International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 09 Issue: 02 | Feb - 2025 SJIF Rating: 8.448 ISSN: 2582-3930

Development of Automated Waste Sorting and Recycling System

Mr. V. Ranjith kumar[1], Mr. K. Vetri Velmurugan[2], V. Sangeeth[3], P.V. Priyadarshan [4], A. Nivash [5]

[1]*Assistant professor, Department of Mechanical Engineering, Sri Sairam Engineering College, Chennai*
[2]*Assistant professor, Department of Mechanical Engineering, Sri Sairam Engineering College, Chennai*
[3]*Student, Department of Mechanical Engineering, Sri Sairam Engineering College, Chennai*
[4]*Student, Department of Mechanical Engineering, Sri Sairam Engineering College, Chennai*
[5]*Student, Department of Mechanical Engineering, Sri Sairam Engineering College, Chennai*

Abstract - The proposed automated waste sorting and recycling system in this research incorporates state-of-the-art sensing technologies and machine learning techniques to make the waste management process efficient and optimized. With the use of computer vision and sensors, the system accurately detects and sorts various forms of waste materials. Following that, the system activates automated sorting processes that divert recyclable products into corresponding recycling streams. By streamlining the sorting process, the system effectively separates recyclable and non-recyclable materials, maximizing the recovery of resources and minimizing recycling stream contamination. By minimizing manual sorting dependency, this automated system not only improves the speed and accuracy of recycling but also enables a safer and cleaner working condition for waste management. As we aim for a more sustainable world, this state-of-the-art recycling system is at the leading edge of reducing environmental footprint and increasing the possibility of material reuse in an ever-changing world. This new technology seeks to maximize resource recovery, reduce environmental footprint, and lead towards a more sustainable waste management system.

Key Words: Design, Automation, Waste management, Sorting, Recycling, Optimization, scalability, sustainability.

1.INTRODUCTION

The suggested research brings forth a pioneering automatic waste recycling and sorting system that combines the latest sensing technologies with machine learning techniques to transform the process of waste management. Through advanced computer vision and sensor technology, the system effectively recognizes and sorts different types of waste materials, initiating automatic sorting processes to route recyclables into their respective recycling channels. This automated method not only accelerates the sorting process but also improves accuracy, lessens contamination, and encourages a cleaner, safer working environment through reduced human contact. Besides enhancing recycling rates, the system is an integral part of maintaining a circular economy by enabling the reuse of precious materials, ultimately helping towards sustainability. By using this smart system, the research seeks to maximize the recovery of resources, minimize environmental footprints, and promote a cleaner, more efficient waste management system.

2. PROBLEM STATEMENT

Given the increasing generation of waste at the global level and the urgency to adopt eco-friendly waste management strategies, the world needs an Automated Waste Sorting and Recycling System immediately. Manual sorting methods being practiced today are not efficient, error-prone, and cannot yield maximum recycling percentages. The task is to develop and deploy an automated system that can sort different waste materials, including plastics, metals, glass, and organic waste, into their respective groups with precision and efficiency. The system should minimize cross-contamination, process a wide range of waste compositions, and perform at a speed and capacity that suits the needs of contemporary waste management plants. The overall aim is to increase recycling efficiency, decrease landfill waste, and encourage the circular economy and meet safety standards and environmental factors.

3. LITERATURE REVIEW

The increase on amount of waste daily in Malaysia due to lack of waste management and enforcement by the government, has created unpleasant views of overflowed waste at the landfill. This paper presents the development of a low-cost recycle bin that automatically sorts different type of recycle waste using an Arduino microcontroller.[1]

A crucial prerequisite for recycling forming an integral part of municipal solid waste (MSW) management is sorting of useful materials from source-separated MSW. Researchers have been exploring automated sorting techniques to improve the overall efficiency of recycling process. This paper reviews recent advances in physical processes, sensors, and actuators used as well as control and autonomy related issues in the area of automated sorting and recycling of source-separated MSW. We believe that this paper will provide a comprehensive overview of the state of the art and will help future system designers in the area.[2]

Waste Management is the most challenging issue of modern society. Fast growth in population, increased factory presence and modern lifestyle have contributed towards the large amount of waste. An efficient waste

management system mainly revolves around waste segregation and processing. Segregation makes it effective to recycle and reuse the waste conventionally. This paper proposes a novel and efficient automated waste segregator and management system at household level. The prototype of the proposed system is developed using an Arduino microcontroller and Raspberry Pi, website to govern the entire process with comfort and simplicity.[3]

In textile industries, after large production of textiles like t-shirts, tracks etc., a vast amount of fabrics waste is produced along with it. These waste are called as pre-production waste in industrial terms. The fabrics waste is collected as bundle and moved further to recycling process or sometimes ends up as landfill. The bundle consist of various materials, colours and patterns of textile fabrics. It is then separated by people manually into individual bundles without any machines and then separated bundles are collected back by industries and recycled to raw material. This segregation process is a tedious and time consuming work and our motive is to automate the segregation process easier and rapidly. Our proposed solution for waste fabrics segregation consist of several levels of process. First, the waste bundle must be separated into smaller units and separation is done using mechanical setup. The part of selection and identification process of the particular colour or pattern is pre-programmed with an algorithm in the controller of the system.[4]

The overwhelming amount of household solid waste generated daily is alarming, and this contributes to the rise in pollution and drastic climate change. In such a context, automated waste classification at the initial stage of disposal can be an effective solution to separate recyclable items. Convolutional Neural Networks based on deep learning are often used for automated waste classification, but however, research works are limited to insufficient categories of waste such as the Trash Net dataset consisting of 2,527 images and 6 categories of waste. This dataset does not include other important categories such as battery, biological, and clothing items to reflect real life environmental problems. Therefore, in this paper, a larger dataset consisting of 15,515 images and 12 categories of common household solid waste was used to evaluate the performance of DenseNet121, DenseNet169, EfficientNetB0, InceptionV3, MobileNetV2, ResNet50, VGG16, VGG19, and Xception Convolutional Neural Network models. Data augmentation was applied to solve the problem of class imbalance, and findings of my first research showed that the Xception model compiled with Adam optimizer outperformed all other models with an accuracy of 88.77% and an F1-score of 0.89.[5]

Solid waste management becomes a big challenge in urban area. As a large amount of different waste material is generated, it needs different kinds of treatment. All this mixed waste cannot be processed at once in a proper manner. One of the important processes in waste management is separation of waste. So far, physical effort is required to separate waste, this may be very harmful for the person who is involved in the waste segregation process. In the proposed system, an efficient automated waste segregation model has been introduced at the origin itself. Thereby, the system will reduce human involvement in the waste segregation process. This will be implemented through the concepts of Convolutional Neural Network (CNN), a Machine Learning algorithm.[6]

4. WORKING

I. BLOCK DIAGRAM

when we plugged in the adaptor power is delivered to the entire system. The program which we are done in the c++ is being uploaded to the arduino. The programming is done like whenever the wet sensor detect the wet object it passes the information correspondingly .The servo 1 works so the opening the collecting trash is opened .waste fallen to the bin, After delay of 1 sec the servo motor returns back so trash closes Similarly If metallic waste enters ,if it detect the corresponding the servo 2 rotates an angle of 100 degree, servo 1 opens , waste fallen to the second bin, after 1 sec delay it will return back When plastic object or any other kind of waste is being detected, the servo motor 2 rotates an angle of 180 degree ,similarly the servo 1 opens and waste is fallen to the third bin after 1 sec delay servo 1 return back.

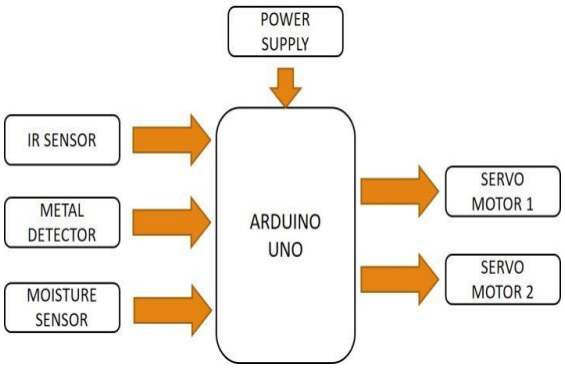

Fig 1: Block Diagram

As initially we put a wet cloth similar as to the blood coated sponge at the moment the wet sensor detects the wetness and the top open and the waste fallen to the wet bin and next we Put a needle as representing metal waste then the sensor detect that and the second servomotor rotates an angle of 100 degree and the waste fallen to the bin after a delay of 1 sec the bin closes and the servomotor 2 returns back and next we put a plastic syringe when the IR sensor detect that the servo motor 2 turns an angle of 180 degree and the third bin reach out there and the waste fallen and bin back to normal position.

II. CIRCUIT DIAGRAM

This is the prototype's circuit schematic. Here, the microcontroller of the Arduino Uno is utilized to link input sensors such the IR sensor, Rain Sensor, and Metal Detector Sensor. The metal detector's positive terminal is connected to pin A0 on the Arduino, and the other terminal is grounded. The microcontroller's digital pins D2 and D4 are connected to the two servo motors. GND is connected to GND, and the out-of-IR sensor is attached to the Arduino's D5 pin. The ADC converter is connected to the rain sensor, and the output of the ADC is connected to the Arduino's D3 pin. On the above figure, the circuit connections are illustrated.

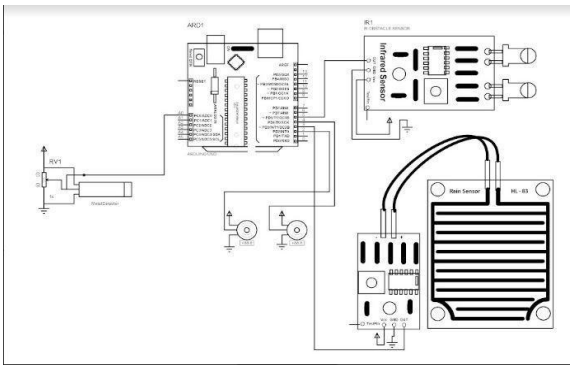

Fig 2: Circuit Diagram

III. SYSTEM ARCHITECTURE

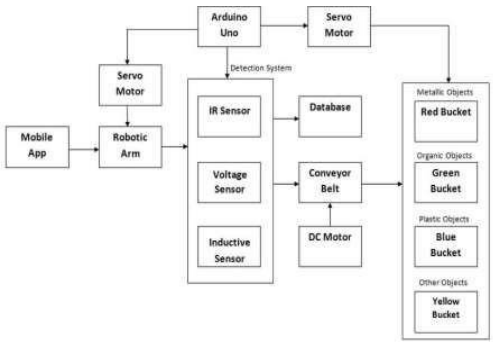

Fig 3: System Architecture

5. FABRICATION

The fabrication of the Automatic Waste Sorting and Recycling System involves assembling both the mechanical and electrical components to create a functional and efficient waste sorting system. First, a stable base is prepared to mount the Arduino Uno microcontroller, sensors, and servo motors. The servo motors are positioned to control the opening and closing of the waste bins, with each bin being assigned to a specific waste type (wet, metal, and plastic). The wet sensor, IR sensor, and metal detector are strategically placed to detect corresponding types of waste. The wet sensor detects moisture for wet waste, the IR sensor identifies plastic, and the metal detector senses metallic objects. These sensors are connected to the Arduino's digital and analog pins, allowing them to send signals to trigger the servo motors. The system is powered using an external adapter to supply the necessary voltage for the servo motors, while the Arduino is powered separately. After connecting all the sensors and motors, the system is programmed using C++ to control the sorting process. The code enables the system to identify the waste type, activate the appropriate servo motor, and direct the waste into the correct bin. Finally, the system is thoroughly tested, and adjustments are made to ensure the servo motors operate smoothly and the waste is sorted correctly. The components are securely fixed to the base, and the waste bins are aligned with the servo motors for proper functioning, completing the fabrication process of this automated recycling system.

6. HARDWARE COMPONENTS USED

6.1 UNO Aurdino :

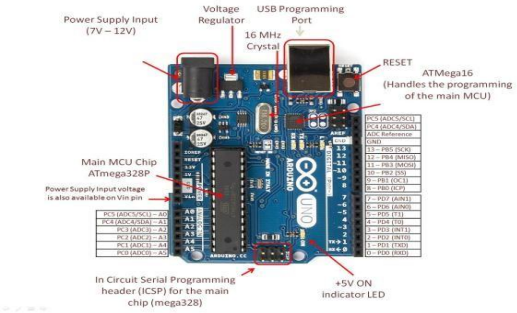

Fig 4: UNO Aurdino

In this project, the Arduino Uno serves as the central microcontroller, coordinating the entire waste sorting system. It receives signals from the various sensors (IR, wet, proximity) to identify the type of waste. Based on the sensor input, the Arduino controls the servo motors to open the appropriate bins. The Arduino Uno ensures seamless communication between all components, making the system fully automated and efficient.

6.2 IR SENSOR :

In this project, the **IR sensor** is used to detect plastic waste. It emits infrared light, and when a plastic object passes through the sensor's detection range, it reflects the infrared light back to the sensor. The sensor then signals the Arduino

microcontroller, which activates the corresponding servo motor to move the plastic waste to the appropriate bin.

6.5 WET SENSOR:

In this project, the **wet sensor** detects moisture in the waste to identify wet or organic materials. When the sensor detects the presence of moisture, it sends a signal to the Arduino microcontroller. This triggers the activation of the servo motor to open the waste bin for wet waste. The wet sensor ensures proper segregation of wet materials, enhancing recycling efficiency and reducing contamination.

Fig 8: Wet Sensor

6.6 ADC CONVERTER:

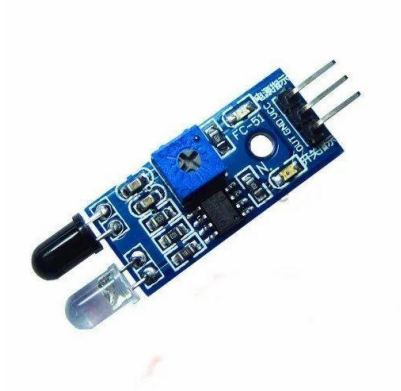

Fig 5: IR Sensor

6.3 METAL DETECTOR:

In this project, a proximity sensor (metal detector) is used to detect the presence of objects near the waste collection area. When an object approaches, the sensor detects the distance and sends a signal to the Arduino microcontroller. This triggers the activation of the corresponding servo motor to open the waste bin. The proximity sensor enhances the system's ability to automate waste sorting by sensing objects before they are processed

Fig 6: Inductive Proximity Sensor

6.4 Proximity Inductive Sensor:

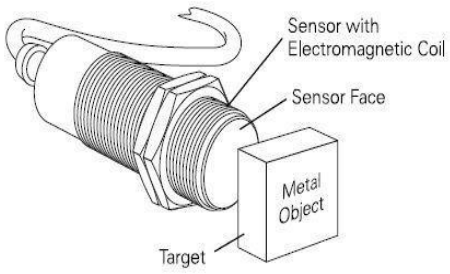

Fig 7: Block Diagram Of Proximity Inductive Sensor

In this project, the **ADC (Analog-to-Digital Converter)** is used to convert the analog signals from the metal detector and wet sensor into digital signals that the Arduino can process. The ADC allows the Arduino to accurately interpret sensor data, enabling it to identify and categorize waste types. It plays a crucial role in ensuring precise detection of materials based on their properties. By converting analog inputs to digital, the ADC ensures smooth communication between the sensors and the microcontroller.

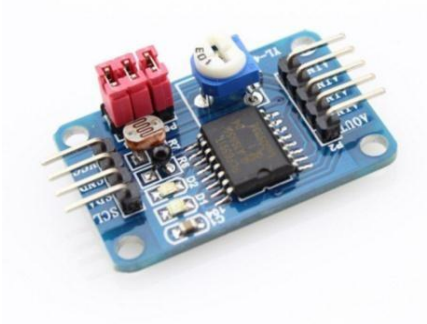

Fig 9: ADC converter

6.7 SERVO MOTOR:

In this project, **servo motors** are used to control the opening and closing of the waste bins. Each servo motor is triggered by the Arduino based on sensor inputs to direct the waste into the correct bin. The motors rotate to specific angles, allowing precise sorting of wet, metal, or plastic waste. Servo motors enable smooth and accurate operation, ensuring efficient waste segregation.

Fig 10: Servo Motor

7. 3D MODEL

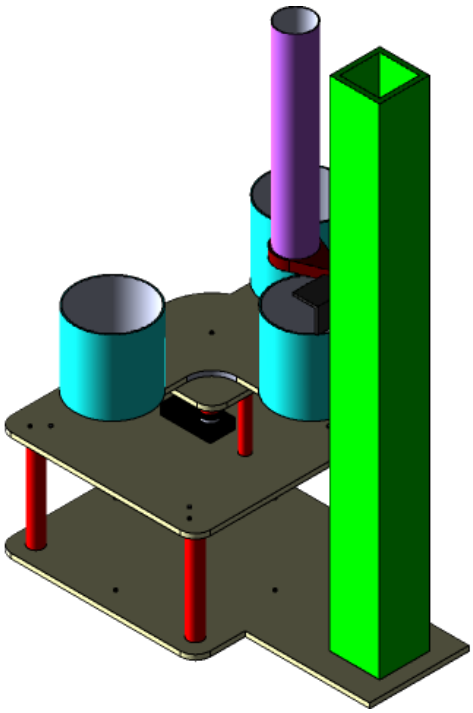

Fig 11: 3D Model

Fig 12: Realistic model

Fig 13: Top view

8. CONCLUSION

In conclusion, the Automatic Waste Sorting and Recycling System developed in this project represents a significant step toward improving waste management efficiency and sustainability. By integrating advanced sensors, servo motors, and an Arduino-based control system, the project successfully automates the sorting process, efficiently categorizing waste into wet, metallic, and plastic materials. This system reduces reliance on manual sorting, improving speed, accuracy, and safety while promoting a cleaner and more hygienic environment. Through its ability to optimize resource recovery and reduce contamination, the system aligns with sustainable practices, supporting a circular economy. Future enhancements, such as the integration

of AI, improved sensor technology, and scalability for larger environments, could further increase the system's impact, contributing to more efficient waste management on a larger scale. Ultimately, this project demonstrates the potential of automation in waste management, offering a practical solution for addressing the growing challenges of waste sorting and recycling, while fostering environmental sustainability.

9. REFERENCES

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