School

of

Electronics and Communication Engineering

Mini Project Report

on

Gesture-Based In-Cabin Control and Embedded ML-Enabled Out-Cabin Airbag Monitoring in Automobiles

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Semester: V, 2023-2024

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2023-2024

SCHOOL OF ELECTRONICS AND COMMUNICATION ENGINEERING

CERTIFICATE

This is to certify that project entitled **"Gesture-Based In-Cabin Control and Embedded ML-Enabled Out-of-Cabin Airbag Monitoring in Automobiles."** is a bonafide work carried out by the student team of **"Atharv Mutalik Desai (01FE21BEC040), Om Rajashekhar Vastrad(01FE21BEC053), Shree Raksha B M(01FE21BEC054), Shreya Vishnu Shanbhag(01FE21BEC061) "**. The project report has been approved as it satisfies the requirements with respect to the mini project work prescribed by the university curriculum for BE (V semester) in the School of Electronics and Communication Engineering of KLE Technological University for the academic year 2023-2024.

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ACKNOWLEDGMENT

Our report expresses gratitude for the guidance, supervision, and inspiration we received. We consider ourselves extremely fortunate to have had such support during the project's completion, We feel really lucky for the support during the project, as its success depended on the substantial help from many people.

We express our sincere gratitude to Prof. Supriya VK, our project mentor, for genuinely caring about our progress and providing the support and guidance needed to complete the job. We appreciate her incredible assistance and direction, even with a busy schedule managing academic matters. Additionally, we feel fortunate for the continuous support, guidance, and oversight from the teaching and non-teaching staff at SoECE, which played a crucial role in the successful completion of our projects.

We appreciate that KLE Technological University's School of Electronics and Communications supplied the resources essential for completing our project.

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-Shreya Vishnu Shanbhag

ABSTRACT

In today's technology-driven era, embedded systems play a pivotal role, in driving innovation across diverse industries. They offer seamless functionality, particularly in dynamic environments such as driving. The integration of smart technology, empowered by advanced computing frameworks like machine learning and artificial intelligence, brings about transformative changes, enhancing performance and efficiency, and paving the way for innovations like autonomous driving.

To address this, the project focuses on implementing a gesture-based system to simplify task initiation through intuitive gestures, thereby improving user interaction and usability. Additionally, to ensure safety in autonomous driving scenarios, the project explores the integration of airbag monitoring systems leveraging embedded machine learning technology. This approach facilitates real-time decision-making and data processing on devices, resulting in reduced latency, enhanced privacy, and improved efficiency across various applications.

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Chapter 1

Introduction

In recent years, the automotive industry has seen a rise in the popularity and complexity of in-car infotainment systems. While these systems offer enhanced functionality, the growing array of features has also raised concerns about potential distractions for drivers. Distractions are typically grouped into categories such as visual, manual, and auditory, as identified. Importantly, research indicates that the most significant impact on driving performance occurs when visual and manual distractions are combined. As vehicles become more advanced with additional features, it becomes increasingly important to address these potential distractions and find ways to ensure that drivers remain focused and safe on the road.

In the sphere of automotive innovation, gesture-based control systems have emerged as a transformative development, offering drivers a comfort-enhancing and user-friendly interface. This hands-free technology allows users to effortlessly interact with in-car functions, providing unparalleled convenience for drivers of all kinds. By simply using natural hand gestures, individuals can seamlessly manage various aspects of their driving environment, such as adjusting infotainment settings, operating the sunroof, and fine-tuning temperature preferences. The introduction of gesture-based controls represents a significant step towards a more user-friendly and enjoyable driving experience, ensuring that user convenience takes center stage. As we navigate the evolution of automotive interfaces, the emphasis on comfort and hands-free control through gesture recognition underscores a commitment to making driving safer and more enjoyable for all users.

1.1 Motivation

The motivation for choosing a gesture sensor for our project is rooted in a dual commitment to advancing user experience and addressing the escalating concerns of driver distraction within the evolving automotive landscape. As modern vehicles become equipped with increasingly intricate features, particularly in infotainment systems, the potential for visual and manual distractions has heightened. The gesture sensor stands out as a strategic choice, driven by its potential to provide an intuitive, user-friendly, and hands-free interface. By allowing drivers to control in-car functions through natural hand gestures, we aim to not only enhance convenience but also prioritize safety by minimizing the need for manual inputs and visual diversions. This deliberate integration reflects our dedication to staying ahead of technological trends, ensuring our solution meets current challenges and anticipates and adapts to the future trajectory of automotive interfaces, ultimately fostering a safer and more enjoyable driving experience. The overarching goal is to foster a safer and more enjoyable driving experience for users.

1.2 Need Statement

An in-cabin gesture sensing system for automobiles fulfills the growing demand for hands-free control, ensuring a safer and more intuitive user experience. Precise real-time recognition of diverse gestures enables seamless management of in-cabin functions, including infotainment, sunroof, and temperature control. Additionally, incorporate collision detection for an airbag monitoring system using Embedded ML, ensuring precise and timely responses for enhanced safety. This innovative system aligns with evolving automotive technology trends, enhancing overall driving satisfaction by minimizing distractions and prioritizing safety.

1.3 Objectives

- Understand the working of Tiny ML in Embedded core.
- Explore Edge Impulse to collect, train, test and validate the data.
- To implement a model to detect gestures for different functionalities.
- To implement a ML model for air-bag system .

1.4 Literature survey

1. **Hand Gesture Recognition System for In-car Device Control Based on Infrared Array Sensor -** The paper proposes the use of an infrared array sensor for hand gesture recognition in an in-car device control system. The infrared array sensor is applied to overcome limitations faced by other in-car device HMI systems, such as being influenced by illumination conditions. The system utilizes a series of image data frames obtained from the sensor for gesture recognition. The infrared array sensor allows the system to work in various conditions, including at night, in tunnels, and on noisy roads. The proposed system is easier to operate and requires less concentration compared to other HMI systems.[1]

2. **Mini Cooper-** In the world of automotive innovation, the Mini Cooper car as shown in figure 1.1[2] introduces gesture features that redefine the driving experience. The integration of air-swirl for volume control signifies a departure from traditional interfaces, allowing drivers to effortlessly adjust audio settings with a simple wave. The call handling feature, enabling users to accept or reject incoming phone calls through intuitive gestures, adds a layer of convenience, emphasizing the car's commitment to hands-free and user-friendly interactions. Moreover, the navigation interaction feature elevates map control with gestures like swiping or pinch-to-zoom, providing an intuitive and responsive way for drivers to navigate their routes. These gesture features not only showcase Mini Cooper's dedication to incorporating state-of-the-art technology but also contribute to a safer and more enjoyable driving environment, where drivers can seamlessly manage in-car functions with natural and effortless gesture

Figure 1.1: Mini Cooper

3. Land Rover Glossary - In the domain of automotive functionality, the Land Rover introduces a distinctive gesture feature known as the "leg swing" for tailgate control, enhancing the user experience with a unique and intuitive interaction. This innovative gesture allows users to effortlessly open or close the car's tailgate by performing a leg swing motion, offering a hands-free and convenient alternative to traditional methods.

4. BMW - In the BMW series of cars as shown in figure 1.2 [3], a variety of progressive gesture features redefine the in-cabin experience, showcasing user-centric design and the integration of advanced technology. For volume control, users can employ a simple and intuitive gesture by rotating a finger either clockwise or counterclockwise, presenting a seamless alternative to traditional controls. The navigation system introduces gestures such as pinch-to-zoom and swiping on the infotainment screen, providing a responsive and user-friendly approach to map control. Moreover, BMW enhances call handling with gestures, enabling users to accept or reject calls through pointing or waving gestures, promoting a hands-free and convenient communication experience.Matching the brand's dedication to innovation and putting users at the center, as shown in Figure 1.2 for the mentioned car model.

5. Design and simulation of MEMS based accelerometer for crash detection and air bags deployment in automobiles- This paper discusses the design and development of a micro-electronics (MEMS)-based accelerometer for crash detection and airbag deployment in automobiles. The accelerometer detects acceleration in three-dimensional space and can detect high-velocity moving objects in impact environments. Accelerometers provide high linearity, cross-sensitivity, and can increase operational speed in crash detection and airbag deployment. The accelerometer can be made within micrometers

(1-1000µm), allowing faster deployment. MEMS is an emerging topic in multidisciplinary engineering, combining microsensors, microelectronics, and microstructures[4].

Figure 1.2: BMW X5

1.5 Problem statement

Gesture-Based In-Cabin Control and Embedded ML-Enabled Out-of-Cabin Airbag Monitoring in Automobiles - Design an in-cabin gesture sensing system to enhance user experience and control in automobiles. The system must accurately recognize and interpret a few gestures in real-time, providing smooth operation for managing various in-cabin functions, such as infotainment control, sunroof operation, and temperature monitoring. Additionally, incorporate collision detection for an airbag monitoring system using Embedded ML, ensuring precise and timely responses for enhanced safety.

1.6 Organization of the report

Chapter 2 provides the prerequisites required to carry out the study. The capabilities and specifications of the board are explored, providing a foundation for understanding.

Chapter 3 discusses the proposed system design and methodology .

Chapter 4 includes a discussion of the algorithm of the complete model and a flowchart of the model.

Chapter 5 In this chapter results for the proposed system design are discussed.

In Chapter 6 The project's conclusion and potential future scope are discussed.

Chapter 2

Preliminaries

The pre requisities required for the implementation of the proposed system is detailed in this chapter.The hardware and software required are discussed.

2.1 Embedded ML Core (Arduino Nano 33-BLE Sense)

The model is trained and tested using the Edge Impulse tool, and then it is deployed using the Arduino IDE on the Tiny-ML board.In this chapter, we list out the interfaces.

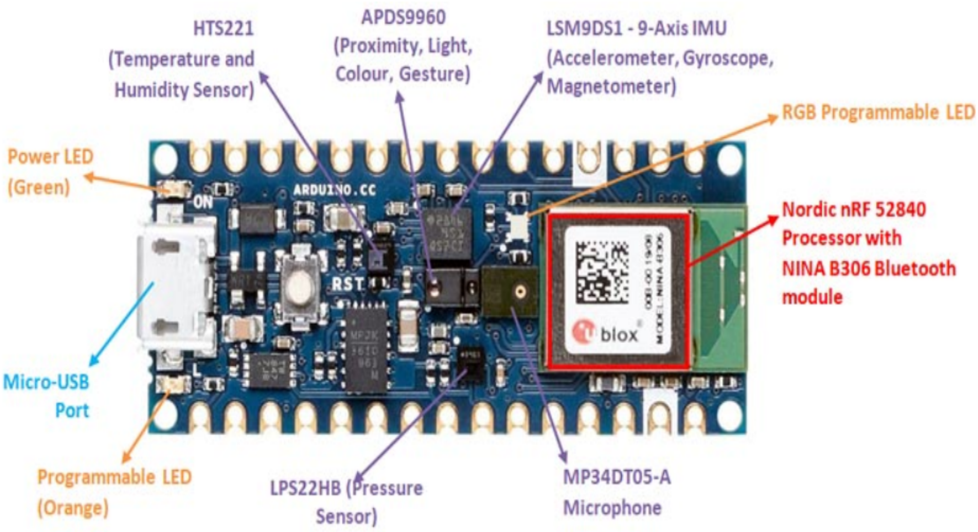

Figure 2.1: Arduino Nano 33 BLE Sense

The Arduino Nano 33-BLE Sense combines a small form size, a variety of environmental sensors, and the ability to run AI using Tiny-ML.
Model: NINA B306.
The Arduino Nano 33 BLE board has the following technical specifications:
- Operating Voltage: 3.3V
- USB-Input Voltage: 5V
- Clock: 64MHz
- Flash: 1MB
- SRAM: 256 KB

A new board in a well-known form format is the Arduino Nano 33 BLE Sense. It includes several integrated sensors:
APDS9960: A sensor that combines multiple functionalities such as proximity sensing, ambient light sensing, RGB colour sensing, and gesture detection.

Proximity Sensing can detect the presence of an object or a hand within a range, making it useful for touchless control applications. RGB Color Sensing can identify and measure the intensity of red, green, and blue light, enabling the identification of different colours The sensor has four separate diodes sensitive to different directions. For a communication method, an I2C is compatible with interface communication with microcontrollers and it has special built-in filters, ultraviolet (UV) and infrared (IR) blocking filter. It has four separate photodiodes for precise sensing

LSM9DS1: The sensor is a compact 9-axis module, combining a 3-axis accelerometer for linear acceleration measurement which measures linear acceleration along the X, Y, and Z axes, a 3-axis gyroscope for tracking angular rate, and a 3-axis magnetometer for sensing magnetic fields and additionally, the sensor is designed for low power consumption, making it more effective for battery-powered devices.

HTS221: The sensor is designed to measure humidity with high precision, making it ideal for applications where accurate humidity monitoring is essential. Additionally, it provides precise temperature measurements, making it suitable for environmental monitoring needs.

2.2 Arduino IDE

Arduino IDE is a fundamental tool for simplifying the development of applications for Arduino boards, offering an accessible platform for programming these devices. It provides an interface for writing, testing, and deploying code, making it ideal for both beginners and experienced developers. The platform supports a wide range of Arduino boards. Arduino IDE helps in deployment and enabling a wide range of real-world application to tackle.

2.3 ML Platform (Edge Impulse)

Edge Impulse simplifies the process of developing embedded machine learning applications, offering developers an efficient solution to create and optimize solutions using real-world data. Edge Impulse is enabling the future of embedded machine learning by assisting developers in creating and optimizing solutions using real-world data.

In Edge Impulse, the project creation phase is the foundation for an application-specific machine-learning model. Data collection follows a variety of sensory inputs that are captured for training. During the model training step, Edge Impulse's powerful tools are used to create algorithms that fit the specific data you've collected. Further deployment allows models to be integrated into various edge devices efficiently. Lastly, testing and iteration are integral, involving real-world application of the model

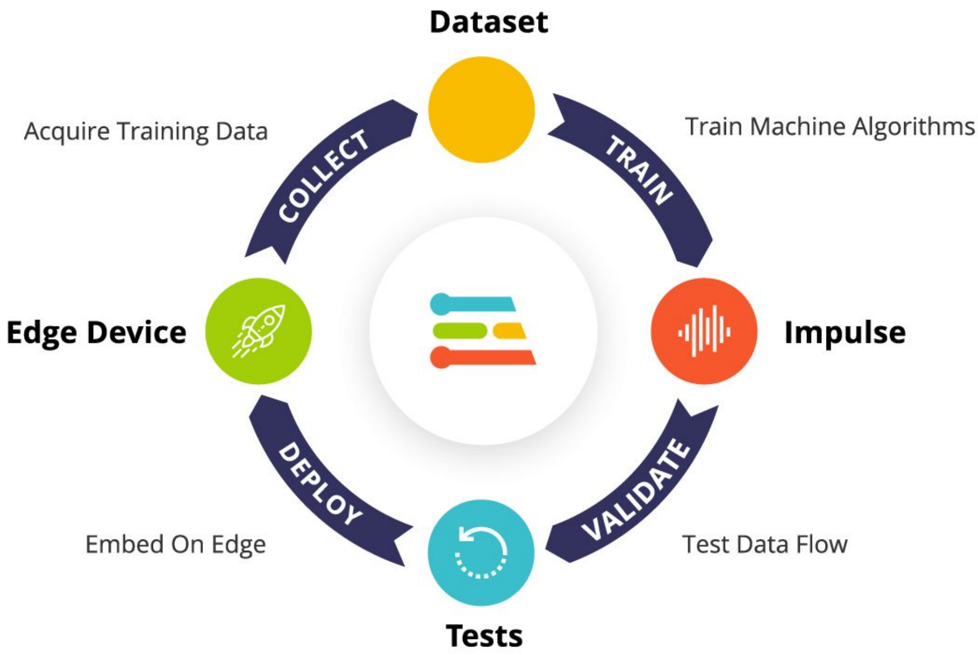

Figure 2.2: Edge Impulse Project Interface

Chapter 3

System Design

This chapter provides a detailed discussion of the proposed model for the in-cabin controlling, monitoring and collision sensing of a car.

3.1 Functional block diagram 1 for in-cabin monitoring system

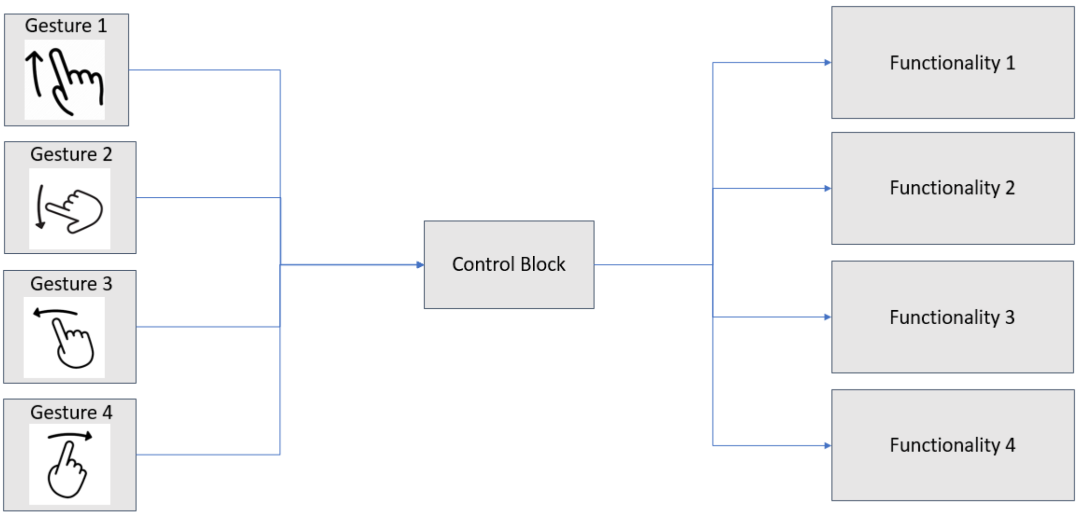

Figure 3.1: Block Diagram of In-Cabin Monitoring System

In the Block Diagram of the In-Cabin Monitoring System (Figure 3.1), the integration of gesture-based control is highlighted. The diagram explains the gestures (Up, Down, Left, Right) to activate specific in-cabin functions. Enhancing user interaction with features like sunroof, air conditioning, audio alerts and indicators.
Functionality 1 for opening and closing of sunroof.
Functionality 2 for controlling air conditioning through monitoring temperature.
Functionality 3 for controlling infotainment like music.
Functionality 4 for controlling indicators.

3.2 Functional block diagram 2 for air bag control system

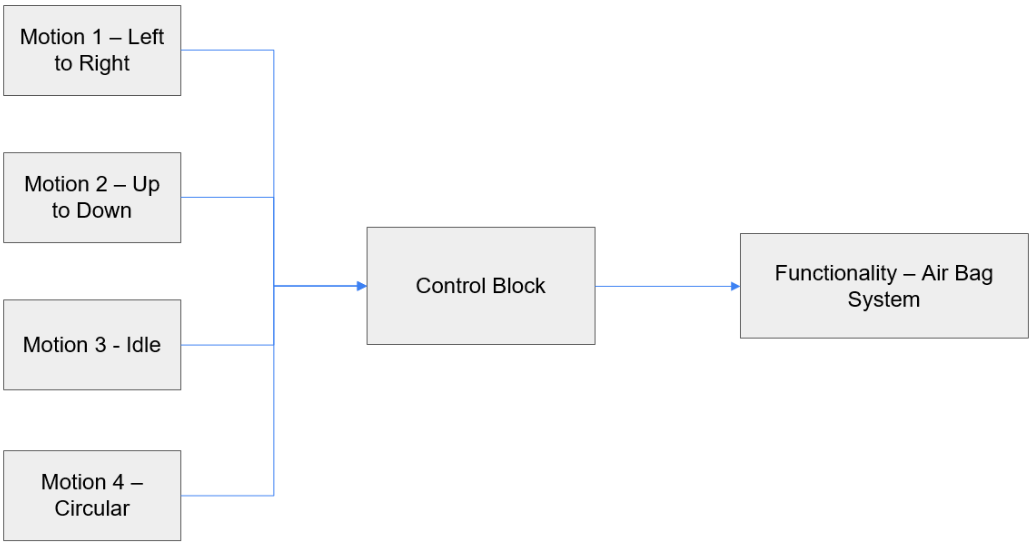

Figure 3.2: Airbag Control System Block Diagram

In Figure 3.2, the Airbag Control System Block Diagram illustrates the integration of motion sensing technology. Key components, including the Airbag Control System. Motion Sensing Technology, likely represented by sensors, detects abrupt changes in vehicle motion, ensuring timely airbag activation and emphasizing its crucial role in enhancing passenger safety.

Chapter 4

Implementation details

The implementation details concerning hardware and software are detailed in this chapter.

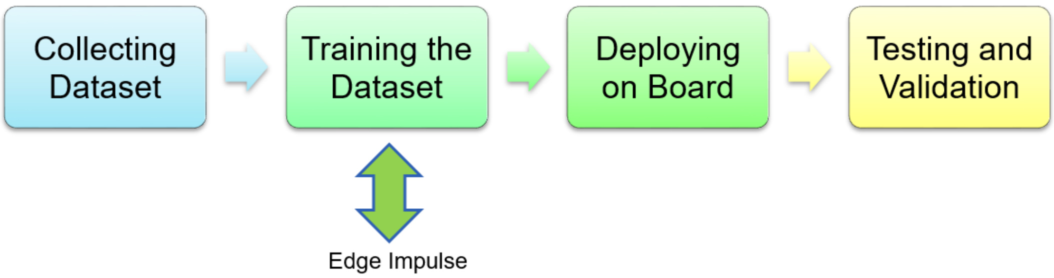

Figure 4.1: Integrating sensors, accelerometers, and neural networks for precise collision detection.

The above Figure 4.1 showcases the integration of gesture sensors, accelerometers, and neural network processing in the airbag deployment system is illustrated above. These components work cohesively to enhance collision detection capabilities and optimize airbag deployment, ensuring passenger safety in critical road situations.

4.1 Specifications and final system architecture

The system architecture used to train the model is a Neural network. The neural network has been designed with the following default training settings (as is in Edge Impulse) with the Number of training cycles (epochs) seeming to be 30, the Learning rate is set to 0.0005 and the Drop rate is taken as 0.25.

4.2 Algorithm

4.2.1 Algorithm For In-Cabin Gesture Monitoring System

Algorithm 1 Gesture Detection Algorithm

1: **S**tart

2: **I**nitialize the gesture sensor and check for initialization success: The APDS9960 gesture sensor is initialized, configuring communication settings and verifying.

3: **C**ontinuously check for available gestures from the APDS9960 sensor: In a continuous loop, the program monitors the sensor for detection of gestures, categorizing them into UP, DOWN, LEFT, or RIGHT.

- **UP:** Toggle the state of a servo motor for a sunroof.
- **DOWN:** Turn on a motor for air conditioning, read the temperature and display it on the serial monitor.
- **LEFT:** Trigger a sequence of beeps using a buzzer.
- **RIGHT:** Analyze PDM data (audio samples) and control indicators based on sound intensity. Repeat the loop continuously.

4: **S**top

4.2.2 Algorithm For Air Bag Control System

Algorithm 2 Airbag Monitoring System Algorithm

1: **E**stablish Edge Impulse Project Create a project on the Edge Impulse platform dedicated to the Airbag Monitoring System.

2: **C**apture Accelerometer Data Retrieve accelerometer data from the sensor, encompassing readings along each axis (x, y, z).

3: **D**efine Data Labels Define labels for the acquired data, encompassing categories like 'Up-Down,' 'Left-Right,' 'Idle,' and 'Circular.'

4: **G**ather and Upload Training Data Aggregate a labeled dataset of accelerometer data for model training, ensuring meticulous labeling for the predefined activities. Upload this dataset to Edge Impulse.

5: **D**esign Model Architecture Choose or design an appropriate machine learning model architecture for processing accelerometer data, using Edge Impulse's pre-built models for added convenience.

6: **T**rain the Model Initiate and oversee the training process on Edge Impulse's platform using the labeled dataset.

7: **E**valuate and Test Assess the accuracy and performance of the trained model by employing a distinct test dataset.

8: **G**enerate and Deploy the Model Upon satisfaction, generate the model for deployment through Edge Impulse.

9: **I**ntegrate the Model into the Algorithm Develop an Arduino BLE Sense 33 library, load the model, and process new accelerometer data seamlessly.

10: **E**xecute the Algorithm Apply the algorithm to real-time or recorded accelerometer data, obtaining predictions or classifications tailored for airbag monitoring.

11: **M**onitor and Refine Continuously monitor the algorithm's performance, iterating on the model or algorithm as needed to enhance accuracy and ensure robust airbag monitoring.

Chapter 5

Results and discussions

5.1 Data Collection

The data is collected in four different labels named left-right, idle, up-down, and circular using Edge Impulse. Twenty samples of ten seconds each are collected for each label

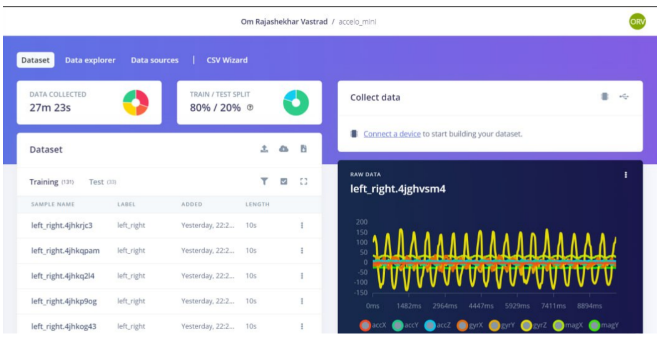

Figure 5.1: Data Collection of left-right motion using Edge Impulse

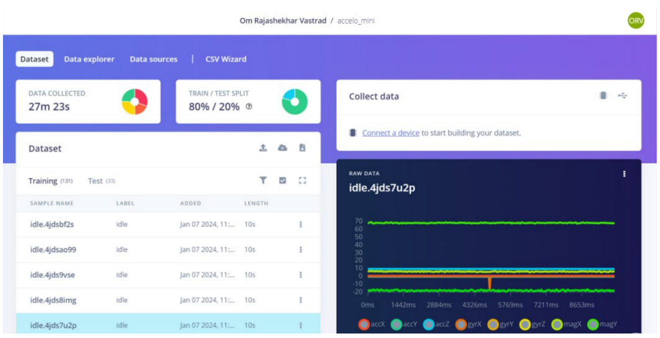

Figure 5.2: Data Collection of idle motion using Edge Impulse

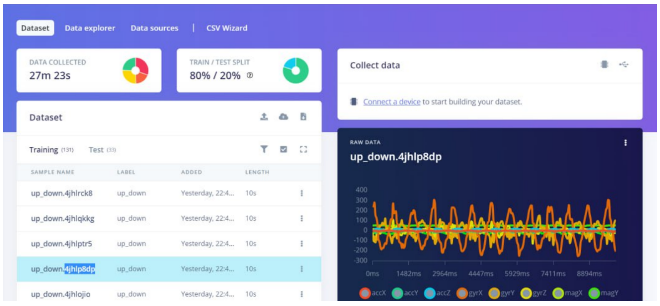

Figure 5.3: Data Collection of up down motion using Edge Impulse

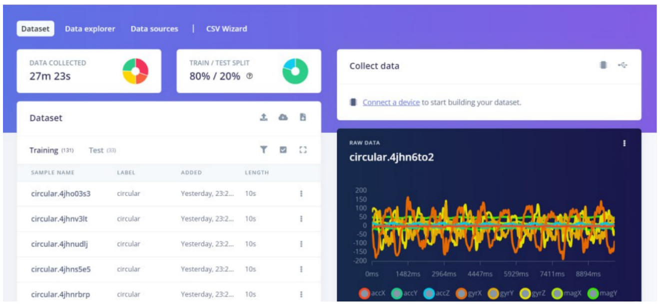

Figure 5.4: Data Collection of circular using Edge Impulse

5.2 EON Tuner

The EON Tuner eliminates the need for manual parameter selection to obtain optimal model accuracy, reducing the user's technical knowledge requirements and decreasing the total time to get from data collection to a trained model deployed on your edge device

The EON Tuner automatically optimizes the hyperparameters of a machine learning model. Hyperparameters are the settings that control the learning process of a machine learning algorithm, such as the number of hidden layers in a neural network or the learning rate of a gradient descent algorithm.

Figure 5.5: Illustration of EON Tuner

5.3 Data Classification Using Neural Network

Confusion Matrix: The model achieves one hundred per cent accuracy as the data is collected in large numbers also due to the small value of the learning rate.

Figure 5.6: Confusion matrix and the classified data

5.4 Deployment

The deployment of the trained model on the microcontroller board allows for real-time gesture recognition in the car, enabling the driver to control various functions without taking their hands off the steering wheel.

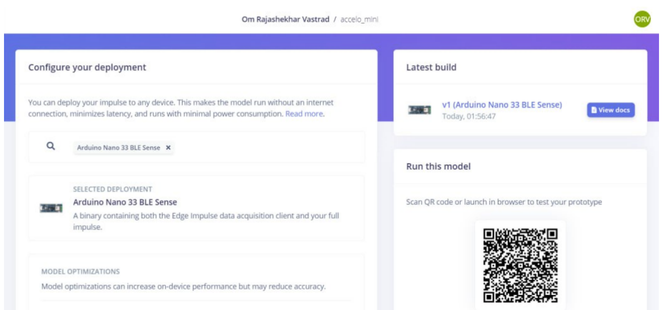

Figure 5.7: Deployment

5.5 Hardware Implementation

Hardware implementation comprises of a gesture-based control system, integrating sensors and circuits for in-cabin command features like sunroof and air conditioning.

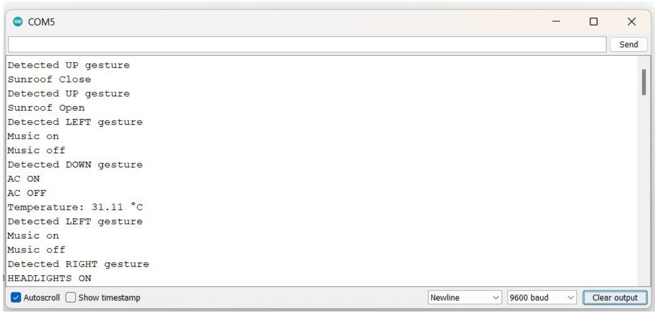

Figure 5.8: Output Results of Gesture Recognition

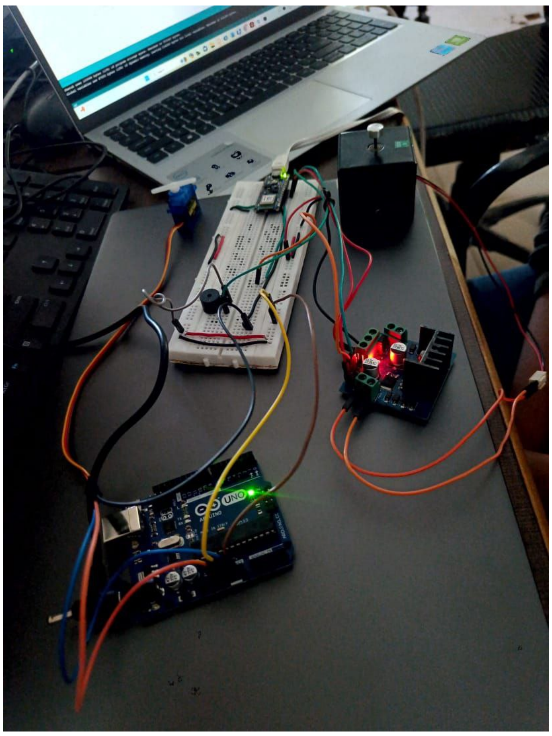

Figure 5.9: Hardware Implementation Setup

The hardware setup involves a gesture sensor linked to an Arduino microcontroller. This system facilitates simple control of in-cabin features through hand gestures. Integrated components include servo motors for sunroof simulation, motors for air conditioning control, a buzzer for warnings, and a Pulse-density modulation (PDM) audio module for indicator lights. These interconnected components ensure a responsive and user-friendly interface

Chapter 6

Conclusions and Future Scope

Gesture-based car systems play a crucial role in utilizing sensors and innovative technology to enhance vehicle dynamics performance. This not only contributes significantly to the vehicle development process but also plays a major role in ensuring driver safety on the road. By leveraging the gestures for in-cabin controls, such as adjusting music volume and managing the sunroof's open/close functions, these systems offer a seamless and hands-free approach to interacting with the vehicle's features. The integration of gesture-based technology in cars reflects a dedication to enhancing driving experiences, making them more efficient, and user-friendly. As the automotive landscape continues to evolve, gesture-based car systems marks the way for a safety, technologically advancement, and enjoyable driving environment.However, it is important to recognize the crucial role of airbag system ensuring passenger safety.The airbag system operates independently, relying on the advanced technologies, including acclerometer for accurate collision dectection.This air bag system come up with a protective cushion based on the requirement during the collision this ensures the safety and a smooth driving experiences

Thus, We can expect improved precision in gesture recognition, enabling more accurate control of in-car features. This may lead to additional in-cabin functions, enhancing the overall driving experience. A gesture-based system can be utilized to provide riders with real-time updates on temperature, and music player control. This could prevent further failures and accident prevention in the long run.

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