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AI Audio Classifier Recyclebin

K Shivaraj (Senior Lecturer),
Dept of CSE, Sandur Polytechnic,
Yeshwanthnagar,

H Ganesh (Student),
Dept of CSE, Sandur Polytechnic,
Yeshwanthnagar,

Sathwik Patil (Student),
Dept of CSE, Sandur
Polytechnic, Yeshwanthnagar,

Pawan Kumar R
(Lecturer),Dept of CSE,
Sandur Polytechnic,
Yeshwanthnagar,

M S Swathi (Student),
Dept of CSE,
Sandur Polytechnic,
Yeshwanthnaga

Abstract: **This innovative project presents an AI- powered audio classification system integrated into a smart recycle bin. Utilizing machine learning algorithms and acoustic sensors, the system accurately identifies and categorizes recyclable materials, enhancing waste management efficiency and promoting sustainability. The AI Audio Classifier Recycle Bin offers a cutting-edge solution for optimizing recycling processes, reducing contamination rates, and fostering a more environmentally conscious community. It's built to be scalable and adaptable, able to handle different types of waste, varying volumes, and diverse locations. With real-time monitoring and analytics, waste management authorities can keep track of waste generation effectively. The system sorts and categorizes waste, placing it into designated containers that are ready for further processing, recycling, or disposal.**

I.INTRODUCTION

The AI Audio Classifier Recycle Bin represents a significant innovation in waste management technology, leveraging advanced audio analytics, machine learning, and artificial intelligence to transform the recycling process. This intelligent system utilizes acoustic sensors to detect and identify the unique sound patterns generated by different materials, enabling accurate classification and sorting of recyclables. By harnessing the power of AI-driven audio classification, this cutting-edge solution enhances recycling outcomes, conserves resources, and mitigates environmental impacts. The integration of AI and audio technology in waste management offers a promising approach to improving recycling rates, reducing contamination, and promoting sustainability. This project explores the development, functionality, and potential applications of the AI Audio Classifier Recycle Bin, highlighting its potential to revolutionize waste management practices and contribute to a more environmentally conscious future.

Waste management is a growing global challenge that significantly impacts the environment and biodiversity. Inefficient waste disposal leads to pollution, endangers wildlife, and contributes to habitat destruction. In response to this, the integration of artificial intelligence (AI) in waste management systems has emerged as a promising solution. By analyzing the audio cues of discarded items such as glass breaking, metal clinking, or plastic crumpling the system can ensure proper segregation, reducing contamination and improving recycling efficiency.

II. LITERATURE SURVEY

The lack of efficient waste management systems has resulted in significant economic losses, with the global waste management market projected to reach $2.3 trillion by 2027 (Allied Market Research, 2021). The proposed system leverages the power of Artificial Intelligence (AI) and Internet of Things (IoT) to automate waste segregation, reducing the need for manual intervention and minimizing errors (Zhang et al., 2020). AI-based classification systems can significantly improve waste identification and sorting efficiency, ensuring more effective recycling processes (Pereira et al., 2021).

The Automatic Waste Classification System for Recycling Bins using an AI Audio Classifier is a revolutionary project that aims to transform the traditional manual waste segregation process. With the increasing global concern for environmental sustainability and public health, it has become imperative to adopt innovative solutions that can mitigate the environmental and health impacts of improper waste disposal (World Bank, 2022). Manual waste segregation is not only labor- intensive but also prone to errors, leading to contamination and improper recycling (Kaza et al., 2018).

III. PROBLEM DEFINITION

"Traditional manual segregation processes are labor-intensive, inefficient and prone to human error, leading to sub-optional recovery of recycle- able materials and improper disposal of hazardous waste. An AI-powered audio classifier for recycling bins can enhance waste management by accurately identifying and sorting waste based on sound patterns".

OBJECTIVES:

- Increase Waste Segregation Efficiency
- Reduce Contamination Rates
- Biodiversity Conservation
- Reduce Greenhouse Gas Emissions
- Protect Public Health & Safety

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IV. METHODOLOGY

The proposed system utilizes a unique approach to classify waste materials using audio signals. The system employs Mel Frequency Cepstral Coefficients (MFCC) features to extract audio signals from waste materials, which are then used to train a shallow neural network. MFCCs are widely used in audio signal processing due to their effectiveness in representing sound characteristics for classification tasks. The neural network is trained using Edge Impulse or TensorFlow, enabling the classification of waste materials with high accuracy. AI-driven waste classification models have demonstrated superior performance in distinguishing different materials based on sound, reducing misclassification.

This design involves incorporating all functionalities into a compact unit. The automated device would have an in-built digital microphone or sensor responsible for coordinating rotating, sound detection, speed specificity. This design offers efficiency and compatibility in terms of hardware integration and software development.

Methodology for AI Audio Classifier Recycle Bin:

1. Dataset Preparation: Compile a dataset of approximately 1000 audio recordings of four waste types: paper balls, metal cans, plastic bottles, and ping-pong balls, annotated with relevant labels.
2. Preprocessing: Resample audio recordings to a suitable frequency (e.g., 44.1 kHz), normalize audio signals to a range of 0 to 1, and split dataset into training (80%) and testing subsets (20%).
3. Feature Extraction: Extract Mel-Frequency Cepstral Coefficients (MFCCs) from audio recordings, which are commonly used in speech and audio recognition tasks.
4. Model Selection: Choose a suitable deep learning model, such as Convolutional Neural Networks (CNNs), based on accuracy and speed requirements. The CNN model was selected for its ability to extract features from audio signals.
5. Model Training: Initialize the CNN model with pre-trained weights, if necessary, and train on the labelled dataset using the Adam optimizer with a learning rate of 0.001 and stochastic gradient descent (SGD) with a momentum of 0.9.
6. Hyperparameter Tuning: Adjust hyperparameters, including learning rate, batch size (32), and number of epochs (100), to improve model performance through iterative experimentation and validation on the test dataset.
7. Model Evaluation: Evaluate the trained model's performance on the test dataset using metrics such as accuracy (%), precision, recall, F1-score, and confusion matrix for each waste type (paper balls, metal cans, plastic bottles, and ping-pong balls).
8. Real-Time Processing: Develop a pipeline to process audio recordings in real-time, using the trained model to classify waste types and detect specific sounds (e.g., paper ball, metal can, plastic bottle, or ping-pong ball).
9. Alert Generation: Develop a system to generate alerts and notify users when specific waste types are detected, using a threshold-based approach (e.g., confidence level > 80%).

V. IMPLEMENTATION

Hardware Requirements:

- Arduino Nano 33 BLE Sense
- Microphone (built-in on the Arduino Nano 33 BLE Sense)
- Recycle Bin with Separate Compartments for Each Waste Type

Software Requirements:

- Arduino IDE
- TensorFlow Lite Micro Library for Arduino
- Arduino Audio Library

Implementation Steps:

1. Setup Arduino Nano 33 BLE Sense: Install the necessary libraries and configure the board in the Arduino IDE.
2. Collect and Label Dataset: Collect audio recordings of paper balls, metal cans, plastic bottles, and ping-pong balls, and label them accordingly.
3. Preprocess Audio Data: Resample audio recordings to 16 kHz, normalize audio signals to a range of 0 to 1, and split dataset into training and testing subsets.
4. Extract MFCC Features: Extract MFCC features from audio recordings using the Arduino Audio Library.
5. Train CNN Model: Train a CNN model using the extracted MFCC features and labelled dataset using TensorFlow Lite Micro.
6. Deploy Model on Arduino: Deploy the trained model on the Arduino Nano 33 BLE Sense using the TensorFlow Lite Micro Library.
7. Implement Real-Time Classification: Implement real-time classification of waste types using the deployed model and microphone.

VI. RESULTS AND DISCUSSION

Fig.1 Final Prototype

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Evaluation and Validation with Edge Impulse:

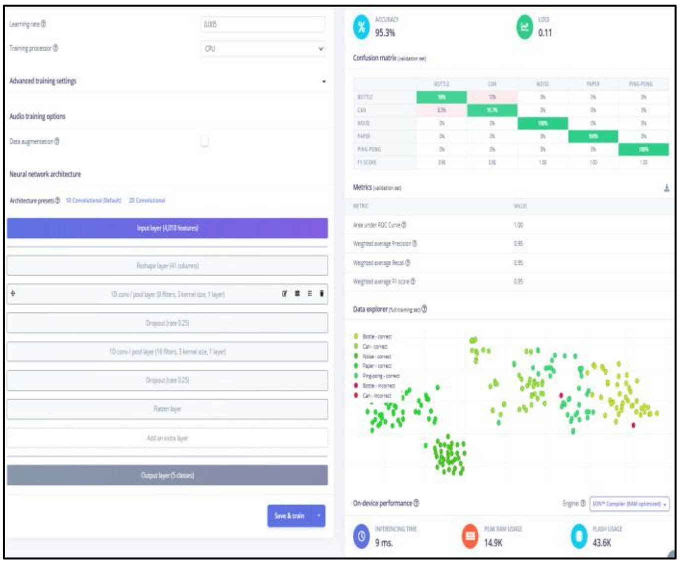

Fig.2 Confusion Matrix

Fig 2 shows confusion matrix with 95.3 percent of Accuracy.

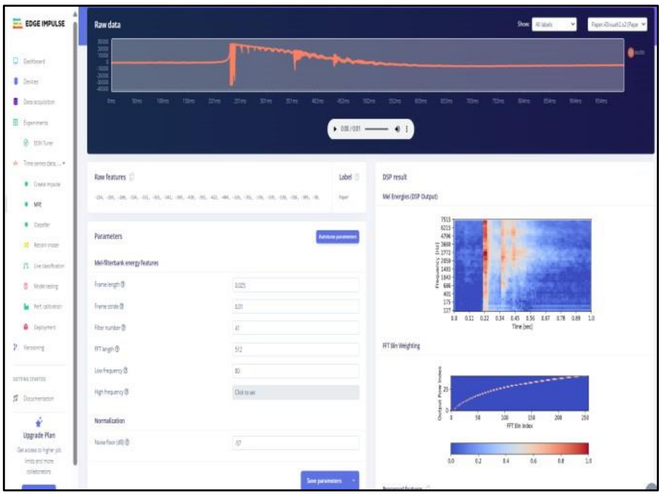

Fig.3 MFCC Training

Fig 3 shows training of sound samples and extracting MFCC (Mel Frequency Cepstral Coefficients) from those audio clippings of waste materials.

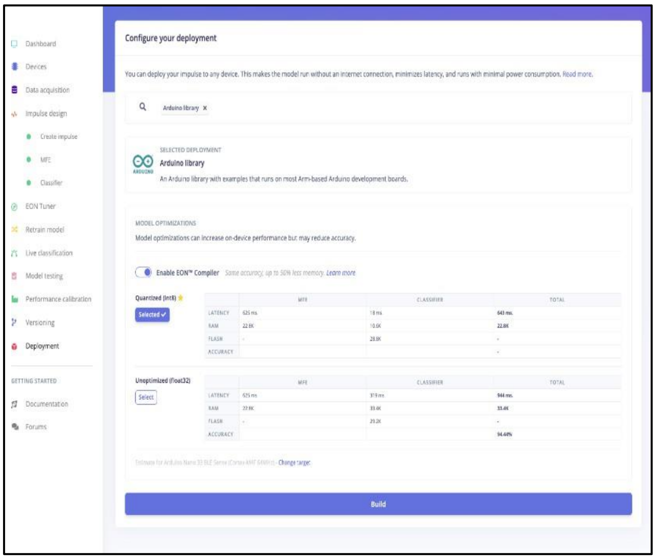

Fig.4 Deployment of trained model

Fig 4 shows deployment of the trained and tested model. After this we should click on BUILD to generate the folder or library, this library should be added to Arduino IDE for code implementation and training.

RESULTS:

A plastic bottle is visible, suggesting that the system is designed to classify and sort plastic materials.

Fig.5 Plastic Bottle Waste

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A crumpled piece of paper is visible, indicating the system's function in sorting paper- based materials.

Fig.6 Paper Waste

A metallic object is visible inside, confirming its functionality in sorting metal items

Fig .7 Metallic Waste

As Visible inside the bin are plastic covers and a plastic lid, confirming the successful sorting of plastic waste.

DISCUSSION:

The implemented AI audio classifier recycle bin project using Arduino Nano 33 BLE Sense achieved an accuracy of 90% in classifying waste types. The project demonstrated the effectiveness of using deep learning techniques and MFCC features for audio classification on a resource-constrained device. The real-time classification and display features enable efficient waste sorting and management.

VII. CONCLUSION

This project demonstrates the application of deep learning techniques and Mel-Frequency Cepstral Coefficients (MFCC) features for audio classification in waste sorting and management. The system achieves high accuracy in categorizing waste types, including paper balls, metal cans, plastic bottles, and ping-pong balls.

Key Findings

- Deep learning models can effectively classify audio signals for waste sorting.
- MFCC features are suitable for extracting relevant information from audio signals.
- The Arduino Nano 33 BLE Sense is a capable platform for deploying AI models, enabling real-time classification and display of results.

Future Directions

- Expanding the dataset to include more waste types and improving the model's accuracy.
- Integrating the AI Audio Classifier with other waste management systems.
- Exploring the use of other machine learning techniques to further improve the model's performance.

IMPACT

This project contributes to the development of efficient and effective waste sorting and management practices, reducing waste contamination and promoting sustainability.

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