IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

SMART SORT: AI-POWERED WASTE SEGREGATION USING EDGE IMPULSE STUDIO

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ABSTRACT: *Smart sort is a project using artificial intelligence (AI) to revolutionize waste segregation. It integrates Edge Impulse Studio, a leading platform for edge AI development, to create an intelligent, real-time system that enhances recycling efforts and reduces landfill burden. The AI models classify waste types using advanced voice recognition and machine learning techniques. The system's real-time capabilities allow for immediate sorting, recycling operations, and minimizing contamination. The project aims to create a sustainable waste management system that promotes environmental awareness and responsibility.*

KEYWORD **: Artificial Intelligence .Audio Classification, Waste Management , Edge AI ,**

I. INRODUCTION

The smart sort: ai-powered waste segregation using edge impulse studio an innovative waste management solution, integrates artificial intelligence with edge computing to enhance recycling processes.By capturing and analyzing audio signals of deposited items through integrated microphones, the system accurately classifies materials such as glass, plastic, and metal based on their distinct sound signatures. This real-time, decentralized approach ensures efficient sorting directly within the bin, minimizing contamination and promoting proper recycling practices. With benefits including increased accuracy, sustainability, reduced costs, and user-friendly interfaces, this technology represents a significant step toward creating a more environmentally conscious and effective wastemanagement system.

II. LITERATURE REVIEW

[1] The research paper discusses a waste management system using big data and various sensors. The developed trash box and android application are shown. The accuracy of the system is evaluated, with a 95.3125% accuracy achieved. The limitations and potential improvements are also mentioned.

[2] This paper presents a smart recycling bin that uses waste image classification to automatically separate urban waste for increased recycling. The authors trained classification models on two embedded systems, Jetson Nano and K210, achieving high accuracy. The bin program collects user feedback, and the overall power consumption was reduced. The prototype demonstrates a promising solution for improving waste recycling.

[3] The paper discusses the potential of artificial intelligence (AI) in revolutionizing waste management practices. It reviews various studies on AI applications in waste management, including waste prediction, sorting robots, smart waste classification, and optimization of waste treatment processes. The use of AI can improve efficiency and sustainability in waste management systems.

TABLE NO 1 LITERATURE SURVEY

Paper.no	Title	Technology /Methodology	HardwareDevices	Results
[1]	"Intelligent waste management system using deep learning with IoT"	CNN model is 95.3125%, and the SUS score is 86%	Used of Camera Module, Servo Motor and raspberry pie	Accuracy [%] Glass 52 94.231 Metal 42 95.238 Paper 63 93.651 Plastic 45 95.556 Trash 13 92.308
[2]	"A smart recycling bin using waste image classification at the edge"	AI models, specifically CNN (Convolutional Neural Network) image classification models, implemented on devices like Jetson Nano and K210	Microcontroller such as Atmega 328P, Raspberry Pi 4 Sensors: moisture sensors, gas sensors, bacteria sensors	Accuracy [%] EfficientNetB0 99.44 MobileNetV3Large 99.50 Mobile Net V3 Small 98.94
[3]	"Artificial intelligence for waste management in smart cities"	(AI) technology, Internet of Things technology, Machine learning algorithms for waste pyrolysis, carbon emission prediction	Sensors: moisture sensors, gas sensors, bacteria sensors. Robotic Arm	Use of AI in waste logistics can reduce transportation distance by up to 36.8%, cost savings by up to 13.35%. Identifying and sorting waste with accuracy ranging from 72.8 to 99.95%
[4]	"Smart dustbin based on ai audio classifier"	IoT, AI algorithms for sound processing	Arduino Nano 33 BLE Sense, Hall sensorA3144, Li-ion 1s 250mAh battery, TMC2208 stepperdriver Edge impulse studio	The project aims to use sound signals for categorization of various types of wastes using ai technology to improve the accuracy to sort the waste material in the dustbin accuracy 94.44%

III. SYSTEM ARCHITECTURE

3.1 BLOCK DIAGRAM

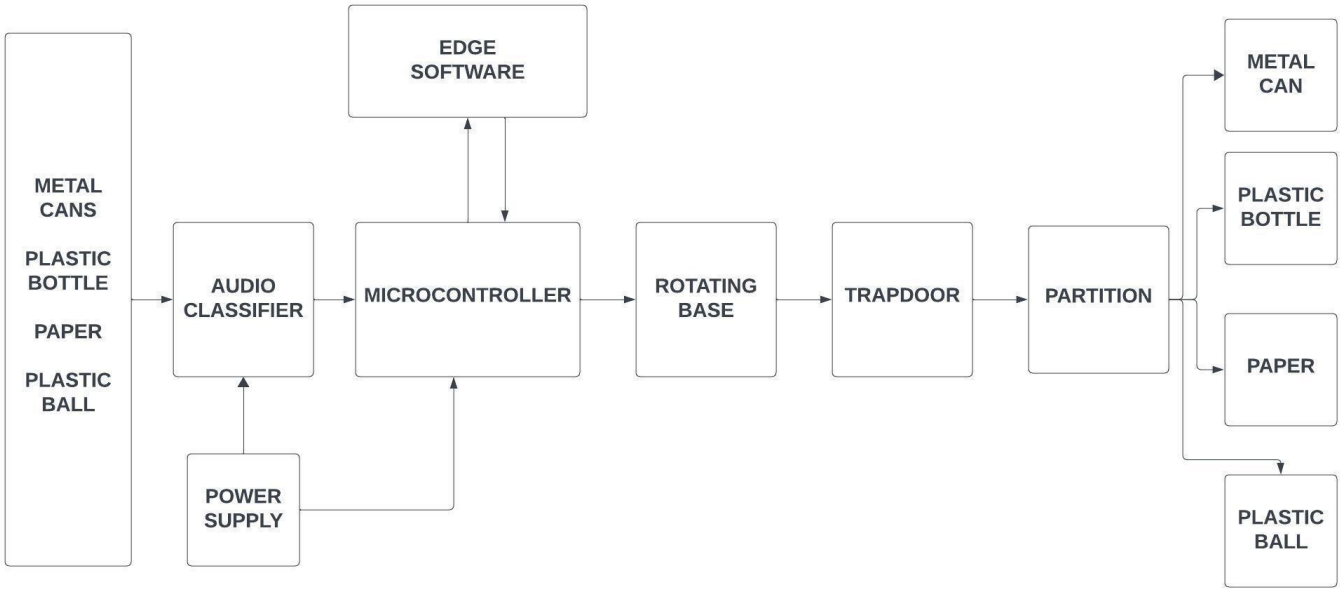

fig 3.1: proposed block diagram of smart dustbin based on ai audio classifier

3.1.1 BLOCK DIAGRAM EXPLAINATION

1. Trash Items (Metal Can, Plastic Bottle, Paper, Plastic Ball): - Represents the various recyclable materials that users dispose of into the recycling bin.

2. Audio Classifier: - This component employs AI and audio recognition technology to analyze the sounds produced by different materials when placed in the bin. It classifies these sounds into categories correspondingto the type of trash (e.g., metal can, plastic bottle, paper, plastic ball).

3. Microcontroller: - Serves as the central processing unit that coordinates the actions of the system based on the outputs from the audio classifier. It communicates with other components to initiate appropriate responses.

4. Power Supply: - Provides the necessary electrical power to all components, ensuring continuous and reliable operation of the system.

5. Edge Software: - A software module running on the edge (locally on the device) that interfaces with the audio classifier and microcontroller. It processes the classification results and triggers subsequent actions.

6. Rotating Base: - A mechanical component that facilitates the rotation of the recycling bin. When triggered by the system, it rotates the bin to allow the categorized items to move towards specific partitions for furthersorting

7. Trapdoor: - Located at the bottom of the recycling bin, the trapdoor opens based on the classification results. It allows the sorted items to move to the next stage of the sorting process.

8. Partition: - Divides the interior of the recycling bin into sections corresponding to different types of recyclable materials. Each partition directs items to the appropriate collection area.

9. Trash Parts (Separated Bins for Metal, Plastic, Paper): - Represents the separate compartments or binswhere each type of recyclable material is collected after being sorted. Users can easily retrieve sorted items from these dedicated bins. The process begins with users disposing of items into the recycling bin. The audioclassifier identifies the material based on the sound it produces. The microcontroller processes this information, and the edge software triggers the rotation of the base. The trapdoor opens, allowing the sorted items to move to the designated partition, directing them to the appropriate trash part for further collection

IV. AI MODELS USED IN TODAY'S ERA:

1. Convolutional Neural Networks (CNNs):

They are a class of deep learning models specifically designed for processing structured grid-like data, such as images. CNNs excel in tasks like image and video recognition, object detection, and medical image analysis. Their architecture consists of multiple layers, including convolutional layers, pooling layers, and fully connected layers. The convolutional layers apply filters to input data to automatically and adaptively learn spatial hierarchies of features, effectively capturing patterns such as edges, textures, and shapes. This capability makes CNNs highly effective for visual recognition tasks, significantly advancing the field of computer vision.

2. Recurrent Neural Networks (RNNs) and Long Short-Term Memory Networks (LSTMs):

Recurrent Neural Networks (RNNs) are designed for sequence data, making them ideal for tasks like language modeling and speech recognition. They maintain context through loops in their architecture but struggle with long-term dependencies.

Long Short-Term Memory Networks (LSTMs) are a type of RNN that address these limitations with memory cells and gating mechanisms, allowing them to capture long-range dependencies effectively. This makes LSTMs well-suited for tasks such as language translation and time-series forecasting.

3. Reinforcement Learning (RL):

These models are a class of machine learning algorithms that learn through trial and error interactions with an environment. Unlike supervised learning, where data is labeled, or unsupervised learning, where the algorithm finds patterns in unlabeled data, RL learns by receiving feedback in the form of rewards or penalties based on its actions. This feedback guides the model to improve its decision-making process over time, aiming to maximize cumulative rewards. RL is widely used in applications such as game playing, robotics, automated trading, and recommendation systems, where agents learn optimal strategies through exploration and exploitation of their environment.

AI MODEL USED IN OUR PROJECT:

1. Anomaly Detection (k-means):

Anomaly detection with k-means clustering identifies outliers based on their distance from cluster centers. It's effective for spotting unusual patterns in data and is used in fraud detection, network security, and system monitoring. The challenge lies in choosing the right number of clusters and handling outliers that can affect accuracy. Anomaly detection using k-means clustering within Edge Impulse Studio, the platform provides tools for preprocessing sensor data, applying the k-means algorithm to detect clusters, and identifying anomalies based on deviations from these clusters' centroids. This enables developers to create efficient and accurate anomaly detection solutions that can run directly on edge devices, making it ideal for real-time monitoring and analysis in IOT (Internet of Things) and edge computing applications.

2. Anomaly Detection (GMM) :

Anomaly detection using Gaussian Mixture Models (GMM) is a statistical technique that identifies outliers or anomalies in data by modeling the data distribution as a mixture of Gaussian distributions. GMM assumes that the data points are generated from multiple Gaussian distributions, allowing it to capture complex data patterns and identify anomalies based on low probability regions of the distribution. In the context of Edge Impulse Studio, GMM-based anomaly detection can be utilized to develop machine learning models that detect anomalies in sensor data collected from edge devices. Edge Impulse Studio provides tools for preprocessing sensor data, training GMM models, and deploying them directly onto edge devices. This enables developers to create efficient and accurate anomaly detection solutions that can run in real-time on

resource-constrained edge devices, making it suitable for a wide range of IoT and edge computing applications**.**

V RESULTS:

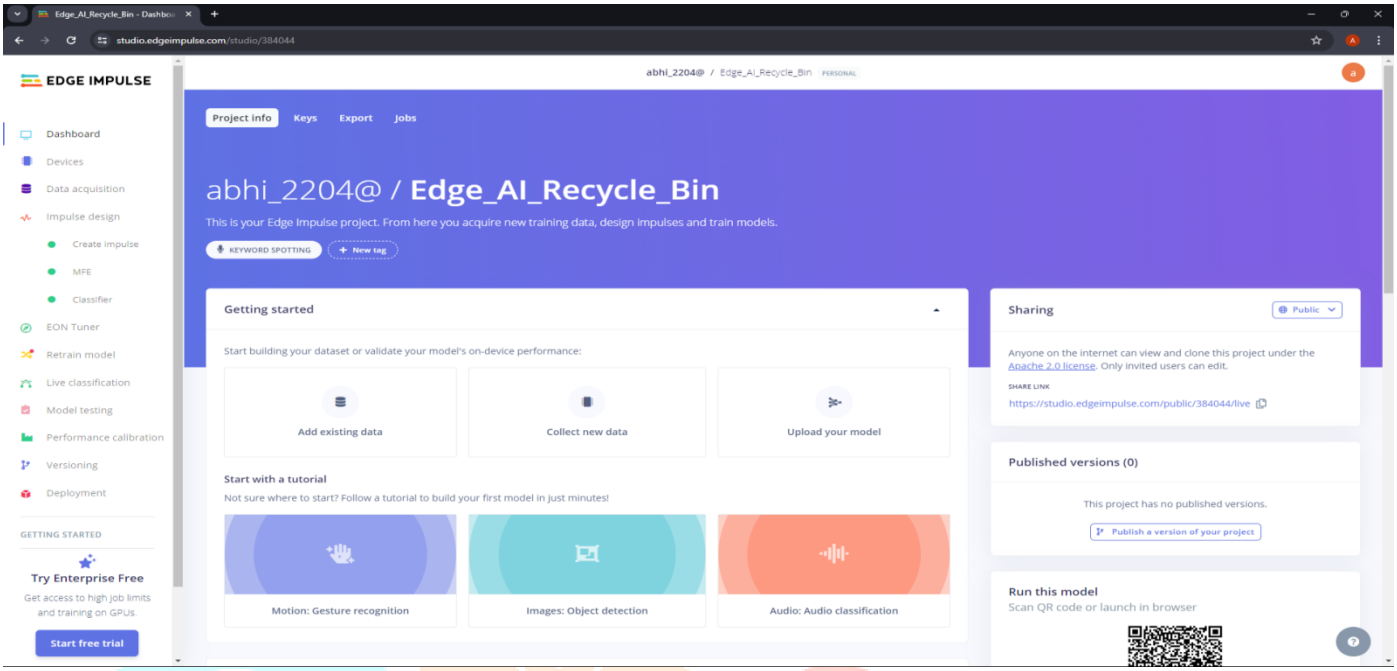

Fig no: 1.1 Dashboard of Edge Impulse Studio

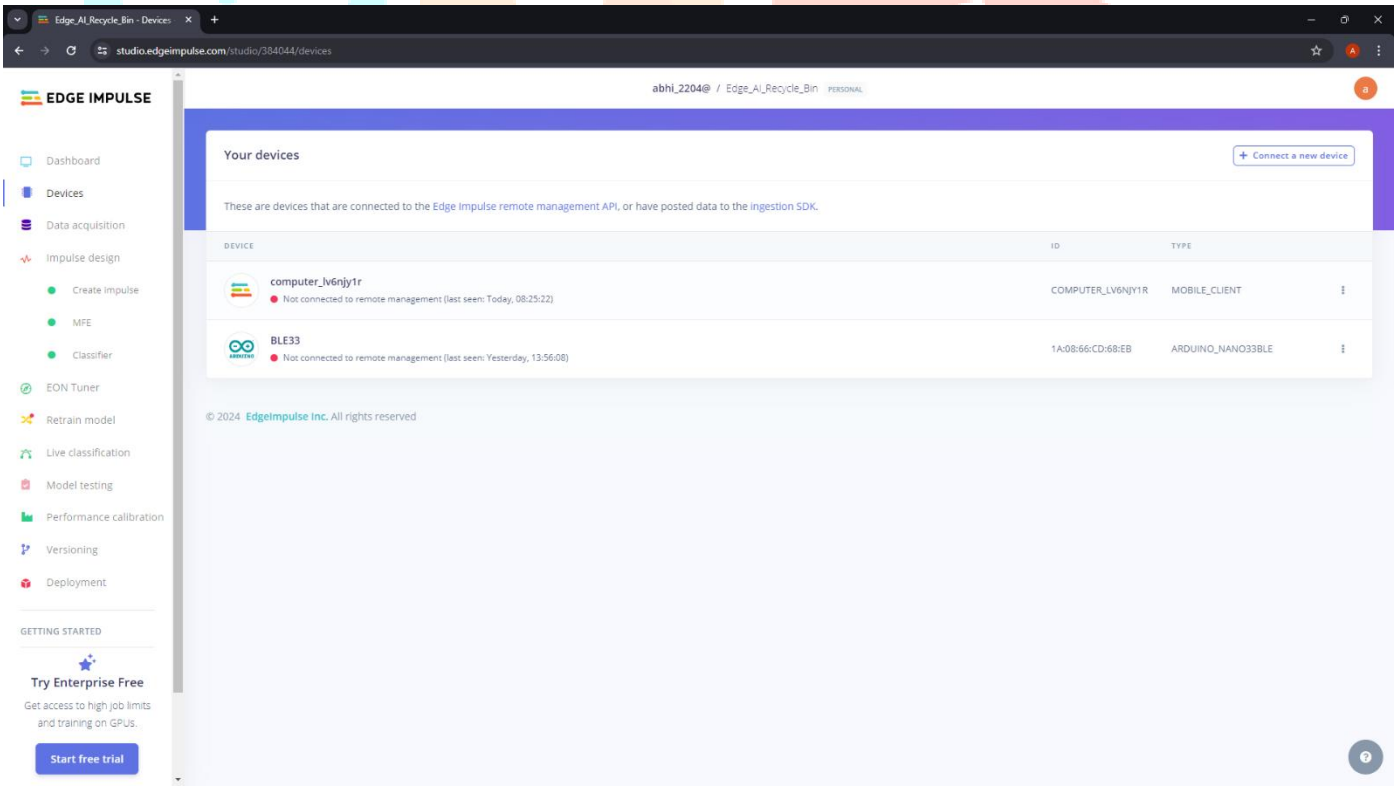

Fig 1.2: Devices connected to Edge Impulse Studio

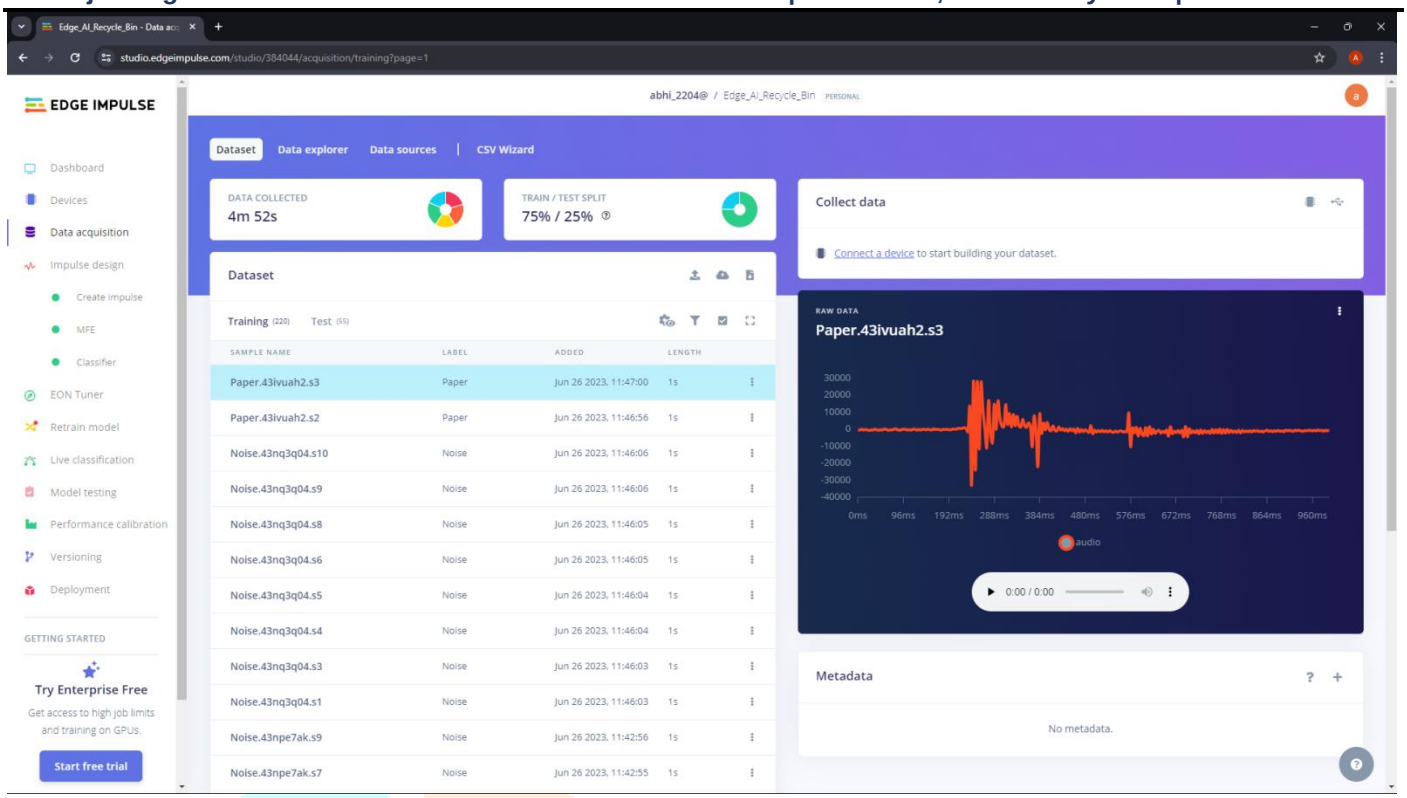

Fig no: 1.3 Datasheet

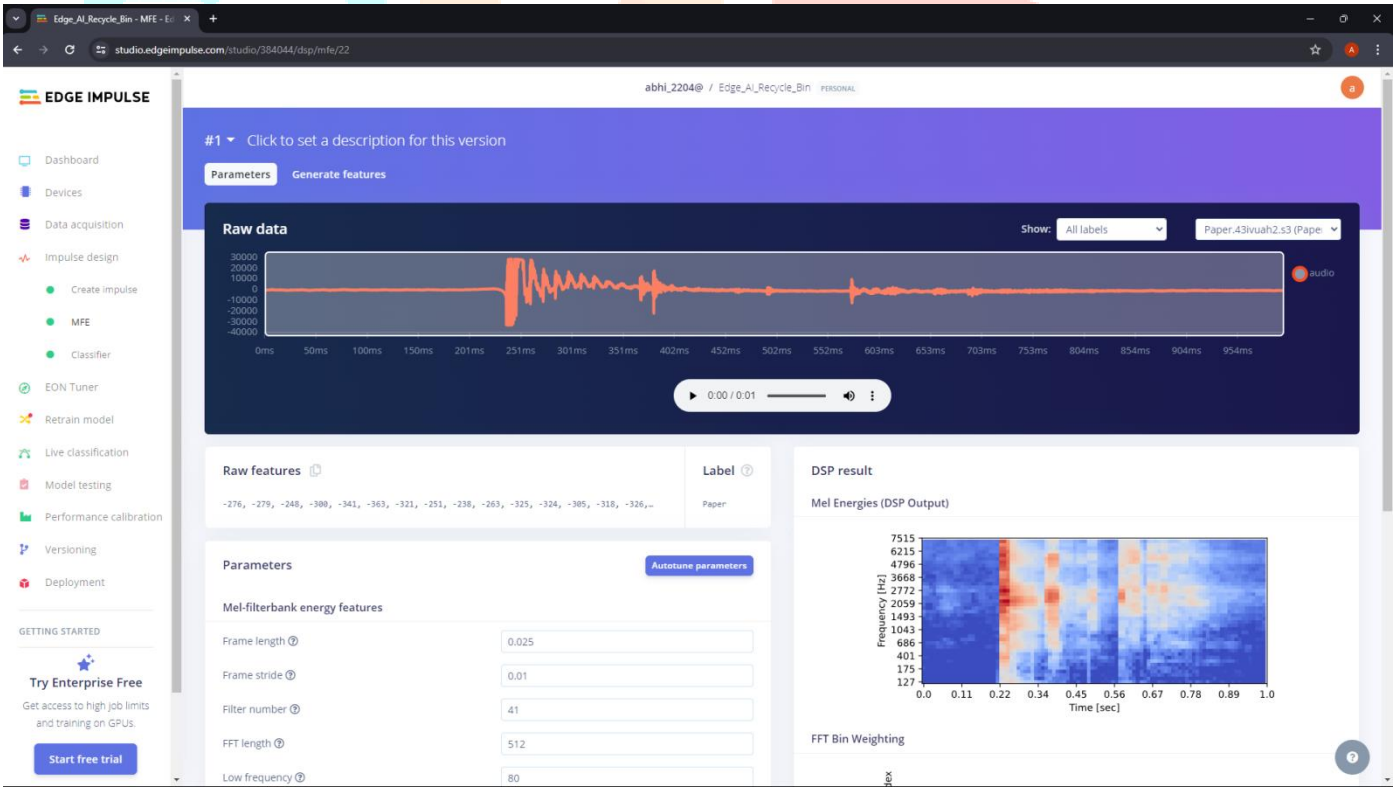

Fig no: 1.4 Recorded Audio Of Paper

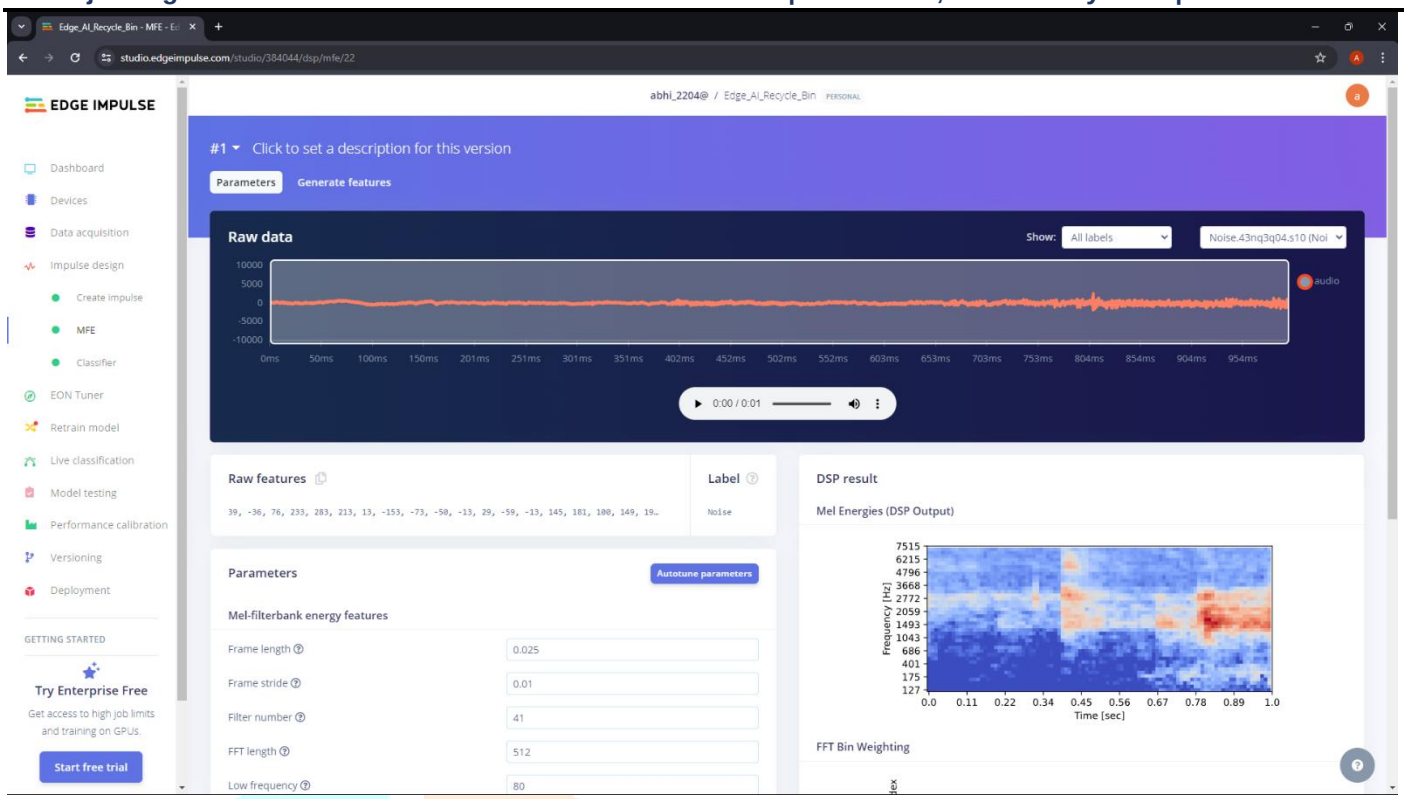

Fig no: 1.5 Recorded Audio Of Noise

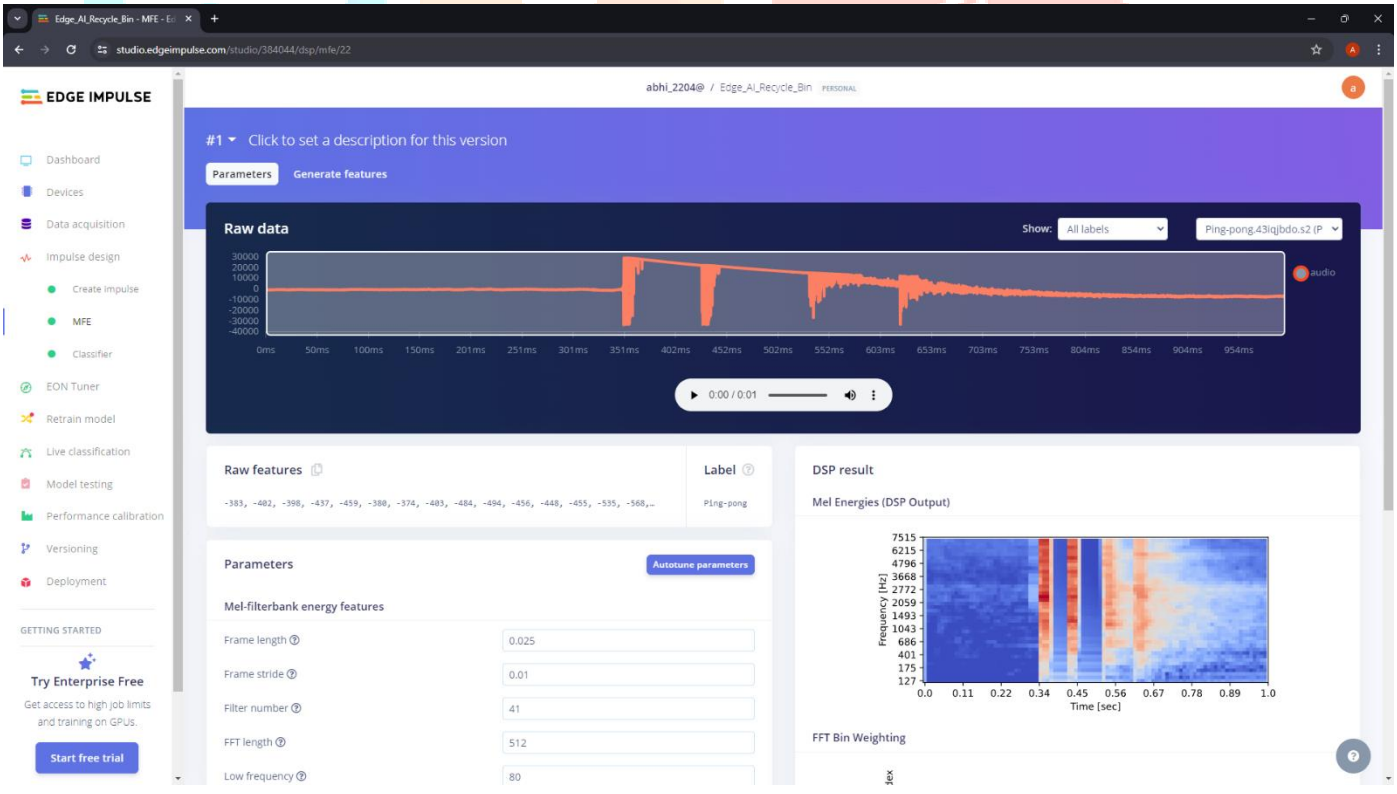

Fig no: 1.6 Recorded Audio Of Ping pong

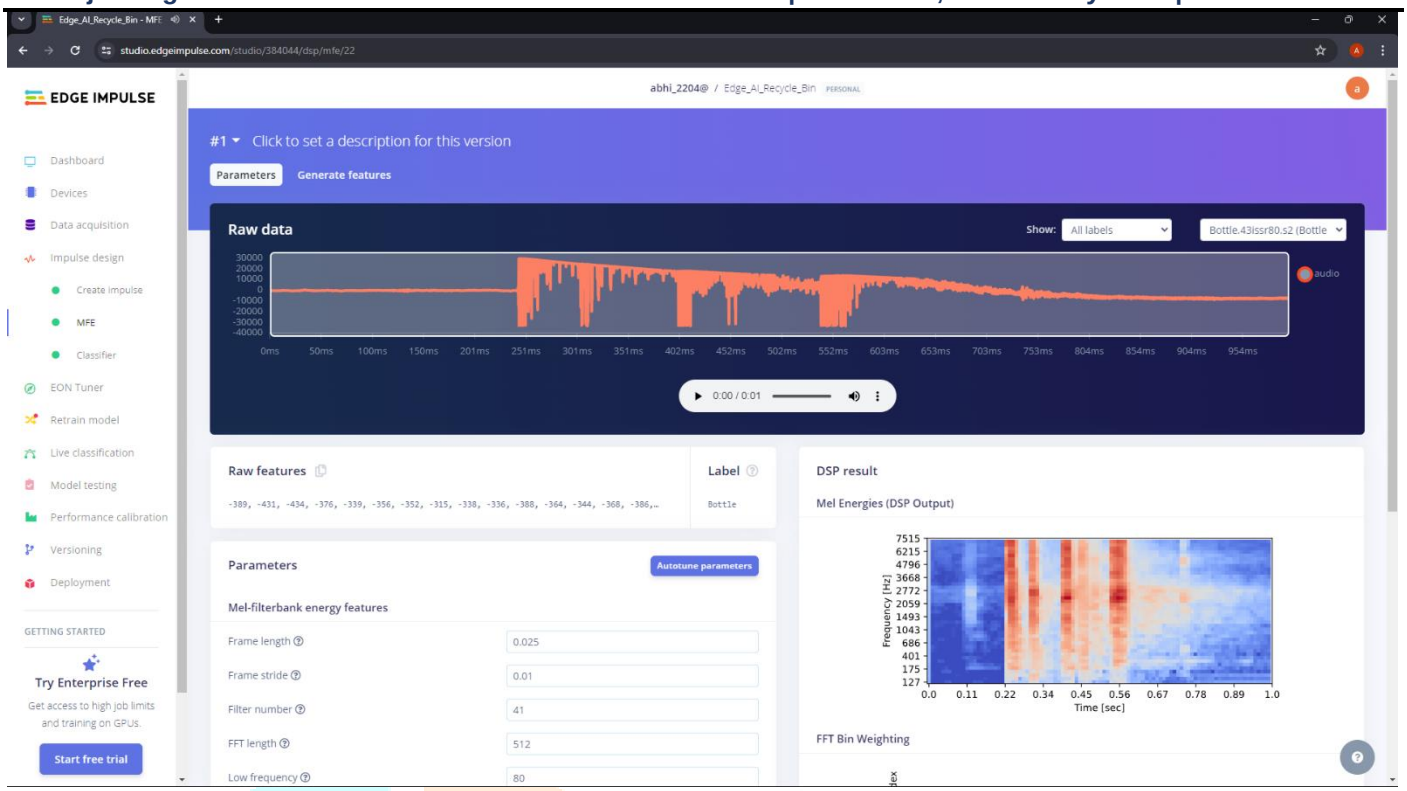

Fig no: 1.7 Recorded Audio Of Bottle

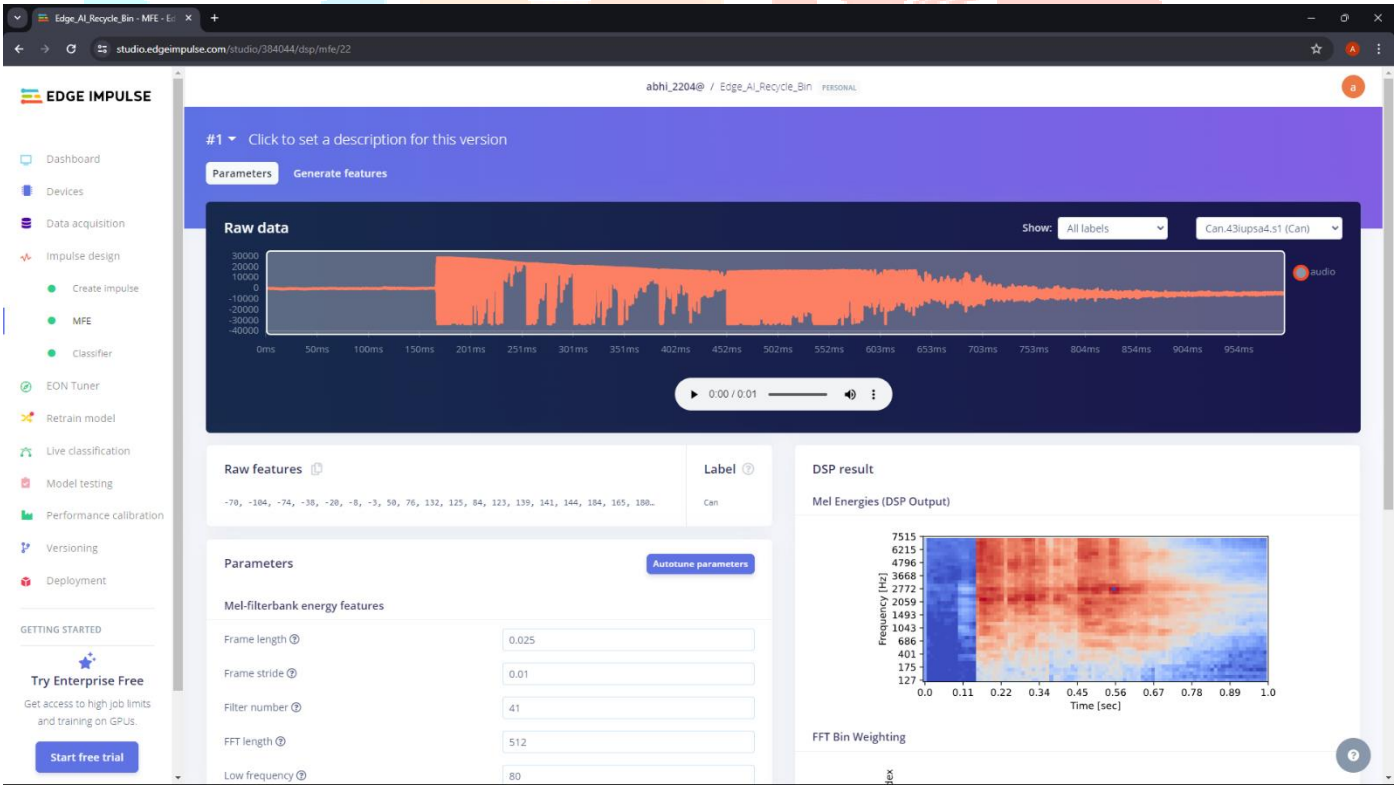

Fig no: 1.8 Recorded Audio Of can

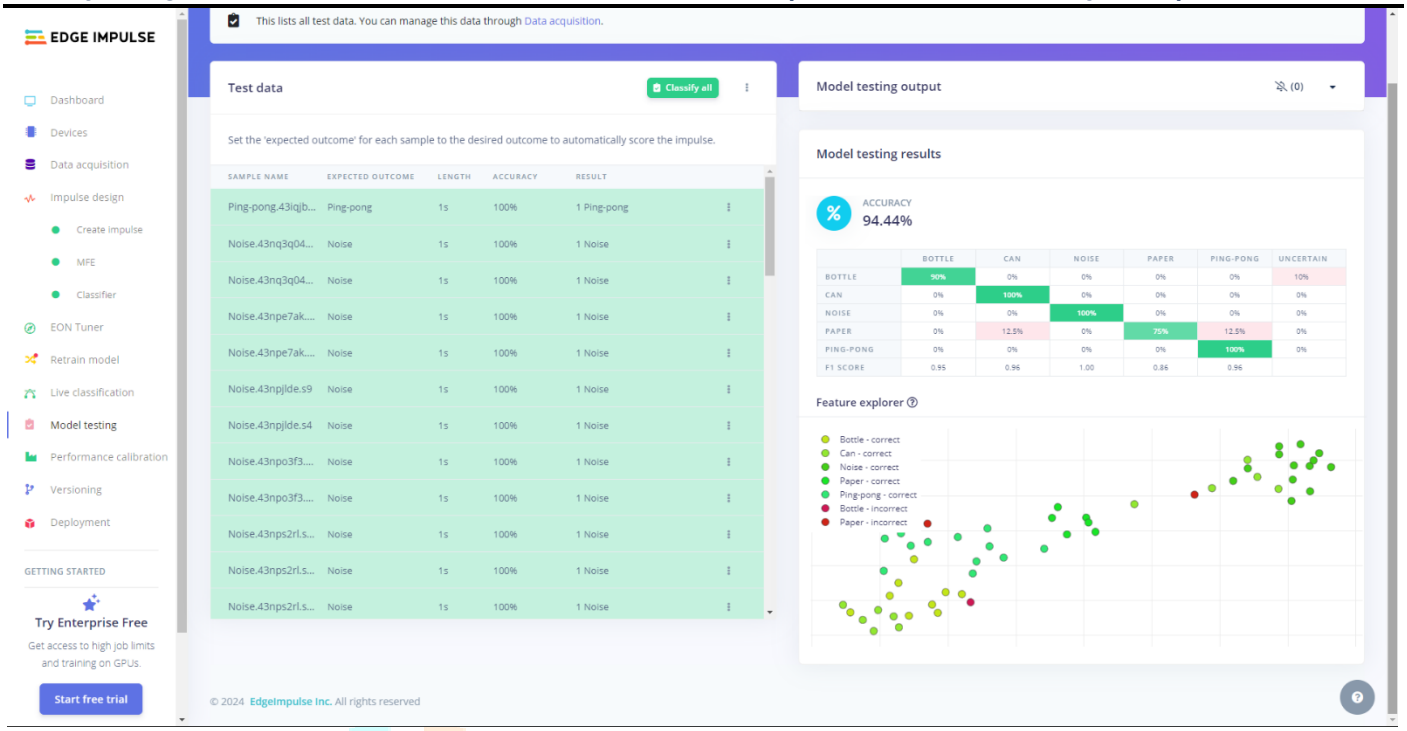

Fig no: 1.9 Test Data & model testing model

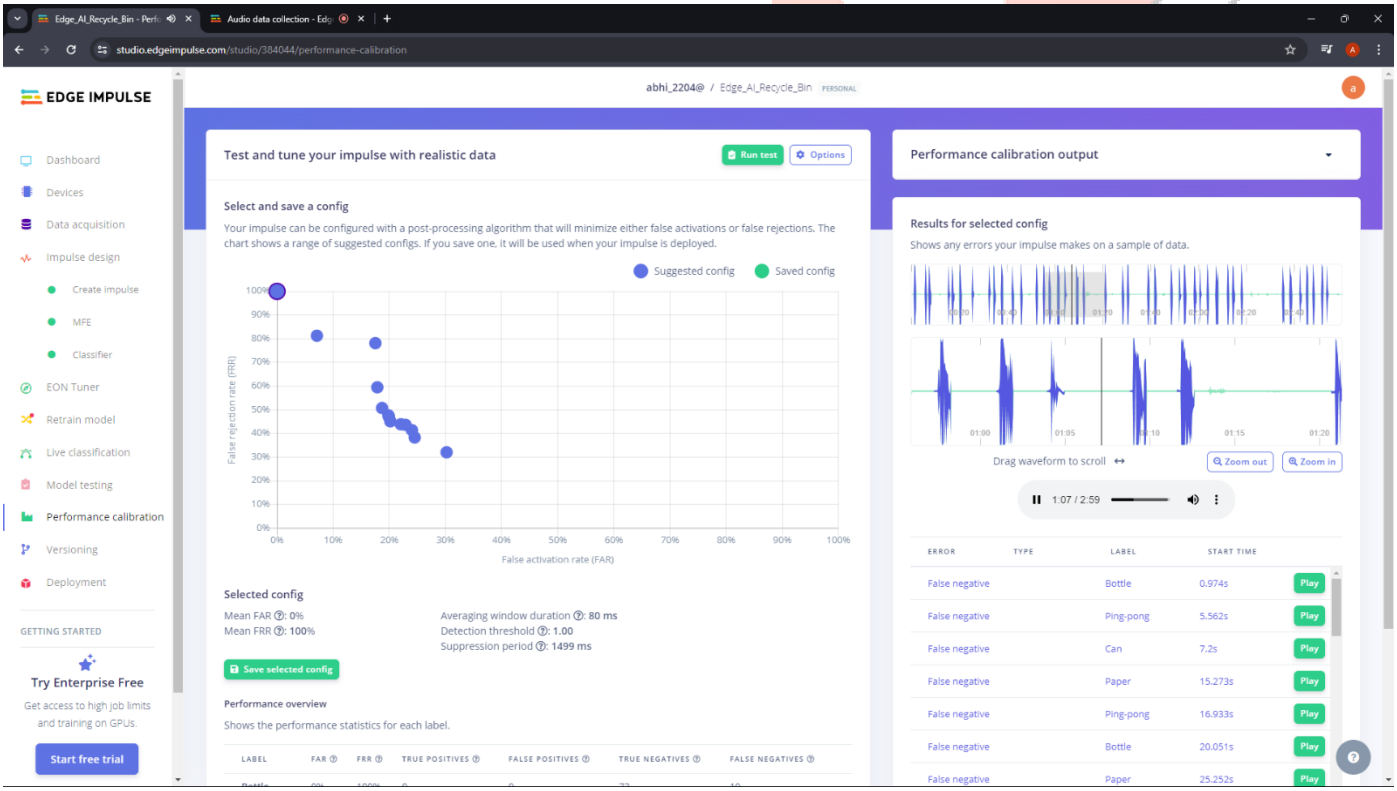

Fig no: 1.10 Realistic Data

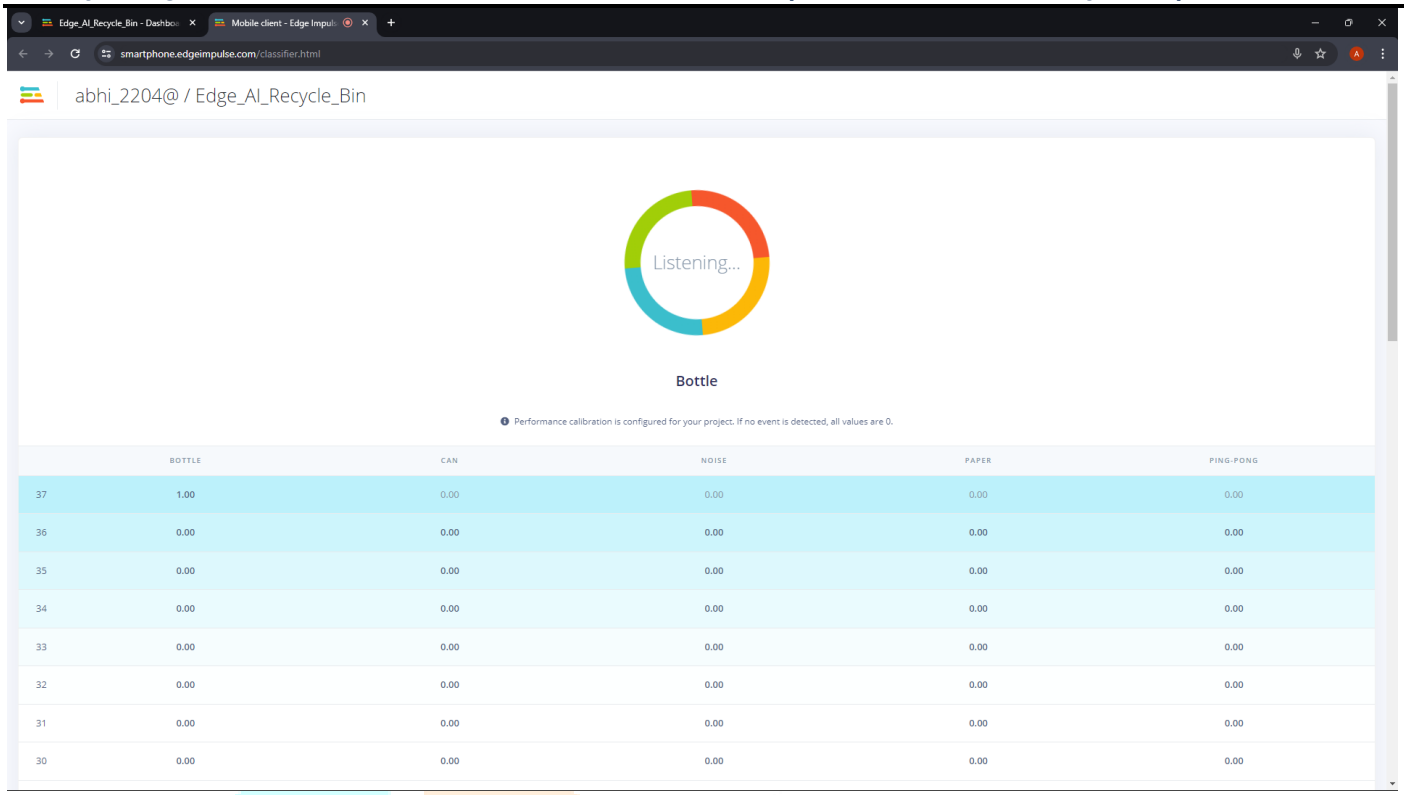

Fig no: 1.11 Classification of Bottle

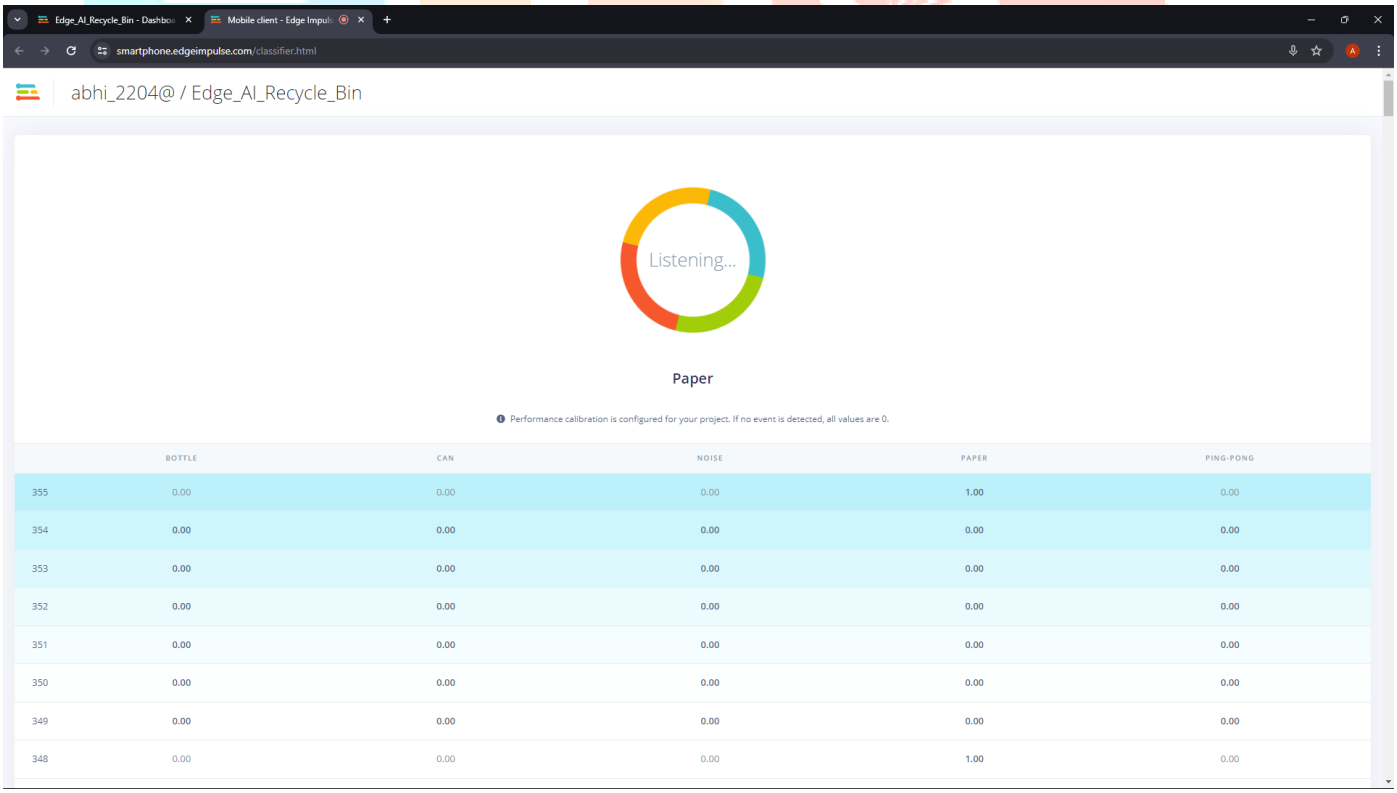

Fig no: 1.12 Classification of paper

VI.CONCLUSION:

In summary, SMART SORT, powered by Edge Impulse Studio, has made significant strides in waste management through AI-driven segregation. Its real-time processing and edge deployment not only improve recycling efficiency but also contribute to environmental conservation by reducing landfill waste. The project's success underscores the transformative impact of AI technologies in addressing sustainability challenges. Moving forward, SMART SORT's adaptable framework and continuous improvement loop promise further advancements in waste management practices. Collaboration with stakeholders and ongoing integration of emerging technologies will enhance its scalability and applicability across diverse waste streams and operational settings. This project serves as a catalyst for future innovations in sustainable waste management, highlighting the pivotal role of AI in shaping a cleaner, greener future. Thus accuracy of this project is around 94.44%.

ACKNOLEDGEMENT:

We express our gratitude to our guide Mrs,Kalyani.A.Barje for her competent guidance and timely inspiration. It is our good fortune to complete our project under her able competent guidance. Her valuable guidance, suggestions, helpful constructive criticism, keeps interest in the problem during the course of presenting this “SMART SORT: AI-POWERED WASTE SEGREGATION USING EDGE IMPULSE STUDIO” project successfully. We are very much thankful to Dr. V.M. Rohokale Head of Department (E&TC) and also Dr. S. D. Markande, Principal, Sinhgad Institute of Technology and Science, Narhe for their unflinching help, support and cooperation during this project work. We would also like to thank the Sinhgad Technical Educational Society for providing access to the institutional facilities for our project work.

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