Autonomous IOT Enabled Hazard Detection and Communication System for Deaf Drivers.

Project Proposal Report

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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.

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

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22/08/2024

Date

Abstract

This research project aims to develop an "Emergency Vehicle Detection and Notification System for Deaf Drivers," addressing the critical issue of alerting deaf drivers to the presence of approaching emergency vehicles. The primary objective of this study is to design a system that detects the sirens of ambulances, fire trucks, and police cars in real-time and notifies the driver through visual and haptic feedback. The system integrates a high-sensitivity MEMS microphone array to capture environmental sounds from all directions, ensuring comprehensive sound detection. By implementing advanced signal processing techniques such as Fast Fourier Transform (FFT) and Mel-Frequency Cepstral Coefficients (MFCC), the system filters out background noise and enhances the recognition of emergency sirens.

A machine learning model, trained on diverse datasets of siren sounds, is employed to accurately identify different types of emergency vehicles. The audio signals are processed using either microcontrollers (e.g., Arduino, ESP32) or microprocessors (e.g., Raspberry Pi), depending on the required computational capacity. Upon detecting a siren, the system triggers visual alerts on a mobile application and activates vibrating covers on the steering wheel or seat, providing tactile feedback to the driver. The communication between the detection unit and the notification system is facilitated through Bluetooth or WiFi modules.

This innovative approach ensures that deaf drivers receive timely and clear notifications of approaching emergency vehicles, thereby significantly enhancing their safety on the road. The system's design prioritizes affordability, modularity, and ease of integration into existing vehicles, making it a practical solution for widespread adoption.

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1. Introduction

The ability to respond to emergency vehicles on the road is a crucial aspect of safe driving, yet it presents a significant challenge for deaf drivers. According to the World Health Organization (WHO), hearing loss affects over 466 million people globally, a substantial portion of whom are licensed drivers . While conventional alert systems rely heavily on auditory cues, such as sirens, deaf drivers are at a distinct disadvantage, potentially delaying their response to approaching emergency vehicles. This research project addresses this critical issue by developing an "Emergency Vehicle Detection and Notification System for Deaf Drivers," aimed at providing these drivers with timely and reliable alerts through visual and haptic feedback.

Research in this domain has explored various methods to assist deaf drivers. Previous studies have investigated the use of visual and vibratory alerts, often relying on camera systems or simple sound level detection to identify emergency vehicles . However, these approaches have limitations, such as susceptibility to environmental noise and challenges in distinguishing between different types of sounds. Recent advancements in audio processing, particularly the use of Fast Fourier Transform (FFT) and Mel-Frequency Cepstral Coefficients (MFCC), have enabled more precise detection of specific sound patterns, including those of emergency vehicle sirens . Furthermore, machine learning techniques, such as Convolutional Neural Networks (CNNs) and Recurrent Neural Networks (RNNs), have shown promise in classifying audio signals with high accuracy, even in complex acoustic environments.

The state of the art in emergency vehicle detection is characterized by a growing emphasis on integrating machine learning with advanced signal processing to enhance detection accuracy and reliability. Despite these advancements, existing systems often lack comprehensive feedback mechanisms tailored for deaf drivers, who require a combination of visual and tactile notifications to ensure timely awareness of approaching emergency vehicles.

In this project, we propose a novel approach that builds on existing research by integrating a high-sensitivity MEMS microphone array with advanced signal processing and machine learning algorithms to accurately detect emergency vehicle sirens. Our system distinguishes itself by its dual notification mechanism, providing both visual alerts on a mobile application and haptic feedback through vibrating covers on the steering wheel or seat. This approach ensures that deaf drivers are promptly alerted, enhancing their ability to respond effectively in emergency situations. The use of affordable and modular hardware, such as Arduino, ESP32, or Raspberry Pi, further ensures that the system is accessible and can be easily integrated into existing vehicles, making it a practical solution for enhancing road safety for deaf drivers.

2. Background & Literature Survey

2.1. Background

Driving safely in modern traffic environments requires drivers to be alert to various auditory signals, especially the sirens of emergency vehicles such as ambulances, fire trucks, and police cars. For deaf drivers, who are unable to hear these critical signals, the risk of delayed response to emergency vehicles is significantly heightened. According to the World Health Organization (WHO), the number of people with hearing disabilities is on the rise, making it imperative to develop systems that address their unique challenges on the road . Current vehicles rely heavily on auditory alerts, but there has been limited progress in developing systems specifically designed for deaf drivers to ensure they are equally informed of their surroundings.

The need for a system that can detect emergency vehicle sirens and notify deaf drivers in real-time is crucial. This research aims to fill this gap by creating a comprehensive "Emergency Vehicle Detection and Notification System for Deaf Drivers." The system will utilize cutting-edge technology to detect the sirens of emergency vehicles and notify the driver through both visual and haptic feedback, significantly improving their ability to react appropriately in critical situations.

2.2. Literature Survey

Over the past decade, there has been an increasing focus on the development of assistive technologies for deaf drivers. Various approaches have been explored, each with its advantages and limitations.

Visual and Haptic Alert Systems: Early studies explored the use of simple visual alerts, such as dashboard lights or screen notifications, to inform deaf drivers of nearby emergency vehicles. These systems, however, were often limited by their reliance on sound level detection, which could easily be confused by loud background noise. In addition, haptic feedback mechanisms, such as vibrating seats or steering wheels, have been proposed to provide a more intuitive form of alert . While these methods improved driver awareness, they were often reactive rather than proactive, lacking the advanced detection capabilities needed to anticipate and differentiate between various types of emergency vehicles.

Signal Processing Techniques: The application of signal processing methods such as Fast Fourier Transform (FFT) and Mel-Frequency Cepstral Coefficients (MFCC) has enabled more precise analysis of audio signals. FFT allows for the conversion of time-domain signals into frequency-domain signals, making it easier to identify the unique frequency patterns characteristic of emergency vehicle sirens . MFCC, on the other hand, captures the power spectrum of a sound signal and has been widely used in speech and audio recognition tasks, offering robustness in noisy environments . These techniques form the backbone of modern audio recognition systems and are crucial for developing a reliable siren detection mechanism.

Machine Learning for Audio Classification: Recent advancements in machine learning, particularly deep learning models such as Convolutional Neural Networks (CNNs) and Recurrent Neural Networks (RNNs), have shown significant potential in classifying and recognizing complex audio signals. Studies have demonstrated that CNNs are effective in extracting spatial hierarchies in sound data, while RNNs are adept at handling temporal sequences, making them ideal for recognizing the patterns in emergency vehicle sirens amidst various background noises . The integration of these models with signal processing techniques has led to more accurate and reliable detection systems.

Current Solutions and Gaps: Several existing systems attempt to tackle the problem of alerting deaf drivers, but they often fall short in key areas. Many are not specifically designed for the unique challenges faced by deaf drivers, or they lack the dual alert mechanism of visual and haptic feedback that is essential for ensuring timely and clear notifications. Additionally, the majority of these systems are either prohibitively expensive or difficult to integrate into existing vehicles, limiting their widespread adoption.

This literature survey highlights the advancements and ongoing challenges in developing effective alert systems for deaf drivers. The proposed research seeks to address these gaps by combining high-sensitivity sound detection with advanced signal processing and machine learning, while also ensuring that the alerts are communicated through both visual and haptic channels. This integrated approach not only builds on existing research but also introduces novel elements designed to enhance the safety and responsiveness of deaf drivers in real-world scenarios.

Figure 1:Emergency Vehicles

3. Research Gap

Despite significant advancements in the field of assistive technologies for drivers, there remains a critical gap in the development of comprehensive systems tailored specifically for deaf drivers. Current solutions primarily focus on either visual or haptic notifications, but few offer an integrated approach that combines both. Moreover, existing systems often rely on basic sound detection methods that struggle to differentiate between emergency vehicle sirens and other environmental noises, particularly in complex acoustic environments.

The literature reveals that while advanced signal processing techniques such as Fast Fourier Transform (FFT) and Mel-Frequency Cepstral Coefficients (MFCC) have been employed in various audio recognition tasks, their application in detecting and accurately identifying emergency vehicle sirens for deaf drivers is still underdeveloped. Furthermore, the use of machine learning models like Convolutional Neural Networks (CNNs) and Recurrent Neural Networks (RNNs) in this domain has shown promise but has not yet been fully realized in a system that integrates these technologies with real-time alert mechanisms.

This research aims to address these gaps by developing a novel "Emergency Vehicle Detection and Notification System for Deaf Drivers" that leverages both advanced signal processing and machine learning to achieve high detection accuracy. The proposed system will integrate a high-sensitivity MEMS microphone array with FFT and MFCC for precise siren detection and employ CNNs or RNNs to enhance the system's ability to recognize emergency vehicle sirens in various acoustic conditions. Unlike existing solutions, this system will provide dual notifications through both visual alerts on a mobile application and haptic feedback via vibrating covers on the steering wheel or seat, ensuring that deaf drivers receive timely and clear notifications.

By filling these gaps, this research seeks to significantly improve the safety and responsiveness of deaf drivers, providing a comprehensive and practical solution that can be easily integrated into existing vehicles. The system's design prioritizes affordability, modularity, and ease of use, making it accessible for widespread adoption, and thus addressing a crucial unmet need in road safety.

References	Comprehensive alert mechanisms for deaf drivers	Integrates high sensitivity sound capture	Advanced signal processing, machine learning	Dual-mode notifications (visual and haptic)
Research 1	✗	✗	✓	✗
Research 2	✗	✓	✗	✗
Proposed System	✓	✓	✓	✓

Figure 2:Research Gap

4. Research Problem

The primary issue addressed in this research study is the significant safety challenge faced by deaf drivers due to their inability to hear the sirens of approaching emergency vehicles. In situations where every second counts, the lack of auditory cues can delay a deaf driver's response, potentially leading to dangerous or even fatal outcomes on the road.

Specifically, this research seeks to answer the following key questions:

1. How can a high-sensitivity MEMS microphone array, combined with advanced signal processing techniques like FFT and MFCC, be effectively utilized to detect the distinct siren sounds of emergency vehicles in real-time?
2. What is the impact of integrating machine learning models, such as CNNs or RNNs, on the accuracy and reliability of emergency vehicle siren detection in complex acoustic environments?
3. How can the detected siren signals be communicated to deaf drivers through a dual alert mechanism that includes both visual notifications on a mobile application and haptic feedback via vibrating covers on the steering wheel or seat, and what are the implications of this approach on driver safety and response times?
4. What are the technical challenges and practical considerations in designing an affordable, modular, and easily integrable system that can be widely adopted by deaf drivers, and how can these be addressed effectively in the proposed solution?

This research aims to tackle these issues by developing a comprehensive system that not only enhances the detection accuracy of emergency vehicle sirens but also ensures that deaf drivers receive timely and clear notifications through multiple sensory channels. The study will explore the technical feasibility of this approach and assess its potential impact on improving road safety for deaf drivers.

5. Objectives

5.1. Main Objectives

The main objective of this research is to develop an "Emergency Vehicle Detection and Notification System for Deaf Drivers" that accurately detects the sirens of emergency vehicles in real-time and promptly alerts deaf drivers through both visual and haptic feedback mechanisms. The system aims to significantly enhance the safety and responsiveness of deaf drivers by providing a reliable, affordable, and easily integrable solution that can be widely adopted.

5.2. Specific Objectives

1. To design and implement a high-sensitivity MEMS microphone array that captures environmental sounds from all directions and effectively isolates the siren sounds of emergency vehicles.
2. To develop and apply advanced signal processing techniques, including Fast Fourier Transform (FFT) and Mel-Frequency Cepstral Coefficients (MFCC), to filter out background noise and enhance the detection of siren frequencies.
3. To train and optimize a machine learning model (e.g., CNNs or RNNs) that can accurately recognize and classify different emergency vehicle sirens amidst varying acoustic environments.
4. To create a robust alert mechanism that provides visual notifications on a mobile application and haptic feedback via vibrating covers on the steering wheel or seat, ensuring that deaf drivers receive timely and clear alerts.
5. To establish seamless communication between the detection unit and the notification system using Bluetooth or WiFi modules, ensuring real-time alert delivery.
6. To evaluate the system's performance and effectiveness in real-world scenarios, ensuring that it meets the safety and usability requirements for deaf drivers.
7. To ensure the system’s affordability, modularity, and ease of integration, making it accessible for widespread adoption and capable of being easily incorporated into existing vehicles.

6. Methodology

6.1. Overall System Description

The proposed "Emergency Vehicle Detection and Notification System for Deaf Drivers" is designed to detect the sirens of emergency vehicles and notify deaf drivers through visual and haptic alerts. The system is composed of several key components that work together to achieve real-time detection and notification:

1. MEMS Microphone Array: A high-sensitivity MEMS microphone array captures environmental sounds from all directions, ensuring that the system can detect sirens even in noisy environments.
2. Signal Processing Unit: The captured audio signals are processed using advanced techniques such as Fast Fourier Transform (FFT) and Mel-Frequency Cepstral Coefficients (MFCC). This unit filters out background noise and enhances the detection of the specific frequency ranges associated with emergency vehicle sirens.
3. Machine Learning Model: A trained machine learning model, such as a Convolutional Neural Network (CNN) or Recurrent Neural Network (RNN), is employed to accurately classify and recognize the siren patterns of different types of emergency vehicles.
4. Microcontroller/Microprocessor: The signal processing and machine learning model are implemented on a microcontroller (e.g., Arduino, ESP32) or microprocessor (e.g., Raspberry Pi). This unit processes the audio signals and runs the detection algorithms in real-time.
5. Notification System: Upon detecting a siren, the system triggers visual alerts on a mobile application and activates haptic feedback mechanisms, such as vibrating covers on the steering wheel or seat. Communication between the detection unit and the notification system is established via Bluetooth or WiFi modules.
6. Mobile Application: The mobile app displays real-time alerts using intuitive graphics, such as a red screen to indicate high-priority hazards, ensuring that the driver is promptly informed.

6.2. Overall System Diagram

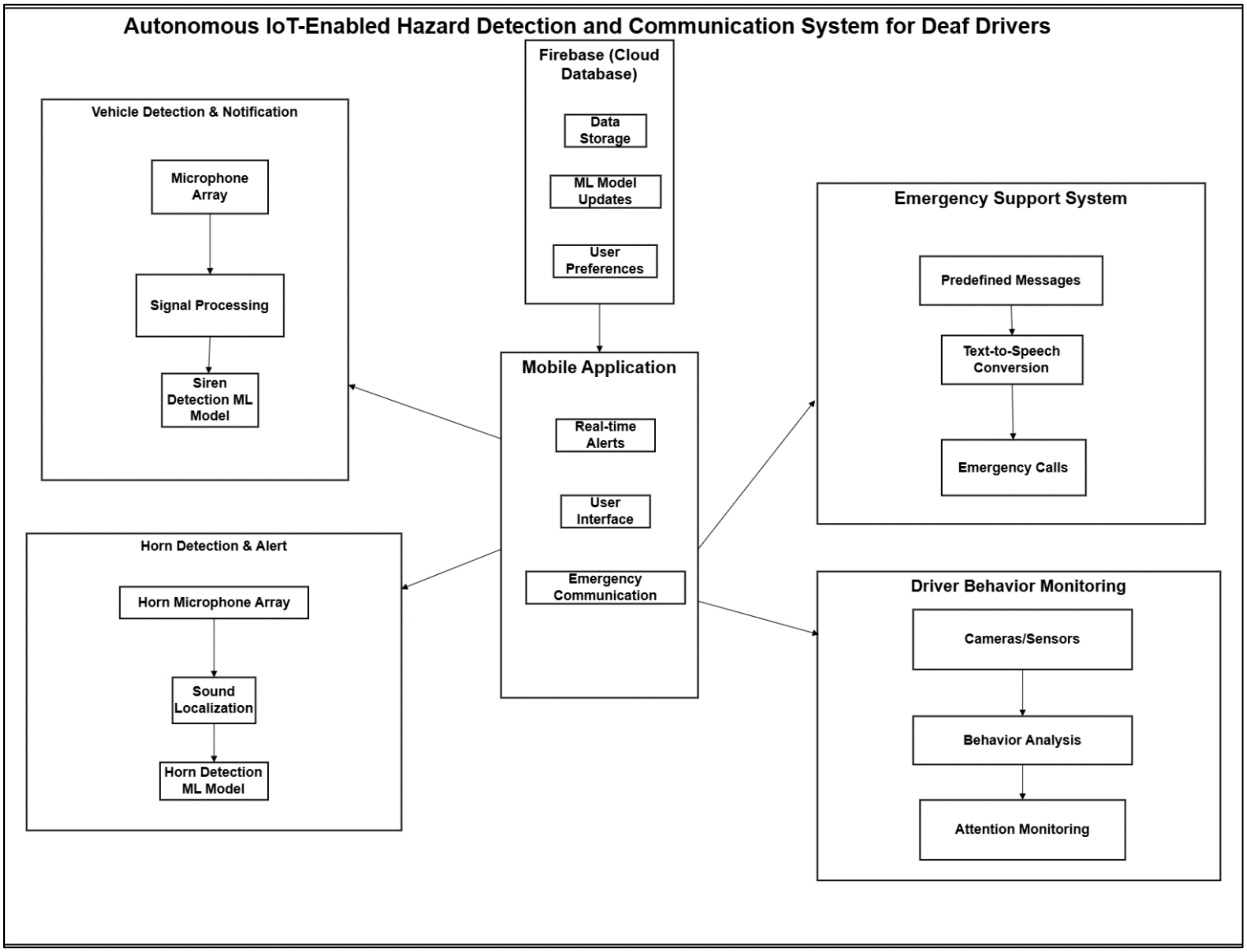
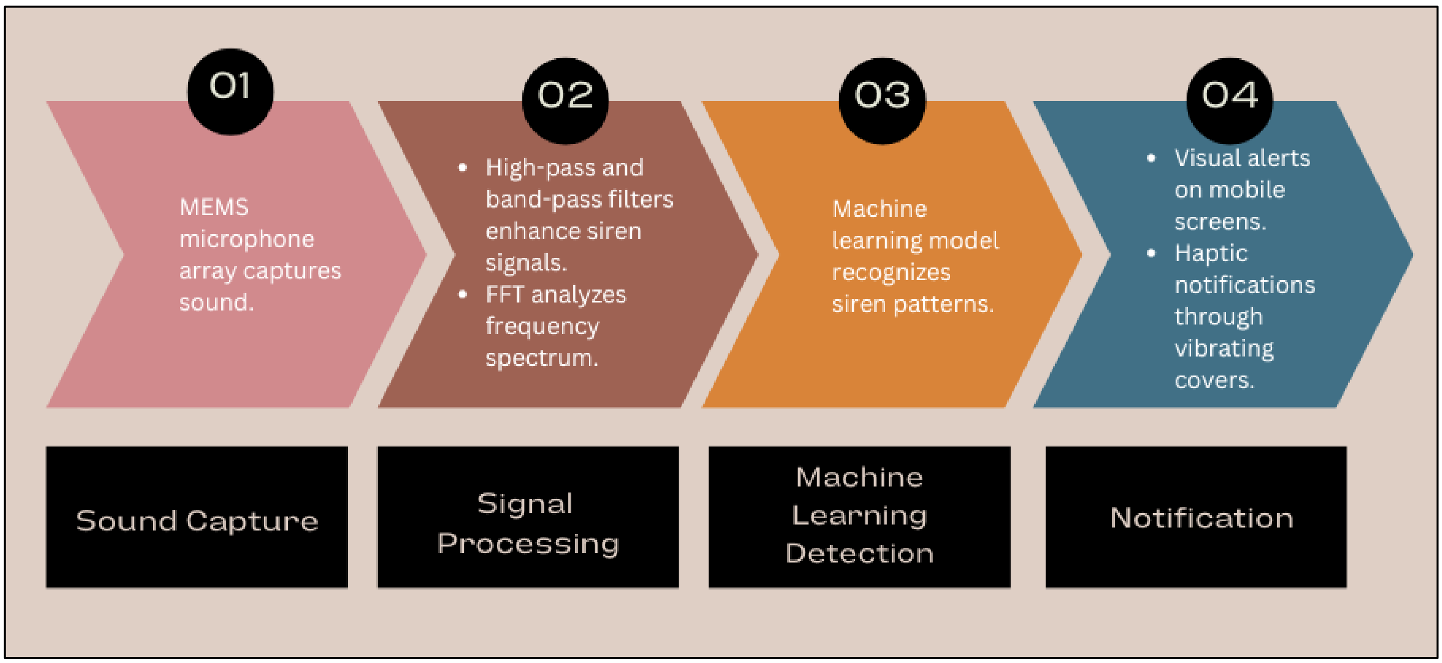
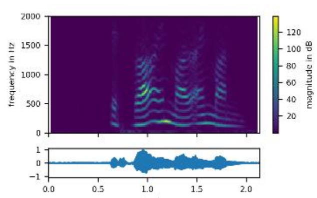


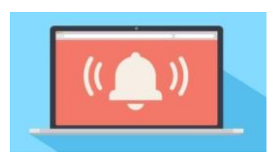
Figure 3:Overall system diagram

6.3. Individual System Diagram

Figure 4:System Diagram







6.4. Proposed Execution Plan

To carry out the project effectively, the following tasks and sub-tasks have been identified:

1. System Design and Development

- Design the overall system architecture.
- Develop the MEMS microphone array for sound capture.
- Implement the signal processing algorithms (FFT, MFCC).
- Train the machine learning model on diverse datasets of emergency vehicle sirens.
- Integrate the detection algorithm into the microcontroller/microprocessor.

2. Notification System Development

- Develop the mobile application for visual alerts.
- Design and integrate the haptic feedback mechanisms (vibrating covers).
- Establish communication between the detection unit and the notification system via Bluetooth/WiFi.

3. Testing and Evaluation

- Conduct lab-based testing to validate the accuracy of the detection system.
- Perform real-world testing in various acoustic environments to assess system reliability.
- Optimize the system based on testing feedback.

4. Final Implementation

- Integrate the entire system into a vehicle prototype.
- Perform final tests to ensure the system meets all safety and usability requirements.

6.5. Materials Needed

- Hardware: MEMS microphone array, microcontrollers (Arduino, ESP32), microprocessor (Raspberry Pi), Bluetooth/WiFi modules, vibration motors, mobile device.
- Software: Signal processing software, machine learning frameworks (TensorFlow, PyTorch), mobile app development tools (Android Studio, Xcode).
- Data: Datasets of emergency vehicle sirens for training and testing the machine learning model.

6.6. Data Collection

The project requires datasets of emergency vehicle sirens to train the machine learning model. These datasets can be collected from publicly available sources or recorded in controlled environments. Additionally, real-world data will be collected during the testing phase to evaluate system performance.

6.7. Time Frame and Schedule

The project is expected to take approximately 6-8 months to complete, divided into the following phases:

- Month 1-2: System Design and Development
- Month 3-4: Notification System Development
- Month 5: Testing and Evaluation (Lab-Based)
- Month 6: Real-World Testing and Optimization
- Month 7: Final Implementation and Integration
- Month 8: Final Testing and Report Writing

A detailed Gantt chart or task chart should be included to visually represent the project timeline and task distribution.

6.8. Anticipated Conclusion

The anticipated outcome of this project is the successful development and implementation of an "Emergency Vehicle Detection and Notification System for Deaf Drivers." The system will be capable of accurately detecting emergency vehicle sirens in real-time and providing deaf drivers with clear and timely notifications through both visual and haptic channels. This system is expected to significantly enhance road safety for deaf drivers, with potential for widespread adoption due to its affordability and ease of integration into existing vehicles.

7. Project Requirements

7.1. Functional Requirements

1. **Siren Detection:**
    - The system must accurately detect the sirens of emergency vehicles using the MEMS microphone array.
    - The detection system should differentiate between various types of emergency vehicles (ambulances, fire trucks, police cars).
2. **Signal Processing:**
    - Implement FFT and MFCC to analyze and filter the audio signals, enhancing the detection of emergency vehicle sirens.
    - The processed signals should be fed into the machine learning model for classification.
3. **Machine Learning Model:**
    - The system must use a machine learning model (CNN or RNN) trained on diverse siren sound datasets to recognize and classify siren patterns.
    - The model must provide a high accuracy rate in identifying emergency sirens amidst background noise.
4. **Notification Mechanism:**
    - Upon detecting a siren, the system must trigger visual alerts on a mobile application.
    - The system should also activate haptic feedback mechanisms, such as vibrating covers on the steering wheel or seat.
5. **Communication:**
    - The system must establish seamless communication between the detection unit and the mobile application via Bluetooth or WiFi modules.
    - The mobile application should receive real-time alerts and display them instantly.
6. **User Customization:**
    - Users should be able to customize the intensity and type of haptic feedback, as well as the visual alert settings on the mobile application.

7.2. Non-Functional Requirements

1. **Performance:**
    - The system should detect and classify sirens in real-time with minimal latency.
    - The system must operate efficiently in various acoustic environments, including high-noise areas.
2. **Reliability:**
    - The system should maintain consistent detection accuracy under different environmental conditions.
    - The communication between the detection unit and the mobile app must be reliable, ensuring that alerts are always delivered.
3. **Scalability:**
    - The system design should allow for future upgrades, such as additional types of alerts or integration with other vehicle systems.
4. **Usability:**
    - The mobile application interface must be user-friendly and intuitive, allowing users to easily understand and interact with the system.
    - The haptic feedback mechanism should be comfortable and not interfere with normal driving operations.
5. **Portability:**
    - The system should be easily installable in a wide range of vehicles without requiring extensive modifications.

7.3. Expected Test Cases

1. **Siren Detection Accuracy:**
    - Test the system's ability to detect different types of emergency vehicle sirens in various noise conditions.
    - Verify the detection range and accuracy in both quiet and noisy environments.
2. **Signal Processing Performance:**

- Test the effectiveness of the FFT and MFCC algorithms in filtering background noise and enhancing siren signals.

3. **Machine Learning Model Evaluation:**
    - Test the model's accuracy in classifying different emergency vehicle sirens.
    - Evaluate the model's performance across various acoustic environments and noise levels.
4. **Notification System Reliability:**
    - Test the responsiveness of the visual and haptic alerts on the mobile application.
    - Verify the reliability of Bluetooth/WiFi communication in delivering real-time alerts.
5. **User Customization Features:**
    - Test the functionality and ease of use of the customization options for haptic feedback and visual alerts.

7.4. Software Solution Requirements

1. **Functional Requirements:**
    - Detect emergency vehicle sirens and provide real-time alerts.
    - Allow users to customize alert settings via the mobile application.
2. **User Requirements:**
    - Users (deaf drivers) require a reliable and easy-to-use system that alerts them to approaching emergency vehicles.
    - Users need the ability to adjust alert preferences according to their comfort and needs.
3. **System Requirements:**
    - Hardware: MEMS microphone array, microcontroller/microprocessor (Arduino, ESP32, Raspberry Pi), Bluetooth/WiFi modules, vibration motors.
    - Software: Signal processing algorithms (FFT, MFCC), machine learning model (CNN/RNN), mobile app development tools (Android Studio, Xcode).

4. **Non-Functional Requirements:**
   - The system must operate with low latency, high accuracy, and be reliable in various environments.
   - It must be scalable, user-friendly, and easily installable.
5. **Use Cases (Tentative):**
   - **Use Case 1: Emergency Siren Detection**
     - The system detects a siren and classifies it as an emergency vehicle.
   - **Use Case 2: Notification Delivery**
     - The system sends a real-time alert to the mobile app and activates haptic feedback.
   - **Use Case 3: User Customization**
     - The user adjusts the intensity of the vibration and the type of visual alert via the mobile app.
6. **Test Cases (Tentative):**
   - **Test Case 1: Siren Detection in Quiet Environment**
   - **Test Case 2: Siren Detection in Noisy Environment**
   - **Test Case 3: Communication Reliability Between Detection Unit and Mobile App**
   - **Test Case 4: Accuracy of Machine Learning Model in Siren Classification**
7. **Wireframes (Tentative):**
   - **Mobile App Home Screen:** Displays current status (e.g., "No Siren Detected"), access to settings.
   - **Alert Screen:** Full-screen red alert with the type of emergency vehicle displayed.
   - **Settings Screen:** Allows customization of haptic feedback, visual alerts, and other preferences.

8. Budget and Budget Justification

1. Hardware Costs

Item	Quantity	Unit Cost (LKR)	Total Cost (LKR)
MEMS Microphone Array	2	300	600
Microcontroller	1	1,000	1,000
Raspberry Pi	1	6,500	6,500
Bluetooth/WiFi Modules	2	1,000	2,000
Vibration Motors	2	800	1,600
Power Supply Unit	1	2,000	2,000
Miscellaneous Components (wires, resistors, etc.)	-	3,000	3,000
Subtotal (Hardware)			**16,700**

2. Software Costs

Item	Quantity	Unit Cost (LKR)	Total Cost (LKR)
Machine Learning Frameworks (TensorFlow/PyTorch)	Free	0	0
Mobile App Development Tools (Android Studio/Xcode)	Free	0	0
Subtotal (Software)			**0**

3. Miscellaneous Costs

Item	Quantity	Unit Cost (LKR)	Total Cost (LKR)
Documentation and Printing	-	2,000	2,000
Subtotal (Miscellaneous)			**2,000**

Total Estimated Budget: LKR 18,700

8.1. Budget Justification

1. **Hardware Costs**: The MEMS microphone array, microcontrollers, and Raspberry Pi are essential components for capturing and processing audio signals in real-time. The Bluetooth/WiFi modules are required for wireless communication, and vibration motors are necessary for the haptic feedback mechanism.
2. **Miscellaneous Costs**: Documentation and printing are required for preparing reports and other project documentation.

This budget aims to cover all necessary expenses to ensure the successful completion of the project while keeping costs reasonable and justifiable.

9. References

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10. Appendices

10.1.Work Breakdown Structure

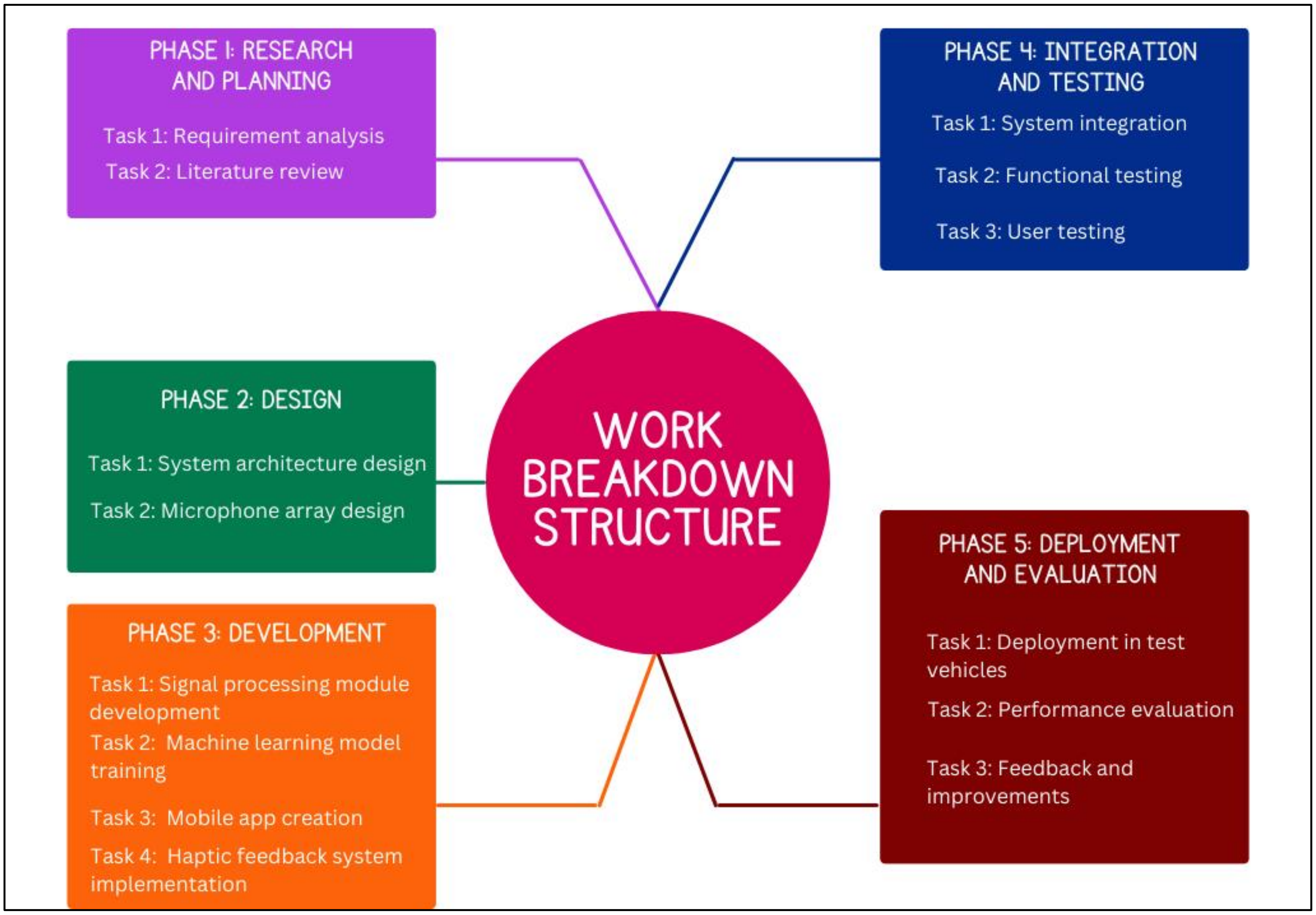

Figure 5:Breakdown Structure

10.2.Commercialization graph

Figure 6:Commercialalation

10.3.Gantt Chart

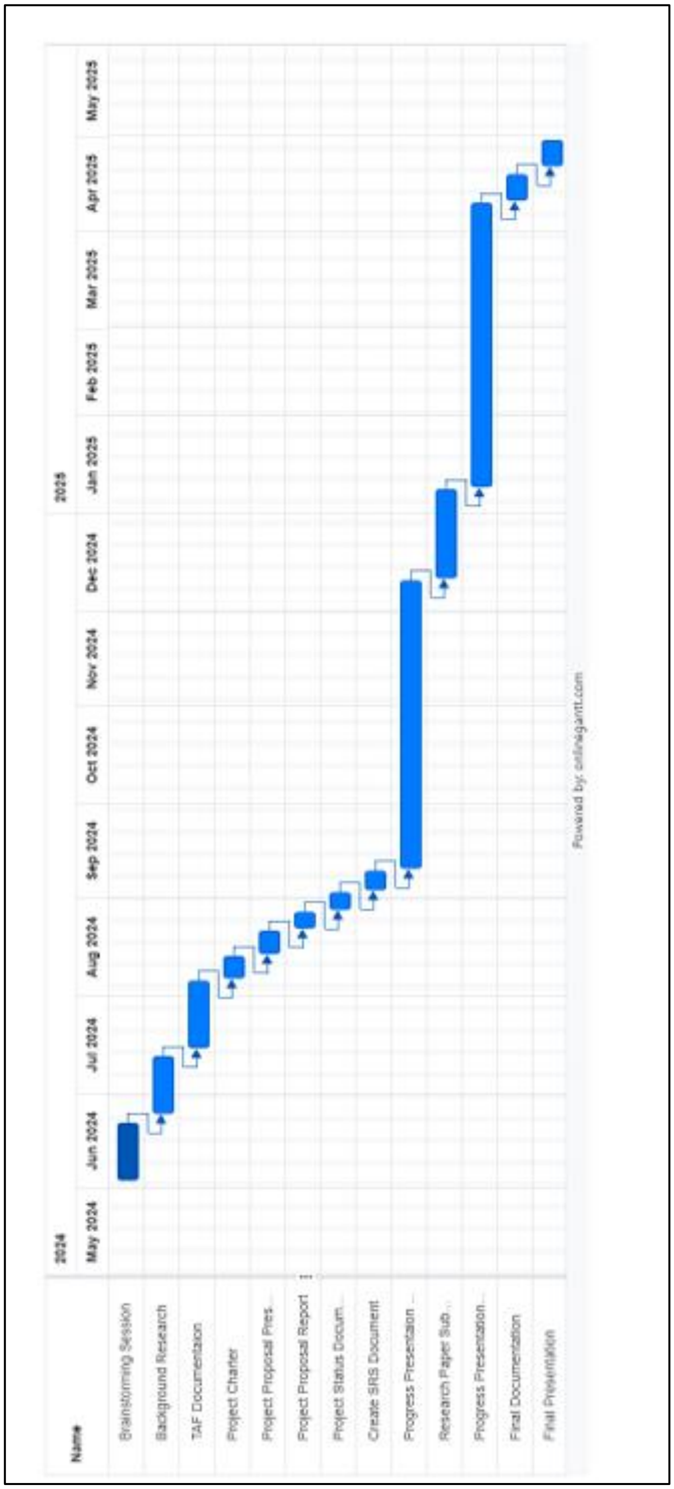

Figure 7:Gantt Chart