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# AUTOMATIC WASTE SORTING MACHINE

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***Abstract:*** With increasing concerns about environmental sustainability, efficient waste management has become a necessity. This paper presents the design and implementation of an Automatic Waste Sorting Machine that classifies waste into three categories: dry, wet, and metal using a combination of IR, raindrop moisture, and inductive sensors. The system is controlled by an Arduino Uno, which processes sensor data and operates a NEMA 17 stepper motor to rotate the waste bin and an MG995 servo motor to control the duct plate. The proposed system aims to automate the waste segregation process, ensuring better resource utilization and reducing human intervention in waste management. The machine is energy-efficient, low-cost, and user-friendly, making it suitable for both domestic and industrial waste sorting applications. This paper discusses the hardware components, working principle, experimental analysis, and future enhancements of the system, with a focus on increasing accuracy and efficiency in waste classification.

***Index terms-*** Waste Management, Sensor-Based Sorting, Arduino Uno, Stepper Motor, Servo Motor, Automation, Recycling, Sustainability, Smart Waste Management

## I. INTRODUCTION

Waste management has become a critical issue as cities grow, industries expand, and populations increase. With the rise in waste generation, improper disposal has led to severe environmental problems such as land and water pollution, overflowing landfills, and increased greenhouse gas emissions. When waste is not properly segregated, recyclable materials get mixed with non-recyclable waste, making recycling less effective and increasing the burden on waste treatment facilities. Addressing these issues requires a shift from traditional manual waste sorting methods to more advanced, automated solutions that can improve efficiency and sustainability.

Traditional waste segregation is largely dependent on human labour, where workers manually separate waste into different categories like biodegradable, recyclable, and non-recyclable materials. However, this method has several drawbacks. First, it is time-consuming and requires significant effort, making it inefficient for large-scale applications. Second, manual sorting is often inaccurate, leading to contamination of recyclables, which reduces their value and usability. Third, and most importantly, it exposes workers to hazardous materials, including toxic chemicals, sharp objects, and infectious waste, increasing health risks. Additionally, the rising costs of labour make manual sorting an expensive and unsustainable solution for managing the growing volume of waste in urban areas.

To address these challenges, automated waste sorting systems have emerged as a practical and efficient alternative. These systems use sensors, microcontrollers, and mechanical components to automatically classify waste based on its properties. By reducing human involvement, automation enhances accuracy, efficiency, and safety, making waste management more effective and environmentally friendly. Automated systems also promote recycling, helping to reduce landfill waste and maximize resource recovery.

This study presents the Automatic Waste Sorting Machine, designed to automate the waste segregation process in a cost-effective and energy-efficient manner. The system is built around an Arduino Uno microcontroller, which processes sensor data and controls various components. Waste detection begins with an infrared (IR) sensor, which detects the presence of waste and triggers the sorting process. To differentiate between wet and dry waste, a raindrop moisture sensor measures the moisture content, while an inductive proximity sensor is used to detect metal waste through electromagnetic field detection.

Once the type of waste is identified, a NEMA 17 stepper motor rotates the waste bin to align with the correct disposal compartment. A MG995 servo motor then operates a duct plate that directs the waste into the appropriate bin. The entire system is powered by a 12V rechargeable lithium-ion battery, ensuring continuous operation even in locations with unreliable electricity. A buzzer provides real-time feedback to inform users about the sorting status.

The primary objective of this project is to develop an affordable, efficient, and user-friendly waste segregation system that can be used in homes, offices, industries, and public spaces. Automating waste classification reduces the need for human intervention, improves sorting accuracy, and enhances the overall recycling process. This study also explores potential improvements to the system, such as AI-based image recognition for more precise classification, IoT connectivity for real-time waste monitoring, and solar-powered operation for sustainability. By integrating smart technologies into waste management, this system aims to contribute to a cleaner environment and a more sustainable approach to waste disposal.

## II. OBJECTIVES

- To automate waste classification using sensor-based detection to enhance accuracy.
- To reduce human effort and minimize direct contact with waste materials.
- To improve waste recycling rates and facilitate better resource utilization.
- To develop a scalable, cost-effective, and energy-efficient waste sorting system.

## III. METHODOLOGY

The development of the Automatic Waste Sorting Machine follows a structured approach to ensure efficient and accurate waste classification. The methodology consists of several stages, from design and component selection to testing and optimization.

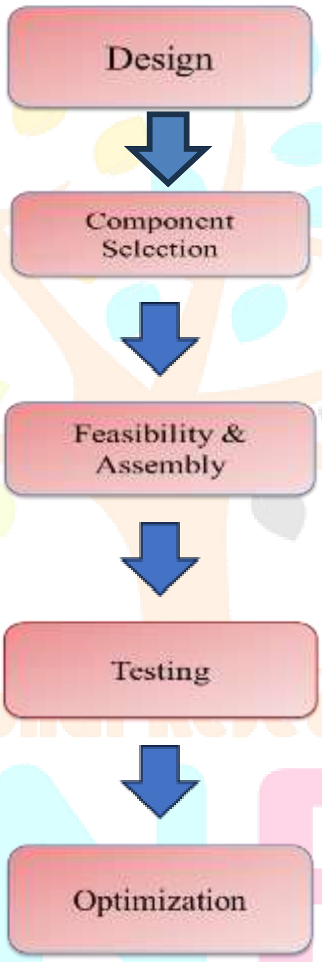


Fig 1: Methodology

**Step 1: Design**

The first step in building the Automatic Waste Sorting Machine is designing its overall structure to ensure efficiency and durability. This starts with CAD modelling, where software like Catia V5 is used to create a digital blueprint of the machine. This helps in visualizing how different components like sensors, motors, bins, and the microcontroller fit together. Next comes layout planning, which involves strategically positioning each part to optimize the sorting process. The placement of sensors must allow for quick and accurate waste detection, while the motors and bins should be arranged to ensure smooth movement and proper waste segregation. Lastly, material selection is crucial for the machine's durability and stability. Metal sheets are often used for the outer casing because they are lightweight and easy to work with. Iron frames provide strength, ensuring the machine remains sturdy during operation, while plastic components are ideal for flexible parts that require corrosion resistance. This step ensures that the waste sorting machine is not only functional but also practical, setting the foundation for effective automation.

**Step 2: Component Selection**

The system is built using carefully selected components to achieve efficient sorting.

1.Microcontroller:

The Arduino Uno is the main control unit of the system, responsible for processing sensor data and managing waste sorting. It detects waste type, controls the stepper motor to rotate the bin, and moves the servo motor to direct waste into the right bin. It also activates a buzzer for alerts. The Arduino Uno is chosen for its simplicity, reliability, and ability to work with multiple sensors and motors.


Fig 2: Arduino

2.Sensors:

- IR Sensor:

  The IR sensor is used to detect when waste is placed in the input section. It works by emitting infrared light and sensing the reflection. If an object is detected, the system is triggered to start the sorting process. This helps ensure the machine only activates when needed, making the operation more efficient.

Fig 3: IR Sensor

- Inductive Proximity Sensor:

  The inductive proximity sensor is perfect for detecting metal waste due to its ability to sense metallic objects without direct contact. In the system, it would trigger the Arduino to take the appropriate action when metal waste is detected, ensuring the sorting process is accurate.

Fig 4: Inductive Proximity Sensor

- Raindrop Moisture Sensor:

  The raindrop moisture sensor in the system will help determine whether the waste is wet or dry by measuring the level of moisture present. This data can then guide the Arduino to sort the waste correctly, ensuring that wet waste is directed to the appropriate bin, and dry waste to another.

Fig 5: Raindrop moisture Sensor

3.Actuators:

- NEMA 17 Stepper Motor:

  The NEMA 17 stepper motor will handle rotating the sorting bin to the right position. Since it offers precise control, it's perfect for accurately directing waste into the correct bin. With the A4988 driver, the Arduino can control the motor smoothly and make sure it moves to the right spot every time.

Fig.6: Stepper Motor

- MG995 Servo Motor:

  The MG995 servo motor will control the duct plate that directs the waste into the right bin. It is perfect for this job because it can make precise adjustments to the plate's angle. The Arduino will use the servo to move the plate depending on what the sensors detect, making sure the waste goes where it needs to.

Fig 7: Servo Motor

4.Power Supply:

A 12V rechargeable lithium-ion battery is used, with step-down converters for other components.


Fig 8: Battery

5.Feedback:

The buzzer provides auditory feedback, alerting the user when the waste is detected, when sorting is complete, or when maintenance is required.

**Step 3: Feasibility & Assembly**

Once the components are selected, they are integrated and assembled to build the prototype.

- Circuit Design: The electrical connections between the sensors, motors, and Arduino are implemented.
- Mechanical Assembly: The waste chute, rotating bin, and servo-controlled duct plate are fixed in place.
- Programming: Arduino IDE is used to code the logic for the Reading sensor inputs, classifying waste, Controlling motors for sorting.
- Initial Testing: The system is checked for basic functionality to ensure all components work as expected.

**Step 4: Testing**

The machine is tested under various conditions to measure its performance.

1. Sorting Accuracy Test: Different waste materials (metal, wet, dry) are placed in the input section. The machine classifies and sorts them into the correct bin.
2. Sorting Speed Test: The average time taken to sort a single waste item is recorded.
3. Power Consumption Analysis: The energy usage of sensors, motors, and microcontroller is measured.
4. Battery Life Test: The system is run continuously to evaluate battery efficiency.
5. Environmental Adaptability Test: The system is tested under different lighting conditions and temperatures to check sensor reliability.

**Step 5: Optimization**

After testing, improvements are made to enhance system performance.

- Algorithm Optimization: The Arduino program is refined for faster processing and motor control.
- Sensor Calibration: Sensors are fine-tuned for better accuracy.
- Energy Efficiency: Motor operations are optimized to reduce power consumption.
- Structural Enhancements: The waste chute and bin movement are improved for smoother operation.

## IV. WORKING PRINCIPLE

1. IR Sensor detects waste presence, activating the sorting process.
2. Raindrop moisture sensor identifies wet/dry waste, ensuring accurate classification.
3. Inductive sensor detects metal waste, improving separation efficiency.
4. Arduino processes sensor data and sends appropriate signals to the motors.
5. Stepper motor rotates the bin to align it with the appropriate waste type.
6. Servo motor opens the duct plate, directing waste into the designated bin.
7. Buzzer alerts the user once sorting is completed, ensuring operational transparency.

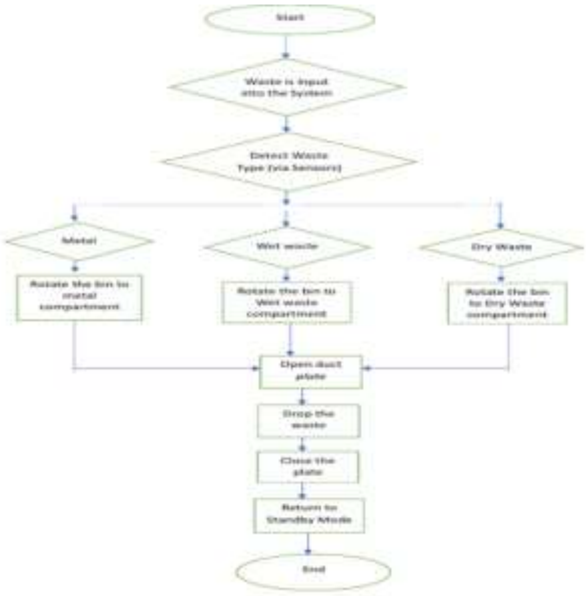

Fig 9: Working Flow Diagram

## V. RESULTS AND DISCUSSION

### 5.1 Performance Analysis

The results show that the Automatic Waste Sorting Machine works efficiently in detecting and classifying waste into dry, wet, and metal categories. With a sorting accuracy of 95%, the system effectively minimizes errors, ensuring proper segregation. The waste detection accuracy of 98% confirms that the sensors are highly reliable in identifying waste materials before sorting.

On average, the machine takes 5-7 seconds per item, making it a quick and efficient solution for waste management. It consumes 36W of power, making it energy-efficient while still performing all necessary functions. The battery lasts between 6-8 hours, allowing for extended operation without frequent recharging. Overall, these results highlight that the system is accurate, fast, and practical for real-world use.

| Parameter | Performance |
|---|---|
| Sorting Accuracy | 95% |
| Waste Detection Accuracy | 98% |
| Sorting Time per Item | 5-7 seconds |
| Power Consumption | 36W |
| Battery Life | 6-8 hours |

Table 1: Result Table

### 5.2 Discussion

The Automatic Waste Sorting Machine successfully automates waste segregation, making the process faster, more accurate, and less labour-intensive. The combination of IR, moisture, and inductive sensors allows for effective classification of dry, wet, and metal waste. However, some challenges remain. For instance, materials with mixed properties, such as damp paper or plastic with thin metal coatings, sometimes cause misclassification. The rotating bin mechanism works well but requires more stability at higher speeds to ensure precise waste placement. While the system operates efficiently with a 12V rechargeable battery, incorporating solar power could further enhance its sustainability. Overall, this project demonstrates a practical and cost-effective approach to waste management, with future improvements in AI-based waste recognition, IoT connectivity, and expanded material classification offering even greater potential.

## VI. FUTURE SCOPE

1. Advanced AI Integration : Use of AI and machine learning for more accurate waste classification through image and sensor data analysis.

1. IoT Connectivity: Real-time monitoring and data sharing with municipal waste systems through IoT-enabled devices.

2. Solar-Powered Operation: Solar panels for energy self-sufficiency, making the system eco-friendly and reducing operating costs.

3. Multi-Material Sorting: Enhanced detection for complex materials like e-waste, hazardous chemicals, and textiles.

4. Robotic Automation: Robotic arms for dynamic waste handling and sorting, improving flexibility and scalability.
5. Smart Bin Integration: Deployment in public smart bins with automatic alerts for waste collection when bins are full.
6. Industrial and Commercial Expansion: Custom solutions for industries like construction, healthcare, and electronics recycling.
7. Data Analytics & Reporting: Generating detailed reports on waste composition for better environmental planning and policy-making.

Sustainability & Green Certifications: Supporting businesses in achieving environmental certifications through improved waste management practices.

## VII. CONCLUSION

The Automatic Waste Sorting Machine presents an efficient, cost-effective, and environmentally sustainable approach to waste management by automating the segregation process. Utilizing a combination of IR, moisture, and inductive sensors, the system accurately classifies waste into dry, wet, and metal categories, reducing human intervention and improving recycling efficiency. The integration of stepper and servo motors ensures precise sorting, while the Arduino Uno microcontroller enables seamless operation. This system not only minimizes manual labour and associated health risks but also enhances resource utilization, ultimately contributing to a cleaner and more sustainable environment.

Future enhancements, such as AI-powered waste recognition, IoT-based real-time waste monitoring, and solar-powered operation, can further improve its efficiency and adaptability for smart cities and large-scale waste management applications. With its scalable and user-friendly design, the proposed system serves as a practical solution for both domestic and industrial waste management, paving the way for a more automated and sustainable future.

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