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Waste Sorting Machine for Dry, Wet and Metal Waste

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Abstract: *Waste segregation at the source is a critical step toward efficient waste management and environmental sustainability. This paper presents the design and implementation of an automated waste sorting system capable of classifying waste into dry, wet, and metallic categories. The system utilizes a combination of Infrared (IR), inductive proximity sensor and raindrop sensor to detect the waste and distinguish between different types of waste. An Arduino microcontroller serves as the central processing unit, coordinating sensor inputs and controlling actuators. The sorting mechanism employs servo motors for gate actuation and a stepper motor for conveyor belt movement, ensuring precise positioning and segregation. The proposed solution offers a cost effective and scalable alternative to manual waste sorting, with potential applications in households, urban waste collection centers, and recycling facilities. Experimental results demonstrate reliable waste classification with minimal error, highlighting the system's practicality and effectiveness in real-world scenarios.*

Keywords: Waste sorting system, Arduino, IR sensor, Proximity Sensor, Raindrop sensor

I. INTRODUCTION

Waste management has become a critical global concern due to rapid urbanization, population growth, and increased consumption. Improper handling and disposal of waste, especially when dry, metal, and wet wastes are mixed, lead to environmental pollution, health hazards, and the loss of recyclable materials. Traditional waste segregation methods are often labour-intensive, time-consuming, and prone to human error. To address these challenges, automation and embedded systems are increasingly being used in smart waste management solutions. Managing waste properly is very important for keeping our environment clean and healthy. With the increase in population and urban growth, the amount of waste produced every day is also growing. Most of this waste includes items like food leftovers, plastic, paper, and metal. If this waste is not sorted properly, it can cause pollution, make recycling difficult, and even harm human health. Traditionally, waste is separated by hand, which takes a lot of time and is unsafe and unpleasant for the people doing the work. To solve this problem, automated waste sorting machines have been developed. These machines can sort waste quickly and correctly without needing much human help.

One such machine is the Dry, Wet, and Metal Automated Waste Sorting Machine. This machine is designed to automatically separate waste into three categories:

- ***Dry Waste*** – This includes items such as plastic, paper, wood, cloth, and packaging materials. These are usually recyclable and not biodegradable.
- ***Wet Waste*** – This includes food waste, fruit and vegetable peels, tea bags, and other biodegradable items. Wet waste decomposes easily and can be used to make compost.
- ***Metal Waste*** – This includes objects made of iron, aluminium, and other metals. These materials can be recycled and reused after proper processing.

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Waste management has evolved significantly over the decades, beginning with simple open dumping and progressing toward more systematic approaches such as land filling, incineration, and recycling. However, as the global population increases and urban centres become more densely populated, the volume and complexity of solid waste have also grown. Manual waste segregation, a practice still widely used in many developing regions, is not only inefficient but also hazardous to human health. To improve efficiency and hygiene, automated waste sorting technologies have emerged, integrating various sensor based and robotic mechanisms. Early automation efforts focused primarily on separating recyclable materials using conveyor belts and basic magnetic or air-blown systems. However, these methods often fell short in accuracy and cost-effectiveness, especially when handling diverse waste streams such as mixed domestic waste containing organic material, plastics, and metals. The key contributions of this work include the development of a functional prototype that combines moisture and metal sensing technologies with mechanical actuation to sort waste in real time. The system utilizes an Arduino microcontroller for control logic, which allows for easy programmability and integration with additional sensors or modules if required. A three-bin separation mechanism driven by servo and DC motors ensures accurate waste deposition based on sensor input. The machine has been tested under various conditions and demonstrates promising results in terms of classification accuracy, processing time and reliability.

II. LITERATURE REVIEW

Automated waste segregation systems have become increasingly relevant due to the growing need for efficient, hygienic, and scalable waste management solutions. Many low-cost systems rely on simple sensor-based detection techniques to categorize waste into different types. Infrared (IR) sensors are frequently used in these systems to detect the presence of an object and determine certain surface characteristics. These sensors are effective in basic material identification tasks, such as distinguishing between reflective and non to categorize waste into different types. Infrared (IR) sensors are frequently used in these systems to detect the presence of an object and determine certain surface characteristics. These sensors are effective in basic material identification tasks, such -reflective surfaces, organic items entering which is useful in detecting dry or non-organic items entering the sorting area.

Proximity sensors are commonly integrating Proximity sensors are commonly integrated to sense the approach of waste material and initiate the sorting mechanism. based systems that use proximity data to control gripper movements or actuator positions, some designs eliminate the need for such complex hardware by using driven bin rotation or gate switching. This method reduces mechanical complexity and cost while still allowing accurate control over sorting approach of waste material and initiate the sorting mechanism. Unlike robotic-arm-based systems that use proximity data to control gripper movements or actuator positions, some designs eliminate the need for such complex hardware by using proximity feedback to control motor-driven bin rotation or gate switching. This method reduces mechanical complexity and cost while still allowing accurate control over sorting sequences.

Moisture detection, often implemented through raindrop sensors, is employed to identify wet or organic waste. These sensors work by measuring surface conductivity, allowing the system to determine whether the waste item contains moisture. When combined with other sensor data, raindrop sensors enable basic two- or three-way classification of waste. Although not as precise as advanced imaging or chemical sensing systems, they provide an effective, low-power solution for real Moisture detection, often implemented through raindrop played to identify wet or organic waste. These sensors work by measuring surface conductivity, allowing the system to determine whether the waste item contains moisture. When combined with other sensor data, raindrop sensors enable classification of waste. Although not as precise as advanced imaging or chemical sensing systems, they power solution for real-time classification in environments with limited resources.

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III. PROPOSED DESIGN

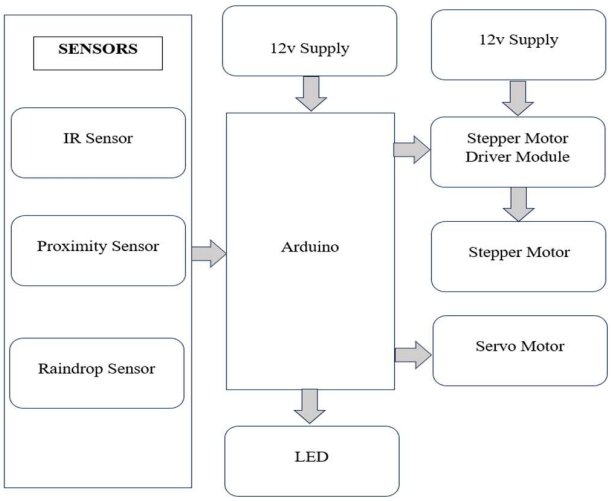

Fig.1 Block Diagram

Working:

The dry metal waste segregation system is designed to efficiently classify waste based on its moisture content and metallic properties. The system begins by detecting the presence of waste using an IR sensor. Once detected, the waste is in drop moisture sensor to determine if it is. The dry metal waste segregation system is designed to efficiently classify waste based on its moisture content and metallic properties. The system begins by detecting the presence of waste using an IR sensor. Once detected, the waste is analysed using a raindrop moisture sensor to determine if it is wet or dry. If moisture is detected, the waste is directed to a separate disposal area.

For dry waste, a proximity sensor checks for metallic properties. If metal is identified the servo motor activates and it rotates the bin to collect the waste and goes to its original position. It is same for other, when dry waste or wet waste is identified the servo motor rotates the bin to collect the wet or dry. If moisture is detected, the waste is directed to a separate disposal area. For dry waste, a proximity sensor checks for metallic properties. If metal is identified the servo motor rotates the bin to collect the waste and goes to its original position. It is same for other, when dry waste or wet waste is identified the servo motor rotates the bin to collect the an auditory alert when the sorting process is complete. The 12v power supply is given to Arduino Uno and waste and then goes back to original position.

A buzzer provides an auditory alert when the sorting process is complete. The 12v power supply is given to Arduino Uno and Separate 12v power is given to servo motor driver. By utilizing automated sensing and mechanical sorting, this system enhances efficiency in waste segregation and promotes effective recycling practices. The waste segregation process functions by executing three important sequences that start with waste recognition followed by sorting. The IR sensor to find waste items together raindrop moisture sensor that decides if the waste moisture or remains dry. The proximity sensor uses to determine material composition by identifying metal-based substances. Those waste materials showing signs of moisture get into the appropriate bin for wet waste disposal. The system performs metal content evaluation without moisture because no presence of moisture has been detected.

Dry waste sorting equipment first measures metallic properties to identify dry materials as metal waste before depositing all additional waste in the non-metallic dry waste collection containers. Specific classification methods allow precise sorting of materials according to their moisture content and material types. A precise material handling capability results from working with both stepper motors and is given to servo motor driver. By utilizing automated sensing and mechanical sorting, this system enhances efficiency segregation and promotes effective recycling practices. The waste segregation process functions by executing three important sequences that start with waste recognition followed by sorting. The IR

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sensor to find waste items together with a raindrop moisture sensor that decides if the waste contains moisture or remains dry. The proximity sensor uses to determine material composition by identifying metal substances. Those waste materials showing signs of moisture get automatically separated into the appropriate bin for wet waste disposal. The system performs metal content evaluation without moisture because no presence of moisture has been detected. Dry waste sorting equipment first measures metallic properties to identify dry materials as before depositing all additional waste in the non waste collection containers.

The servomotor operates the sorting system to direct w separation bins. The sorting process starts, when the waste is detected by IR sensor it checks if it is wet waste, dry waste or metal waste and after detecting the servo motor rotates that particular bin the waste is dropped in that activates when waste classification and sorting succeed in finishing the operation. The buzzer function system activates for successful waste completion. The entire system runs in real continuously while performing classifications time feedback from sensors and motors gives the system an efficient and responsive operation to perform precise waste separation with no delays. A stepper motor manages the operations to distribute waste into suitable sorting bins correctly. The servomotor operates the sorting system to direct waste objects into proper separation bins. The sorting process starts, when the waste is detected by IR sensor it checks if it is wet waste, dry waste or metal waste and after detecting the servo motor rotates that bin the waste is dropped in that bin.

TABLE-1 Calibration

Sr. No	Waste Category	Property Detected	Bin(Position)
1	Dry	Low Moisture	Bin1(0^{o})
2	Metal	Metallic Conductivity/Eddy Current	Bin2(120^{o})
3	Wet	High Moisture	Bin3(240^{o})

IV. RESULTS & DISCUSSION

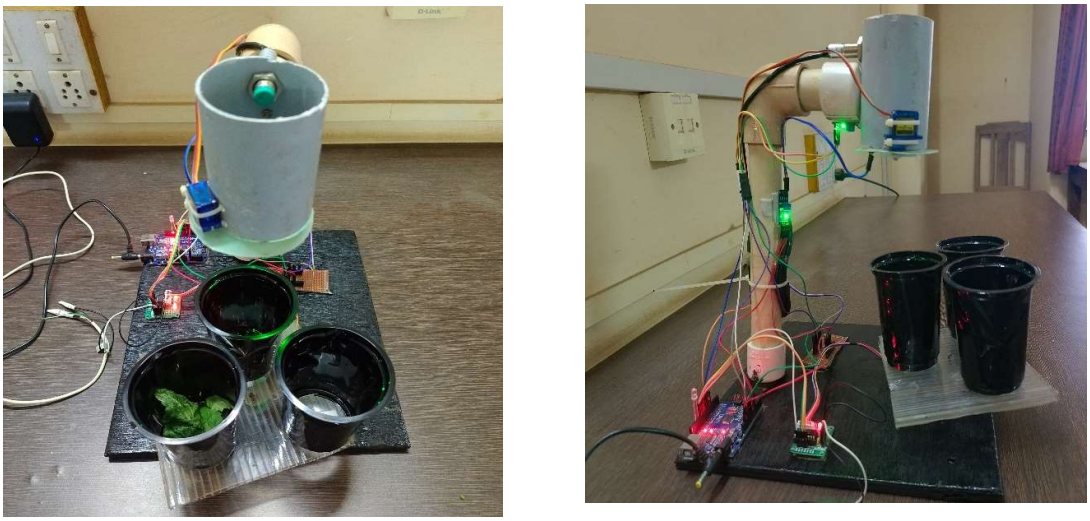

Fig.2 Results

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V. ADVANTAGES & DISADVANTAGES

Advantages:

1. Increased Recycling Rates: Separating waste at the source makes it much easier and more efficient to recover valuable materials like paper, plastic, glass, and metal for recycling.
2. Reduced Landfill Volume: Less waste goes to landfills, extending their lifespan and minimizing the need for new, environmentally.
3. Economic Benefits: Recycled materials can be sold, generating revenue. Also, composting wet waste creates valuable fertilizer, reducing the need for chemical alternatives.
4. Environmental Protection: It drastically reduces air pollution (from methane gas) and water/soil pollution (from toxic leachate) that come from mixed waste in landfills.
5. Community Engagement and Awareness: Implementing such a system encourages citizens to be more responsible with their waste, fostering greater environmental awareness and community participation.

Limitations:

1. High Initial Cost: Setting up the necessary bins, vehicles, and facilities is expensive.
2. Odor and Pest Issues from Wet Waste (if not managed well): While sorting helps, large-scale collection and processing of wet waste can still lead to Odor problems or attract pests if not handled very quickly and properly.

VI. CONCLUSION

This waste segregation system uses automation to manage waste more effectively. With the help of sensors and accurate motors, it can quickly and efficiently identify and separate dry metal waste. The system works by combining hardware components with Arduino programming, making it capable of detecting different types of waste materials accurately. Currently, the system performs well thanks to its strong base in embedded systems and automation technology. In the future, it will be improved by adding machine learning, which will make waste classification more accurate. The system will also be upgraded to use less power and handle a wider range of waste materials.

Overall, this project supports environmental protection by using smart and sustainable waste management methods. It reduces human effort, promotes recycling, and lays the groundwork for smarter, AI-powered waste management in the future.

Future Scope:

The future scope of a dry, metal, and wet waste management system project is vast and driven by technological advancements, increasing environmental awareness, and the push towards a circular economy.

1. Smarter Sorting & Processing: Future systems will use more robots and AI to sort waste much faster and more accurately, even for complex materials, improving how much we can recycle and recover.
2. Local & Decentralized Solutions: There will be a shift towards smaller, community-level facilities for composting and basic recycling, reducing the need to transport waste long distances and making management more efficient.
3. Resource-Focused & Circular Economy: The focus will move beyond just waste disposal to seeing waste as a valuable resource. This means designing products that are easier to recycle and turning more organic waste into energy (like biogas) or high-quality compost, integrating waste management deeply into a sustainable "circular economy."

VII. ACKNOWLEDGMENT

We would like to express our sincere gratitude to all those who contributed to the successful completion of our project titled Waste Segregation System. First and foremost, we extend our heartfelt thanks to our instructor for their invaluable guidance, support, and constructive feedback throughout the course of the project. Their insights were instrumental in shaping the development of our system. We also acknowledge the academic resources, research papers, and online tutorials that provided us with essential knowledge on automated waste segregation, sensor integration, and motor control.

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