Smart Recycle Bin

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***Abstract*— The rapid growth of global population and urbanization has caused a significant increase in waste production. Traditionally, recycling rely heavily on manual inspection, are time -consuming and inefficient. This project uses soundwave analysis and machine learning to classify waste such as plastic, paper, and aluminium. Seed Studio XIAO nRF52840 Sense microphone capture accoustic signal, which are analyzed using an AI model developed in edge impulse. Through extensive training, the system has achieved a classification accuray if 98.4% which shows that the project is reliable and can sort the waste automatically based on their accoustic properties. Convolutional Neural Network (CNN) was use in the models to capture the soundwave by converting audio streams into spectogram, which will provide visual representation of spectrum frequency, that optimized for embeded devices, ensuring low latency and high efficiency. By automating the waste sorting, this project promotes sustainability in waste management practices, reduce environmental impact and demonstrates the potential of AI-driven solution in addressing a global waste management challenge.**

Keywords—waste classification, soundwave analysis, machine learning, Convolutional Neural Network (CNN), sustainability.

I. INTRODUCTION

Waste management was one of the main issues in Malaysia. The amount of garbage thrown away has risen steadily in Malaysia in tandem with the nation's population growth, and most of the waste has gone into landfills. According to the National Solid Waste Department, Malaysia currently has 165 landfills, eight sanitary landfills, and three inert landfills for materials such as sand and concrete. Local environmental experts have forecasted no space will be available by 2050 if nothing is done to reduce waste [1]. Figure 1 shows the national recycle rate from 2013 to 2021.

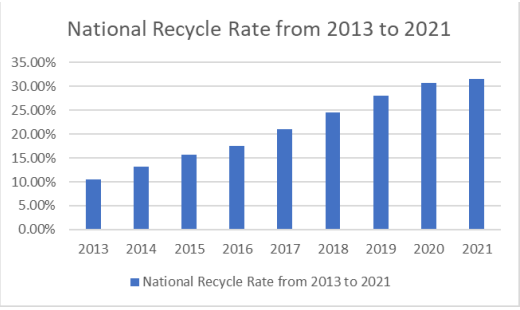

Fig. 1. National Recycle Rate 2013 to 2021

According to SWcorp, in 2021, Malaysia has recorded national recycle rate of 31.52%, this rate was more than the previous year which recorded recycle rate of 30.67%. However, this rate was less than the target ,32% that has been set by the Ministry of Housing and Local Government. By using microphone technology for soundwave analysis, this project aims to revolutionize waste sorting processes. The main goal is to create an automated system that can precisely recognize and classify various waste items, including aluminum, paper, and plastic, using their acoustic characteristics. The suggested system uses machine learning and improves recycling efficiency, saves operating costs, and supports environmental sustainability. In summary, this project sets the groundwork for a more efficient and eco-friendly way to recycle by fixing the technological and practical problems that come up with current waste management methods.

Existing waste sorting methods often demonstrate inefficiencies and inaccuracies, leading to significant environmental and economic repercussions. [1] Artificial intelligence presents a promising solution to address these challenges, enabling the development of intelligent waste management systems capable of accurately classifying and sorting waste. This research paper investigates the design and implementation of a smart recycle bin project that leverages AI-powered audio classification and edge computing to enhance the efficiency and precision of waste sorting. Furthermore, the current waste management systems face a lack of real-time data processing, hindering the optimization of waste collection and disposal. This, in turn, exacerbates the inefficiencies and undermines the overall effectiveness of waste management [2]. This, in turn, worsens the inefficiencies and hampers the overall effectiveness of waste management. It is crucial to have cutting-edge solutions that utilize AI technology to process real-time data. These solutions can effectively tackle the challenges at hand, leading to more precise and efficient waste classification. Ultimately, this will greatly contribute to improving recycling efforts and minimizing landfill waste.

Based on the highlighted issues, there is a need for smart recycle bin to be developed. In [3], smart recycling bin using waste image classification at the edge was deveoped. The purpose of this research was to develop a smart recycling bin that uses AI-powered image classification to differentiate between various waste types, such as plastic, paper, metal, glass, and cardboard. The system was designed to increase recycling rates in urban areas by integrating built-in AI capabilities. The researchers aimed to create a cost-effective and energy-efficient solution that could be deployed in homes and on streets. The MobileNet image classification model was trained on a dataset of waste images, similar to how a student prepares for an exam. The system was tested on two embedded platforms, Jetson Nano and Kendryte K210, to address different power and cost requirements for various applications. The purpose of this research was to develop a smart recycling bin that uses AI-powered image classification to differentiate between various waste types, such as plastic, paper, metal, glass, and cardboard. The system was designed to increase recycling rates in urban areas by integrating built-

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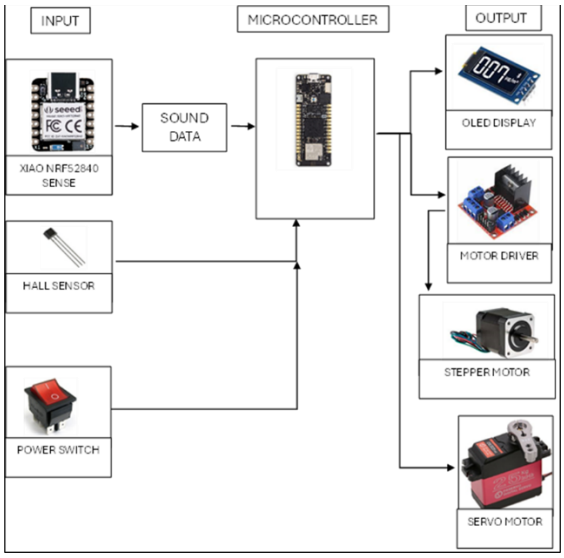
One key disadvantage of the project in [3] is that, the usage of image classification required a camera to be installed in the bin, which made the system more complex and costly. In contrast, the audio classification approach utilizes a microphone that can be placed anywhere, providing more flexibility. The image classification method, however, has specific requirements in terms of the angle and lighting conditions to work properly, limiting its versatility and ease of deployment compared to the audio-based approach. While the image classification offers high accuracy, the added complexity and cost associated with the camera setup may be a drawback in certain applications or settings where simpler and more cost-effective solutions are preferred.

The discussion above suggests that there are opportunities to enhance intelligent waste management systems, particularly in improving classification accuracy and real-time monitoring capabilities. This research presents a proof-of-concept prototype for a smart recycle bin that leverages an AI audio classifier and Edge Impulse to address these limitations. The project aims to develop a novel approach to waste sorting by harnessing the capabilities of audio classification, providing a more robust and efficient solution compared to traditional image-based methods.

II. METHODOLOGY

This block diagram on Figure 3.1 highlights the integration of various input, processing, and output components for optimized waste classification and management. The XIAO NRF52840 SENSE component is designed to detect the sound made by the waste as it is deposited into the bin, leveraging audio analysis to help classify the type of waste. The Hall Sensor is utilized to detect separate compartments within the bin, ensuring that each type of waste is sorted into its designated section. Additionally, the Power Switch manages the overall power supply to the microcontroller and other components, providing a straightforward means to turn the system on and off.

The Arduino Portenta C33 microcontroller, which is at the heart of the system, interprets sensor input data and uses control algorithms to make decisions in real time. It has good communication capabilities with both output actuators and input sensors. One of the outputs is an OLED display that shows the user the state of the system and the kind of waste that has been detected. By transforming control signals into the proper current and voltage levels required to drive the motors, the Motor Driver acts as an interface between the microcontroller and the motors. The Stepper Motor rotates the bin to different compartments based on the categorization given by the sound analysis, while the Servo Motor opens and closes the bin lid.



The block diagram of smart recycle bin

The flowchart on Figure 3.2 uses a variety of forms to represent the sequential sequence of the process in different ways. Based on the flowchart that has been created, after starting, the system will be initialized, then the LED will be on, and then the system will capture any soundwaves, if yes, the system will go through the sound data to classify the waste. Then the system count will add 1 until the count reaches 10. If the count is greater than 10, the stepper motor will turn to the reserve compartment, and if it is less than 10, the motor will turn to the classify compartment. Then the servo motor will be open to drop the waste, and the OLED display will display the waste that has been detected.

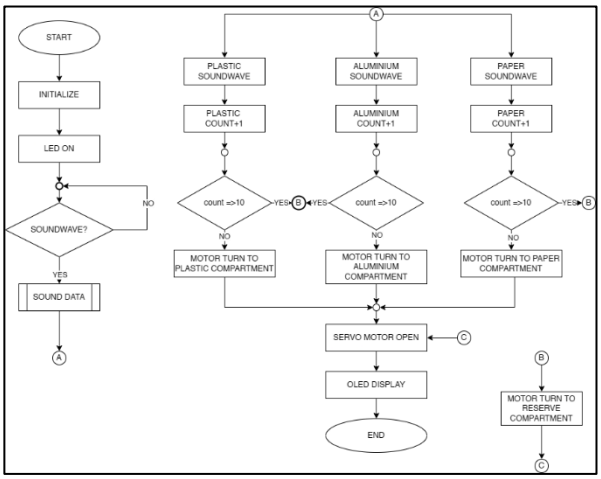


Fig. 2. The flowchart of smart recycle bin

The circuit diagram on Figure 3 shows how each component was connected. The Arduino portenta act as a main microcontroller while the XIAO nRF52840 sense was used as a slave to detect and classify the waste and send the result to Arduino Portenta by using I2C communication protocol. Apart from that, the stepper motor was connected to the stepper motor driver which has a power supply of 12V for the stepper motor and 5V for the driver while the step and direction pin connect to pin 4 and 5 of Arduino portenta. The buck converter is responsible for supplying a 5V voltage to OLED, servo motor, hall sensor and Arduino portenta. Besides, the servo motor connected to pin 3 of Arduino portenta and hall sensor was connected to pin 2.

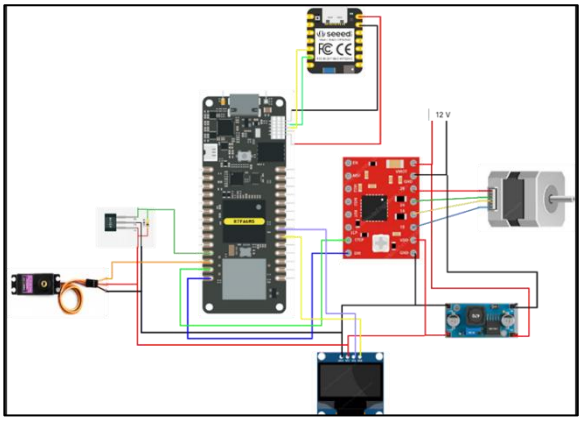


Fig. 3. Circuit diagram of the smart recycle bin

III. Results & Discussion

The servo motor was programmed to open the lid when waste is detected and close it after a delay. The Figure 4 show the code for servo motor which void operate function. In this code, the servo motor will go to the left with full speed (180) for 1.5 seconds (1500) and go to the right (0) full speed for 1.5 seconds (1500). Finally the servo will go to a full stop (90) for 3 seconds (3000).

```
void operateServo() {
    myservo.write(180);
    delay(1500);
    myservo.write(0);
    delay(1500);
    myservo.write(90);
    delay(3000);
}
```

Fig. 4. Code snipper for servo motor

The stepper motor aligns the bin with the appropriate container based on the classification result. The code snippet in Figure 5 shows that the setup code for the stepper motor which the number 925, 2775, 0, 4625, 6475 represents the how many steps need to be taken from a reference point that been called home which will be determined by the neodymium magnet.

```
// Compartment positions
const int NUM_COMPARTMENTS = 5;
int compartment[NUM_COMPARTMENTS] = {925, 2775, 0, 4625, 6475};
volatile byte receivedData = 0;
bool isHomed = false;  // Flag to track if home position is set
```

Fig. 5. Code snipper for stepper motor

Fig. 6. Proof of concept of smart recycle bin

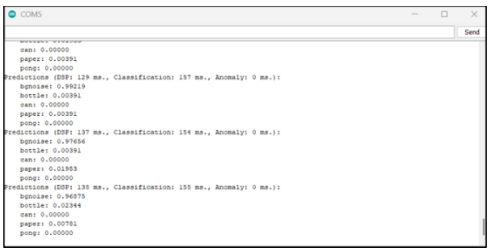


Fig. 7. The Xiao nrf serial monitor

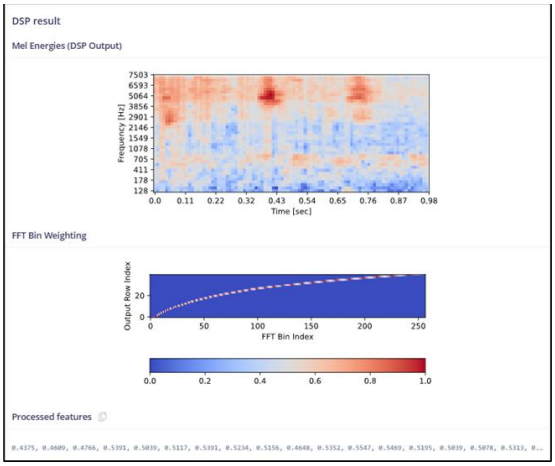


Fig. 8. Digital Signal Processing result

Fig. 9. Accuray and confusion matrix

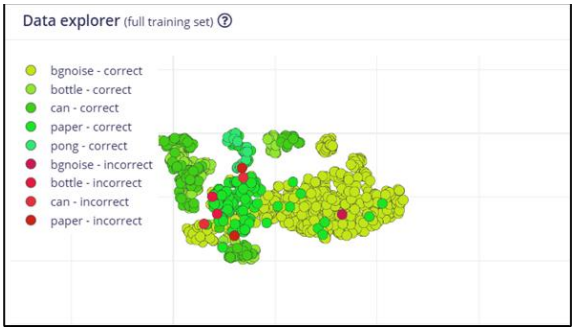


Fig. 10. Data explorer graph

Fig. 11. The output displayed on Node-red.

IV. Conclusion & Recommendations

This project successfully developed and implemented a proof-of-concept prototype for a smart recycle bin utilizing an AI audio classifier and Edge Impulse. By classifying recyclable materials based on their unique sound signatures, the prototype demonstrated a novel approach to waste sorting, offering a potential alternative to traditional image-based methods. This audio-based classification method proved effective in distinguishing between different types of recyclables, even in noisy environments, contributing to improved accuracy in waste sorting. Integrating the AI model with Edge Impulse enabled efficient deployment on a low-power microcontroller, facilitating real-time processing and minimizing power consumption. This smart recycle bin has the potential to significantly impact targeted users by simplifying the recycling process, reducing contamination rates, and promoting greater participation in recycling programs. Furthermore, the system's real-time monitoring capabilities provide valuable data on waste composition and bin levels, enabling more efficient waste collection and management.

For future improvements, integrating additional sensors, such as fill-level sensors, could enhance the system's functionality and provide more comprehensive waste management data. Exploring alternative machine learning models and data augmentation techniques could further improve the accuracy and robustness of the audio classifier. Finally, developing a user-friendly interface for interacting with the smart recycle bin and accessing real-time data would enhance user experience and promote wider adoption of the technology.

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