SMART WASTE SEGREGATION SYSTEM

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Abstract - *In recent days, managing household waste has become a major challenge due to the increasing population and improper waste disposal practices. Our* ***Smart Waste Segregation System*** *aims to improve waste management by automatically identifying and separating different types of waste using simple sensors and a microcontroller. The system uses an* ***IR sensor*** *to detect waste entry, a* ***metal detection sensor*** *to identify metal waste, and a* ***raindrop sensor*** *to distinguish between wet and dry waste. Based on these inputs, the system processes the data and uses* ***servo motors*** *to direct the waste into the appropriate bins without any manual intervention. A* ***16×2 LCD display*** *provides real-time information about the waste type and system status, making it user-friendly. The system is powered by a* ***lithium-ion battery****, ensuring portability and continuous operation. This approach not only reduces human effort but also improves waste segregation efficiency, leading to better recycling practices. By promoting proper waste disposal at the source, the system contributes to a cleaner environment and supports sustainable waste management solutions in households and small-scale applications.*

Key Words: **Smart Waste Segregation, Arduino Nano, Sensors, Automation, Recycling, Servo Motor.**

1. INTRODUCTION

In recent years, improper waste management has become a serious environmental concern due to rapid urbanization and increasing population. A large amount of household waste is generated daily, and in many cases, it is not properly segregated at the source. Traditional waste segregation methods rely heavily on manual effort and public awareness, which often leads to mixing of wet, dry, and metal waste. This reduces recycling efficiency, increases environmental pollution, and makes waste processing more difficult. To address these challenges, a Smart Waste Segregation System is proposed to provide an automated, efficient, and low-cost solution for waste classification and disposal.

The system uses an Arduino Nano as the main controller along with simple sensors to detect different types of waste. It automatically identifies waste and directs it into the appropriate bin without human intervention. This approach minimizes errors, improves efficiency, and promotes proper waste management practices.

1.1 Automated Waste Segregation

One of the key features of this system is its ability to segregate waste automatically. When waste is placed into the system, an IR sensor detects its presence and activates the process. The system then analyzes the waste using other sensors and determines its category. Based on the result, the waste is directed into the correct bin using servo motors. This reduces the need for manual segregation and ensures better waste management at the source.

1.2 Sensor-Based Waste Detection

The system uses multiple sensors to accurately identify waste types. A metal detection sensor is used to detect metallic objects such as cans and metal pieces. If no metal is detected, a raindrop sensor checks the moisture content to determine whether the waste is wet or dry. This combination of sensors improves the accuracy of classification and ensures proper separation of waste materials.

1.3 User-Friendly Display and Operation

To make the system easy to use, a 16×2 LCD display is integrated to show real-time information about the detected waste type and system status. This helps users understand how the system is working. The system is powered by a lithium-ion battery, and an LM7805 voltage regulator ensures a stable power supply for smooth operation.

1.4 System Architecture

The system is designed using a simple and efficient architecture consisting of three main parts:

1. Input Layer: Sensors such as IR sensor, metal detection sensor, and raindrop sensor collect data about the waste.

2. Processing Layer: Arduino Nano processes the sensor data and decides the waste category.

3. Output Layer: Servo motors direct the waste into the correct bin, and the LCD display shows the result.

This structured approach ensures reliable and efficient performance of the system.

2. LITERATURE SURVEY:

[1] IoT-based Smart Waste Segregation System that automatically classifies waste into metal, wet, and dry categories. It uses sensors such as metal (proximity), IR, and moisture sensors to detect different types of waste. The system is controlled by an Arduino microcontroller, which processes sensor data and directs waste into appropriate bins using servo motors. It reduces manual effort and improves efficiency in waste management. The system can also be enhanced using AI and IoT for better accuracy and real-time monitoring. Overall, it provides a smart and eco-friendly solution for modern waste management challenges.

[2] a smart and low-cost waste segregation system that automatically classifies waste into dry and wet categories. It uses a machine learning model in Python to identify waste from images and sends the result to an Arduino Uno. The Arduino then controls a servo motor to direct waste into the correct bin, while an LCD displays the result. The system works offline, making it affordable and easy to use in homes, schools, and public places. It achieved around 91% accuracy during testing and provides fast and reliable performance. Overall, it offers a simple and efficient solution for improving waste management.

[3] DeepWaste, a mobile application that uses deep learning to classify waste into trash, recycling, and compost categories. It uses Convolutional Neural Networks (CNNs) like ResNet50 to achieve high accuracy in waste classification. The system works by capturing images through a mobile phone and providing instant results without needing internet connectivity. The model was trained on a dataset of over 1200 images and achieved an average precision of around 88.1%. It helps reduce incorrect waste disposal and promotes better environmental practices. Overall, DeepWaste offers a simple, fast, and user-friendly solution for smart waste management.

[4] IoT-based Smart Trash Bin designed to improve waste management in urban areas. The system uses NodeMCU, ultrasonic sensors, IR sensor, and moisture sensor to monitor garbage levels and segregate waste into dry and wet categories. It sends real-time notifications to users through the Blynk app when the bin reaches a threshold level. The servo motor automatically directs waste based on moisture detection. This system helps reduce overflow, improves cleanliness, and supports efficient waste collection. Overall, it provides a smart and cost-effective solution for managing waste in public places.

[5] automatic waste identification systems used in smart waste segregation. It analyzes sensors, datasets, and machine learning techniques used for classifying waste materials. Image-based sensors and edge computing devices are widely used for processing data. Convolutional Neural Networks (CNNs) are the most commonly used algorithms for waste classification. The study highlights challenges such as limited datasets, difficulty in real-world conditions, and similarity between waste materials. Overall, the paper emphasizes the need for improved datasets, real-world testing, and sensor fusion for better performance.

[6] reviews the use of hyperspectral imaging (HSI) and machine learning for plastic waste detection. HSI uses near-infrared sensors to capture spectral information of plastics for accurate identification. It is effective in detecting different types of plastics and microplastics. However, black plastics are difficult to detect due to carbon-black absorbing light in the spectrum. Machine learning models also show good accuracy in classifying plastic waste using datasets. Overall, combining HSI with machine learning improves plastic detection and waste management systems.

[7] an IoT-based Smart Waste Management System that improves garbage collection and environmental safety in urban areas. The system uses sensors such as ultrasonic, moisture, metal, air quality (MQ135), and load cell to monitor waste type, level, and surrounding air quality. It segregates waste into wet, dry, and metallic categories automatically using sensor-based detection and servo mechanisms. The system also tracks bin location using GPS and sends real-time alerts through the Blynk app. Machine learning models are used to classify air quality levels and garbage weight for better decision-making. Overall, the system enhances cleanliness, reduces health risks, and supports efficient waste management.

REFERENCES	ADVANTAGES	LIMITATIONS
[1]	1. Reduces human effort and improves waste segregation efficiency. 2. Enhances recycling by accurately separating different types of waste.	1. Sensor accuracy may reduce when waste materials are mixed. 2. Initial setup and maintenance cost can be higher for advanced features.
[2]	1. High accuracy (around 91%) using machine learning for waste classification. 2. Low-cost, portable, and works without internet connectivity.	1. Limited to only dry and wet waste classification. 2. Requires camera/image input, which may be affected by lighting conditions.
[3]	1. Provides real-time waste classification using deep learning with good accuracy (~88%). 2. Works on mobile devices without requiring expensive hardware or internet.	1. Accuracy may vary due to different shapes, lighting, and image quality. 2. Requires a large dataset and training for better performance and generalization.
[4]	1. Provides real-time monitoring and alerts using IoT (Blynk app). 2. Automatically segregates waste and prevents bin overflow.	1. Requires internet/Wi-Fi connection for monitoring and notifications. 2. Limited segregation (only dry and wet waste).
[5]	1. Uses advanced Machine Learning (CNN) for accurate waste classification. 2. Supports automation, reducing human effort in waste segregation.	1. Requires large datasets and high computational resources. 2. Performance may decrease in real-world conditions due to complex waste variations.

[6]	1. Provides accurate detection using spectral information of materials. 2. Machine learning improves classification and sorting of plastic waste.	1. Cannot effectively detect black plastics due to light absorption. 2. Technology is still in early stages and requires advanced equipment.
[7]	1. Provides real-time monitoring of garbage level, air quality, and bin location using IoT. 2. Automatically segregates waste into wet, dry, and metallic categories, reducing manual effort.	1. Requires high initial setup cost and technical expertise for deployment. 2. Depends on internet connectivity and sensor accuracy for proper functioning.

3. PROPOSED MODEL:

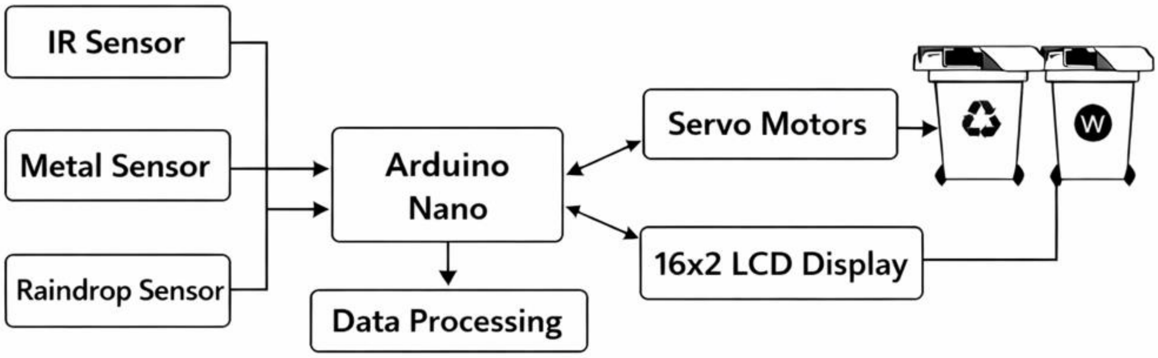

Fig: 1 System Architecture

This system shows how a **Smart Waste Segregation System** automatically manages waste using simple sensors and a microcontroller. It collects input from an **IR sensor**, **metal detection sensor**, and **raindrop sensor** (Fig 1). The IR sensor detects when waste is placed into the system, while the metal sensor identifies metallic waste and the raindrop sensor checks for moisture content. This data is processed by the **Arduino Nano**, which decides the type of waste. Based on this decision, **servo motors** are activated to direct the waste into the appropriate bin. The system also uses a **16×2 LCD display** to show the detected waste type and system status. This automated process reduces manual effort, improves accuracy, and ensures proper waste segregation at the source.

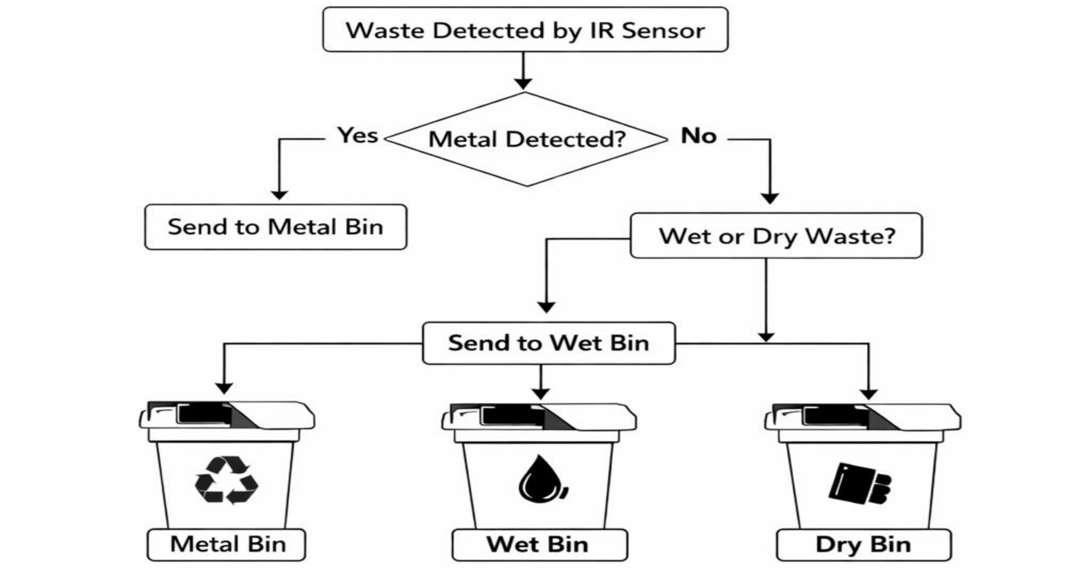

Fig: 2 Waste Segregation Process

Fig 2 shows the working of the waste segregation system based on sensor inputs. When waste is inserted, the IR sensor detects its presence and activates the system. The metal detection sensor first checks whether the waste contains metal. If metal is detected, it is immediately directed to the metal bin. If not, the raindrop sensor checks whether the waste is wet or dry. Based on this result, the system decides the correct category and activates the servo motors to move the waste into the respective bin. This process is repeated continuously for every waste input, ensuring efficient and real-time waste segregation. This helps reduce waste mixing, improves recycling efficiency, and supports cleaner waste management practices.

4. RESULT AND DISCUSSION

The **Smart Waste Segregation System** is designed to improve waste management by automatically identifying and separating different types of waste. This system uses sensors and a microcontroller to reduce manual effort and improve segregation accuracy. By integrating simple hardware components like sensors, servo motors, and display units, the system ensures an efficient and user-friendly approach to waste handling. It helps in reducing waste mixing, improving recycling efficiency, and promoting a cleaner environment.

4.1 System Operation

At the core of the system is the **Arduino Nano**, which controls the entire process. It receives input data from sensors and processes it to determine the type of waste. Once the waste is identified, the system automatically activates the servo motors to direct the waste into the appropriate bin. This automated operation ensures smooth functioning without human intervention.

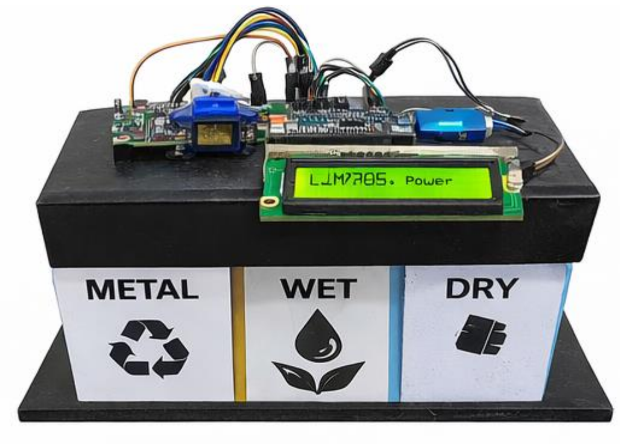

Fig: 3 System Prototype

Figure 3 shows the working prototype of the Smart Waste Segregation System, including sensors, Arduino Nano, and waste bins.

4.2 Waste Detection Mechanism

The system uses multiple sensors to detect different types of waste. The **IR sensor** detects when waste is placed into the system. The **metal detection sensor** identifies metallic waste such as cans or metal pieces. If no metal is detected, the **raindrop sensor** checks for moisture to determine whether the waste is wet or dry. This combination of sensors improves classification accuracy and ensures proper segregation.

4.3 Automated Waste Segregation

Once the waste type is identified, the Arduino sends signals to the **servo motors**. These motors rotate and guide the waste into the correct bin, such as metal, wet, or dry waste bins. This process happens automatically and continuously for each input, ensuring efficient waste handling and reducing human effort.

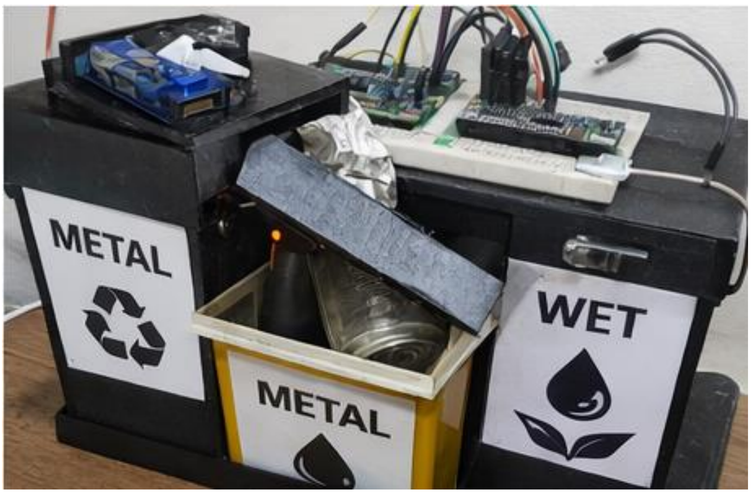

Fig: 4 Waste Segregation Process

Figure 4 shows how waste is automatically directed into different bins using servo motors based on sensor detection.

4.4 Display and User Interaction

The system includes a **16×2 LCD display** that provides real-time information about the detected waste type and system status. This makes the system easy to understand and user-friendly. Users can clearly see how the waste is being processed, which increases awareness about proper waste segregation.

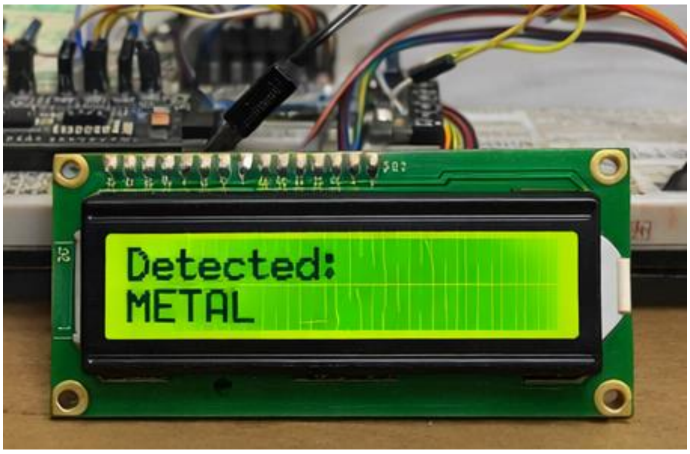

Fig: 5 System Output Display

Figure 5 shows the LCD display output, where the detected waste type such as metal, wet, or dry is displayed. This helps users understand the system's operation in real time.

4.5 Power Management

The system is powered by a **lithium-ion battery**, making it portable and suitable for small-scale applications. The **LM7805 voltage regulator** ensures a stable 5V power supply to all components, allowing the system to operate smoothly without fluctuations.

4.6 Performance and Accuracy

The prototype system achieves an approximate accuracy of **80% to 90%** in waste classification. The accuracy depends on sensor performance and environmental conditions. While the system works effectively for basic waste segregation, improvements can be made by using advanced sensors or AI-based detection techniques.

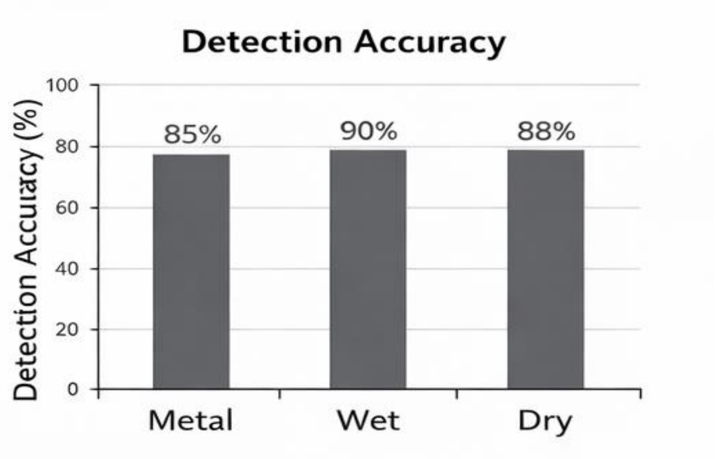

Fig: 6 Performance Graph

Figure 6 shows the accuracy of the system in detecting different types of waste. The graph highlights the efficiency of sensors used in the system.

4.7 Applications

This system can be used in various environments such as households, offices, schools, and public places. It can also be further developed for **smart city waste management systems**, where automated segregation plays an important role in maintaining cleanliness and sustainability.

4.8 Challenges

Some challenges faced during the project include sensor limitations, especially when waste materials are mixed. Environmental factors such as moisture and dust can also affect sensor readings. Additionally, proper alignment of servo motors is necessary for accurate waste direction.

4.9 Future Improvements

The system can be enhanced by integrating **IoT technology** for real-time monitoring and data analysis. Machine learning models can also be used to improve classification accuracy. Additional sensors can be added to detect more types of waste, making the system more advanced and efficient.

4.10 Comparative Analysis

The proposed system is more efficient compared to traditional manual segregation methods. It reduces human effort and increases accuracy. While existing systems rely heavily on manual sorting, this system automates the process using sensors and microcontroller logic. Although the current prototype achieves good performance, future improvements can further enhance its efficiency and reliability.

5. CONCLUSION

The Smart Waste Segregation System provides an effective solution for managing household waste using automation and simple sensor-based technology. It accurately identifies different types of waste such as metal, wet, and dry using a combination of sensors and processes the data using an Arduino Nano. The system automatically segregates waste into appropriate bins using servo motors, reducing the need for manual effort. The LCD display provides real-time information, making the system easy to understand and user-friendly.

By ensuring proper segregation at the source, the system improves recycling efficiency and helps reduce environmental pollution. The use of low-cost components makes it suitable for student projects and small-scale applications. Although the prototype has some limitations in accuracy, it performs efficiently for basic waste segregation tasks.

Overall, this project demonstrates how automation can simplify waste management, promote cleaner surroundings, and support sustainable practices. It can be further enhanced with advanced technologies like IoT and AI for improved performance and large-scale implementation.

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