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Development of Smart Sorter

[1]M. Arpana Christeen, [2]Urvashi Sharma, [3]Yasasvi. P, [4]D. Sri Lakshmi Reddy, [5] Dr. R. Uday Kumar

[1,2,3,4]B.Tech (Mech.Engg.) Students, Dept. of Mechanical Engineering, Mahatma Gandhi Institute of Technology, Gandipet, Hyderabad.
[5]Associate Professor, Dept. of Mechanical Engineering, Mahatma Gandhi Institute of Technology, Gandipet, Hyderabad.

ABSTRACT

In the present scenario, the segregation of material in various applications such as in industries, manufacturing sectors, assembly units, utility areas and also service sectors and also daily needs in human life. Waste management continues to be a pressing issue in urban areas, with improper segregation of waste being a key challenge. The traditional method of manually sorting waste is not only inefficient but also prone to errors, resulting in mixed waste that complicates recycling processes and contributes to environmental pollution. This issue calls for a more efficient and accurate solution to ensure waste is properly categorized and managed. To study on the above, this work developed a Smart Sorter system. This system includes sensors, materials sorting elements, servo motors etc. This innovative system uses advanced sensors to automatically distinguish between organic and inorganic waste. By analyzing various characteristics such as texture, density, and moisture content, the machine ensures waste is sorted with precision, minimizing human intervention and reducing the chances of contamination. The Development of smart sorter system, the benefits of this system is to extend the mechanization and automation. By improving the accuracy and speed of waste segregation, it helps optimize recycling efforts, ensuring that recyclable materials are separated from non-recyclables right from the start. This not only enhances recycling rates but also reduces the environmental impact of waste disposal. The application of this machine could have a wide range of uses, from municipal waste management to industrial sectors and even homes, making it a highly versatile solution. In essence, the Smart Sorter system offers an efficient, eco-friendly solution to one of the most common challenges in waste management today. By enabling better waste sorting, it contributes to a cleaner environment and supports more sustainable waste practices for the future.

Key Words : Micro controller, Sensor, actuator, smart system, sorter

1. INTRODUCTION

The rapid urbanization and population growth have led to a significant increase in waste generation, posing a substantial challenge to waste management systems worldwide. In India, for instance, the municipal solid waste generation is estimated to be around 1.5 lakh metric tons per day, with a significant portion of it being organic waste. The traditional method of waste management, which involves manual segregation, is not only inefficient but also poses health risks to the workers involved(1-5). Moreover, the lack of proper segregation of waste leads to mixed waste, which complicates recycling processes and contributes to environmental pollution.

In recent years, there has been a growing emphasis on the importance of proper waste segregation and recycling. The Government of India has launched several initiatives, such as the Swachh Bharat Abhiyan, to promote cleanliness and waste management. However, despite these efforts, the waste management infrastructure in India remains inadequate, and there is a need for innovative solutions to address this challenge.

The Smart Sorter system is one such innovative solution that uses advanced sensors and automation to segregate waste into different categories (6-9). This system has the potential to revolutionize waste management practices in urban areas by providing an efficient, accurate, and eco-friendly solution to waste segregation. The system uses a combination of infrared (IR) sensors, moisture sensors, electromagnetic sensors, microcontrollers, and servo motors to sort waste into organic, plastic, metallic, paper, and glass categories. The development of the Smart Sorter system is a significant step towards mechanization and automation of waste management practices (10-11). By improving the accuracy and speed of waste segregation, this system can help optimize recycling efforts, reduce contamination, and enhance recycling rates. The application of this system can be extended to various sectors, including municipal waste management, industrial sectors, and even homes, making it a highly versatile solution.

The Smart Sorter system is designed to address the challenges associated with traditional waste management practices. The system is equipped with advanced sensors that can detect the characteristics of waste, such as texture, density, and moisture content, and sort it accordingly. The use of microcontrollers and servo motors enables the system to operate with precision and accuracy, minimizing human intervention and reducing the chances of contamination (12-15). The benefits of the Smart Sorter system are multifaceted. It can help reduce the environmental impact of waste disposal, enhance recycling rates, and promote sustainable waste practices. Additionally, the system can also help reduce the health risks associated with manual waste segregation, improving the overall quality of life for waste management workers.

2. PROBLEM STATEMENT AND OBJECTIVES

The improper segregation of waste is a significant challenge in waste management. The traditional method of manual waste segregation is inefficient and poses health risks to the workers involved. The lack of proper segregation of waste leads to mixed waste, which complicates recycling processes and contributes to environmental pollution. There is a need for an efficient, accurate, and eco-friendly solution to waste segregation that can optimize recycling efforts and reduce the environmental impact of waste disposal.

The objective of this research is to design, develop, and implement a Smart Sorter system that can segregate waste into different categories using advanced sensors and automation. The specific objectives of the work:

- To design and develop a Smart Sorter system that can detect the characteristics of waste, such as texture, density, and moisture content, and sort it accordingly.
- To evaluate the performance of the Smart Sorter system in terms of accuracy, efficiency, and eco-friendliness.
- To explore the potential applications of the Smart Sorter system in waste management practices.

3. WORKING MODEL & ITS COMPONENTS

A Smart Sorter is an embedded system that classifies waste into categories such as metal, wet, dry, and organic waste using sensors and microcontrollers. The general architecture consists of: Input subsystem (sensors), Processing subsystem (microcontroller/embedded processor), Output subsystem (actuators like motors, sorting flaps), Support systems (power, display, alert system, network). The design must support modularity, real-time responsiveness, and fault tolerance for optimal performance. The prototype of Smart Sorter as shown in Figure 1.

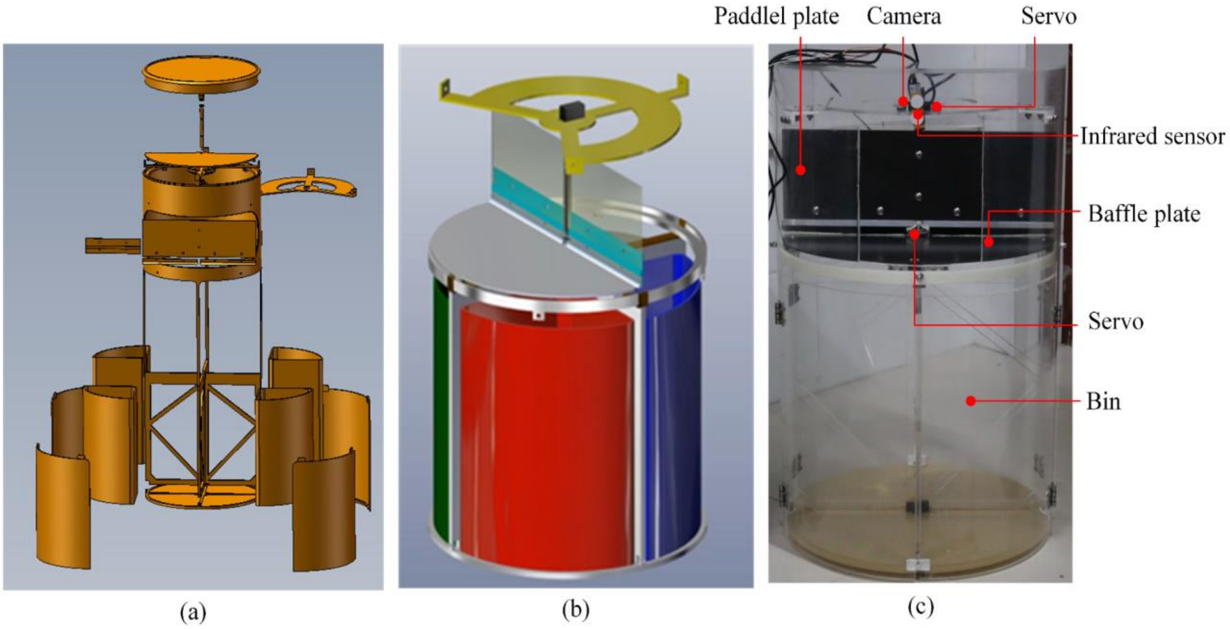

Fig 1. Prototype of Smart Sorter System

Sensors :

IR Sensors – Detect the presence of objects and assist in basic material differentiation.

Electromagnetic Sensors – Inductively detect metals.

Moisture Sensors – Distinguish between wet and dry waste.

Advanced systems:

Color sensors – To separate paper from plastic

Weight sensors – For bin load management.

Ultrasonic sensors – For distance and object size estimation.

Microcontroller Unit (MCU):

This is the brain of the system. Common choices include:

Arduino Uno – For educational or prototyping systems.

Raspberry Pi – For systems requiring network integration or more computational power.ESP32/ESP8266 – For IoT-based applications.

Actuators:

Actuators translate digital decisions into physical movements. Types used include:

- Servo Motors – Rotate flaps precisely.
- Stepper Motors – Control conveyor belts or sorting arms.
- DC Motors – Drive mechanical rollers, fans, or sorters.
- Each actuator is controlled by a driver circuit or relay interfaced with the MCU.

Power Supply

- Stable power is critical. Systems can use:Battery-powered (12V, 5V)
- AC mains with adapters
- Solar-powered options for sustainability
- Power distribution must include: Voltage regulators, Isolation circuits.

Data Flow and Signal Routing

Analog Signals from moisture and IR sensors are read using ADC (Analog to Digital Converters). Digital Signals from proximity sensors are processed as logic HIGH or LOW. Sensor data is passed through conditional logic gates or software flags to determine the sortingpath.

Control Algorithm

The control algorithm uses a decision tree approach: IR detects presence.

1. Metal sensor checks if the object is metallic.

If yes, route to the metal bin.

If not, tthe moisture sensor engages.

2. Moisture sensor determines:

If high → wet waste → organic bin.

If low → dry waste → recyclable bin.

This logic is encoded in firmware written in C/C++ or Python.

System Architecture

The flow chart of Smart Sorter Operation as shown in figure 2.

[Waste Input]

↓

[IR Sensor] → [Object Detected]

↓

[Electromagnetic Sensor] → [Metal?]

↓

[Moisture Sensor] → [Wet/Dry?]

↓

[Microcontroller]

↓

[Sorting Mechanism] → [Bin A / Bin B / Bin C]

Fig 2. Flow chart of Smart Sorter Operation

Sensor Integration and Positioning

Correct placement is vital for optimal detection.

IR Sensor: Placed at the mouth of the input chute.

Electromagnetic Sensor: Positioned along the conveyor to scan each item.

Moisture Sensor: Installed beneath the item detection zone or integrated in the tray.

Design Note: Moisture sensors should be protected against waste build-up using hydrophobic films or mesh.

Communication Interfaces

Modern segregators may need to interact with external systems:

Wi-Fi / Ethernet – For IoT monitoring, alerts, and statistics.

Bluetooth – For mobile app interfacing.

Display Panels – To show bin status, errors, or total sorted units.

MCUs like Raspberry Pi or ESP32 handle these tasks with onboard connectivity.

User Interface and Alerts

LED indicators: Show operational status, bin full alert.

Buzzer: Sounds when bins are full

Touchscreen: For manual override or data viewing (in advanced systems).

4. WORKING MECHANISM OF SMART SORTER

Step 1: Waste Entry

User throws waste into the input chamber.

IR sensor detects an object.

MCU begins scanning routine.

Step 2: Metal Detection

Waste passes electromagnetic sensors.

If metal is detected → actuator directs it to the metal bin.

If not → next sensor is activated.

Step 3: Moisture Measurement

Moisture sensor checks conductivity or permittivity.

High reading → wet waste → organic bin.

Low reading → dry waste → recyclables bin.

Step 4: Sorting Execution

Microcontroller calculates output.

Servo motor activates the flap.

Waste is guided to the correct bin.

Flap-Based Sorting Mechanisms

A rotating flap is positioned at a junction. Based on logic, the flap redirects the item to the appropriate path.

Advanced Detection Techniques

Thermal Imaging (Infrared Thermography): Can distinguish living tissue from inorganics.

Computer Vision Systems: Using cameras and ML to detect shape, color, size.RFID Tags: Used in smart bins for pre-tagged waste items (industrial usage).

Self-Cleaning and Maintenance Systems

Rotating brushes: Keep sensor surfaces clean.

Spray nozzles: For cleaning moist residue.

Self-diagnostics: Trigger maintenance alerts when calibration drifts.

Example: Singapore’s Smart Recycling Bins have internal vacuums to clean sensor windows and prevent incorrect readings.

Waste Bin Feedback System

Weight sensors under each bin monitor fill level.

Alerts are sent to collection teams when bins reach 90% capacity.

Some systems use GSM or Wi-Fi to communicate with cloud platforms.

5. RESULTS AND DISCUSSION

The final system uses a combination of sensors—infrared (IR), moisture, and electromagnetic—to identify material properties. The IR sensor detects the reflectivity of an object, helping to distinguish between plastic, paper, and glass. The moisture sensor identifies organic waste based on its inherent moisture levels, while the electromagnetic sensor isolates metals based on their magnetic conductivity or influence on a field. A microcontroller forms the processing hub, aggregating input from the sensors, executing decision-making algorithms, and issuing signals to servo motors. These motors then guide the waste into one of five dedicated compartments, ensuring accurate disposal without human interference.This chain of operation, from sensing to actuation, is elegant in its simplicity yet profound in its effectiveness. It transforms the everyday action of throwing away garbage into a technologically optimized process, reinforcing hygienic practices while greatly improving environmental outcomes. Unlike static dustbins that treat all waste uniformly, this system gives each material its due pathway—plastic to recycling, organic matter to composting, metal to industrial processing, and paper or glass to their respective recovery streams.Environmentally, the implications are transformative. With clean segregation at source, recyclable materials are preserved in uncontaminated states, improving the viability and profitability of recycling. Organic waste, often a contaminant in mixed bins, can instead be converted into compost or used in anaerobic digestion processes, yielding biogas and reducing methane emissions from landfills. When scaled, the Smart Sorter could contribute significantly to reducing urban landfill volumes, conserving natural resources, and lowering emissions tied to waste mismanagement. Economically, the Smart Sorter proves itself to be a long-term investment. While initial hardware costs may pose a barrier for some adopters, the savings in labour, reduced contamination penalties, and improved recovery rates for recyclables and compostable quickly offset these expenses. In places where environmental regulations are becoming stricter and recycling targets are enforced by law, having an intelligent sorting system ensures compliance and avoids fines, making it a wise infrastructural upgrade. Durability and reliability also emerged as focal points. Mechanical wear, power consumption, moisture ingress, and user misuse are all real-world factors that threaten system performance over time. Hence, the enclosure design, sensor placement, and system resilience were addressed with seriousness, ensuring the prototype not only works under ideal conditions but also under daily usage in varied environments.

6. CONCLUSION

The completion of the Smart Sorter work represents more than the successful application of embedded systems to a practical task—it signifies a step forward in how society can embrace intelligent automation to solve environmental problems at scale. In an age characterized by rapid urbanization, technological expansion, and rising ecological strain, managing waste in an efficient, hygienic, and sustainable manner has emerged as a paramount challenge. This project provides a response to that challenge, focusing particularly on the critical bottleneck of waste segregation.Effective waste management begins with segregation. Without proper separation of waste at the point of disposal, recycling becomes inefficient, composting is hindered, and overall waste handling becomes expensive, hazardous, and environmentally detrimental. Manual sorting is slow, error-prone, and dangerous, especially when workers are exposed to unsorted bio hazardous or chemical materials. The Smart Sorter system was conceptualized with the intention of removing this inefficiency and replacing it with a system rooted in automation, accuracy, and real-time classification.Operationally, the system enhances efficiency and safety. It reduces the manpower required to sort waste and minimizes contact between humans and hazardous or unsanitary materials. By automating sorting, the system ensures consistent performance, which is difficult to achieve with human workers who tire or make errors. This is especially critical in institutional or commercial environments, where large volumes of waste are generated and speed and consistency are essential.Technically, the Smart Sorter showcases the potential of microcontroller-based automation when combined with appropriate sensor technologies. The Work also presented numerous real-world challenges during development, offering valuable learning experiences. Waste is not always neatly categorized; real-life objects often contain multiple materials. This required the sorting logic to be refined and adaptive. Sensor accuracy needed calibration across different lighting conditions and object orientations. Actuation had to be fine-tuned for timing and positioning to avoid mechanical jamming. Each of these challenges deepened our understanding of practical automation design and system integration.

REFERENCES

Neil Laurence Z. Ortaliz, Alfed Edrian D. Ama, Albert Anthony O. Fuentes, Josh Arvin G. Jurado, Engr. Myles Joshua Toledo Tan, "Automatic Waste Segregation system using trained optical and material sensors with user communication capabilities" proceedings of ISER International Conference, Kuala Lumpur, Malaysia, 18th –19th May, 2020.

Md. Shahariar Nafiz; Shuvra Smaran Das; Md. Kishor Morol; Abdullah Al Juabir; Dip Nandi, " ConvoWaste: An Automatic Waste Segregation Machine Using Deep Learning", 2023 3rd International Conference on Robotics, Electrical and Signal Processing Techniques (ICREST), 07-08 January 2023.

Nimisha S Gupta, Deepthi V, Mayakunnath, Rejeth Pal S, Badsha T S, Nikhil Binoy C, "Automatic Waste Segregation", Proceedings of the Second International Conference on Intelligent Computing and Control Systems (ICICCS 2018), IEEE Xplore Compliant Part Number: CFP18K74-ART; ISBN:978-1-5386-2842-3.

Fatin Amanina Azis1*, Hazwani Suhaimi1, Pg Emeroylariffion Abas1, "The Development of an Automated Waste Segregator", Interational Journal of Integrated Engineering, Vol 15 No 4(2023), p 19-30.

Aleena V.J., Kavya Balakrishnan, Rosmi T.B., Swathy Krishna K.J., Sreejith S, T.D. Subha, "Automatic Waste Segregator and Monitoring System", Journal of Microcontroller Engineering and Applications, ISSN: 2455-197X

Alfarrarjeh A, Kim S, Agrawal S, Ashok M, Kim S Y, and Shahabi C Image Classification to Determine the Level of Street Cleanliness: A Case Study *IEEE Xplore* October 2018

[7] Chinnathurai B, Sivakumar R, Sadagopan S, and Conrad J Design and implementation of a semi- autonomous waste segregation robot *IEEE* 2016 pp. 1-6

[8] Pardini K, Rodrigues J, Diallo O, Das A, Albuquerque V, and Kozlov S A Smart Waste Management Solution Geared towards Citizens *MDPI* April 2020

[9] Satyamanikanta S, and Narayanan M Smart garbage monitoring system using sensors with RFID over internet of things *ResearchGate* July 2017

[10] Sultana P, Challa P, and Jayavel S IOT Based Garbage Monitoring system *ResearchGate* November 2017

[11] Parikh P, and Vasani R Smart Dustbin-An Intelligent Approach to Fulfill Swatchh Bharat Mission *ResearchGate* October 2017

[12] Keerthana S, Kiruthika B, Lokeshvaran R, Midhunchakkaravarthi B, and Dhivyasri G A Review on Smart Waste Collection and Disposal System *Journal of Physics: Conference Series* 2021.

[13] Suwetha G Node MCU based smart garbage monitoring system *International Journal of Advance Research, Ideas and Innovations in Technology* 2019

[14] Gutierreza J, Jensenb M, Heniusa M and Riazc T Smart Waste Collection System Based on Location Intelligence *Science Direct* 2015

[15] Chakraborty S, Mehta A, Sheikh S, Jha A, and Manjunath C Smart Waste Management System ResearchGate May 2021