GAS AND SMELL DETECTION SYSTEM USING ML ALGORITHM

- Dhir Gandhi (21BEI014)
- Het Patel (21BEI034)

Guide: Dr. Vijay Savani

PROJECT OVERVIEW

- The aim of this project is to develop a gas and smell detection system using a gas sensor and ESP32 microcontroller board by applying machine learning algorithm on raw gas resistance data.
- This system has potential applications in industries as well as robotics to mimic human smelling capabilities. It provides flexibility to detect any type of gas and smell using just one sensor, which makes the system modular and adaptive.

HARDWARE

1. **<u>BME688 Devkit:</u>**

- The BME688 Devkit consists of an array of 8 BME688 sensors, SD Card Slot, CR1220 battery holder and PCF8523 RTC.
- This kit allows for testing and developing use cases based on temperature, barometric pressure, humidity and gas sensing.
- The BME688 is an environmental sensor which supports AI algorithms and can detect any type of gases and smells by measuring their unique electronic fingerprint to distinguish different gas compositions.
- Can be used for detection of unusual gases and smells, which might indicate for instance a leakage or fire.

2. **<u>Adafruit Huzzah32 ESP32 Feather Board:</u>**

- This ESP32 based microcontroller processes BME688 devkit board sensor data and provides predictions.
- Also logs gas sensor data in an SD card for Machine Learning model training in the BME AI-Studio desktop application.
- Provides BLE (Bluetooth Low Energy) functionality for real-time data monitoring in the BME AI-Studio app on mobile phone.

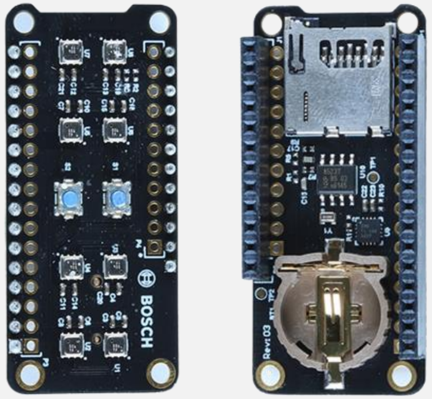


Fig 1. BME688 Devkit

Fig 2. Adafruit Huzzah32 ESP32 Feather Board

HARDWARE SPECIFICATIONS

Feature	Description
Sensor Type	Environmental (Temperature, Humidity, Pressure, Gas)
Operating Voltage	1.71V to 3.6V
Temperature Range	-40°C to +85°C
Humidity Range	0% to 100%RH
Pressure Range	300 to 1100 hPa
Gas Sensor	VOC and gas sensor with AI features
Interface	I2C, SPI
Dimensions	3.0mm x 3.0mm x 0.93mm

Table 1. BME688 Devkit Specifications

Feature	Description
Microcontroller	ESP32 (dual-core processor with Wi-Fi and Bluetooth)
Operating Voltage	3.3V
Clock Speed	240 MHz
Flash Memory	4MB
GPIO Pins	20 (with support for ADC, DAC, PWM, and I2C)
Connectivity	Wi-Fi 802.11 b/g/n and Bluetooth BLE 4.2
Power	USB or LiPo battery (100mA charge rate)
Dimensions	51mm x 23mm

Table 2. Adafruit Huzzah32 ESP32 Feather Board

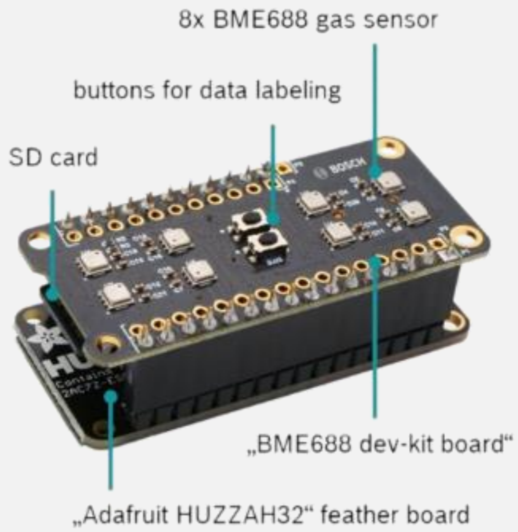


Fig 3. Integrated System

SOFTWARE SUITE

1. **BME AI-Studio Desktop Application:**

- The BME Al-Studio software enables sensor configuration, data analysis & labelling, training and optimization of application-specific solutions.
- It helps in creation of config file for the BME688 Devkit. This config file contains the data for identification of gas and smell.
- Various settings are available to train the ML algorithm.
- The data channels to be used for training can also be configured.
- Training method, batch size, epoch and data splitting can be configured.
- The software also shows confusion matrix and provides classification report such as Accuracy and F1 Score.
- The BME688 development kit can be configured with the BME Al-Studio Software. This allows to optimize performance, duty cycle, heater profile and power consumption on specific application needs.

2. **BME AI-Studio Mobile App:**

- The BME688 Devkit board connects to mobile phone via Bluetooth.
- This mobile app enables data monitoring of the BME688 Devkit board in real time.
- All the eight BME688 sensors can be monitored and the data is plotted on a graph.
- It can also label data by just clicking a single button on the mobile phone.
- The trained ML algorithm can be tested using this app.

3. **BSEC2 Software Library:**

- It is a library for Arduino IDE which allows for developing custom codes using the trained ML model from BME AI Studio.

METHODOLOGY

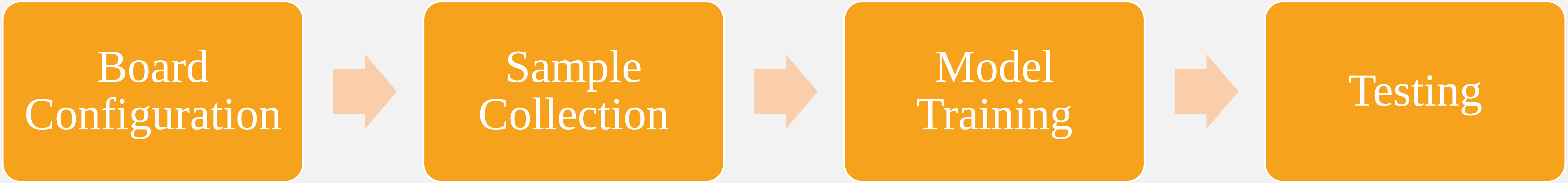
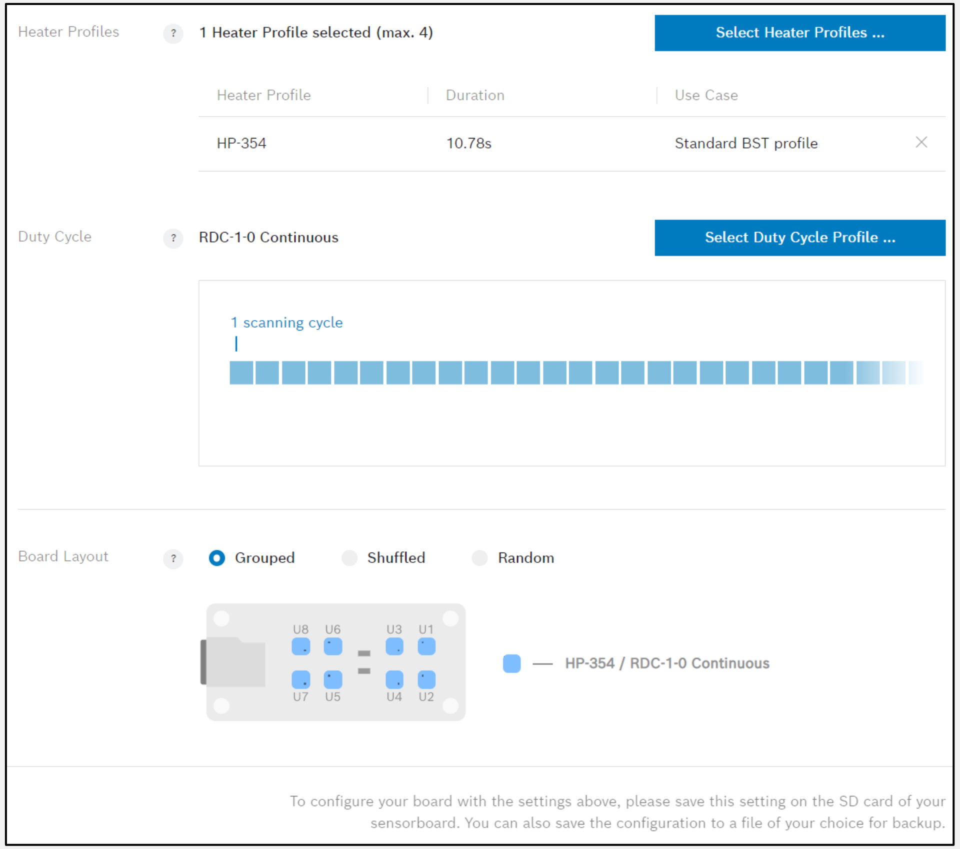
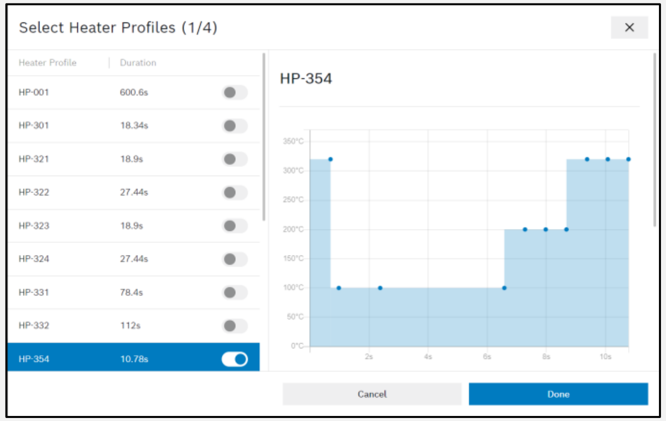


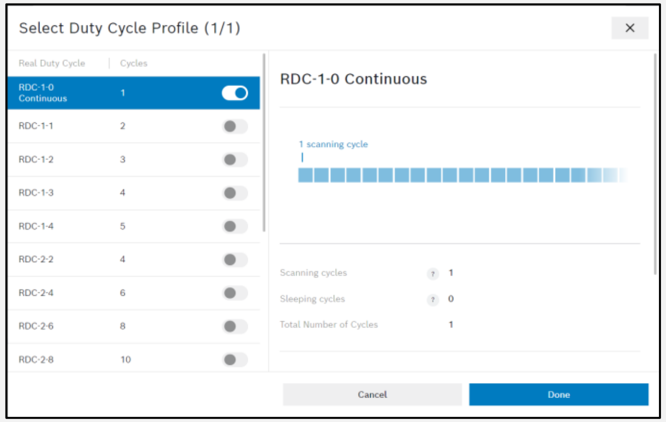
Fig 3. Methodology Block Diagram

BOARD CONFIGURATION

- The BME688 devkit, equipped with Bosch's environmental sensors, is first set up and configured. This involves flashing firmware onto the devkit's ESP32 microcontroller board and configuring the heater profile, duty cycle and board layout using the BME AI-Studio Desktop application. We have used the default heater profile HP-354 and RDC 1-0 continuous duty cycle. After selecting the parameters, the config file is saved on a microSD card.

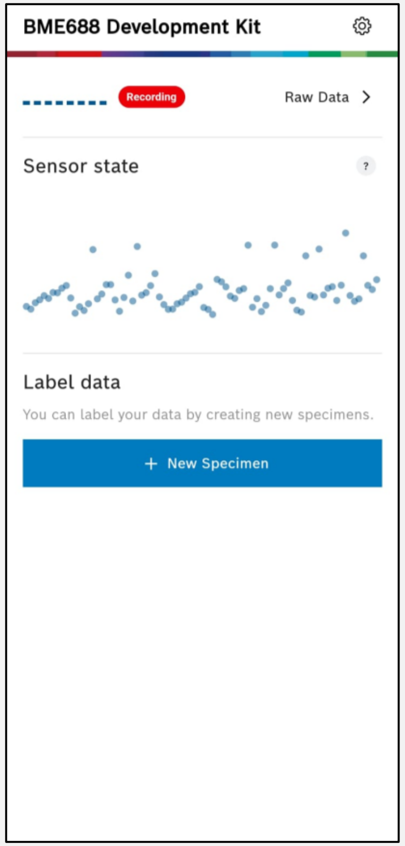






SAMPLE COLLECTION

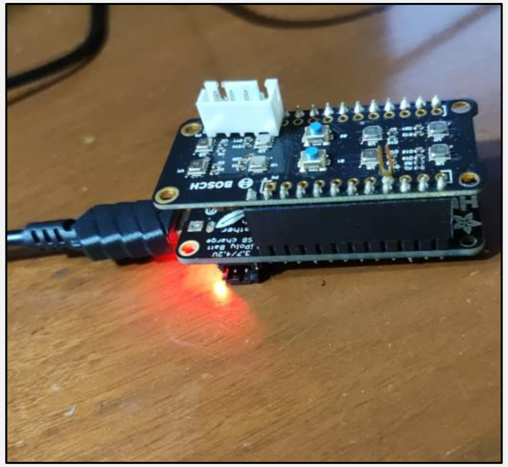
- The next step involved using the BME688 devkit and mobile app to gather environmental samples. The devkit collected various sensor data, including gas resistance and air quality readings, which were stored for further analysis. Labels can be assigned to the data using the mobile app. 3 samples of 1 hour each for air, coffee and tea were collected by placing the sensor close to them as shown in the images below:



BME AI-Studio Mobile App

Coffee

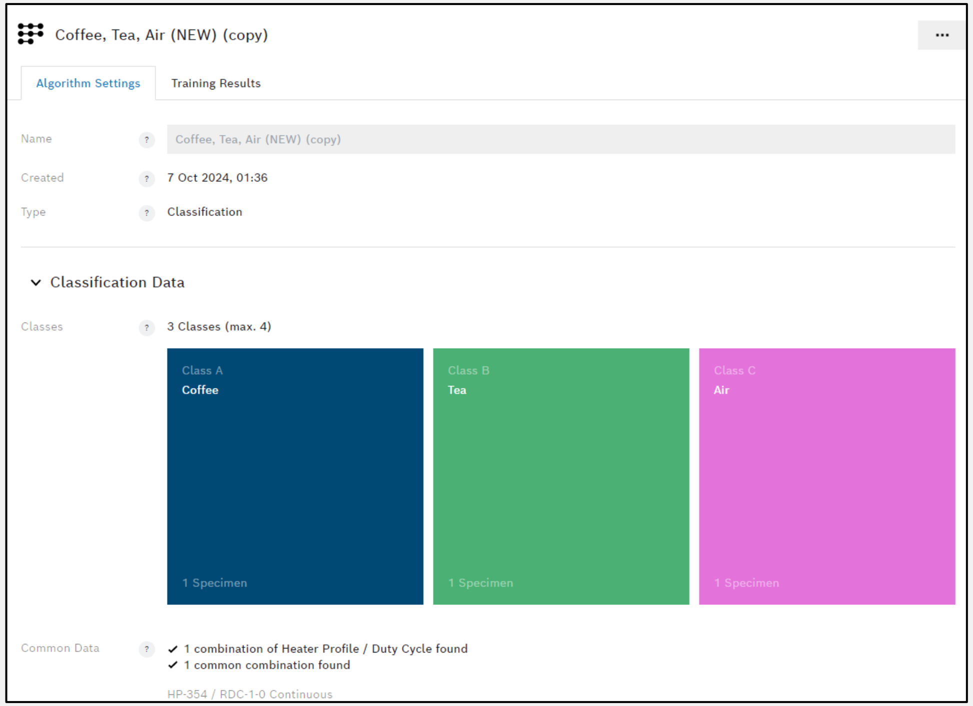
Tea

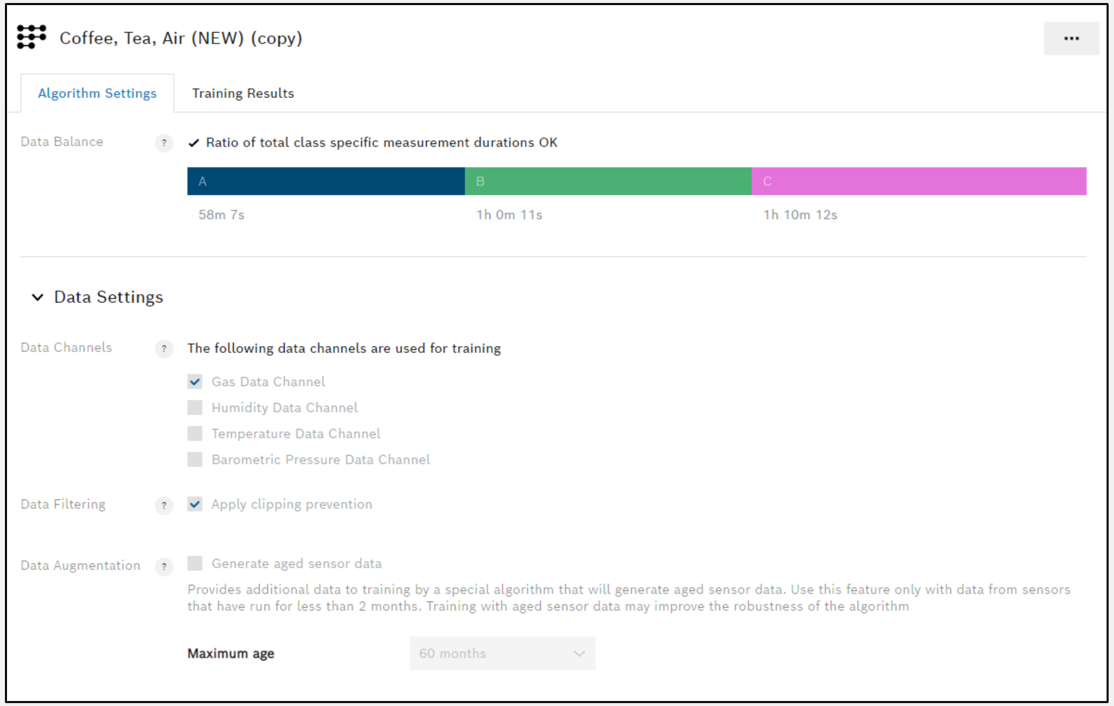


Air

MODEL TRAINING (1/2)

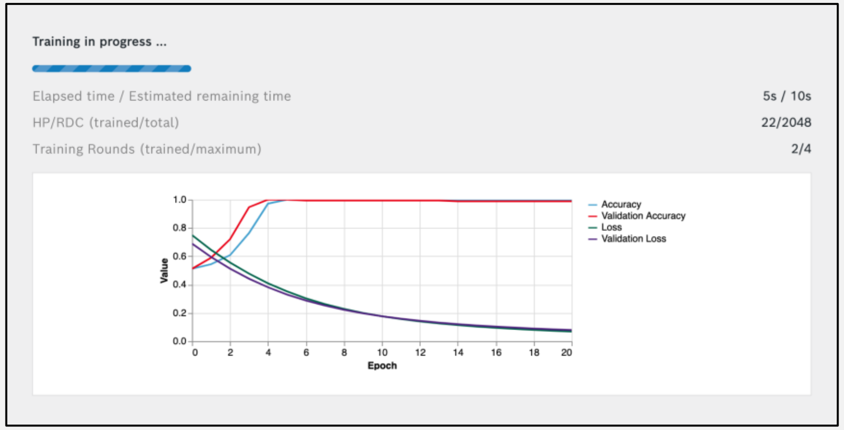
- In the BME AI-Studio Desktop application, the environmental data from the sample collection phase is used to train machine learning models. The AI-Studio leverages this data to create predictive models or identify patterns, such as classifying air quality, detecting specific gas compositions, or learning environmental behaviour. Users can define what scenarios they want the model to focus on, adjusting the training process according to their use cases. AI-Studio's training algorithms apply deep learning techniques to make the model more accurate and adaptable to various environmental conditions.

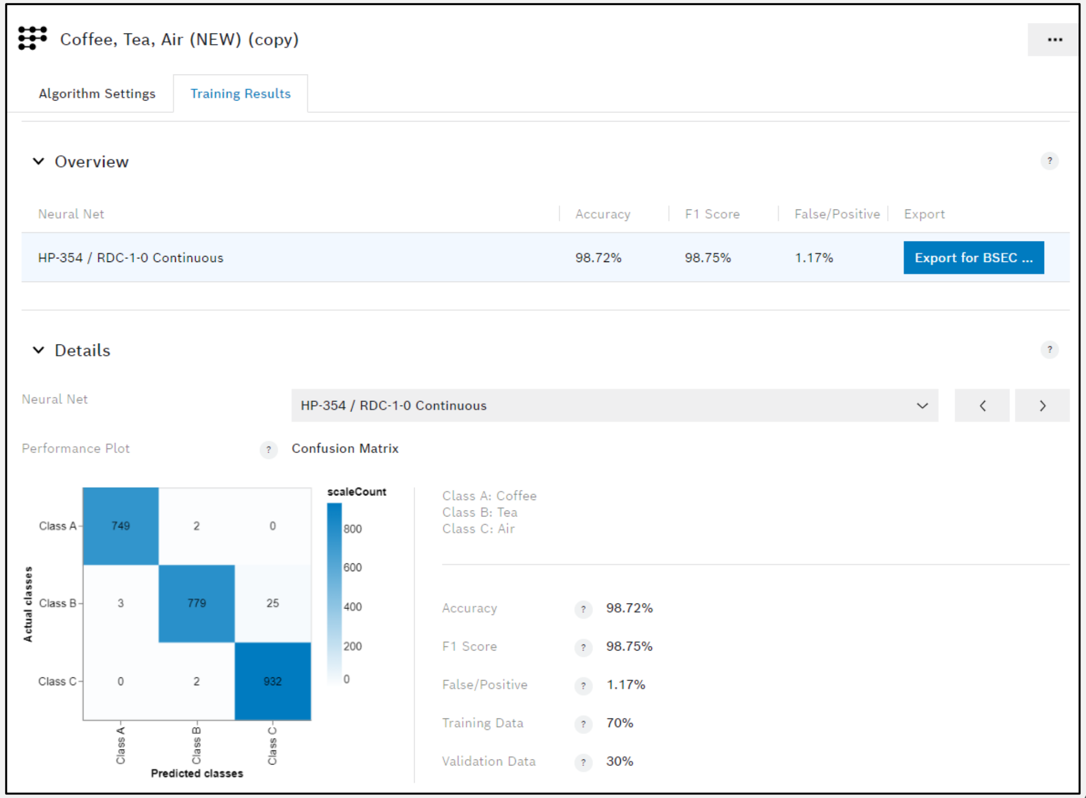




MODEL TRAINING (2/2)

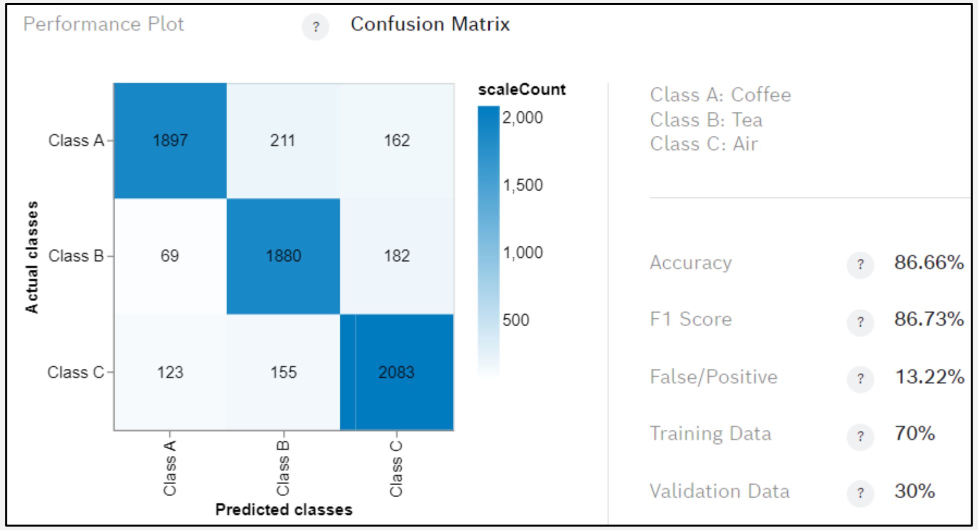
- The app offers various options for selecting data and multiple parameters for model training. It also has feature of clipping prevention and data augmentation. Classification and regression, both options are available. We can also select the batch size, epoch and data splitting. Once data training is completed, a confusion matrix, accuracy, F1 score and false/positive are generated. The trained model can now be exported and saved on the microSD card for use with the BME688 devkit.





TESTING

- After training, the model is tested in real world. This testing phase ensures that the machine learning model is functioning as expected and is able to predict or classify environmental conditions based on sensor readings. The BME mobile app is used to test the model predictions. Testing helps fine-tune the system and check its accuracy in recognizing environmental patterns such as gas mixtures, pollution levels, or weather conditions.
- If the model is not performing as expected, then more data can be collected and the model can be trained again. It is also important to make sure that multiple data set is collected for same specimen under different environmental conditions to ensure that the trained model is robust.
- We achieved 86.66% accuracy, 86.73% F1 score and 13.22% false/positive. The confusion matrix can be seen in the figure below. On the right side are the classification results. The current class and the predicted class are displayed using the BME AI Studio mobile application. From the results, it can be concluded that the sensor is performing very well and can be used reliably for smell detection.



CONCLUSION

- Thus, in this project, we presented an affordable solution for gas and smell detection identification with an AI-capable sensor dev kit. The sampling was performed in a controlled environment. We found that identifying tea and coffee is possible with the module. Also, it was interesting to find that other type of tea and coffee were not recognized, meaning that the system's applicability might be extended to detecting specific type of tea and coffee. This is an interesting prospect for the application.

Future Scope:

- The future scope for the BME688 gas sensor is promising in several industries due to its compact size, low power consumption, and versatility in detecting a wide range of gases:

1. **Air Quality Monitoring**: Enhanced IoT-based smart city networks to monitor pollution levels and ensure environmental safety.
2. **Health Applications**: Integration in wearable devices for real-time health monitoring (e.g., detecting exhaled gases for early disease detection).
3. **Smart Agriculture**: Used in smart farming systems to monitor environmental conditions for optimized crop growth and soil health.
4. **Smart Home Automation**: Detecting harmful gases in homes and industries for early hazard prevention.
5. **Consumer Electronics**: Integration into smartphones and smart devices for personal air quality tracking.

REFERENCES

[1] “Overview | Adafruit HUZZAH32 - ESP32 Feather | Adafruit Learning System.” Accessed: Oct. 07, 2024. [Online]. Available: https://learn.adafruit.com/adafruit-huzzah32- esp32-feather

[2] “Gas sensor BME688 | Bosch Sensortec.” Accessed: Oct. 07, 2024. [Online]. Available: https://www.bosch-sensortec.com/products/environmental-sensors/gas-sensors/bme688/

[3] “BME688 Software | Bosch Sensortec.” Accessed: Oct. 07, 2024. [Online]. Available: https://www.bosch-sensortec.com/software-tools/software/bme688-software/

[4] B. Molnar and A. Geczy, “Electronic Nose Based on AI-capable Sensor Module for Beverages Identification,” in *Proceedings of the International Spring Seminar on Electronics Technology*, IEEE Computer Society, 2024. doi: 10.1109/ISSE61612.2024.10603721.

[5] A. Xu, T. Cai, D. Shen, and A. Wang, “Food Odor Recognition via Multi-step Classification.”

[6] “BME AI-Studio Documentation.” Accessed: Oct. 07, 2024. [Online]. Available: https://www.bosch-sensortec.com/software/bme/docs/

THANK YOU