Autonomous IoT-Enabled Hazard Detection and Communication System for Deaf Drivers

Project ID: 24-25J-132

Project Proposal Report

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Supervisor: Dr. Kapila Dissanayaka

B.Sc. (Hons) Degree in Information Technology
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Declaration

We declare that this is our own work, and this proposal does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any other university or Institute of higher learning and to the best of our knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

Name	Student ID	Signature
Fernando W.T.R.P	IT21278280	WRP [signature]

The above candidates are carrying out research for the undergraduate Dissertation under my supervision.

Dissanayake KD ....

(Signature of the supervisor)

22/08/2024. ....

Date

Abstract

The purpose of this study is to develop an advanced, highly precise system designed to enhance the situational awareness of deaf drivers by accurately detecting and localizing vehicle horn sounds. Deaf drivers face significant challenges in responding to auditory cues in traffic, which can compromise their safety. Existing solutions, while helpful, often lack the necessary accuracy and real-time responsiveness needed to effectively alert drivers to critical sounds such as vehicle horns. This study addresses these shortcomings by implementing a comprehensive system that not only detects horn sounds but also localizes their source (determines if the sounds are coming from behind the car on the left or right side) and provides immediate visual and haptic feedback to the driver.

The research focuses on the design and development of a Continued Vehicle Horn Detection and Alert System. This system employs two strategically placed microphones behind the vehicle to capture horn sounds within a 10-meter range. The sound signals are processed using Time Difference of Arrival (TDOA) algorithms to estimate the direction of the horn, whether it is coming from the left or right side of the vehicle. Additionally, the system measures the intensity of the horn sound on a scale of 1 to 10, helping to prioritize alerts based on the urgency of the situation. The sound frequency is analyzed using machine learning models to accurately classify and differentiate between multiple vehicles, thereby improving the system's reliability in complex traffic environments.

The system includes a vibrating steering wheel cover that provides haptic feedback, ensuring that alerts are felt by the driver. Visual alerts are delivered through a mobile app with a split-screen interface, featuring color-coded alerts to clearly indicate the direction of the horn sound.

The findings from this research indicate that the system is capable of providing real-time alerts with high accuracy, significantly improving the situational awareness of deaf drivers. The integration of visual and haptic feedback, along with a user-friendly mobile application interface, ensures that the alerts are easily interpretable and actionable. In conclusion, the developed system offers a novel and effective solution to the safety challenges faced by deaf drivers, filling a critical gap in existing driving assistance technologies .

Key words : Deaf Drivers, Haptic Feedback, Machine Learning, Real-Time Alert System, Vehicle Horn Detection

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Introduction

The safety of deaf drivers is a critical concern in modern road traffic systems, where auditory cues such as vehicle horns play a vital role in alerting drivers to potential hazards. Deaf drivers are at a disadvantage because they cannot hear these critical alerts, making it essential to develop systems that enhance their situational awareness through other sensory inputs, such as visual and haptic feedback. The proposed research component, "Continued Vehicle Horn Detection and Alert System," seeks to address this issue by developing a system that accurately detects and localizes vehicle horn sounds, providing timely visual and haptic alerts to deaf drivers.

Research in this domain has evolved significantly over the past decade. Various studies have explored the integration of IoT (Internet of Things) devices and advanced signal processing techniques to assist drivers with hearing impairments. For example, the development of automatic emergency signal recognition systems has laid the groundwork for detecting auditory cues in real-time and converting them into actionable alerts for drivers [1]. Moreover, IoT-based horn detection systems have shown promise in improving safety for four-wheel driving by utilizing microphones and sound processing algorithms to detect horn sounds and alert drivers accordingly [2].

To implement the proposed system effectively, a solid understanding of several relevant technologies and techniques is required. Acoustic signal processing is fundamental for capturing and analyzing the frequencies of car horns, enabling the system to identify and classify sounds accurately. Machine learning (ML) techniques, particularly those focused on sound classification, are crucial for distinguishing between different types of vehicle horns and prioritizing alerts based on the urgency of the sound [3]. Additionally, sound localization methods, such as the Time Difference of Arrival (TDOA), are essential for determining the direction of incoming sounds, allowing the system to provide accurate visual cues about the source of the horn [4].

The state of the art in this field includes various approaches to assist deaf drivers by converting auditory information into visual or haptic feedback. Systems like "The Sight for Hearing" have demonstrated the potential of IoT-based solutions to enhance driving safety by providing real-time alerts through visual displays and vibrations [5]. Additionally, mobile applications that support deaf drivers, such as those that offer iconographic interfaces or urgent communication tools, have been developed to facilitate better interaction with their environment [6]. These tools often feature color-coded interfaces and split-screen designs to help drivers understand the direction and nature of potential hazards .

Past research has primarily focused on developing systems that provide visual or haptic alerts based on detected auditory signals. However, these systems often lack the precision and integration necessary for a seamless driving experience. The proposed research aims to build on this foundation by developing a more integrated and specialized system that combines sound localization, real-time alerts, and a user-friendly mobile app interface. This system will feature a split-screen interface on the mobile app, color-coded to indicate the direction of the detected horn sound, and a vibrating steering wheel cover to provide tactile feedback, enhancing the overall safety and awareness of deaf drivers [8].

Background and Literature Survey

The "Continued Vehicle Horn Detection and Alert System" is designed to enhance situational awareness for deaf drivers by accurately detecting and localizing vehicle horn sounds, providing timely visual and haptic alerts. This section offers a detailed overview of the research domain, the background of the problem, relevant studies, and the significance of this research, with a specific focus on its application in Sri Lanka, where the number of deaf drivers is steadily increasing.

Overview of the Domain

Assistive technologies for drivers have seen significant advancements, particularly with the integration of IoT, machine learning, and advanced signal processing techniques. These technologies enable the development of intelligent systems that can detect and respond to various driving conditions in real-time. However, there is a notable gap in systems tailored for deaf drivers, who rely heavily on visual and tactile feedback due to their inability to hear auditory signals like vehicle horns [1]. This research aims to address this gap by introducing a system that not only detects but also localizes and prioritizes vehicle horn sounds, thereby enhancing the safety and driving experience of deaf individuals.

Background of the Problem

In Sri Lanka, the growing number of deaf drivers presents unique challenges, particularly concerning road safety. Deaf drivers face significant difficulties due to their inability to perceive auditory signals, such as vehicle horns, which are crucial for avoiding potential hazards. Research indicates that deaf drivers are more likely to be involved in accidents due to delayed reactions and difficulty in interpreting environmental cues [5][2]. Existing assistive systems often fail to meet the specific needs of deaf drivers, particularly in the accurate detection and localization of sounds.

To address these issues, the proposed system deploys microphones on the vehicle to detect horn sounds, measure their intensity, and provide visual and haptic feedback to the driver. This approach not only improves the driver's situational awareness but also reduces the cognitive load associated with constantly monitoring the environment visually.

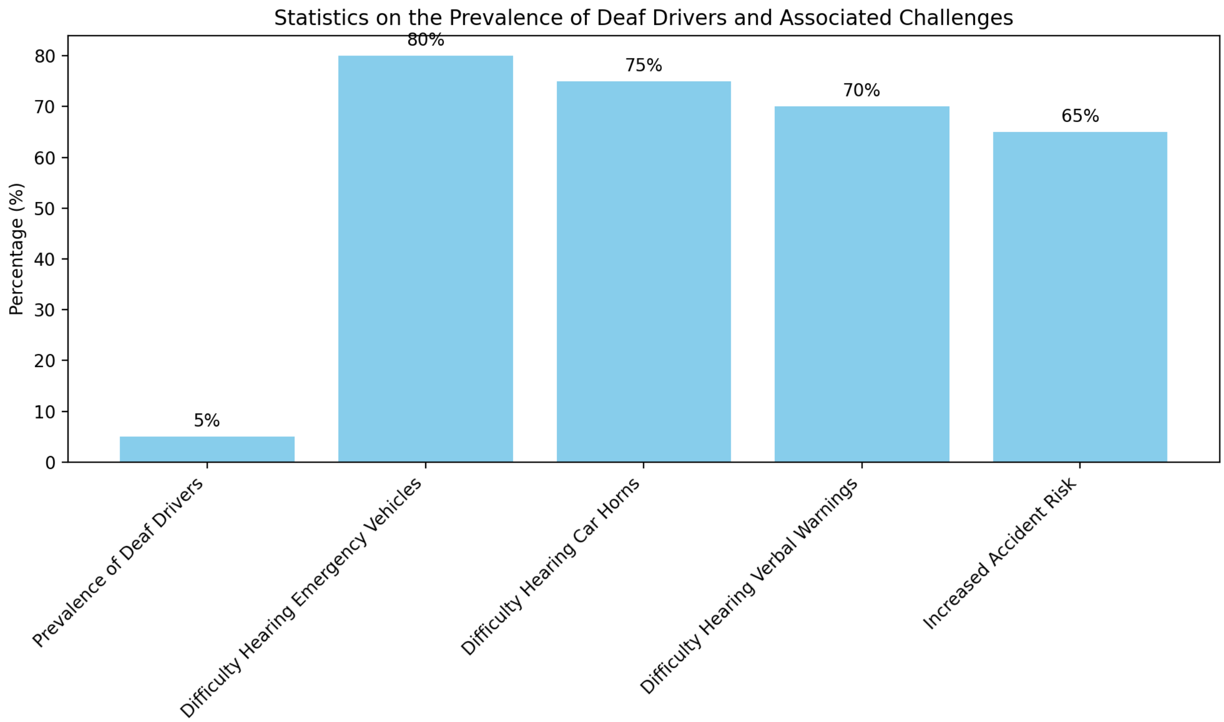

Figure 1 : illustrates the challenge faced by deaf drivers in perceiving auditory signals, which is a critical aspect of safe driving

Contribution to Existing Knowledge

This research introduces a novel approach to sound localization using Time Difference of Arrival (TDOA) algorithms. The TDOA algorithm calculates the time delay between sound detection by two microphones placed at different locations on the vehicle, allowing for precise determination of the direction from which the horn sound originates [4]. This method is particularly relevant in Sri Lanka's urban driving environment, where traffic density can lead to frequent use of vehicle horns.

Moreover, the research employs machine learning techniques to analyze and classify horn sounds based on frequency patterns and intensity levels. By training models to recognize different types of horn sounds, the system can prioritize alerts based on urgency, providing more contextually relevant feedback to the driver [3]. This builds upon previous work that focused primarily on basic sound detection without incorporating machine learning or advanced signal processing techniques [6].

The mobile application developed as part of this research features a split-screen interface with color-coded alerts, indicating the direction of the detected horn sound. This user-friendly design enhances the system's usability, making it accessible to a wide range of users with varying levels of technological proficiency [9]. The integration of haptic feedback through a vibrating steering wheel cover ensures immediate and clear alerts, even when the driver's visual attention is divided [8].

Significance of the Research

The significance of this research is twofold. Firstly, it addresses a critical gap in assistive technologies for deaf drivers, particularly in Sri Lanka, where the road traffic environment can be challenging due to high congestion and frequent use of vehicle horns. By providing a reliable method for detecting and localizing horn sounds, this system enhances road safety for deaf drivers, reducing the likelihood of accidents and improving their driving experience.

Secondly, this research contributes to the broader field of IoT-based assistive technologies by demonstrating the application of machine learning and signal processing in solving complex real-world problems. The insights gained from this study could inform the development of similar systems for other applications, such as pedestrian safety or emergency vehicle detection, further advancing the field of intelligent transportation systems.

For fund providers, investing in this research offers the potential to support a technology with significant social impact, improving the quality of life for deaf drivers and promoting safer driving practices. The successful implementation of this system could also open up opportunities for commercialization, particularly in regions with similar traffic conditions to Sri Lanka.

Research Gap

In the field of assistive driving technologies for deaf drivers, the primary research gap revolves around the lack of comprehensive systems that integrate multiple sensory inputs and outputs to enhance situational awareness. Most existing solutions focus on isolated features, such as horn detection or visual alerts, but fail to provide a holistic approach that addresses the multifaceted needs of deaf drivers. This lack of integrated systems, particularly those that combine detection, localization, and multi-modal alert systems, represents a significant challenge and opportunity for innovation.

Features/Capabilities	Research A	Research B	Research C	Proposed Research
Real Time Horn Sound Detection	✓	✗	✓	✓
Sound Localization (Direction Detection)	✗	✓	✗	✓
Machine Learning for Sound Classification	✗	✗	✓	✓
Sound Intensity Analysis & Prioritization	✗	✗	✗	✓
Visual Alerts (Mobile Split Screen) & Haptic Feedback Alerts (Vibrating Steering Wheel Cover)	✗	✗	✗	✓
Comprehensive Safety Enhancement	✓	✗	✗	✓

Figure 2 : Comparison Between Existing Systems

Identified Gaps

1. Lack of Integrated Systems: Current research primarily focuses on individual aspects of assistive technologies, such as real-time horn detection or visual alerts, but these systems are not integrated to offer a comprehensive solution for deaf drivers. The gap lies in the need for a system that not only detects horn sounds but also localizes the source and provides appropriate visual and haptic feedback [1].
2. Sound Localization and Classification: Research on sound localization and classification for assistive driving technologies is still in its infancy. Existing studies often overlook the importance of accurately identifying the direction of sound and classifying different types of sounds using machine learning techniques. Addressing this gap is crucial for improving the situational awareness of deaf drivers [5].
3. Multi-modal Feedback Mechanisms: There is a significant gap in research related to the implementation of multi-modal feedback mechanisms. Most systems rely solely on visual alerts, which may not be sufficient in all driving situations. The combination of visual and haptic feedback, such as vibrating steering wheels, remains underexplored in the current literature [2].
4. Application in Developing Countries: In developing countries like Sri Lanka, the adoption of advanced assistive driving technologies is limited. Research often fails to consider the unique challenges faced by drivers in these regions, including the prevalence of hearing disabilities and the lack of infrastructure to support sophisticated driving systems. This presents an opportunity to develop systems that are adaptable to the specific needs and conditions of these regions.

Proposed Contribution

This research seeks to fill the identified gaps by developing a Continued Vehicle Horn Detection and Alert System that integrates sound localization, machine learning-based sound classification, and multi-modal alerts (visual and haptic). The proposed system will address the following:

- Holistic Integration: By combining real-time horn detection, sound localization, and machine learning-based classification, the system will provide comprehensive situational awareness to deaf drivers. This integrated approach will ensure that drivers are not only aware of the presence of a horn but can also discern its direction and urgency.
- Enhanced Feedback Mechanisms: The inclusion of both visual and haptic alerts will ensure that drivers receive timely and noticeable alerts, significantly improving their response time and overall safety.
- Applicability in Developing Countries: The system will be designed with adaptability in mind, ensuring that it can be effectively implemented in regions with varying levels of technological infrastructure, such as Sri Lanka. This focus on broader applicability will extend the benefits of the research beyond advanced economies, contributing to global driving safety.

By addressing these gaps, the proposed research will make significant contributions to the existing body of knowledge and scientific development in the field of assistive driving technologies. The outcomes are expected to enhance the safety and driving experience for deaf drivers and provide a model for future research in this domain.

Research Problem

Problem Statement

Deaf drivers face unique challenges on the road due to their inability to hear crucial auditory cues, such as vehicle horns, which play a vital role in alerting drivers to potential hazards and urgent situations. The lack of effective assistive driving technologies that can compensate for this sensory limitation significantly reduces the situational awareness and safety of deaf drivers. Current solutions are inadequate in several critical aspects, including real-time sound detection, localization, and the effective communication of alerts through non-auditory means. The proposed research aims to address these gaps by developing an advanced system that accurately detects and localizes vehicle horn sounds, providing timely visual and haptic feedback to enhance the driving experience and safety of deaf drivers.

Research Questions

1. **How can an IoT-enabled system effectively detect and localize vehicle horn sounds to enhance situational awareness for deaf drivers?**
    - This research question focuses on developing a solution that integrates IoT technologies and machine learning algorithms to provide deaf drivers with real-time alerts of nearby vehicle horns. It aims to address the challenge of accurately detecting and interpreting auditory signals, transforming them into actionable visual and haptic feedback to improve the safety and awareness of deaf drivers on the road.
2. **What machine learning algorithms are most effective for classifying vehicle horn sounds in noisy urban environments?**
    - This question aims to explore which machine learning techniques are best suited for differentiating vehicle horn sounds amidst background noise. The goal is to ensure that the system can accurately classify and prioritize horn sounds even in complex and dynamic driving environments, such as busy city streets.
3. **How can the system optimize the placement and calibration of microphones to achieve maximum detection accuracy and coverage?**

    - This question investigates the optimal setup of the system's hardware components to ensure accurate sound detection and localization. It seeks to understand the best practices for microphone placement and calibration to maximize the system's effectiveness in detecting horn sounds from different directions and distances.
4. **How does the intensity of a vehicle horn sound correlate with the urgency of the alert, and how can this be effectively communicated to the driver?**
    - This question explores how the system can assess the intensity of horn sounds to prioritize alerts based on urgency. By understanding the relationship between sound intensity and alert importance, the system can provide drivers with more precise and meaningful notifications.
5. **What are the key user interface design principles for conveying sound alerts through visual and haptic feedback to ensure ease of use and driver comprehension?**
    - This question delves into the design of the system's user interface, focusing on how visual and haptic feedback can be effectively used to communicate alerts. It seeks to determine the most intuitive ways to present information to drivers, ensuring that alerts are easily understood and acted upon.
6. **What impact does the integration of this system have on the overall driving experience and safety of deaf drivers, and how can this be quantitatively measured?**
    - This question aims to evaluate the effectiveness of the system in enhancing the driving experience and safety of deaf drivers. It focuses on developing metrics and methodologies to quantitatively measure improvements in situational awareness and driving safety brought about by the system.

Research Problems

1. **Lack of Real-Time Sound Detection and Localization for Deaf Drivers:**
    - Deaf drivers face a significant disadvantage on the road due to their inability to hear vehicle horns, which serve as crucial auditory cues for indicating nearby hazards or urgent situations. Current assistive technologies lack the precision and speed required to detect and localize horn sounds in real-time effectively. This limitation poses significant safety risks and reduces situational awareness for deaf drivers. The research problem seeks to address this gap by developing a system that accurately detects vehicle horn sounds, determines their direction, and provides immediate alerts, enhancing the overall driving experience for the hearing impaired.
2. **Inefficiency of Existing Machine Learning Algorithms in Noisy Environments:**
    - Existing sound detection systems struggle to accurately identify vehicle horn sounds in noisy urban environments, where background noise can interfere with sound classification. The challenge lies in developing machine learning algorithms that can effectively filter out background noise and focus on detecting relevant horn sounds. This problem highlights the need for robust algorithms

capable of distinguishing between various sound frequencies and intensities to ensure accurate detection.

3. **Inadequate Microphone Placement and Calibration for Optimal Sound Detection:**
    - Proper microphone placement and calibration are crucial for accurate sound detection and localization. However, there is a lack of standardized guidelines for optimizing the hardware setup in vehicles, leading to inconsistent detection accuracy. This research problem focuses on identifying the best practices for microphone placement and calibration to ensure maximum coverage and reliability in detecting horn sounds from different directions and distances [40].
4. **Difficulty in Prioritizing Alerts Based on Sound Intensity and Urgency:**
    - While vehicle horn sounds vary in intensity, current systems often fail to prioritize alerts based on the urgency of the sound. This can lead to either over-alerting the driver with low-priority sounds or under-alerting for critical situations. The research problem involves developing a method to assess sound intensity accurately and prioritize alerts based on their urgency, ensuring that deaf drivers receive timely and relevant notifications.
5. **Challenges in Designing Intuitive User Interfaces for Deaf Drivers:**
    - Designing user interfaces that effectively convey sound alerts through visual and haptic feedback is challenging. Many existing systems do not adequately consider the ease of use and comprehension for deaf drivers, leading to potential misinterpretations of alerts. This research problem focuses on identifying key user interface design principles that enhance the intuitiveness and effectiveness of visual and haptic feedback, ensuring drivers can quickly understand and respond to alerts.
6. **Scalability and Adaptability of the System Across Different Vehicle Types:**
    - The adaptability and scalability of assistive systems across various vehicle types and configurations remain a significant challenge. Each vehicle may require different hardware setups and calibration adjustments to maintain detection accuracy and reliability. This research problem addresses the need for a flexible system design that can be easily adapted to different vehicles, ensuring consistent performance across all setups.
7. **Evaluating the Impact of the System on Driving Safety and Awareness:**
    - Measuring the effectiveness of the system in enhancing the driving experience and safety of deaf drivers is complex. There is a need for quantitative metrics and methodologies to evaluate the impact of the system on situational awareness and safety. This research problem seeks to develop assessment tools and frameworks to measure improvements in driving safety and awareness, providing concrete evidence of the system's benefits for deaf drivers.

Objectives

The primary objectives of this research are designed to address the critical challenges faced by deaf drivers in detecting and localizing vehicle horn sounds. These objectives aim to enhance the safety and situational awareness of deaf drivers by developing a comprehensive system that integrates advanced technologies.

Main Objective:

- **Enhance Situational Awareness for Deaf Drivers:** The main objective of this research is to develop an IoT-enabled system that can effectively detect, localize, and prioritize vehicle horn sounds, providing real-time alerts to deaf drivers through visual and haptic feedback. This system aims to improve the overall driving experience and safety for deaf drivers by addressing the challenges associated with auditory signal interpretation [1]-[3].

Specific Objectives:

1. **Detect Vehicle Horn Sounds:**
    - **Objective Details:** The goal is to create a robust detection system capable of distinguishing vehicle horn sounds from other environmental noises within a 10-meter range. This involves deploying sensitive MEMS microphones and developing noise-robust sound detection algorithms that can operate effectively in various driving environments, including urban areas with high ambient noise levels. The system will utilize frequency analysis and pattern recognition techniques to accurately identify the distinct acoustic signature of vehicle horns.
2. **Sound Localization:**
    - **Objective Details:** The focus of this objective is to implement advanced sound localization techniques to accurately determine the direction of the horn sound. The system will use Time Difference of Arrival (TDOA) methods and beamforming algorithms to calculate the time delay between sound waves reaching two or more spatially separated microphones. This will allow the system to pinpoint whether the sound originates from the left or right side of the vehicle, providing directional cues to the driver.
3. **Prioritize Alerts:**
    - **Objective Details:** This objective aims to develop an alert prioritization system that analyzes the intensity of detected horn sounds. The system will assess the amplitude and frequency characteristics of the sound to gauge its urgency. Higher-intensity sounds or those that match critical frequency patterns will trigger more immediate and prominent alerts. This prioritization is essential to

ensure that the driver is informed of the most critical situations first, improving their ability to respond effectively in high-stress scenarios.

4. **Provide Real-Time Alerts:**
    - **Objective Details:** The final objective is to design and implement a user interface that provides real-time visual and haptic feedback to the driver. The system will convert detected and localized horn sounds into intuitive visual signals on a dashboard display and vibrations on the steering wheel. This multimodal feedback approach will ensure that deaf drivers receive timely and clear notifications, helping them make informed driving decisions. The interface design will be user-friendly, with easily interpretable signals to avoid overwhelming the driver.

Methodology

Overall System Diagram

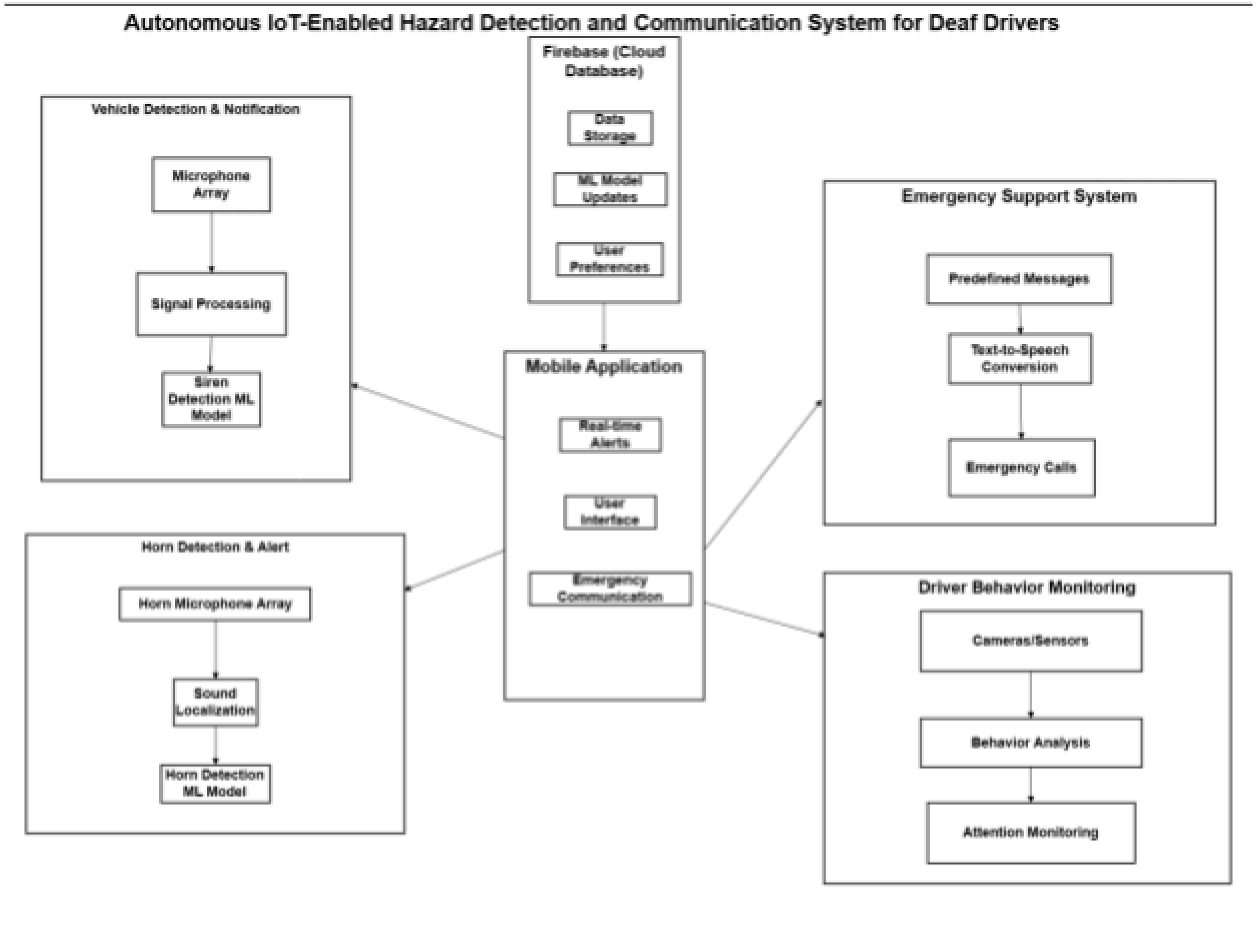

Figure 3 : Overall System Diagram

Individual System Diagram

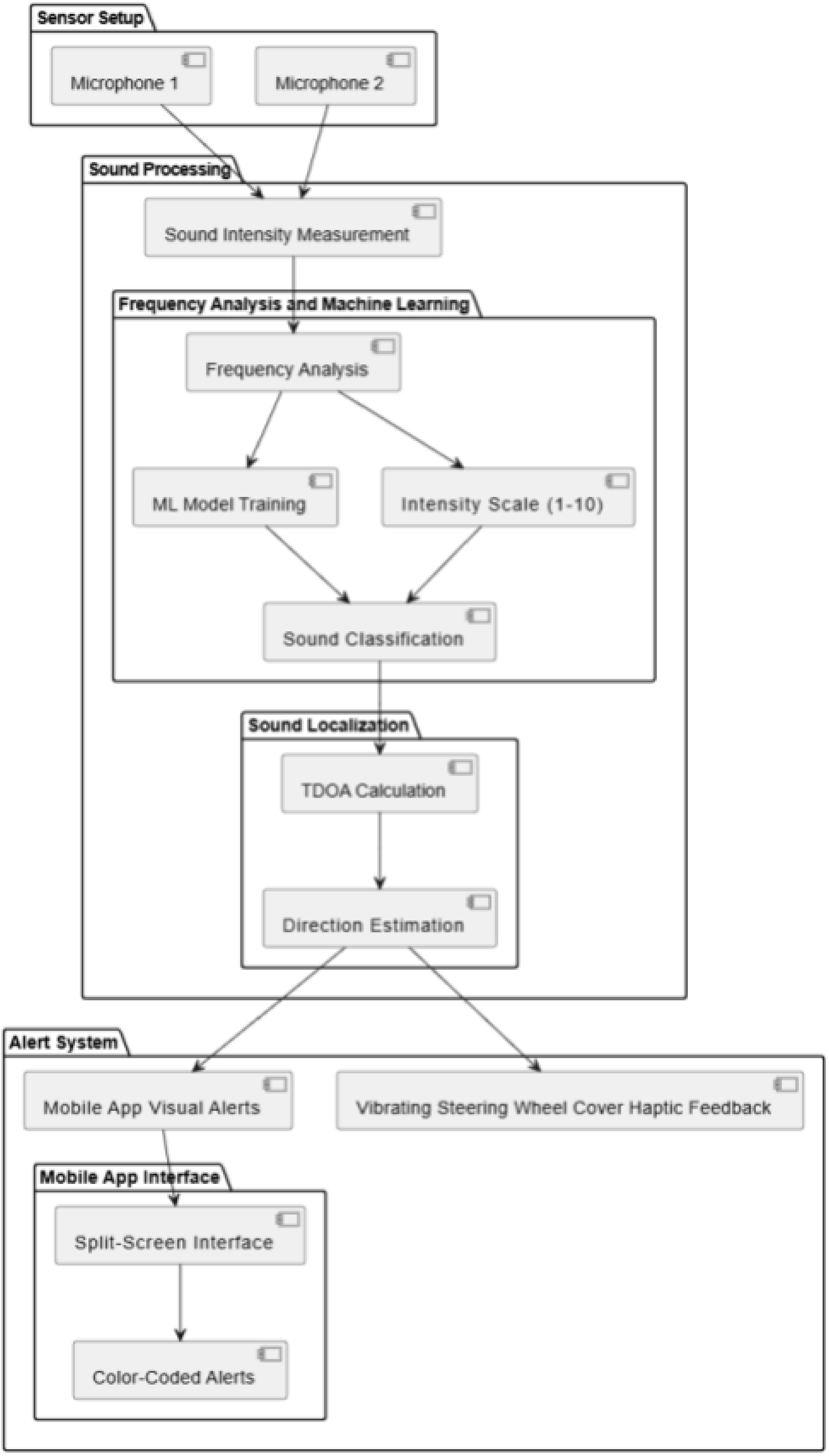

Figure 4 : Individual System Diagram

1. Sensor Setup and Initial Testing

Objective: Deploy a reliable sensor system to capture vehicle horn sounds effectively, ensuring accurate detection and data collection.

1. **Microphone Selection:**
   - **Criteria:** Select two high-sensitivity MEMS (Micro-Electro-Mechanical Systems) microphones, known for their small size, low power consumption, and ability to capture a wide frequency range, particularly the frequency range of typical vehicle horns (around 300 to 4000 Hz).
   - **Considerations:** Ensure the microphones are omnidirectional to capture sounds from all directions, and capable of operating in various environmental conditions (e.g., temperature fluctuations, moisture).
2. **Microphone Placement:**
   - **Distance:** Position the two microphones 1 meter apart, mounted on the rear of the vehicle. This distance helps in accurately capturing the Time Difference of Arrival (TDOA) of the horn sound waves.
   - **Height:** Mount the microphones at an appropriate height (e.g., bumper level) to maximize the exposure to sound waves from other vehicles while minimizing interference from road noise.
3. **Initial Testing and Calibration:**
   - **Test Procedure:** Conduct initial tests in a controlled environment to ensure the microphones accurately capture sound. Test with various horn types and intensities, and at different distances and angles relative to the microphones.
   - **Calibration:** Calibrate the microphones to ensure they are synchronized and their recordings can be accurately compared. This involves ensuring the microphones have the same gain settings and compensating for any differences in their output signals.
   - **Data Logging:** Record the captured sound data in a time-stamped format to facilitate subsequent analysis. Verify that the sound data is clear, with minimal background noise.

4. **Data Transfer Mechanism:**
   - **Wired/Wireless Setup:** Decide on a wired or wireless data transfer mechanism between the microphones and the central processing unit (CPU). Wireless data transfer using Bluetooth or Wi-Fi may be more convenient but must be tested for latency and reliability.
   - **Data Integrity:** Ensure the data transfer mechanism maintains the integrity of the captured sound data, with no loss or distortion during transmission.

2. Sound Intensity Measurement

Objective: Measure the intensity of the captured vehicle horn sounds to prioritize alerts based on the urgency.

1. **Sound Intensity Scale Development:**
    - **Scale Design:** Develop a scale from 1 to 10 to categorize the intensity of horn sounds. The scale is designed to correlate with the perceived loudness and urgency of the horn, with 1 being very low intensity and 10 being extremely loud.
    - **Reference Levels:** Establish reference intensity levels using a sound level meter (in decibels, dB) for each scale point, e.g., 1 may correspond to 60 dB (soft horn) and 10 to 120 dB (very loud horn).

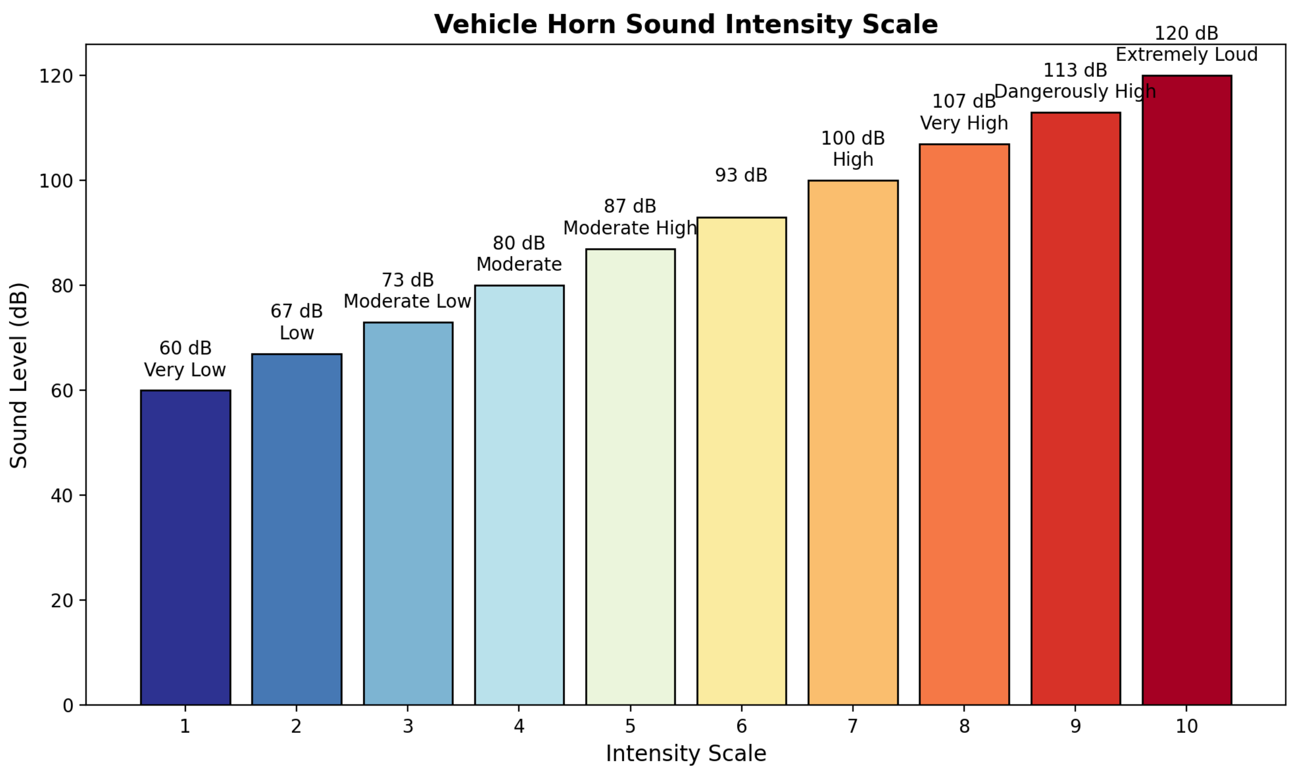

Figure 5 : Vehicle Horn Sound Intensity Scales

2. **Handling Intensity:**

Use Recorded Data:

- **Utilize Pre-Recorded Values: Leverage pre-recorded intensity values on a scale from 1 to 10.**
- **Set Alert Thresholds: Define alert levels based on these intensity values. For instance, trigger an alert when the intensity value is 5 or higher.**

Dynamic Adjustment:

- **Adjust for Noise: Analyze recorded data to adjust thresholds according to background noise levels, especially in noisy environments.**
- **Prevent False Alerts: Establish clear thresholds to avoid false alerts from low-intensity noise.**

3. Frequency Analysis and Machine Learning:

Analyze Frequencies:

Fourier Transform:

- **Use the Fast Fourier Transform (FFT) to convert recorded horn sounds into their frequency components.**
- **Implement FFT on Arduino to process sound data in real-time and identify the frequency ranges of the horn sounds.**

Frequency Range:

- **Focus on the frequency range of 300 Hz to 4000 Hz, where most vehicle horns are located.**
- **Configure Arduino to filter and process frequencies within this range.**

Extract Features:

MFCCs (Mel-Frequency Cepstral Coefficients):

- **Extract MFCCs from horn sounds to enhance classification accuracy.**
- **Use Arduino to capture sound data and send it to the mobile app, where MFCCs can be calculated and analyzed.**

Train Machine Learning Model:

Choose Model:

- **Select a suitable machine learning model for classification, such as Support Vector Machine (SVM), Random Forest, or Convolutional Neural Network (CNN).**
- **Train the model using data processed from Arduino and recorded horn sounds.**

Use Data:

- **Utilize the processed sound data, including intensity levels and features extracted on Arduino, to train the machine learning model in the mobile app.**

4. Sound Localization

Objective: Determine the direction of the horn sound to provide directional alerts to the driver.

1. **Time Difference of Arrival (TDOA) Calculation:**
    - **Signal Processing:** Use cross-correlation to calculate the time delay between the sound signals arriving at the two microphones. This delay is crucial for determining the direction of the sound.

    - **Mathematical Model:** Apply the TDOA formula:

$$\boxed{TDOA = \frac{d\sin(\theta)}{c}}$$

Figure 6 : TDOA Formula

where d is the distance between microphones, θ is the angle of incidence of the sound wave, and c is the speed of sound in air (approximately 343 m/s).

    - **Angle Estimation:** From the TDOA value, calculate the angle θ to estimate whether the sound is coming from the left or right side of the vehicle.

2. **Algorithm Implementation:**
    - **Robustness:** Develop an algorithm that can accurately estimate the direction even in the presence of environmental noise and reflections. Use filtering techniques to clean the sound signal before processing.
    - **Real-time Processing:** Ensure the algorithm operates in real-time, processing the incoming sound data quickly enough to provide immediate feedback to the driver.
3. **Validation and Testing:**
    - **Controlled Tests:** Test the localization algorithm in a controlled environment where the direction of the sound source is known. Use a variety of angles and distances to validate the accuracy of the direction estimation.
    - **Field Tests:** Conduct field tests in real driving conditions, measuring the system's ability to localize sounds amidst typical road noise and traffic conditions.

5. Visual and Haptic Alert Integration

Objective: Design and implement an alert system that provides immediate, clear, and effective feedback to the driver.

1. **Haptic Feedback Mechanism:**
    - **Steering Wheel Cover Design:** Integrate vibration motors into the steering wheel cover to provide haptic feedback. These motors will vibrate on the left or right side, corresponding to the direction of the detected horn sound.
    - **Vibration Patterns:** Develop distinct vibration patterns based on the intensity and urgency of the sound. For instance, a continuous strong vibration may indicate a high-intensity sound, while a short pulse may indicate a lower intensity.

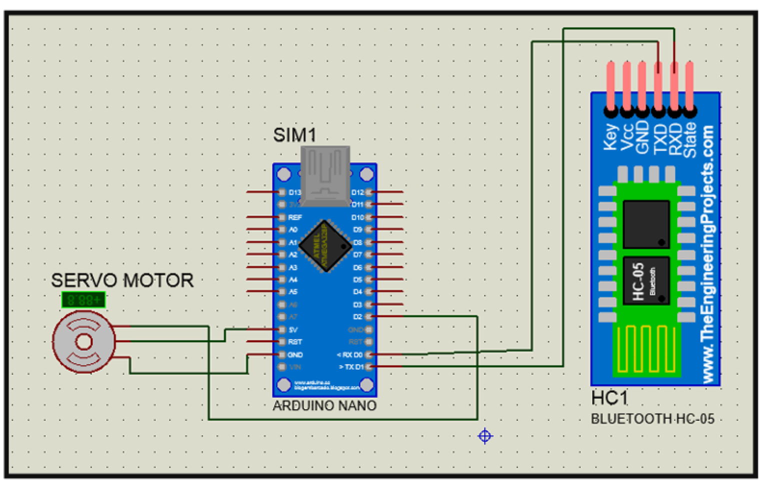

Figure 7 : Circuit used for the Vibrating Steering Wheel Cover

2. **Visual Alert Design:**
    - **Mobile App Interface:** Develop a mobile app interface that displays visual alerts. The app should have a split-screen layout, with separate sections for the left and right sides of the vehicle.
    - **Color Coding:** Use color-coded alerts to indicate the intensity of the detected horn sound. For example, green for low intensity, yellow for medium, and red for high intensity.
3. **Integration with Sound Localization:**
    - **Real-time Synchronization:** Ensure that the visual and haptic alerts are synchronized with the sound localization system, providing the driver with immediate feedback that matches the detected direction and intensity of the sound.
    - **User Testing:** Conduct user tests to validate the effectiveness of the alerts. Measure how quickly and accurately drivers respond to the alerts in a simulated environment, and gather feedback to refine the alert design.

6. Mobile App Interface

Objective: Design a user-friendly mobile application that provides clear and effective alerts and visual feedback to enhance situational awareness for deaf drivers.

1. **Interface Layout Design:**
    - **Split-Screen Design:** Implement a split-screen interface with the left half dedicated to detecting and displaying alerts for sounds originating from the left side of the vehicle, and the right half for the right side.
    - **Alert Indicators:** Incorporate large, easily recognizable icons or symbols (e.g., an ear with a cross symbol) that light up based on the direction of the detected horn sound.

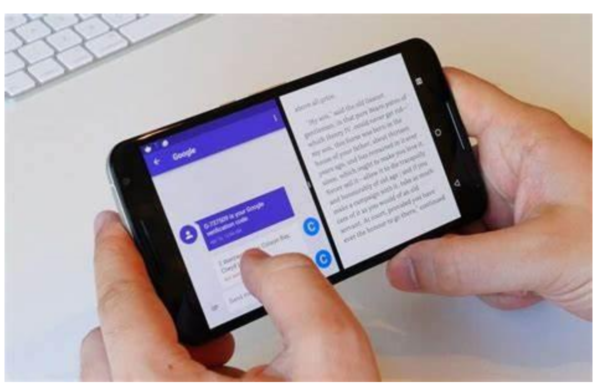

Figure 8 : Split Screen Interface

2. **Visual Alert System:**
    - **Color-Coded Alerts:** Integrate a color-coded system where the intensity of the horn sound dictates the color of the alert on the screen. For example:
        - **Green:** Low intensity, minor alert.
        - **Yellow:** Medium intensity, moderate alert.
        - **Red:** High intensity, critical alert.
    - **Intensity Display:** Display the sound intensity level (1 to 10) as a numeric value alongside the color-coded alert for precise information.
3. **Sound Localization Visualization:**
    - **Directional Arrows:** Use directional arrows or indicators that point towards the left or right, guiding the driver’s attention to the side where the horn sound originated.
    - **Dynamic Movement:** Allow the indicators to dynamically move or pulse in the direction of the sound, providing a more intuitive understanding of where the alert is coming from.
4. **Integration with Haptic Feedback:**
    - **Synchronization:** Ensure that the visual alerts on the mobile app are perfectly synchronized with the haptic feedback provided by the steering wheel, so the driver receives consistent and clear signals.
    - **Haptic Feedback Settings:** Include settings within the app for adjusting the intensity and pattern of the haptic feedback, allowing customization based on the driver’s preferences.
5. **User Interaction Features:**
    - **Alert History:** Provide a history log feature where drivers can review recent alerts, including the direction, intensity, and time of each detected horn sound.
    - **Emergency Notification System:** Incorporate a quick-access emergency button that allows the driver to send a pre-set emergency message to contacts or authorities if they feel threatened or overwhelmed by the alert.
6. **Testing and Validation:**
    - **User Experience Testing:** Conduct comprehensive user experience (UX) testing with deaf drivers to ensure that the interface is intuitive, responsive, and effective in real-world driving scenarios.
    - **Feedback Iteration:** Gather feedback from testers and iterate on the app design to address any usability issues or suggestions for improvement.
7. **System Integration and Final Testing:**
    - **Full System Integration:** Integrate all components, including sensors, ML models, sound localization algorithms, haptic feedback, and the mobile app into a cohesive system. Ensure seamless communication between hardware and software components.
    - **End-to-End Testing:** Perform end-to-end testing in various driving environments to validate the system's overall performance. Test for factors such as response

time, accuracy of sound detection and localization, effectiveness of alerts, and user satisfaction.

8. **Deployment and Maintenance:**
    - **App Deployment:** Prepare the mobile app for deployment on popular platforms like Android and iOS. Ensure it is compatible with a wide range of smartphones and in-car infotainment systems.
    - **Ongoing Updates:** Plan for regular updates to the app to introduce new features, improve performance, and address any bugs or issues reported by users.

Project Requirements

1. Functional Requirements

Functional requirements define the specific behaviors and functionalities the system must have to fulfill its intended purpose. For the **Continued Vehicle Horn Detection and Alert System**, the key functional requirements are:

- **Horn Detection:**
  - The system should accurately detect vehicle horn sounds within a 10-meter range.
  - The microphones should continuously capture sound data, which will be processed to identify horn sounds.
- **Sound Localization:**
  - The system must determine the direction of the horn sound, using Time Difference of Arrival (TDOA) algorithms to calculate whether the sound is coming from the left or right of the vehicle.
- **Real-Time Alerts:**
  - The system should provide immediate feedback to the driver through visual alerts on the mobile application and haptic feedback via the steering wheel cover.
- **Data Logging:**
  - The system should log detected horn sounds along with their intensity, frequency, and localization data for later analysis.

2. User Requirements

User requirements describe the needs and expectations of the end users, in this case, deaf drivers. These requirements ensure the system is user-friendly and meets their specific needs:

- **Ease of Use:**
  - The mobile application interface should be intuitive, allowing users to easily understand the alerts without requiring technical knowledge.
- **Visual and Haptic Feedback:**
  - The alerts must be clear and distinct, with visual indicators on the mobile app and vibration patterns on the steering wheel that clearly signal the direction of the horn sound.
- **Reliability:**
  - The system should operate reliably under various driving conditions, including different weather and noise environments.

3. System Requirements

System requirements are the technical specifications that the system must meet to function correctly:

- **Hardware Requirements:**
  - Two high-sensitivity MEMS microphones for sound capture.
  - An IoT processing unit (e.g., Arduino or Raspberry Pi) to process sound data.
  - A haptic feedback device, such as a vibrating steering wheel cover.
  - A mobile device running Android or iOS for the mobile application.

Figure 9 : Microcontroller - Arduino Uno Board

Figure 10 : Arduino Board Compatible Microphone Sensor

Figure 11 : Servo Motor

- **Software Requirements:**
    - Machine learning libraries (e.g., TensorFlow, PyTorch) for sound classification.
    - Real-time operating system for the IoT device to ensure timely processing.
    - Mobile development framework (e.g., Flutter, React Native) for the app.
- **Network Requirements:**
    - Bluetooth or Wi-Fi connectivity between the IoT device and the mobile application.

4. Non-Functional Requirements

Non-functional requirements specify the quality attributes of the system, including performance, usability, and reliability:

- **Accuracy:**
    - The system should have high precision in detecting and classifying horn sounds, with minimal false positives.
- **Performance:**
    - The system should process and respond to horn sounds within 1 second to ensure timely alerts.
- **User-Friendliness:**
    - The mobile application should have an intuitive design, requiring minimal user interaction while driving.
- **Durability:**
    - The hardware components should be robust and capable of withstanding the rigors of vehicle installation and operation in various environmental conditions.

5. Use Case

Use cases describe specific scenarios in which the system will be used. Tentative use cases include:

- **Use Case 1:** A vehicle approaches from behind with a honking horn. The system detects the sound, determines it is coming from the right, and alerts the driver with a right-side visual cue on the app and a corresponding vibration on the right side of the steering wheel.

Use Case ID : UC1
Title : Detecting and Alerting Based on the Direction of a Honking Horn
Primary Actors: Driver
Secondary Actors: Vehicle approaching from behind (Honking Horn)
Preconditions: - The vehicle is equipped with a sound detection system. - The driver is using the connected mobile app.
Trigger : The system detects a honking sound from a vehicle approaching from behind.
Main Flow: **1. Sound Detection: The system's microphones capture the sound of the horn.** **2. Direction Analysis: The system processes the sound and determines it is coming from the right side.** **3. Alert Generation: The system generates a visual alert on the mobile app's right side.** **4. Haptic Feedback: The system activates a vibration on the right side of the steering wheel.** **5. Driver Awareness: The driver acknowledges the approaching vehicle on the right side.**
Postconditions: **1. The driver is alerted to the vehicle approaching from the right.** **2. The system continues monitoring.**
Alternative Flows: **1. Misidentification: If the system incorrectly identifies the direction, it may log the event for analysis.**

Table 1 - Use Case 1

6. Test Cases

Test cases outline the tests that will be conducted to verify the system meets its requirements:

- **Test Case 1:**

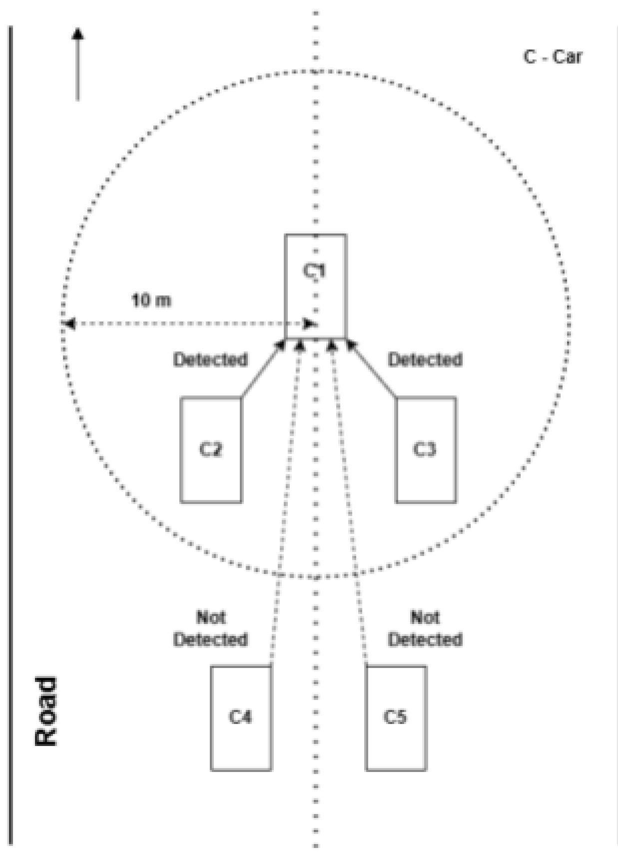

Figure 12 : Verify the system accurately detects horn sounds within the specified 10-meter range.

- **Test Case 2:**

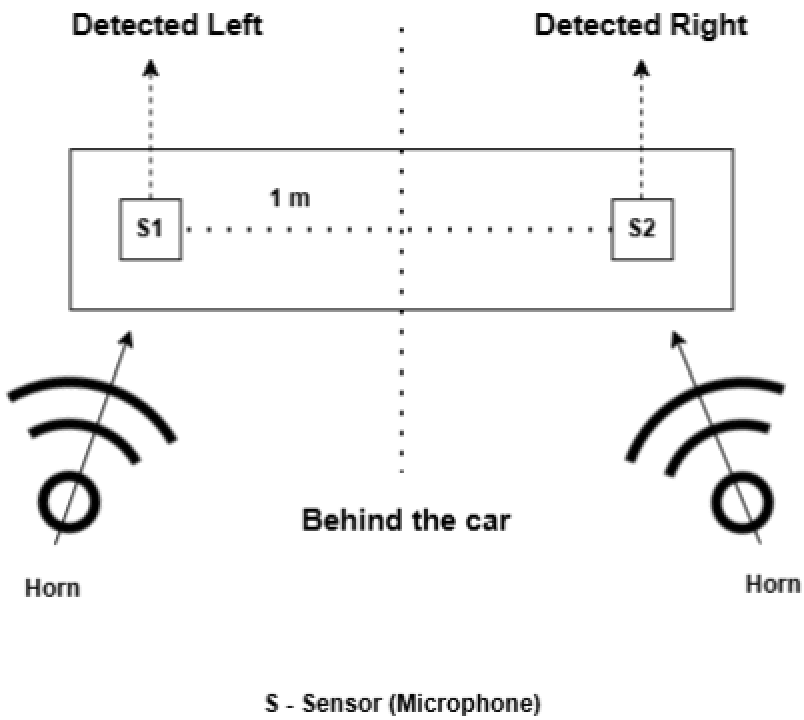

Figure 13 : Test the system's ability to correctly localize the direction of the horn sound.

- **Test Case 3:**

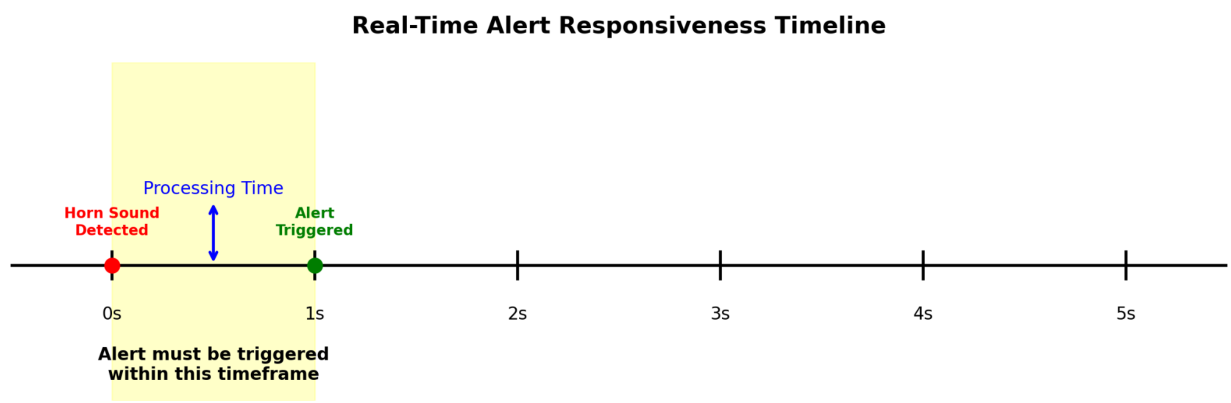

Figure 14 : Evaluate the responsiveness of the real-time alerts, ensuring they are triggered within 1 second of horn detection.

7. Wireframes

Wireframes provide a visual blueprint for the system's user interface, focusing on layout and navigation:

- **Wireframe 1:** A split-screen interface on the mobile app, with left and right sections to indicate the direction of detected horn sounds.

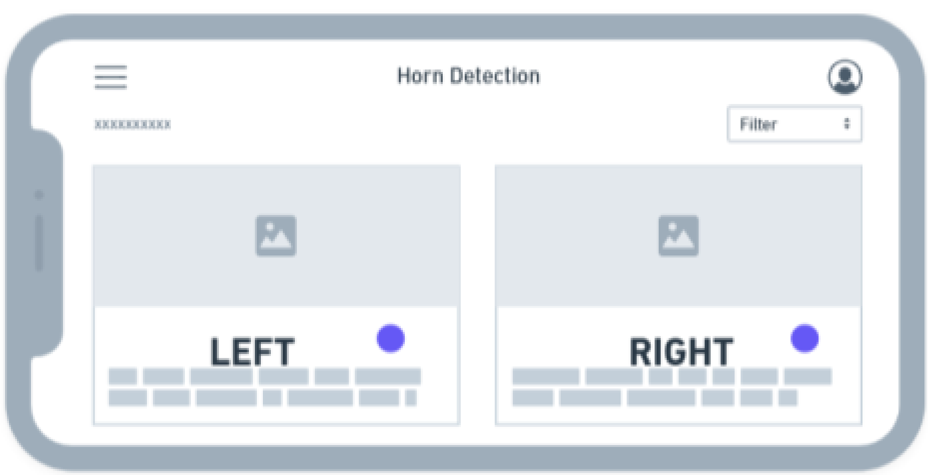

Figure 15 : Wireframe 1.

- **Wireframe 2:** A settings page where the user can adjust alert preferences, such as vibration intensity and visual alert colors.

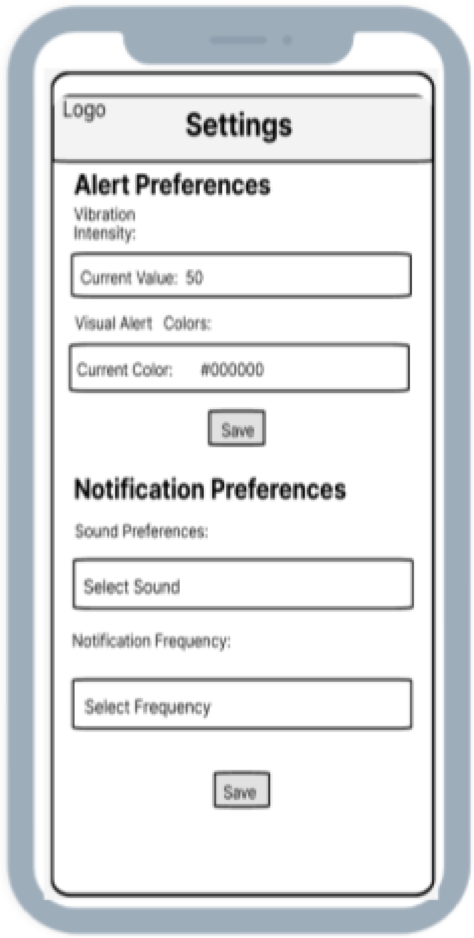

Figure 16 : Wireframe 2

8. Technologies

The system will leverage the following key technologies:

- **Microphones:** High-sensitivity MEMS microphones for capturing and detecting vehicle horn sounds.
- **Machine Learning Algorithms:** Analyzing and classifying sound frequencies to ensure accurate identification of horn sounds.
- **IoT Devices:** Integrating sensors and processing units for seamless operation.
- **Mobile Application:** Providing a user-friendly interface for visual alerts.
- **Haptic Devices:** Delivering tactile feedback via a vibrating steering wheel cover.

9. Techniques

The system employs the following techniques:

- **Frequency Analysis:** Differentiating between various vehicle horn sounds based on frequency.
- **Machine Learning Models:** Classifying horn sounds based on frequency patterns.
- **Time Difference of Arrival (TDOA):** Estimating the direction of incoming horn sounds.

Budget Plan

Category	Item	Quantity	Cost per Unit (LKR)	Total Cost (LKR)
Hardware Costs	Microphones	2	175	350
	Haptic Device (Steering Cover)	1	1400	1400
	IoT Device (Microcontroller + Wi-Fi)	1	1000	1000
	Miscellaneous Sensors & Components	-	3900	3900
Software Costs	Machine Learning Software (Open-source)	-	0	0
	Mobile App Development Tools (Open-source)	-	0	0
Testing & Miscellaneous Costs	Field Testing (Fuel, Misc.)	-	-	5000
	Contingency Fund	-	-	3000
Total Estimated Budget				**14650**

Table 2 : Budget Plan

Budget Justification

1. **Hardware Costs (LKR 6650):**
    - **Microphones (LKR 350):** Essential for capturing and detecting vehicle horn sounds accurately within the defined range.
    - **Haptic Device (LKR 1400):** The haptic device provides real-time tactile feedback, alerting the driver through vibrations, which is crucial for the system's effectiveness.
    - **IoT Device (LKR 1000):** The microcontroller, equipped with Wi-Fi, integrates the sensors and processes the data in real-time, ensuring seamless operation and communication with the mobile app.
    - **Miscellaneous Sensors & Components (LKR 3900):** This covers additional necessary components like resistors, capacitors, and other electronic parts needed for circuit integration.
2. **Software Costs (LKR 0):**
    - No costs are allocated for software as open-source tools and frameworks will be used for machine learning, sound analysis, and mobile application development.
3. **Testing & Miscellaneous Costs (LKR 8000):**
    - **Field Testing (LKR 5000):** This budget is allocated for real-world testing, covering fuel and other minor expenses that ensure the system works under actual driving conditions.
    - **Contingency Fund (LKR 3000):** This is reserved for unforeseen expenses, providing flexibility to address any unexpected issues that may arise during the project development.

The total estimated budget of **LKR 14650** is carefully planned to ensure all critical components of the project are covered, with a strong focus on hardware reliability and real-world applicability.

Commercialization of the Project

- **Market Potential**: The system addresses a growing demand for assistive vehicle safety technology for deaf drivers, with potential for partnerships with car manufacturers and funding from disability support organizations.

- **Target Audience**: Primarily designed for deaf drivers needing enhanced situational awareness, the system also appeals to automotive companies and organizations advocating for disability rights and safety.

- **Revenue Generation**: Revenue will come from direct sales, partnerships with car manufacturers, subscription services for software updates and premium features, and funding from government and disability organizations.

- **Promotional Strategies**: Marketing efforts will include targeted campaigns within the deaf community, partnerships with advocacy groups, live product demonstrations at trade shows and events, and digital marketing strategies to reach a wider audience.

- **Goal**: Establish the system as a vital safety feature in the automotive industry, achieving widespread adoption and enhancing road safety for deaf drivers.

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Appendices

Work BreakDown Structure

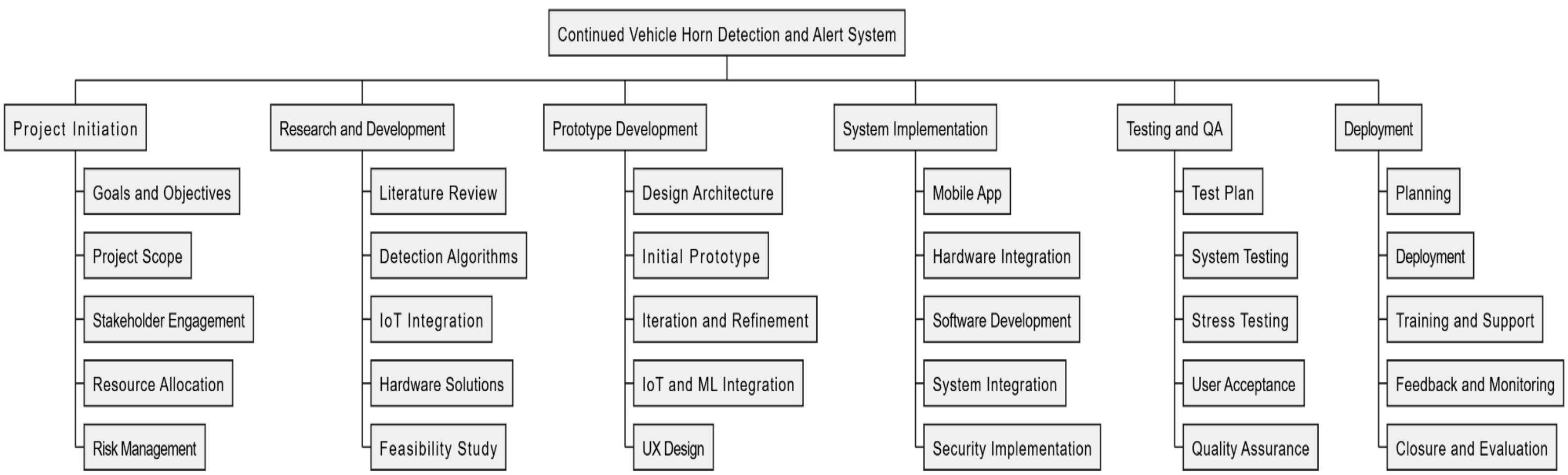

Figure 17 : Work Breakdown Structure

GANTT Chart

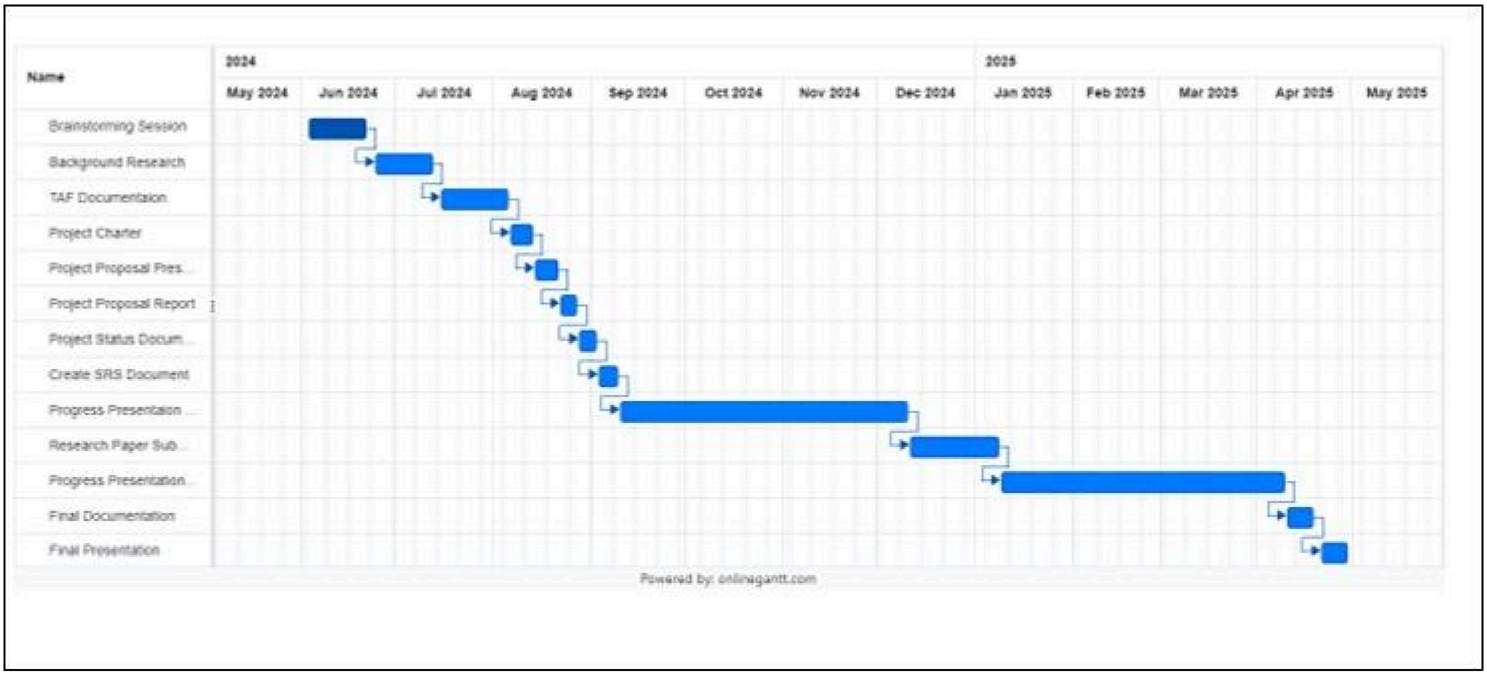

Figure 18 : Gantt Chart