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Design and Fabrication of Smart Waste Segregation Bins

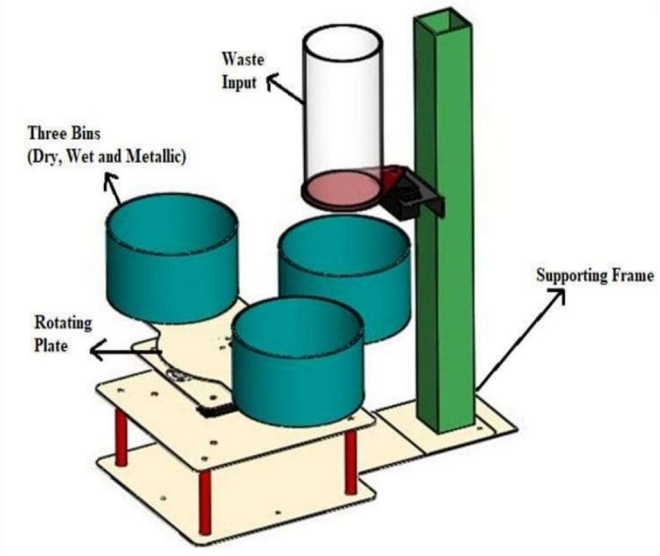
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Abstract: ***This project presents the design, fabrication, and performance analysis of a Smart Waste Segregation Bin capable of automatically classifying waste into wet, dry, and metallic categories using sensor-based automation. Improper waste segregation is a major issue in modern waste management systems, leading to inefficient recycling and environmental degradation.The proposed system integrates an infrared sensor for object detection, a moisture sensor for identifying wet waste, and a metal detection sensor for metallic waste identification. These sensors are interfaced with a micro-controller that processes real-time data and controls a servo-based actuation mechanism to direct waste into designated compartments. The system is compact, cost-effective, and suitable for small-scale applications such as residential complexes, educational institutions, and public areas. Experimental evaluation indicates an overall efficiency of approximately 85–90%. The system reduces human effort, enhances hygiene, and promotes sustainable waste management practices. Future enhancements may include IOT integration and AI-based classification for improved performance.***

I. INTRODUCTION

The rapid increase in population and urbanization has led to a significant rise in the generation of municipal solid waste. Improper waste disposal and lack of segregation at the source contribute to environmental pollution, health hazards, and inefficient recycling processes. Effective waste management begins with proper segregation of waste into categories such as biodegradable, non-biodegradable, and recyclable materials. Traditional waste segregation methods rely heavily on manual sorting, which is inefficient, labor-intensive, and often unsafe. Workers are exposed to harmful substances, and the accuracy of segregation depends on human judgment, which can lead to errors. To address these issues, the Smart Waste Segregation Bin has been developed as an automated solution. The system uses sensor-based technology and micro-controller control to identify and separate waste materials. By reducing human intervention and improving efficiency, the system contributes to sustainable waste management practices and supports the development of smart cities.

II. CAD MODEL



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III. COMPONENT DESCRIPTION

The system consists of several interconnected components that work together to achieve automated waste segregation. The Arduino micro-controller serves as the central processing unit, receiving input from sensors and controlling the output mechanism.An infrared sensor is used to detect the presence of waste and initiate the system operation. A moisture sensor measures the water content in the waste to determine whether it is wet or dry. A metal detection sensor identifies metallic components based on electromagnetic properties.The actuation system consists of a servo motor that rotates a flap mechanism to direct waste into the appropriate bin. A regulated power supply ensures stable operation of all electronic components. The structural frame is designed using lightweight and durable materials to provide stability and ease of maintenance.

IV. ATTACHMENTS

The system is designed with a modular structure consisting of an input section, sensing chamber, actuation mechanism, and output bins. The waste input section allows users to dispose of waste easily. The sensing chamber houses the sensors, which analyze the waste properties. The actuation mechanism consists of a rotating flap controlled by a servo motor. Based on sensor inputs, the flap directs the waste into one of the designated bins for wet, dry, or metallic waste. The entire system is supported by a rigid frame to ensure stability and efficient operation.

V. WORKING PRINCIPLE

The Smart Waste Segregation Bin operates on the principle of sensor-based detection and automated actuation. When waste is introduced into the system, the infrared sensor detects its presence and activates the system. The waste passes through the sensing chamber, where the moisture sensor determines whether it is wet or dry, and the metal sensor checks for metallic content. The micro-controller processes these inputs and classifies the waste accordingly. The servo motor is then activated to rotate the flap mechanism, directing the waste into the appropriate bin. The system resets after each cycle, ensuring continuous operation.

VI. EXPERIMENTAL SETIUP

The experimental setup consists of a compact assembly of sensors, micro-controller, and mechanical components mounted on a stable frame. Sensors are positioned strategically to ensure accurate detection of waste properties.The Arduino is programmed to process sensor inputs and control the servo motor.
The system is powered using a regulated power supply. Various types of waste materials are tested to evaluate system performance under different conditions.

VII. MATERIAL SELECTION

Material selection plays a crucial role in ensuring the durability, efficiency, and cost-effectiveness of the system. Lightweight plastic materials are used for the outer body to reduce weight and prevent corrosion. The supporting frame is constructed using mild steel to provide structural strength and stability.Sensors are selected based on sensitivity, response time, and compatibility with the micro-controller. The servo motor is chosen for its precision and ability to provide controlled rotational motion. Proper material selection ensures long-term reliability and efficient operation of the system.

VIII. DESIGN CALCULATIONS

A. Motor Power Calculation

$P=V\times I P=V\times I$
Voltage (V) = 5V
Current (I) = 1A
P = 5 × 1 = 5 W

B. Torque Calculation

$T=F\times r T=F\times r$
Force = 2 N
Radius = 0.05 m
T = 0.1 Nm

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C. Servo Selection Justification

Required torque < 1 Nm

Standard servo (e.g., SG90) sufficient

IX. SYSTEM DESIGN & ARCHITECTURE

The system architecture consists of input, processing, and output stages. The input stage includes sensors that detect waste properties. The processing stage consists of the micro-controller, which analyzes sensor data. The output stage includes the servo motor and segregation bins.The design ensures smooth flow of operation, minimal delay, and accurate classification. The modular structure allows easy maintenance and scalability.

X. RESULTS

The Smart Waste Segregation Bin successfully performs automated waste classification with satisfactory accuracy. The system demonstrates reliable performance for different types of waste materials and maintains consistent operation.The results confirm that the system reduces manual effort and improves efficiency in waste management. The compact design and cost-effectiveness make it suitable for real-world applications.

XI. BILL OF MATERIALS (BOM)

SRNO	COMPONENTS	PRICE
1	Arudino	500
2	Ir sensor	150
3	Moisture sensor	150
4	Metal sensor	300
5	Servo motor	250
6	Metal and frame	800
7	Miscellanous	500

XII. FUTURE SCOPE

The Smart Waste Segregation Bin has significant potential for future development and large-scale implementation. With the integration of advanced technologies such as Artificial Intelligence (AI) **and** Machine Learning (ML), the system can be enhanced to identify and classify waste with higher accuracy, including complex materials like multi-layer plastics and biomedical waste.In the future, the system can be connected to the Internet of Things (IOT) for real-time monitoring, data collection, and remote operation. This will help municipalities and organizations track waste generation patterns and optimize waste collection routes.

XIII. ADVANTAGES

The Smart Waste Segregation Bin offers several advantages over traditional waste disposal methods:

1) Automatic Segregation: Reduces human effort and errors
2) Time Efficient: Faster waste sorting process
3) Improved Hygiene: Minimizes human contact with waste
4) Eco-Friendly: Promotes recycling and proper waste management
5) Cost-Effective (Long Term): Reduces labor and operational costs
6) Reduces Pollution: Prevents mixing of hazardous and non-hazardous waste
7) User-Friendly: Easy to operate and maintain

XIV. APPLICATIONS

The Smart Waste Segregation Bin can be widely used across various sectors to improve waste management efficiency:

1) Households: For daily segregation of dry, wet, and recyclable waste
2) Hospitals: Safe handling and separation of biomedical waste

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3) Educational Institutions: Promoting awareness and automated waste sorting
4) Municipal Corporations: Large-scale waste management in cities
5) Industrial Areas: Segregation of industrial and hazardous waste
6) Public Places: रेलवे स्टेशन, airports, malls, parks, etc.

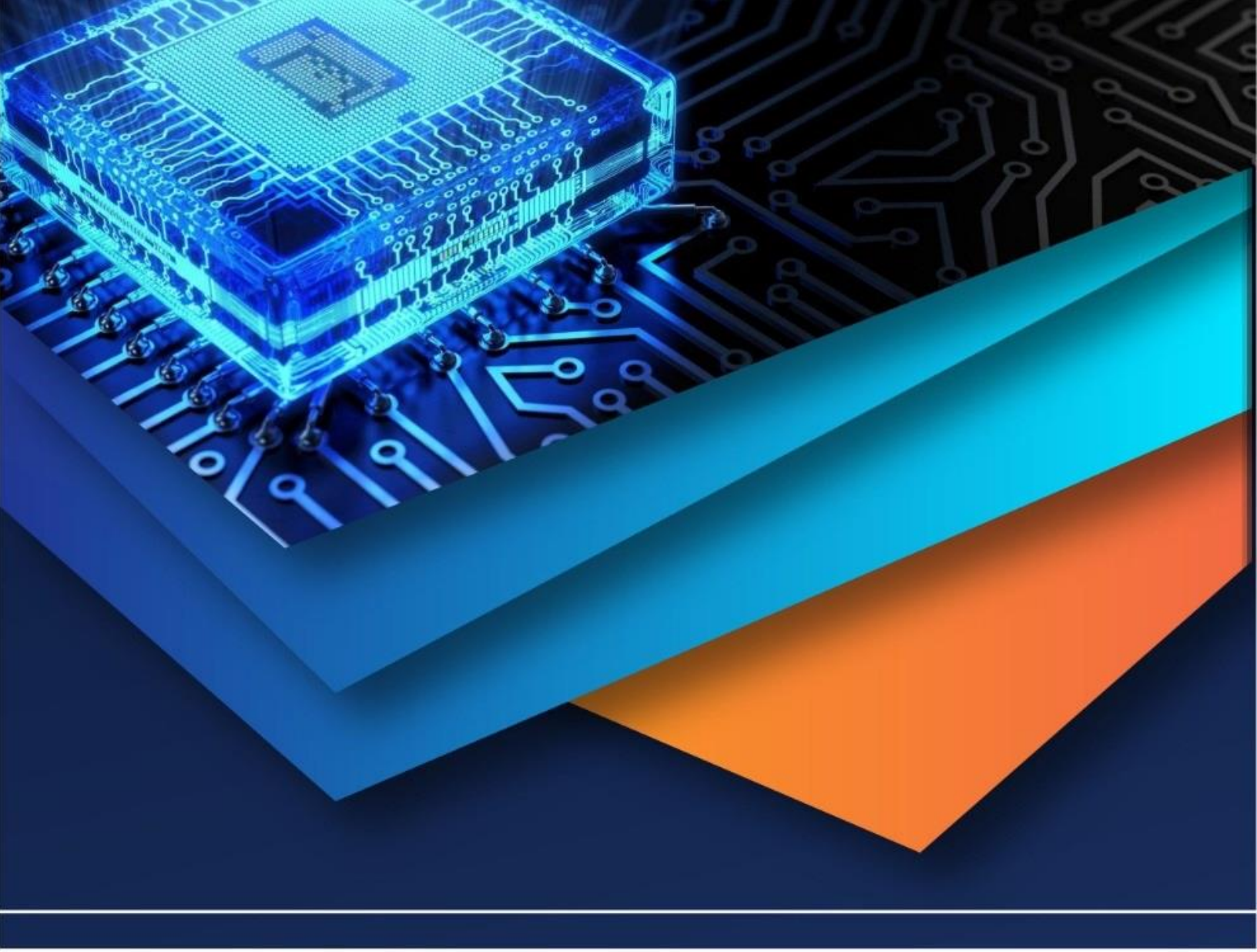
This system helps in reducing manual effort and ensures proper waste disposal in all environments.

XV. CONCLUSION

In conclusion, the Smart Waste Segregation Bin is an innovative and practical solution to the growing problem of improper waste disposal. By utilizing sensors, automation, and intelligent sorting mechanisms, the system ensures efficient segregation of waste at the source.This not only improves recycling efficiency but also reduces environmental pollution and health risks associated with manual waste handling. The system aligns with modern sustainability goals and supports cleaner and smarter living environments.With further advancements and large-scale implementation, this technology can play a vital role in transforming traditional waste management systems into smart, automated, and sustainable solutions

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