing an intelligent sensor-based automated waste segregation system to address these problems and enhance waste management procedures' precision, effectiveness, and hygienic conditions.

The suggested system makes use of a variety of cutting-edge sensing technologies, such as infrared or ultrasonic sensors to detect the presence and location of waste products, moisture sensors to identify biodegradable (wet) trash, and inductive sensors to detect metallic elements. A microcontroller that serves as the central control unit processes the real-time data that these sensors continuously collect. Based on programmed decision-making algorithms, the system classifies the waste and activates actuators such as servo motors to direct materials into separate compartments designated for wet, dry, and metallic waste.

Additionally, real-time monitoring of bin status, system performance, and garbage levels is made possible by the integration of Internet of Things (IoT) technology, which helps smart city frameworks make data-driven decisions and improve collection schedules. This function improves the sustainability and overall efficiency of the system.



In summary, the suggested automated trash segregation system provides an affordable, scalable, and eco-friendly solution that tackles contemporary waste management issues while encouraging resource efficiency, cleanliness, and sustainable urban growth.

**Keywords:** - Sensor-Based Systems, Microcontrollers, IoT, Smart Waste Management, Environmental Sustainability, Automated Waste Segregation, and Efficient Recycling.

## 1. INTRODUCTION

Globally, the production of solid waste has significantly increased due to the ongoing rise in urbanization, industrial expansion, and population growth. Because inappropriate disposal methods lead to pollution, health risks, and the depletion of natural resources, managing this increasing amount of waste has become a significant environmental and social concern. The problem has been made worse by the widespread use of single-use items and non-biodegradable materials, making effective waste management systems a need rather than a choice. To lessen the impact on the environment and guarantee a healthier living environment, sustainable waste management is crucial.

Inadequate segregation at the source is one of the main obstacles to efficient waste management. It is challenging to process waste effectively when different kinds of waste, like organic, plastic, and metal, are combined. Large volumes of waste are frequently dumped in landfills as a result of this lack of segregation, which also lowers the possibility of recycling. Environmental deterioration, such as soil contamination, water pollution, and the release of dangerous gases, results from such practices over time. As a result, early waste material classification and separation are critical to increasing overall waste management effectiveness..

Manual labor is a major component of conventional waste segregation techniques, which has various drawbacks. In addition to being sluggish and ineffective, the procedure exposes workers to potentially dangerous substances like biological contaminants, poisonous chemicals, and sharp objects. These dangers emphasize the need for more dependable and safe substitutes that can reduce human intervention while increasing precision and speed.

The creation of sensor-based automated waste segregation systems presents a viable remedy in this situation. Waste can be efficiently identified and classified by using sensors that can detect characteristics like moisture content, metallic content, and object presence. After processing the sensor data, a microcontroller-based control system instructs mechanical parts to classify the waste. This method improves accuracy, minimizes human labor, and guarantees

Additionally, these systems can be made to function well in a variety of settings, such as homes, businesses, and factories. Future advancements like remote monitoring and intelligent waste management solutions are made possible by the integration of cutting-edge technologies. All things considered, automated waste segregation is a big step in the direction of effective, secure, and ecologically friendly waste management techniques.



## 2. LITERATURE SURVEY

Prasetyani, L., Mulyanto, P., Fauziah, A., Nugroho, A.D., Muhammad Faiz, A., & Yahya [1] developed a smart automated coolant management system aimed at improving sustainability in manufacturing environments. The system uses sensors and control techniques to maintain optimal coolant conditions, thereby enhancing efficiency and reducing resource wastage. This approach contributes significantly to industrial automation and sustainable practices. However, the system is limited to manufacturing applications and does not address waste segregation.

Das, T. [2] proposed an Arduino-based automatic voice-controlled system for smart applications. The system allows users to operate devices using voice commands, improving accessibility and ease of use. It demonstrates the effectiveness of microcontroller-based automation in modern smart environments. However, it lacks integration with sensor-based waste classification systems.

Gayathri, N., Divagaran, A.R., Akhilesh, C.D., Aswiin, V.M., & Charan, N. [3] designed an IoT-based smart waste management system focused on monitoring waste levels. The system provides real-time data to improve waste collection efficiency and reduce unnecessary operations. It supports better planning and resource utilization. However, it does not include automatic segregation of waste types.

Adiono, T., Anindya, S.F., Fuada, S., Afifah, K., & Purwanda, I.G. [4] developed an Android-based smart home system using MIT App Inventor. Their approach simplifies mobile application development and enables device control through Bluetooth communication. It improves user accessibility and ease of implementation. However, it lacks advanced automation and waste management capabilities.

Thanjaivadivel, M., & Rajasekaran, T. [5] proposed an edge computing-based deep learning system for biodegradable waste classification. The model improves classification accuracy and enables faster processing by reducing dependency on cloud systems. It enhances decision-making in smart waste systems. However, it increases computational complexity and system cost.

Kasote, A., Kolage, P., Sadgir, N., Avhad, G., Vispute, D., & Student [6] developed a smart home automation system using a Telegram chatbot and Android application. The system allows remote control of appliances through messaging platforms, enhancing user interaction. It provides convenience and flexibility in operation. However, it lacks sensor-based automation and intelligent waste classification.

Wijaya, A.A., Suhardi, & Sari, K.P. [7] conducted a comparative analysis of ultrasonic sensors for smart waste applications. Their study evaluates sensor accuracy and reliability in detecting waste levels. It highlights the importance of precise sensing in automated systems. However, it focuses only on detection and not on segregation.

S, P., T, S.K., M, S.P., V, D.S., V, S., & K, R.A. [8] proposed an IoT-based automated waste disposal system for medical waste segregation. The system improves safety by handling hazardous



waste effectively and ensures proper monitoring. It supports better disposal practices in healthcare environments. However, it is limited to medical waste only.

Devkar, M., Raikar, A., Patil, B., Hajwani, A., & Pawar, G. [9] introduced SmartBinGo, a real-time waste monitoring system for smart cities. The system tracks bin levels and optimizes waste collection routes. It improves efficiency and reduces operational costs. However, it does not include automatic waste segregation.

Sharma, V. [10] developed a soil moisture sensor-based automated irrigation system. The system optimizes water usage based on environmental conditions and reduces manual effort. It improves agricultural efficiency. However, it is not applicable to waste management.

Bharadwaj, A.S., Rego, R., & Chowdhury, A. [11] proposed an IoT-based solid waste management framework for smart cities. Their model integrates sensors and communication technologies for efficient waste handling. It provides a conceptual foundation for smart waste systems. However, it lacks practical implementation of segregation.

Bavuluri, J., Sha, A.B., Lin, D., & Strenger, S. [12] developed a sensor-based automation system for smart home environments. The system enhances device control and improves user convenience. It demonstrates the importance of sensor integration in automation. However, it does not address waste management.

Sahu, T., & Verma, A. [13] designed a Raspberry Pi-based automated irrigation system. The system controls water flow using environmental data, improving efficiency. It reduces resource wastage in agriculture. However, it is not related to waste segregation.

Rijah, U.L., & Abeygunawardhana, P.K. [14] developed a smart waste segregation system for home environments. The system improves waste classification at the source and promotes recycling. It is suitable for small-scale use. However, it lacks scalability.

Surakusumah, R.F., Yusuf, M., & Tarif, E.A. [15] proposed an IoT-based environmental monitoring system. The system collects real-time environmental data to support sustainability. It highlights the role of sensors in monitoring applications. However, it is not specifically designed for waste segregation.

Ahmed, A.H. [16] developed a smart home energy monitoring and management system. The system tracks energy usage and improves efficiency through automation. It enhances energy conservation in smart homes. However, it does not focus on waste management.

Mondal, S. [17] proposed a smart parking system using Arduino and ultrasonic sensors. The system detects vehicle presence and manages parking efficiently. It demonstrates sensor-based automation. However, it is unrelated to waste management.

Vinay, B.K., et al. [18] developed an IoT-based irrigation management system for smart farming. The system optimizes water usage using sensor data. It improves efficiency and reduces wastage.



However, it does not address waste segregation.

Sudharshan, N., et al. [19] implemented a renewable energy-based smart irrigation system. The system promotes sustainable energy use in agriculture. It reduces dependence on conventional energy sources. However, it is not applicable to waste management.

Table 1 Comparative review of Sensor Based Automated Smart Waste Segregation System

| Paper / Project           | System Architecture                            | Cost             | Ease of Implementation               | Performance                  | User Experience          | Limitations                        |
|---------------------------|------------------------------------------------|------------------|--------------------------------------|------------------------------|--------------------------|------------------------------------|
| Prasetyani et al. [1]     | Sensor-based automated coolant system          | Moderate (<\$70) | Moderate (industrial setup required) | Efficient resource control   | Limited user interaction | Not applicable to waste management |
| Das [2]                   | Arduino-based voice control system             | Moderate (<\$60) | Easy (voice module integration)      | Accurate command response    | Hands-free operation     | Ineffective in noisy environments  |
| Gayathri et al. [3]       | IoT-based waste monitoring system              | Moderate (<\$80) | Moderate (IoT setup)                 | Real-time monitoring         | User-friendly interface  | No automatic segregation           |
| Adiono et al. [4]         | Android-controlled smart home system           | Low (<\$50)      | Easy (App Inventor based)            | Stable operation             | Easy mobile control      | Lacks intelligent automation       |
| Thanjaivadivel et al. [5] | AI-based waste classification (Edge computing) | High             | Complex (ML + edge setup)            | High accuracy classification | Advanced system          | High computational cost            |
| Kasote et al. [6]         | Telegram + Android home automation             | Low              | Easy                                 | Reliable control             | Convenient remote access | No sensor-based decision making    |
| Wijaya et al. [7]         | Ultrasonic sensor-based detection system       | Low              | Easy                                 | Good detection accuracy      | Minimal interaction      | Only detection, no segregation     |



|              |                                |          |          |                     |                         |                              |
|--------------|--------------------------------|----------|----------|---------------------|-------------------------|------------------------------|
| S et al. [8] | IoT-based medical waste system | Moderate | Moderate | Safe waste handling | Limited to specific use | Only medical waste supported |
|--------------|--------------------------------|----------|----------|---------------------|-------------------------|------------------------------|

3. PROPOSED METHODOLOGY

The Smart Waste Segregation System is designed as an automated solution to efficiently classify and separate waste materials using sensor-based detection and an embedded control unit. The system integrates multiple sensing elements, including a moisture sensor, metal detector, and ultrasonic sensor, with a microcontroller such as Arduino or NodeMCU. These components collectively enable the identification and segregation of waste into categories like wet, dry, and metallic, thereby reducing the need for manual intervention and improving overall efficiency.

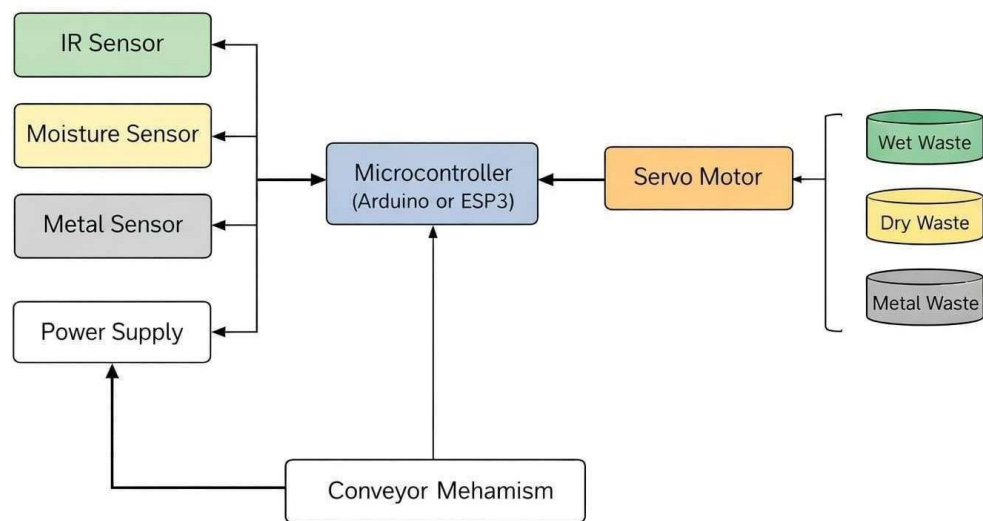


Fig.1 Block Diagram of Sensor Based Automated Smart Waste Segregation System

The illustration depicts a smart fan system that regulates its speed according to temperature readings and enables remote control and monitoring via an Android app. This system incorporates sensors, a microcontroller, and communication technology to deliver effective and convenient cooling.

The process starts with the Temperature Sensor (DHT11), which consistently tracks the surrounding temperature. The DHT11 is an economical digital sensor that can assess both temperature and humidity. It transforms the analog temperature readings from the environment into a digital signal that can be interpreted by a microcontroller. This sensor is vital for supplying real-time information, which serves as the basis for the system's "smart" functionality.

The DHT11 sensor sends temperature information to the ESP32 microcontroller. The ESP32 is a robust and versatile microcontroller equipped with built-in Wi-Fi and Bluetooth, making it well-suited for Internet of Things (IoT) applications. It receives data from the sensor and utilizes this

information to control the fan's operation. The microcontroller processes the incoming signals, assesses the temperature against set thresholds, and produces control signals accordingly.

Using the processed information, the ESP32 controls the Fan through Pulse Width Modulation (PWM). PWM enables the fan speed to be adjusted smoothly rather than simply switching it on or off. This method promotes energy efficiency, minimizes noise, and extends the lifespan of the fan. For instance, if the temperature in the room exceeds a specific threshold, the ESP32 increases the PWM signal's duty cycle, which causes the fan to operate at a higher speed for improved cooling. Conversely, if the temperature falls, the fan speed is lowered to conserve energy.

Moreover, the system includes an Android application that connects to the ESP32 using Bluetooth or Wi-Fi. This application allows users to monitor the temperature in real-time, adjust the fan speed remotely, and even receive notifications if the temperature exceeds critical levels. This functionality enhances user convenience and facilitates the remote management of the system.

The Smart Temperature-Controlled Fan System effectively integrates sensor technology, intelligent management, and wireless connectivity. It guarantees the fan functions at its best based on the surrounding conditions, minimizes unwarranted energy usage, and offers users an interactive interface that can be controlled remotely. These systems are commonly used in residential, commercial, and industrial settings where automated climate regulation can enhance comfort and energy efficiency.

#### 4. RESULT & DISCUSSION

##### Result:-



Fig 1

Fig 2

##### Discussion:-

An important development in contemporary waste management techniques is the creation and deployment of a sensor-based automated smart trash segregation system. The experimental setup's results, which are displayed in the accompanying figure, demonstrate the system's capacity to



precisely categorize and separate various waste types, minimizing human labor.

To determine the type of waste materials, the system mainly uses a variety of sensors, including metal detectors, moisture sensors, and infrared (IR) sensors. For separate groups like metallic and moist waste, the segregation accuracy seems to be relatively high based on the observed data. This is explained by the obvious physical characteristics of these materials: wet garbage may be successfully recognized by moisture content detection, while metals show strong electromagnetic reactions. However, when waste materials have mixed qualities, like coated metals or semi-wet polymers, there may be minor differences or overlaps in sensor readings.

The outcomes make it clear that the system operates effectively in controlled environments. The total performance of the system is greatly influenced by the response time of the sensors and the actuation mechanism (such as servo motors or conveyor-based sorting). The results' rapid detection and sorting point to a well-synchronized combination of mechanical and sensor components. This is crucial for real-time applications, particularly in settings like industrial waste management facilities, residential complexes, and public trash cans.

The system's scalability is another crucial feature that the results emphasize. Sensor modules can be easily expanded and customized because to their modular construction. To more precisely identify hazardous or recyclable materials, for example, more sensors like gas or optical sensors can be added. Because of its adaptability, the system can be used in both urban and rural environments to meet various waste management needs.

The system has significant drawbacks despite its benefits. Accurately separating complex or mixed garbage is one of the main problems. For instance, due to sensor sensitivity limitations, items like partially contaminated recyclables or multilayer packaging might not be appropriately categorized. In these situations, the findings may occasionally exhibit misclassification, suggesting the need for more sophisticated sensing methods or machine learning-based classification algorithms.

Dependency on the environment is another restriction. Temperature, humidity, and dust are examples of external conditions that can impact sensor function. For example, too much moisture in the surroundings could affect the moisture sensor's readings and cause false positives. In a similar vein, dust buildup on sensors can eventually lower detection accuracy. Thus, to guarantee constant operation, routine maintenance and calibration are required.

Cost and power consumption are also crucial factors. Despite the system's efficiency, the employment of numerous sensors and actuators raises the total energy consumption. Optimizing power usage becomes essential for large-scale implementation. Adoption in low-income areas may also be constrained by the comparatively high initial cost of installation. Long-term labor cost savings and increased recycling efficiency, however, can justify these expenditures.

The findings also point to the possibility of integrating the infrastructure of smart cities. The system may send information about garbage types, quantities, and collection needs to a centralized



monitoring platform by integrating Internet of Things (IoT) technologies. This makes it possible to design waste collection routes more effectively, lessens overflow problems, and increases the general effectiveness of municipal waste management systems.

## 5. CONCLUSION

Through the use of sensors and microcontroller-based control, the developed sensor-based automated waste segregation system provides an efficient and clever method of classifying waste into categories like wet, dry, and metallic materials. The system increases waste sorting accuracy, which is crucial for improving recycling processes, while also improving hygiene and safety by eliminating the need for manual handling. Segregation automation guarantees that recyclable materials are used appropriately rather than being thrown away and greatly reduces human labor.

Furthermore, effective separation during the initial phase aids in reducing environmental pollution and lessening the strain on landfills. The suggested system is cost-effective, reliable, and suitable for use in diverse settings, including homes, industrial sectors, public spaces, and smart city initiatives. Its scalable architecture also facilitates future enhancements with advanced technologies for better performance and monitoring. In summary, this system offers a viable and sustainable answer to the waste management issues of today. By fostering appropriate waste management practices, it helps in conserving the environment, optimizing resources, and creating cleaner and healthier spaces for future generations.

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