A

Project Report

on

Karna Rakshak: Hearing Analysis with Digital Audiometry

Submitted to

Sant Gadge Baba Amravati University, Amravati

Submitted in partial fulfilment of

the requirements for the Degree of

Bachelor of Engineering in

Computer Science and Engineering

Submitted by

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Under the Guidance of

Mr. C. M. Mankar

Asst. Prof. CSE Dept.

Department of Computer Science and Engineering

Shri Sant Gajanan Maharaj College of Engineering,

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SHRI SANT GAJANAN MAHARAJ COLLEGE OF ENGINEERING, SHEGAON – 444 203 (M.S.)

DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING

CERTIFICATE

This is to certify that **Ms. Dnyaneshwari Chatarkar, Mr. Rudransh Nemade, Ms. Sayli Agrawal,** and **Mr. Vallabh Ghongde** students of final year Bachelor of Engineering in the academic year 2023-24 of Computer Science and Engineering Department of this institute have completed the project work entitled "**Karna Rakshak: Hearing Analysis with Digital Audiometry**" and submitted a satisfactory work in this report. Hence recommended for the partial fulfillment of degree of Bachelor of Engineering in Computer Science and Engineering.

Mr. C. M. Mankar
Project Guide

Dr. J. M. Patil
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Internal Examiner	**External Examiner**
C.M. Mankar	Dr. G. J. Sawak
Name and Signature	**Name and Signature**
Date: 10/05/2024.	**Date:** 10/05/2024

Acknowledgement

It is our utmost duty and desire to express gratitude to various people who have rendered valuable guidance during our project work. We would have never succeeded in completing our task without the cooperation, encouragement and help provided to us by then. There are a number of people who deserve recognition for their unwavering support and guidance throughout this report.

We are highly indebted to our guide **Prof. C. M. Mankar** for his guidance and constant supervision as well as for providing necessary information from time to time. We would like to take this opportunity to express our sincere thanks, for his esteemed guidance and encouragement. His suggestions broaden our vision and guided us to succeed in this work.

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Dnyaneshwari Chatarkar

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Vallabh Ghongde

ABSTRACT

One of the five senses essential to an individual's day-to-day functioning. Despite adequate mindfulness, society has a stigma attached to hearing loss. It's one of the most important issues in today's reality, and it's growing exponentially. Early detection and intervention are the best way to prevent and treat this problem. Access to hearing health care has never been more important on a global scale. By 2050, an estimated 900 million people worldwide will be suffering from disabling hearing loss.

The challenges of pure-tone audiology include large and costly equipment, limited availability, lack of experts, and poor data management. All of these issues prevent widespread adoption and comprehensive patient care.

Pure-tone audiometry is being revolutionized by app-based solutions. These solutions make hearing tests easier and more convenient to use. Users can take routine hearing tests remotely using app-based platforms. This means early detection of hearing issues and prompt treatment when needed. In addition to convenience, app solutions offer powerful data tracking and analysis tools. This improves our knowledge of hearing health and allows for personalized care plans. By addressing key issues such as limited accessibility and inadequate data management, app-based technologies represent a major breakthrough in the field. These technologies have the potential to dramatically improve hearing health outcomes around the world.

Keywords: Pure Tone Audiometry, Decibel, Hearing loss, Frequency

Contents

List of Abbreviations and Symbols

Abbreviation	Stands for
PTA	Pure Tone Average
Hz	Hertz
$dB\ HL$	Decibels Hearing Level
HL	Hearing Loss
dB	Decibels
WHO	World Health Organization
$NIDCD$	National Institute on Deafness and Other Communication Disorders
MLE	Maximum Likelihood Estimation
UI	User Interface
iOS	iPhone Operating System
$Android$	Android Operating System
$React.js$	React JavaScript
API	Application Programming Interface
OTA	Over-The-Air
CLI	Command-Line Interface
$SDKs$	Software Development Kits
$HTML$	Hypertext Markup Language
CSS	Cascading Style Sheets
ORM	Object-Relational Mapping
$CRUD$	Create, Read, Update, Delete
MVC	Model-View-Controller
MVT	Model-View-Template
URL	Uniform Resource Locator
XSS	Cross-Site Scripting
$CSRF$	Cross-Site Request Forgery
SQL	Structured Query Language
$ACID$	Atomicity, Consistency, Isolation, Durability

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INTRODUCTION

Helen Keller once famously remarked, "Blindness cuts us off from things, deafness cuts us off from people." According to the World Health Organization (WHO), approximately 466 million people worldwide are estimated to have disabling hearing loss. Around 60% of childhood hearing loss can be prevented with early detection and regular check-ups. Our mobile application, "Karna Raksha," offers essential Hearing Tests like Pure-Tone Audiometry, ensuring comprehensive assessment of users' auditory health. We advocate the principle "precaution is better than cure," allowing individuals of all ages to proactively conduct regular basic hearing tests on their personal devices.[1]

The consequences of losing the ability to hear extend far beyond the individual, impacting social, economic, and educational spheres. Those unable to hear as well as someone with normal hearing, defined by hearing thresholds of 25 decibels or better in both ears, experience what is termed hearing loss. Ranging from mild to severe, individuals with hearing loss are categorized as 'Hard of hearing,' while complete absence of hearing capability is termed 'Deafness.'[3] Yet, the journey to diagnosis and intervention is often prolonged, with the average waiting time for a hearing-impaired patient to receive appropriate consultation hovering around seven years. Shockingly, among the 360 million worldwide afflicted by hearing loss, 32 million are children, as reported by the National Institute on Deafness and Other Communication Disorders (NIDCD). In the United States alone, 15% of adults aged 18 and above, equivalent to 37 million individuals, report experiencing hearing loss.

In response to this urgent need, app-based solutions in pure-tone audiometry have emerged as a vital tool. Offering accessibility and convenience, these platforms enable early detection of hearing impairments, facilitating timely interventions and treatments. By enabling users to undergo audiometry tests regularly and remotely, app-based solutions streamline the identification of potential hearing issues. Moreover, their flexibility allows users to schedule tests at their convenience, unconstrained by clinic hours or geographical limitations.[5] Beyond accessibility, these applications hold promise for advancing our understanding of hearing health through robust data tracking and analysis. By facilitating large-scale studies and personalized testing protocols, app-based solutions enhance the efficiency of audiometric assessments and pave the way for optimized patient care strategies. In integrating app-based technologies into pure-tone audiometry, we take a crucial step towards improving accessibility, early detection, and data-driven insights in the field, ultimately fostering enhanced hearing health outcomes for individuals worldwide.

1.1 Motivation

Our sense of hearing plays a vital role in connecting us to the world around us, yet it often gets taken for granted. Hearing health is an area that deserves much more attention considering the surprising number of people affected. Studies show that hearing loss is remarkably widespread, with one in three individuals over 65 experiencing some degree of impairment. Despite this prevalence, a major concern is that many people don't recognize the signs of hearing loss in themselves. This can lead to a delay in seeking help, which can have significant consequences. Untreated hearing loss can not only make it difficult to follow conversations and participate in social activities, but it can also contribute to feelings of isolation, depression, and even affect cognitive function.

The good news is that not all hearing loss is irreversible. Certain types can be prevented by practicing safe noise exposure. This means being mindful of volume levels, especially when using headphones or attending loud events. Furthermore, early detection and intervention are key in managing hearing loss and minimizing its impact. Initiatives like World Hearing Day play a crucial role in raising awareness about hearing health and encouraging people to get regular hearing checkups. By prioritizing our hearing health, we can ensure we continue to experience the richness of the world around us and maintain strong connections with loved ones.

The motivation behind developing an app for conducting pure tone auditory tests and analyzing hearing lies in several key factors:

Accessibility

Traditional hearing tests often require specialized equipment and trained professionals, which can be both time-consuming and expensive. By creating an app that allows individuals to conduct these tests at home, accessibility to hearing assessments is greatly increased, especially for those in remote areas or with limited access to healthcare facilities.

Early Detection

Hearing loss can have a significant impact on an individual's quality of life, affecting communication, social interactions, and overall well-being. Early detection of hearing loss is crucial for implementing interventions and preventing further deterioration. An app that provides easy access to regular hearing tests can facilitate early detection and prompt intervention.

Convenience

Many people may not prioritize regular hearing screenings due to inconvenience or lack of awareness. By offering a user-friendly app that individuals can use at their convenience, the barriers to scheduling and attending traditional appointments are reduced, encouraging more frequent testing.

Monitoring Progress

For individuals with known hearing impairments or those undergoing treatment for hearing-related conditions, regular monitoring of hearing thresholds is essential to track progress and adjust interventions as needed. An app that allows for easy and frequent testing enables users to monitor their hearing health over time and communicate with healthcare professionals more effectively.

Education and Awareness

Beyond providing testing capabilities, an app can also serve as a platform for educating users about hearing health, the importance of regular screenings, and strategies for hearing conservation. By raising awareness and providing valuable information, the app can empower individuals to take proactive steps to protect and preserve their hearing.

Overall, the development of an app for conducting hearing analysis with pure tone auditory tests addresses the need for accessible, convenient, and proactive solutions to promote hearing health and well-being.

1.2 Problem Statement

To develop a digital solution for pure tone audiometry that can enhance accessibility, affordability, and early detection of hearing impairments. To address the limitations of offline audiometry tests and provide a more comprehensive assessment of hearing health.

1.3 Aim

This project aims to develop a user-friendly, accessible, and affordable digital solution for pure-tone audiometry. This solution will address the limitations of traditional offline audiometry tests and contribute to a more comprehensive assessment of hearing health.

1.4 Objectives

The objective of the project is to develop an online hearing assessment platform that offers immediate results based on pure tone audiometry tests, presenting findings through an audiogram format. This mobile-friendly solution aims to enhance accessibility, convenience, and affordability, significantly reducing testing duration while ensuring timely detection.

These are the following objectives:

1. To enable early detection of deafness.
2. To provide users with periodic updates about their auditory health, presented as a percentage.
3. To personalized profiles will enable users to track their well-being assessment results over time on their auditory health.
4. To raise public awareness about the importance of regular auditory well-being assessments and position the platform as a valuable resource.
5. To provide result interpretations based on different age groups.

1.5 Scope of Project

1. Develop a user-friendly digital platform for pure tone audiometry.
2. Ensure accessibility across diverse demographics, addressing geographical and socioeconomic barriers.

3. Design cost-effective solutions to enhance affordability and widespread adoption.
4. Implement advanced algorithms for early detection of hearing impairments.
5. Integrate comprehensive assessment features to surpass limitations of traditional offline tests.
6. Focus on creating intuitive user interfaces for easy navigation and usage.
7. Bridge the gap in access to hearing healthcare services by empowering individuals to proactively manage their auditory well-being.

LITERATURE REVIEW

Kashyap Patel., [1] this research studies about the HearTest application, designed for measuring hearing thresholds via smartphones, demonstrates high accuracy akin to traditional audiometers in testing on individuals with normal hearing. However, it's underscored that HearTest isn't a substitute for professional audiologist evaluation, necessitating further refinement and validation, especially for those with hearing impairment and in diverse settings.

De Wet Swanepoel., [2] the paper studies that automated audiometry provides reliable, accurate, and time-efficient hearing assessments for normal-hearing and hearing-impaired adults and holds significant potential for reaching underserved areas where hearing health professionals are unavailable.

Levent Renda., [3] studies that Smartphone hearing test applications demonstrate strong validity compared to traditional pure-tone audiograms, with results consistently exceeding 0.75 for each ear and frequency. Moreover, the mean absolute difference between smartphone test results and audiograms is less than 8.8 dB. These findings indicate the potential for smartphone-based audiometric tests to provide cost-effective solutions and alleviate the demand for audiological services, particularly in underserved areas.

Marcin Masalski., [4] research offers the method of hearing self-test carried out on mobile devices with bundled headphones demonstrates high compatibility with pure-tone audiometry, which confirms its potential application in hearing monitoring, screening tests, or epidemiological examinations on a large scale.

Lekha V. Yesantharao BS., [5] the study evaluated smartphone apps Mimi and uHear for audiometric testing accuracy compared to in-clinic tests, indicating potential for virtual hearing loss detection using mobile applications.

Hung Thai-Vana., [6] online digital audiometry has been demonstrated as a clinically accurate method for hearing assessment and showed that the mean difference between the two audiometric test results remained within 5 dB HL for both air and bone conduction thresholds at all tested frequencies.

Ravneet Ravinder Verma., [7] a large-scale multicentric study to identify the degree and type of HL, social awareness campaigns, widespread neonatal screening, strengthening treatment facilities and well-funded rehabilitation programmes can counter the rising prevalence of hearing impairment in India. The prevalence of hearing loss in India varies, with rates ranging from 1.59 to 8.8 per 1000 births in neonates, 6.6% to 16.47% in children, and 6% to 26.9% in the community.

Alexandria L Irace., [8] the paper reviews smartphone apps for hearing assessment, highlighting their potential in remotely screening age-related hearing loss, despite varying features and limited validation studies, smartphone-based hearing test apps may facilitate remote screening for hearing loss, but limitations surrounding app validation, usability, equipment calibration, and data security should be addressed.

François Charih., [9] the paper presents an open-source algorithm to automatically extract hearing thresholds from audiograms, streamlining the adjudication process for compensating workplace-related hearing loss.

Kyra Taylor., [10] the paper proposes an automated hearing impairment diagnosis software utilizing machine learning to accurately classify the type, degree, and configuration of hearing loss, aiding audiologists and otolaryngologists efficiently.

Wessam Shehieb., [11] the paper proposes an Assistive Intelligent Hearing Aid System (AIHAS) utilizing smart glasses with bone conduction tech, smartphone connectivity, smart filters, and an Auditory Assistive mode for hearing-impaired patients.

METHODOLOGY

3.1 How do humans hear?

Human hearing is a complex process that involves the intricate coordination of various structures in the ear and the brain. Here's a simplified explanation of how humans are able to hear:

1. Sound waves travel through the air and enter the outer ear, also known as the pinna.
2. The sound waves then travel through the ear canal and reach the eardrum (tympanic membrane), causing it to vibrate.
3. The vibrations originating from the eardrum travel to three tiny bones located in the middle ear known as the ossicles, which include the malleus, incus, and stapes.
4. The ossicles amplify and transmit the vibrations to the oval window, a membrane-covered opening those leads to the inner ear.
5. In the inner ear, the vibrations cause the fluid-filled cochlea to move, which stimulates tiny hair cells (cilia) lining the cochlear walls.
6. The motion of the hair cells transforms mechanical vibrations into electrical signals.
7. These electrical signals are then transmitted via the auditory nerve to the brainstem and further to the auditory cortex in the brain.
8. The brain processes these electrical signals into recognizable sounds, allowing us to perceive and interpret the sound waves as speech, music, or other auditory stimuli.

This process of converting sound waves into electrical signals and interpreting them as sound is essential for our ability to hear and understand the world around us.

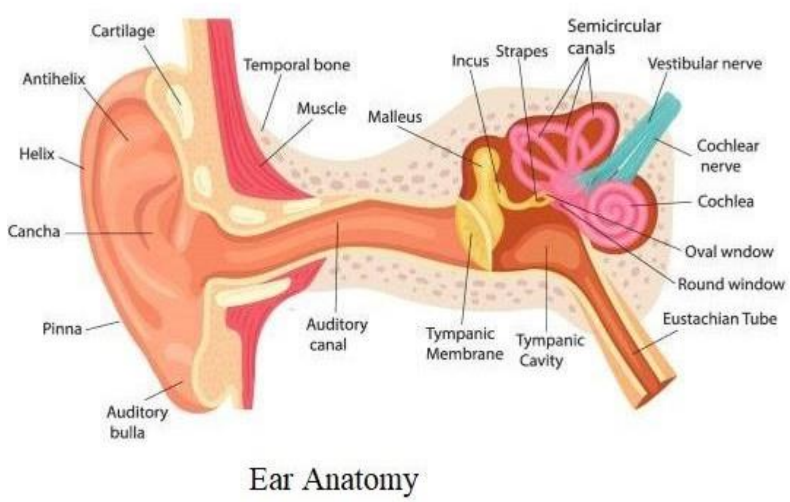


Fig 3.1: Ear Anatomy

Sound is measured in two key ways:

- volume or level – measured in decibels (dB)
- The pitch or frequency of the sounds, indicating whether they are high or low, is measured in hertz (Hz).

Hearing tests typically occur in a tranquil environment carefully insulated from external noise disturbances. During the hearing test, the individual listens to sounds presented by an audiologist and indicates their perception by pressing a button. The test results are then represented on an audiogram, depicting the volume or loudness of each sound, typically measured in decibels (dB).

Sounds become louder from the top down – softest near the top of the graph. Pitch or frequency which is measured in hertz (Hz). The frequency goes from low (125Hz) on the left to high (8000Hz) on the right – similar to a piano (low notes on the left, higher to the right).

Normal hearing is when the softest sounds heard are between -10 and 20 dB. If the sounds are louder than 20 dB and you still can't hear them, then there is a hearing loss. The lower the line on the audiogram chart representing your hearing test results, the greater the degree of hearing loss. Mild hearing loss is between 21dB and 40 dB. You often have difficulty following speech, especially in noisy situations. This kind of hearing loss is frequently noticed by family members before the affected individual becomes aware of it themselves. Moderate hearing loss is between 41dB and 70 dB.

You often have difficulty following speech and other quiet noises. Severe hearing loss is between 71dB - 90 dB. You are unable to hear speech even in quiet surroundings and do not hear general noises such as traffic unless it's loud. Profound hearing loss is greater than 90 dB. You experience difficulty hearing most sounds unless they are very loud. In the audiology clinic, testing is conducted using headphones, referred to as 'air conduction thresholds,' as the sound needs to travel through the air of the ear canal to be perceived. This method enables the audiologist to assess the entire hearing system comprehensively. Alternatively, hearing can be tested using a bone conductor – a device that rests on the bone behind the ear (held in place by a metal band stretching over the top of the head). This bone conductor transmits sound vibrations directly to the inner ear through the bones of the skull. The audiologist can evaluate inner ear hearing directly using this procedure.

To identify the location of any hearing loss, the audiologist would compare the results of the air conduction and bone conduction tests. The lowest sound that can be heard at any tone or frequency is the threshold of hearing – this information, including air conduction and bone conduction results for each ear, is recorded on the audiogram.

Each type of hearing loss requires specific evaluation and management strategies, which may include hearing aids, cochlear implants, auditory training, or medical interventions depending on the underlying cause and severity.

3.2 Pure Tone Audiometry

Pure tone audiometry (PTA) is a diagnostic test used to evaluate an individual's hearing sensitivity across different frequencies. It is one of the most common tests conducted by audiologists to assess hearing loss and determine the type, degree, and configuration of hearing impairment.

Here's how the pure tone audiometry test is typically conducted:

- Preparation: The individual undergoing the test is usually seated in a soundproof booth or room to minimize external noise interference. They wear headphones connected to an audiometer, which is a specialized piece of equipment used to generate pure tones at various frequencies and intensities.

- Explanation: The audiologist explains the test procedure to the individual and provides instructions on how to respond to the presented tones. Responses are typically given by pressing a button, raising a hand, or verbally indicating when a tone is heard.
- Testing Frequencies: The audiometer presents pure tones at specific frequencies, typically ranging from low frequencies (e.g., 250 Hz) to high frequencies (e.g., 8000 Hz or higher). Each ear is tested separately. The audiologist starts with frequencies in the speech range (e.g., 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz) and may test additional frequencies if necessary.
- Threshold Determination: The audiologist begins testing at an intensity level that is easily audible and gradually decreases the intensity until the individual can no longer hear the tone. This process is repeated for each frequency tested. The softest intensity level at which the individual responds to at least 50% of the presentations is recorded as the hearing threshold for that frequency.
- Air Conduction and Bone Conduction: Pure tone audiometry assesses both air conduction and bone conduction thresholds. During air conduction testing, the pure tones are presented through headphones, and the thresholds represent the individual's ability to hear sounds through the normal pathway (outer ear, middle ear, inner ear, and auditory nerve). Bone conduction testing involves using a bone oscillator placed behind the ear to deliver vibrations directly to the inner ear, bypassing the outer and middle ear. This helps determine if the hearing loss is conductive (outer or middle ear) or sensorineural (inner ear or auditory nerve).
- Recording Results: The audiologist records the individual's responses on a chart called an audiogram. The audiogram plots the hearing thresholds for each frequency tested, showing the softest intensity levels at which the individual can hear tones across the frequency range. The results are interpreted to determine the type, degree, and configuration of hearing loss, as well as any asymmetries between the ears.

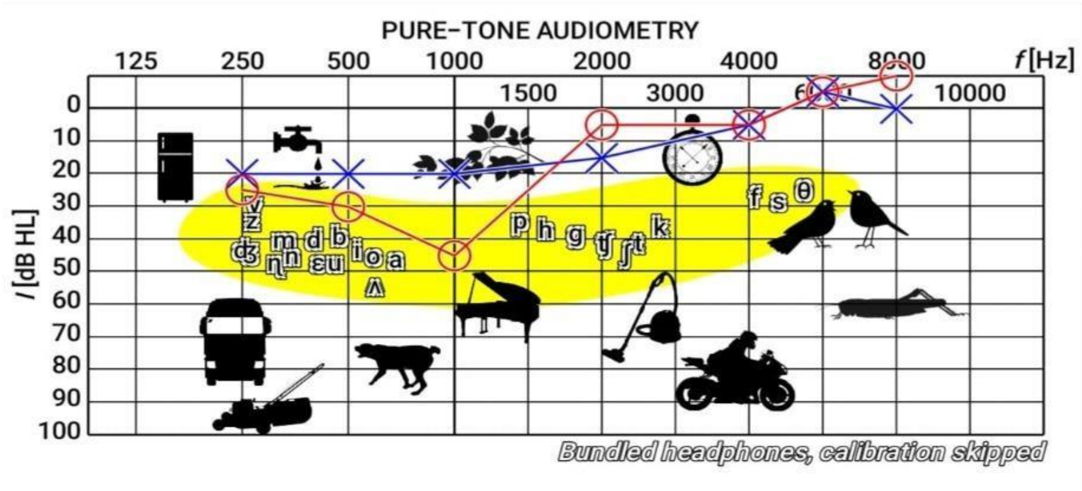


Fig 3.2: Pure Tone Audiometry

3.3 Audiogram

An audiogram is a graph that represents an individual's hearing ability across different frequencies (measured in Hertz, Hz) and sound intensities (measured in decibels, dB). It is commonly used in audiology to assess hearing loss and to determine the type, degree, and configuration of hearing loss.

Here's how an audiogram is produced and the parameters involved:

1. Testing Procedure: Audiograms are typically generated through a process called pure-tone audiometry. During this test, the individual sits in a soundproof booth or room and wears headphones. The audiologist presents pure tones (single-frequency sounds) at various frequencies and intensities through the headphones.
2. Frequency (Hz): The horizontal axis of the audiogram represents frequency, which refers to the pitch of the sound. Frequencies commonly tested range from low frequencies (usually around 250 Hz) to high frequencies (usually up to 8000 Hz or higher). Each frequency is tested individually.
3. Intensity (dB HL): The vertical axis of the audiogram represents intensity, which refers to the loudness of the sound. Intensity is measured in decibels Hearing Level (dB HL), which is a standardized unit used in audiometry. The intensity levels tested typically range from very soft sounds (around 0 dB HL) to very loud sounds (up to 120 dB HL or higher).

4. Symbols and Responses: During the audiometry test, the individual indicates when they hear a sound by pressing a button or raising their hand. The audiologist records the softest intensity level at which the individual responds to each frequency. These responses are plotted on the audiogram as symbols, typically using different shapes or colors to represent the left and right ears.

3.4 Types of Hearing Loss:

Based on the results plotted on the audiogram, the audiologist can determine the type of hearing loss:

- Conductive Hearing Loss: This type of hearing loss occurs when there is a problem with the outer or middle ear, such as earwax buildup, fluid in the middle ear, or damage to the ossicles (small bones in the middle ear).
- Sensorineural Hearing Loss: This type of hearing loss occurs when there is damage to the inner ear (cochlea) or the auditory nerve. It is often permanent and may be caused by aging, noise exposure, genetic factors, or certain medical conditions.
- Mixed Hearing Loss: This occurs when there is a combination of conductive and sensorineural hearing loss.

Table 3.1: Grades of Hearing impairment

Category	**Pure-tone Audiometry (dB hearing level)**	**Hearing Experience in Quiet Environment**
Normal hearing	-10.0 to 4.9 dB hearing level 5.0 to 19.9 dB hearing level	Excellent hearing Good hearing
Mild hearing loss	20.0 to 34.9 dB hearing level	Does not have problems hearing speech
Moderate hearing loss	35.0 to 49.9 dB hearing level	May have difficulty hearing normal voice
Moderately severe hearing loss	50.0 to 64.9 dB hearing level	Can hear loud speech
Severe hearing loss	65.0 to 79.9 dB hearing level	Can hear loud speech directly in one’s ear
Profound hearing loss	80.0 to 94.9 dB hearing level	Has great difficulty hearing

Source: Global Burden of Disease Expert Group on Hearing Loss.

Degree and Configuration of Hearing Loss: The audiogram also provides information about the degree (severity) and configuration (pattern) of hearing loss. The degree of hearing loss is categorized as mild, moderate, severe, or profound based on the average hearing thresholds at specific frequencies. The configuration refers to the shape of the audiogram, indicating which frequencies are affected and to what extent.

Overall, audiograms are valuable tools for assessing hearing ability and guiding treatment decisions for individuals with hearing loss. They provide a visual representation of an individual's hearing thresholds, which can help audiologists diagnose hearing disorders, fit hearing aids, and monitor changes in hearing over time.

3.5 Interaction Flow

The digital audiometer system's interaction flow creates a smooth experience for users by integrating frontend UI interaction, backend processing, database interaction, and graphical representation. At first, users interact with the front-end interface to enter test parameters and start the audiometry test. Afterwards, the parameters are received by the backend system, which then uses the audiometry algorithm to create the necessary test tones. These sounds are then delivered to users in a regulated way through the frontend user interface. At the same time, the backend system is keeping track of user responses to assess their ability to hear each tone and calculate the corresponding hearing thresholds. The database is crucial in this process, as it stores and retrieves user data, test configurations, and test results as needed. Importantly, test results are stored in the database for later reference and analysis. Once the backend processing is finished, it creates visual representations of audiogram results using the calculated hearing thresholds. The frontend UI showcases the audiogram graphs, allowing users to visually analyze their hearing abilities in a comprehensive manner. Working together, this series of interactions guarantees a smooth and informative user experience during the audiometry testing procedure.

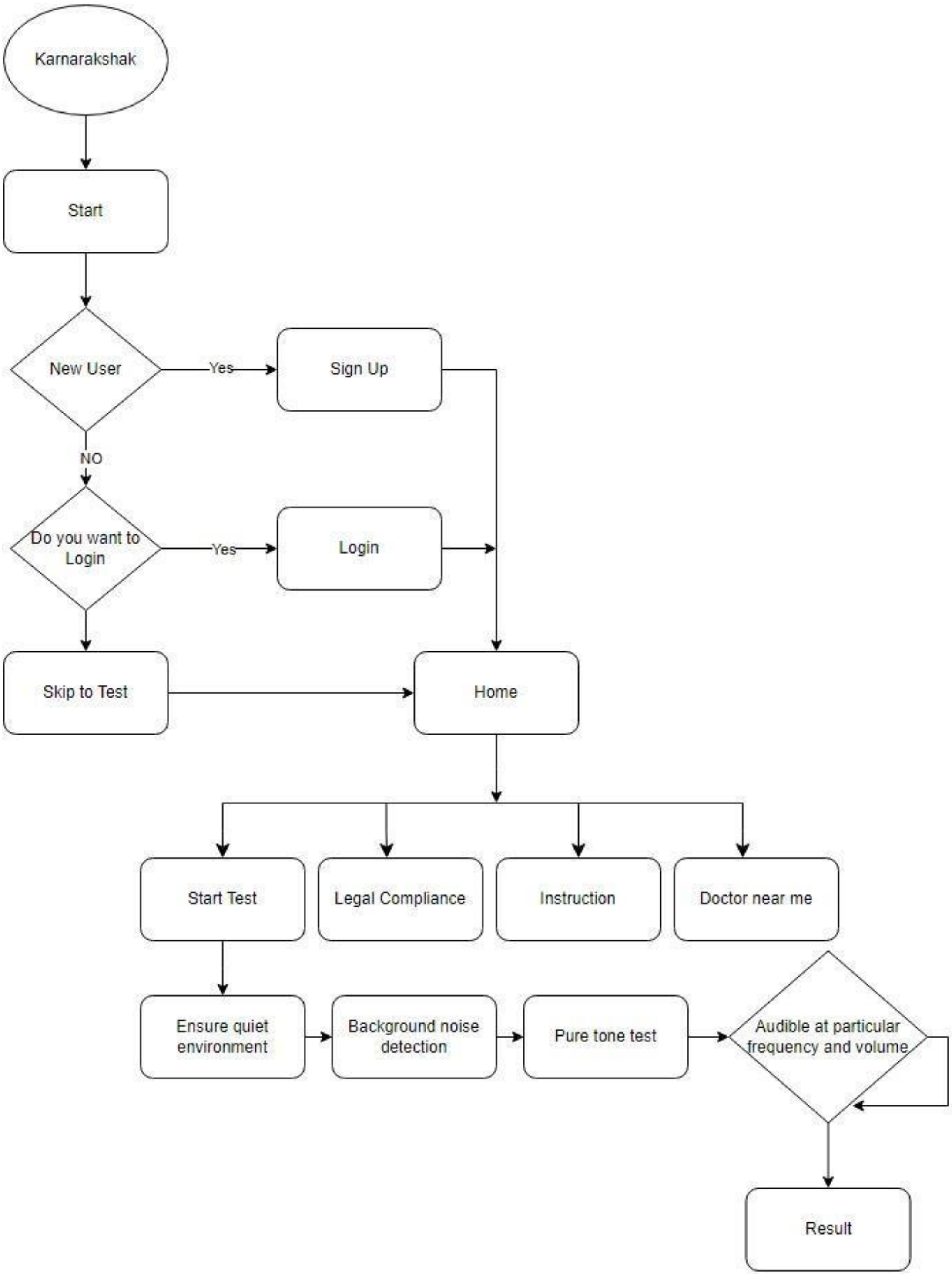


Fig 3.5: Interaction Flow

IMPLEMENTATION

4.1 System Architecture

The hearing analysis app's architecture comprises a frontend, backend, and database components. The frontend, developed using frameworks like React Native, offers a user-friendly interface for interaction. The backend, hosted on a server, manages data processing, business logic, and database interaction through RESTful or APIs, employing technologies like Python with Django. The database, powered by a chosen Database Management System (DBMS) such as SQLite, stores user profiles, hearing test results, and application settings, ensuring data integrity and security. Together, these components form a cohesive system enabling users to assess their hearing health effectively.

4.1.1 Frontend:

The digital audiometer system's frontend encompasses the crucial user interface (UI) components pivotal for user interaction during audiometry testing. Crafted with React.js, this interface ensures smooth engagement with diverse functionalities. Users can easily input test parameters like frequency and loudness levels through intuitive input forms. Throughout the testing phase, interactive elements offer instant user feedback, including buttons to signal tone perception. Moreover, the frontend presents audiogram results graphically, aiding in the understanding and analysis of test outcomes. With its comprehensive design, this frontend ensures a user-friendly and effective audiometry testing journey.

React Native

React Native stands out as a favored framework utilized for crafting mobile applications through the integration of JavaScript and React. Developers can save time and work by writing code only once and having it run on both the iOS and Android platforms. React Native leverages the React framework's component-based architecture, enabling developers to create highly modular and reusable UI components.

One of the key advantages of React Native is its ability to provide a native-like user experience while still using JavaScript. It achieves this by translating JavaScript code into native code during runtime, allowing developers to access native features and APIs seamlessly.

React Native also boasts a vibrant ecosystem with a wide range of third-party libraries, tools, and community support, which further accelerates development and simplifies tasks like state management, navigation, and data fetching.

Expo

Expo represents an open-source platform tailored for constructing versatile native applications compatible with Android, iOS, and web platforms, leveraging the power of JavaScript and React. It provides a set of tools and services that simplify the development process, allowing developers to focus on building their apps without worrying about the underlying complexities of configuration and setup.

Here are some key features of Expo:

1. Unified Development Environment: Expo provides a unified development environment that includes a command-line interface (CLI), a development server, and a set of development tools. This environment streamlines the setup process and eliminates the need for platform-specific development tools and SDKs.
2. Built-in Components and APIs: Expo comes with a rich set of pre-built UI components and APIs that cover common use cases such as camera, location, notifications, and more. These components and APIs abstract away platform-specific implementation details, making it easy to add native functionality to your app using JavaScript.
3. Expo facilitates over-the-air (OTA) updates, which let developers update their programs without submitting them for approval to the app store. This enables developers to fix bugs, add new features, and improve performance quickly and efficiently.
4. Expo Go App: Expo provides the Expo Go app, which allows developers to preview their apps instantly on their devices during development. This app serves as a development client for running Expo projects locally on iOS and Android devices without the need for complex setup or configuration.
5. Managed Workflow: Expo offers a managed workflow that abstracts away the native build process, allowing developers to focus on writing JavaScript code. This workflow handles tasks such as building, signing, and publishing your app-to-app stores, simplifying the deployment process.

6. Ejecting to Bare Workflow: For developers who require more control over their app's native code or need to integrate custom native modules, Expo provides an option to "eject" to a bare workflow. This process generates a standard React Native project with access to native code and dependencies, while still retaining Expo's development tools and services.
7. Community and Ecosystem: Expo has a vibrant community of developers who contribute to its development, share knowledge, and provide support through forums, documentation, and open-source projects. This community-driven ecosystem ensures that Expo remains up-to-date and well-supported.

4.1.2 Backend

The backend of the digital audiometer system orchestrates the logic and processing required for conducting audiometry tests efficiently. Powered by Python with Django, this backend integrates diverse components to streamline test administration. Central to its functionality is an advanced audiometry algorithm crafted to produce pure tones and precisely compute hearing thresholds based on user feedback. Additionally, the backend encompasses API endpoints devoted to managing user interactions, ensuring seamless communication between frontend and backend elements. Database integration is fundamental, furnishing robust storage and retrieval functionalities for user data and test outcomes. Collectively, these components constitute a cohesive backend infrastructure crucial for delivering dependable and thorough audiometry testing services.

Django

Django serves as a sophisticated web framework crafted in Python, prioritizing swift development and fostering a clean, practical design approach. It follows the Model-View-Controller (MVC) architectural pattern, but with a slight variation known as Model-View-Template (MVT). The fundamental objective of Django revolves around simplifying the development process of intricate, database-centric websites, accentuating the reusability and adaptability of its components.

Here are some key features of Django:

- Object-Relational Mapping (ORM): Django provides an ORM that abstracts database interactions, allowing developers to work with database models using Python objects. This makes it easy to define database schemas, query data, and perform CRUD (Create, Read, Update, Delete) operations without writing raw SQL.

- Admin Interface: Django comes with a built-in admin interface that automatically generates CRUD interfaces for models defined in your application. This admin interface is highly customizable and can be used to manage site content, user authentication, and permissions.
- URL Routing: Django uses a URL routing mechanism to map URLs to views, allowing developers to define URL patterns and associate them with specific view functions. This decouples URL handling from view logic and enables clean, expressive URL designs.
- Template System: Django provides a powerful template system that allows developers to build HTML templates with dynamic content using Django's template language. Templates can include template tags, filters, and template inheritance, making it easy to create reusable and maintainable HTML layouts.
- Authentication and Authorization: Django includes built-in support for user authentication, registration, and session management. It also provides a flexible authorization system for defining access control rules based on user roles and permissions.
- Form Handling: Django simplifies form handling by providing a forms library that generates HTML forms from Python classes and handles form validation, data cleaning, and error handling automatically. This reduces boilerplate code and improves code maintainability.
- Security Features: Django includes built-in security features to protect against common web security vulnerabilities such as Cross-Site Scripting (XSS), Cross-Site Request Forgery (CSRF), SQL injection, and Clickjacking. These features help developers build secure web applications by default.
- Localization and Internationalization: Django comes with built-in support for both localization (l10n) and internationalization (i18n), making it simple for developers to build multilingual websites. It provides tools for translating text strings, formatting dates and numbers, and handling language-specific content.
- Reusable Apps: Django encourages the development of reusable and pluggable apps that can be easily integrated into Django projects. The Django community maintains a rich ecosystem of third-party apps and libraries for common use

cases such as content management, e-commerce, and RESTful APIs.

4.1.3. Database

The database employed by the digital audiometer system plays a pivotal role in storing and managing vital data pertaining to user profiles, test configurations, and audiometry test outcomes. Utilizing SQLite technology, this database ensures reliability and efficiency in handling the system's data needs. It comprises several key components, beginning with user profiles containing essential demographic information crucial for tailored testing experiences. Additionally, the database stores test configuration settings, encompassing parameters such as frequency range and step size, to maintain consistency and adaptability in test execution. Furthermore, it houses comprehensive audiometry test results, capturing essential data such as hearing thresholds for each frequency tested, along with metadata like test timestamps, enabling analysis and monitoring of user progress over time. Through these integral components, the database serves as a robust repository, indispensable to the functionality and efficacy of the digital audiometer system.

SQLite

In the realm of database management systems, SQLite emerges as a true anomaly, embodying the essence of efficiency and power within its modest confines.

At its core, SQLite is a lightweight, serverless, self-contained database engine, designed to operate directly on disk files. This unique architecture eliminates the need for complex setup procedures or dedicated server instances, making SQLite an appealing choice for developers seeking simplicity without sacrificing functionality.

Despite its diminutive stature, SQLite boasts an impressive array of features that rival those of its larger counterparts. From its adherence to the principles of ACID (Atomicity, Consistency, Isolation, Durability) compliance to its support for standard SQL syntax, SQLite stands as a paragon of reliability and versatility.

Crossing the boundaries of operating systems, SQLite seamlessly integrates with a myriad of platforms, including Windows, macOS, Linux, and beyond. Its portability ensures that developers can leverage SQLite's capabilities across diverse environments, from desktop applications to mobile devices and embedded systems.

One of SQLite's most striking attributes is its minuscule footprint, typically weighing in at a mere 500KB. This lean profile makes SQLite an ideal choice for deployment in resource-constrained environments, where space and memory are at a premium.

Despite its compact size, SQLite offers robust support for a variety of data types, including INTEGER, TEXT, REAL, and BLOB. Furthermore, developers can harness the power of triggers and views to implement complex business logic and data manipulation within their applications.

Whether you're crafting a sleek mobile app, a desktop utility, or an IoT device, SQLite serves as a steadfast companion, providing a reliable foundation for your data storage needs. Its simplicity belies its strength, offering a potent solution that seamlessly integrates into the fabric of modern software development.

4.2. Audiometry Algorithm

1. Generating Pure Tones with Varying Frequencies and Loudness Levels

Algorithm Name: Tone Generation Algorithm

This step involves generating pure tones at varying frequencies and loudness levels to be presented to the user during the audiometry test.

Define Parameters:

- Determine the sampling rate: This is the number of data points recorded per second during audio sampling. Common sampling rates include 44100 Hz (samples per second), which is the standard for CD-quality audio.
- Choose the duration of the tone: This is the length of time for which the tone will be generated, usually specified in seconds.
- Specify the range of frequencies: Determine the range of frequencies (in Hertz, Hz) that you want to generate tones for.
- Determine the intensity levels: Choose the range of loudness levels (in decibels, dB) that you want to test.

Loop Through Frequencies and Intensities:

- Iterate over each frequency in the specified range.
- Within each frequency loop, iterate over each intensity level.

Calculate Waveform:

- For each frequency and intensity combination, calculate the waveform of the pure tone using a sine function.
- The sine function generates a smooth oscillating waveform that represents the tone.
- The formula for generating a sine wave at a given frequency is: waveform(t) = A * sin(2 * π * f * t), where A is the amplitude, f is the frequency, and t is time.

Normalize Waveform:

- Normalize the waveform to ensure that its amplitude falls within the range [-1, 1].
- This step ensures that the waveform is compatible with audio systems and does not cause distortion or clipping.

Output Waveform:

- Save or play the generated waveform for each frequency and intensity combination.
- Optionally, you can display the waveform on a graph or plot for visualization.
- Playing the waveform allows you to hear the tone and verify its characteristics.

Repeat:

- Repeat the generation process for all combinations of frequencies and intensities.
- This step ensures that tones are generated for the entire specified range of frequencies and intensities.

Output:

- Provide the generated tones for further analysis or use in applications such as pure tone audiometry testing.

- The generated tones can be used to assess hearing sensitivity, diagnose hearing disorders, or perform other audio-related tasks.

2. Presenting Tones to the User in a Controlled Manner

Algorithm Name: Tone Presentation Algorithm

This step entails presenting the generated tones to the user in a controlled manner through the user interface of the audiometry test.

The "Tone Presentation Algorithm" is a process for presenting pure tones to individuals during auditory testing, such as pure tone audiometry. Here's an explanation of each step of the algorithm:

<u>Initialization:</u>

- Set up the testing environment, which typically includes a soundproof booth or room and audiometric equipment.
- Ensure that the individual undergoing the test is comfortably seated and wearing headphones or earphones connected to the audiometer.

<u>Define Parameters</u>:

- Determine the range of frequencies to be tested: Select the frequencies (in Hertz, Hz) to be presented to the individual. Common frequencies range from 125 Hz to 8000 Hz, with specific frequencies chosen based on clinical requirements.
- Specify the intensity levels to be tested: Choose the loudness levels (in decibels Hearing Level, dB HL) to be presented at each frequency. Intensity levels typically range from 0 dB HL (very soft) to 100 dB HL (very loud).

<u>Randomization (Optional):</u>

- Randomize the order of presentation of frequencies and intensity levels to minimize potential bias or order effects.
- Randomization helps ensure that the individual's responses are not influenced by the order in which tones are presented.

<u>Presentation of Tones:</u>

- Present each tone (pure tone) to the individual one at a time, starting with the lowest frequency and intensity level.
- Use the audiometer to generate the tones at the specified frequencies and intensity levels.
- Present each tone for a duration of typically 1 to 2 seconds to allow the individual to respond.

Response Collection:

- Instruct the individual to respond when they hear each tone by pressing a button, raising a hand, or verbally indicating that they can hear the tone.
- Record the individual's responses, including whether they heard the tone and their perceived loudness or clarity of the tone.

Threshold Determination:

- Adjust the intensity level of each tone based on the individual's responses using a predetermined step size (e.g., 5 dB or 10 dB).
- Continue presenting tones at increasing or decreasing intensity levels until the individual's hearing threshold (the softest level they can reliably hear) is determined for each frequency.

Data Analysis:

- Analyze the individual's responses to determine their hearing thresholds at each tested frequency.
- Plot the individual's thresholds on an audiogram, a graph that displays hearing sensitivity as a function of frequency.
- Interpret the results to assess the individual's hearing status, including the type, degree, and configuration of any hearing loss.

Documentation and Reporting:

- Document the test results, including the individual's responses and hearing thresholds, in the patient's medical record.
- Generate a report summarizing the test findings and recommendations for further management or intervention, if necessary.

3. Recording User Responses (whether they can hear the tone or not)

Algorithm Name: Response Recording Algorithm

This step involves recording the user's responses indicating whether they can hear each presented tone or not during the audiometry test.

The "Response Recording Algorithm" is a process used to record an individual's responses during auditory testing, such as pure tone audiometry. Here's an explanation of each step of the algorithm

Initialization:

- Prepare the testing environment, including setting up the audiometric equipment and ensuring that the individual is comfortably seated and ready to undergo the test.

Define Parameters:

- Determine the method of response recording: Choose a method for the individual to indicate when they hear each tone, such as pressing a button, raising a hand, or verbally responding.
- Specify the criteria for a valid response: Define the criteria for determining whether the individual's response is valid, such as the timing of the response and the clarity of the response signal.

Presentation of Tones:

- Present each tone (pure tone) to the individual one at a time, following the Tone Presentation Algorithm.
- Use the audiometer to generate tones at the specified frequencies and intensity levels, and present each tone for the predetermined duration.

Response Collection:

- Instruct the individual to respond when they hear each tone according to the chosen method (e.g., pressing a button).

- Record the individual's responses, including the timing and nature of each response.
- Ensure that responses are recorded accurately and reliably to avoid errors or discrepancies in the test results.

Response Validation:

- Verify that each response meets the predetermined criteria for validity.
- Discard any responses that do not meet the criteria or are deemed unreliable, such as delayed responses or unclear signals.

Data Logging:

- Log the individual's responses in a structured format, including the frequency and intensity level of each presented tone and the corresponding response.
- Ensure that the recorded data is organized and labeled correctly for further analysis and interpretation.

Real-time Feedback:

- Provide real-time feedback to the individual during the test to confirm whether their responses are being recorded accurately.
- Feedback may include visual or auditory cues to indicate when a response has been detected and recorded.

Quality Control:

- Monitor the response recording process to identify and address any issues or inconsistencies that may arise.
- Conduct periodic checks to ensure the integrity and accuracy of the recorded data.
- Documentation and Reporting:
- Document the individual's responses and any relevant observations or findings in the patient's medical record.
- Generate a report summarizing the response recording process and the individual's performance during the auditory test.

4. Calculating Hearing Thresholds Based on User Responses

Algorithm Name: Hearing Threshold Calculation Algorithm (MLE)

This step employs Maximum Likelihood Estimation (MLE) to calculate hearing thresholds based on the user's responses to the presented tones during the audiometry test. MLE aims to find the intensity level at which the observed responses (i.e., whether the subject hears the stimulus or not) would occur with the highest likelihood.

The Maximum Likelihood Estimation (MLE) algorithm for calculating hearing thresholds is a statistical method used in pure tone audiometry to determine the softest sound levels (thresholds) at which an individual can reliably hear tones at different frequencies. Here's an explanation of each step of the algorithm:

<u>Initialization:</u>

- Define the parameters: Determine the frequency range and intensity levels to be tested in the audiometric evaluation.
- Set the starting intensity level: Choose an initial intensity level to begin the threshold estimation process (e.g., 0 dB HL for normal hearing individuals).

<u>Tone Presentation:</u>

- Present pure tones to the individual at the specified frequencies and intensity levels according to the Tone Presentation Algorithm.
- Use a predetermined step size (e.g., 5 dB or 10 dB) to adjust the intensity level of each tone based on the individual's response.

<u>Response Recording:</u>

- Record the individual's responses to each presented tone using the Response Recording Algorithm.
- Determine whether the individual reliably hears each tone and responds accordingly.

<u>Threshold Estimation:</u>

- Apply the MLE algorithm to estimate the individual's hearing thresholds at each tested frequency.

- Use the recorded responses to calculate the likelihood of the individual hearing each tone at different intensity levels.
- Estimate the hearing threshold as the intensity level corresponding to the highest likelihood of the individual hearing the tone reliably.

Iterative Process:

- Iterate the threshold estimation process for each frequency tested, adjusting the intensity levels based on the individual's responses.
- Continue presenting tones and refining the threshold estimates until reliable thresholds are determined for all tested frequencies.

Quality Control:

- Monitor the threshold estimation process to ensure the reliability and accuracy of the calculated thresholds.
- Verify that the recorded responses meet the predetermined criteria for validity and consistency.

Data Analysis:

- Analyze the calculated thresholds to assess the individual's hearing sensitivity at different frequencies.
- Plot the estimated thresholds on an audiogram for visualization and interpretation.
- Documentation and Reporting:
- Document the calculated thresholds and any relevant observations or findings in the individual's medical record.
- Generate a report summarizing the audiometric evaluation and the individual's hearing status based on the threshold estimation results.

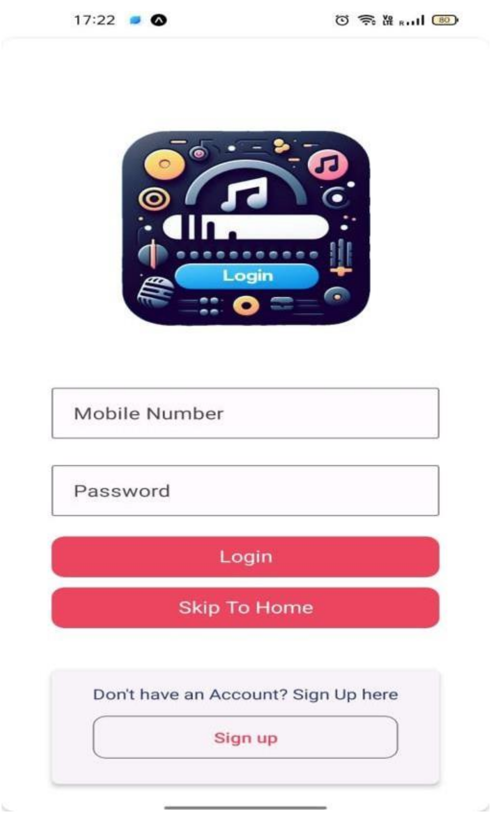
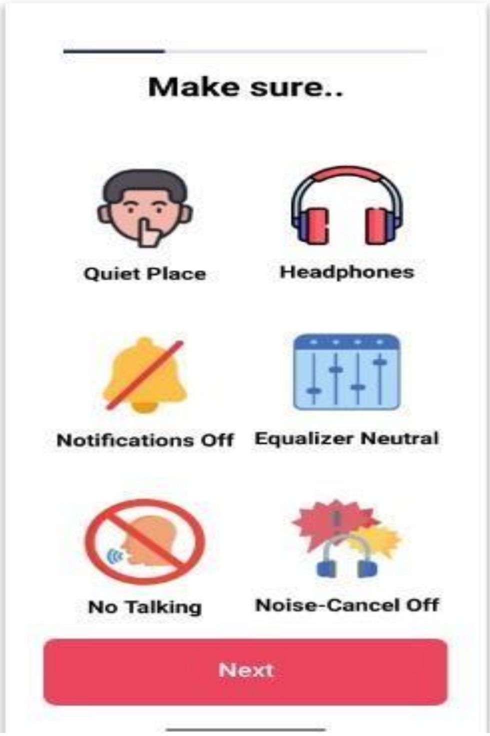


Fig. 4.1 Login Screen

Fig. 4.2 Feature Buttons



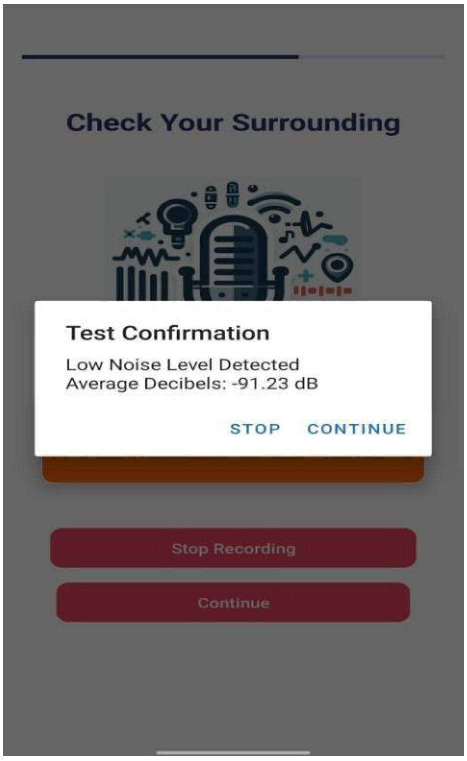


Fig. 4.3 Instruction Screen

Fig. 4.4 Surrounding Noise Detection

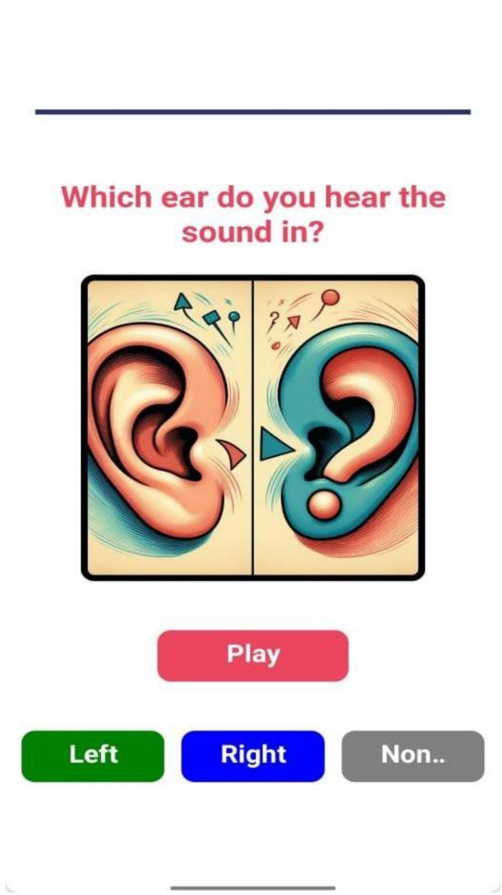


Fig. 4.5 Earphone Test

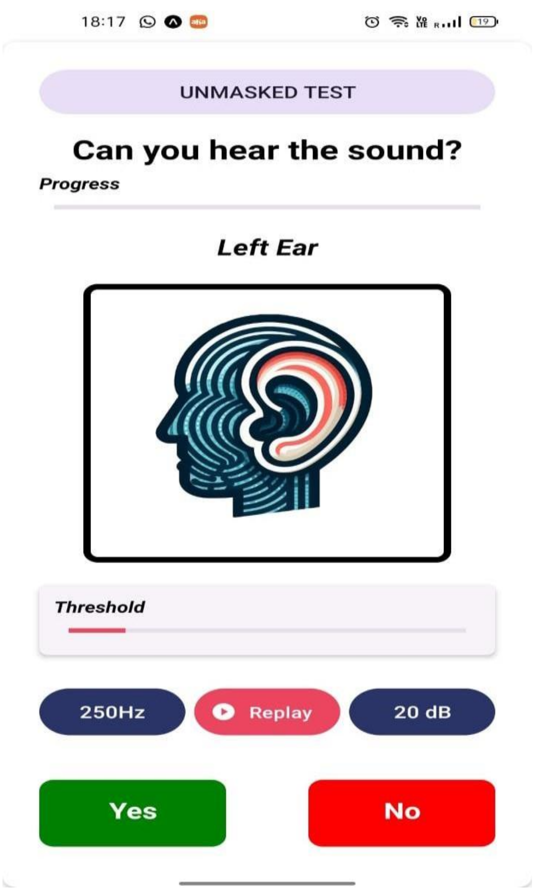


Fig. 4.6 PTA Screen

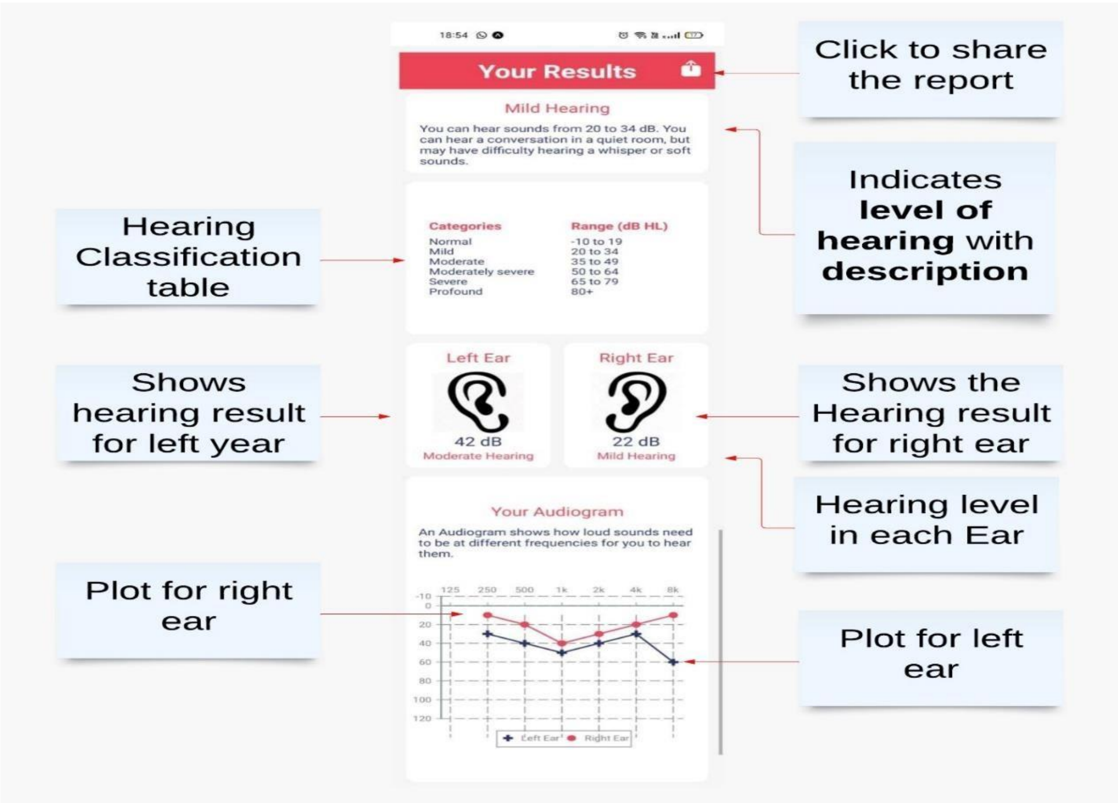


Fig. 4.7 Output Screen containing audiogram and PTA

RESULT AND DISCUSSION

The output of the audiometry test comprises two main components: the Pure Tone Average (PTA) and the audiogram of the left and right ears.

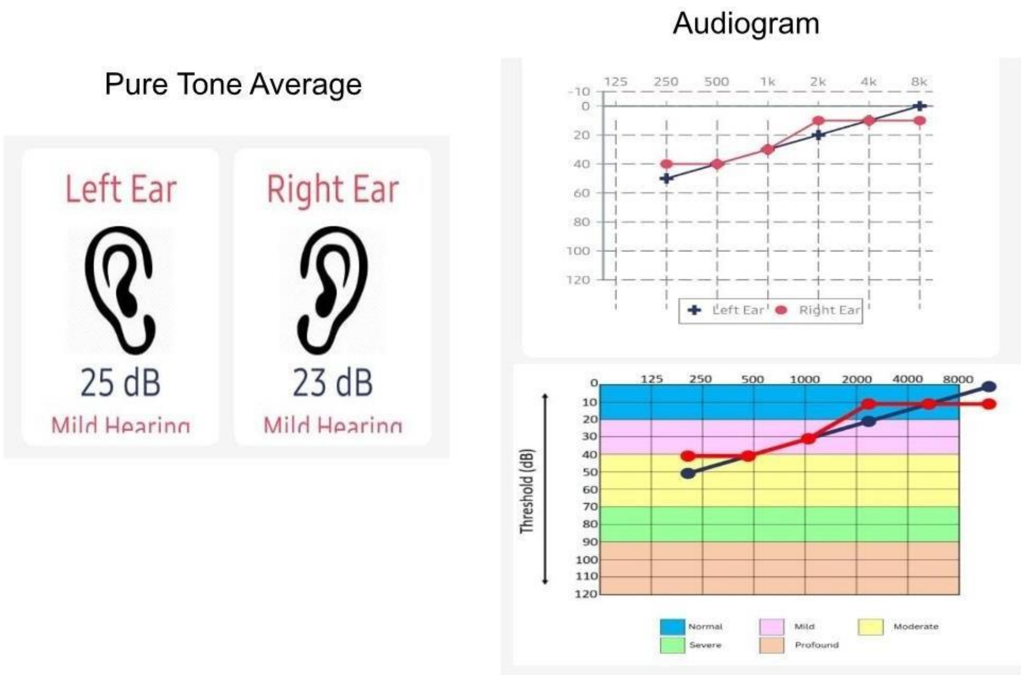


Fig 5.1: Audiogram Output

5.1 Pure Tone Average (PTA)

The PTA stands for Pure Tone Average serves as a summary measure of hearing sensitivity across a subset of frequencies commonly associated with speech perception. In our study, the PTA is calculated as the arithmetic mean of the thresholds measured at select frequencies, usually chosen between 1,000, 2,000, 4,000, and 500 Hz. By averaging the thresholds at these frequencies, we obtain a single value that represents the overall hearing sensitivity of the individual within the speech frequency range.

5.2 Audiogram

The audiogram provides a graphical representation of an individual's hearing thresholds across a range of frequencies, typically from 125 Hz to 8,000 Hz, for both the left and right ears. Each point on the audiogram represents the minimum sound intensity (in decibels Hearing Level, dB HL) required for the individual to detect pure tones at a specific frequency. The audiogram allows visual assessment of the pattern and severity of hearing loss, if present, across different frequencies and ears.

The graph illustrates the average frequency thresholds of 50 students across a range of frequencies. Each data point on the graph represents the average hearing threshold measured for a specific frequency, with frequencies ranging from 250 Hz to 8000 Hz.

Fig 5.2 The average frequency thresholds of 50 students

The graph provides valuable insights into the hearing sensitivity of the student population across different frequencies. A higher threshold value indicates poorer hearing sensitivity, while a lower threshold value suggests better hearing acuity at that frequency.

Significance:

Understanding the average frequency thresholds of the student population is essential for identifying any potential hearing impairments or areas of concern. This information can inform interventions and support strategies to promote optimal hearing health and academic success among students.

CONCLUSION

Karna Rakshak is a hearing analysis application, centered on pure tone audiometry, represents a significant advancement in the field of audiology. This app provides a user-friendly platform for conducting comprehensive hearing assessments, offering both convenience and accessibility to users. By digitizing the traditional audiometry process, the app streamlines testing procedures and enhances data accuracy.

The results generated by the app in the form of audiometry present a comprehensive overview of an individual's hearing capabilities across various frequencies. Through graphical representations and numerical data, users gain insights into their hearing thresholds, aiding in the diagnosis and management of hearing-related conditions. Moreover, the app facilitates the tracking of changes in hearing over time, enabling healthcare professionals to monitor progress and tailor interventions accordingly.

The incorporation of innovative features, such as customizable testing parameters and automated analysis algorithms, further enhances the app's utility and versatility. Additionally, the seamless integration of the app with existing healthcare systems enables efficient data sharing and collaboration among clinicians.

In conclusion, the development of this hearing analysis app signifies a significant milestone in the digitization of audiological assessments. Its user-centric design, comprehensive results, and advanced functionalities make it a valuable tool for both healthcare professionals and individuals seeking to understand and manage their hearing health effectively.

FUTURE SCOPE

In order to enhance the effectiveness and robustness of hearing analysis systems, future research endeavors could focus on the following areas:

a. Obstacle Detection: Implementing obstacle detection mechanisms within the app can improve accessibility for users with visual impairments or other disabilities. By incorporating features such as voice-guided navigation, haptic feedback, or obstacle recognition algorithms, the app can ensure a seamless user experience for individuals with diverse needs. Research efforts could explore machine learning techniques to enhance obstacle detection accuracy and reliability, ultimately improving the accessibility and usability of the system.

b. Multi-lingual Support: To cater to a broader demographic of users, integrating multi-lingual support into the app can be invaluable. This would involve translating user interfaces, instructions, and feedback messages into multiple languages, allowing individuals from different linguistic backgrounds to use the app effectively. Future research could focus on developing robust localization and translation algorithms, as well as exploring culturally sensitive approaches to ensure inclusivity and accuracy in multi-lingual support.

By addressing these areas in future research endeavors, the effectiveness and accessibility of hearing analysis systems can be significantly enhanced, ultimately empowering individuals worldwide to better understand and manage their hearing health.

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Hearing Analysis with Digital Audiometry

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Abstract: One of the fundamental five senses that are essential to daily life is hearing. Despite sufficient mindfulness, society has a disgrace around hearing misfortune. It is one of the critical issues in this present reality and is expanding dramatically. Early recognition and intercession are the method for forestalling and treating this issue. Access to hearing health care is becoming an increasingly pressing issue on a global scale, as it is estimated that by 2050, around 900 million individuals will be affected by disabling hearing loss. The obstacles that pure-tone audiometry encounters encompass large and expensive equipment, restricted accessibility, scarcity of professionals, and ineffective data management. These challenges impede the widespread acceptance and holistic patient care. App-based solutions revolutionise pure-tone audiometry by enabling early detection of hearing impairments through accessible and convenient testing. They offer users the flexibility to undergo tests regularly and remotely, facilitating swift interventions when necessary. Beyond convenience, these solutions provide robust data tracking and analysis capabilities, enhancing our understanding of hearing health and enabling personalized care strategies. Integrating app-based technologies represents a pivotal advancement, addressing key challenges in the field such as accessibility and data management. Ultimately, these innovations contribute to improved hearing health outcomes on a global scale.

Keywords: Pure Tone Audiometry, Decibel, Hearing loss, Frequency

I. INTRODUCTION

Helen Keller famously said, 'Blindness cuts us off from things, deafness cuts us off from people'. The World Health Organization estimates that 466 million (46.6 crore) individuals worldwide suffer from a debilitating hearing loss. Approximately 60% of instances of childhood hearing impairment could be prevented through early detection and consistent monitoring. The "KarnaRakshak" is a mobile application that performs Hearing Tests such as Pure-Tone Audiometry, ensuring a thorough assessment of users' auditory health. Our application emphasises the principle "precaution is better than cure," enabling individuals of all ages, from children to the elderly, to proactively perform regular basic hearing tests on their personal devices.

An individual may have social, economic, and educational setbacks if they lose this capacity. Hearing loss is defined as the inability to hear as well as someone with normal hearing, which is defined as hearing thresholds of 25 dB or better in both ears. "Hard of hearing" refers to someone with a hearing loss ranging from mild to severe, whereas "deafness" refers to the complete absence of any hearing ability. According to statistical data, the average waiting time for a hearing impaired patient to receive appropriate consultation is approximately seven years. According to the National Institute on Deafness and Other Communication Disorders (NIDCD), among the 360 million individuals globally affected by hearing impairment, 32 million are children. Within the United States alone, 15% of adults aged 18 and older—amounting to approximately 37 million individuals—have disclosed experiencing hearing impairment. The imperative for app-based solutions in pure-tone audiometry stems from a multifaceted spectrum of needs within the field. Central to this necessity is the capacity for early detection of hearing impairments, a capability that app-based platforms uniquely offer through their accessibility and convenience. By providing users with the ability to undergo audiometry tests regularly and remotely, these solutions facilitate the timely identification of potential hearing issues, enabling swift interventions and treatments where necessary. Moreover, the inherent convenience of app-based audiometry extends beyond accessibility, offering users the flexibility to schedule tests at their convenience, independent of clinic hours or geographical constraints. In parallel, the robust data tracking and analysis capabilities of these applications hold immense promise for advancing our understanding of hearing health on a broader scale. By facilitating large-scale studies and enabling tailored testing protocols based on individual demographics and needs, app-based solutions not only enhance the efficiency of audiometric assessments but also pave the way for personalised interventions and optimised patient care strategies. As such, the integration of app-based technologies in pure-tone audiometry represents a pivotal step towards improving accessibility, early detection, and data-driven insights in the field, ultimately contributing to enhanced hearing health outcomes for individuals worldwide.

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II. LITERATURE SURVEY

Kashyap Patel., [1] This research studies about the HearTest application, designed for measuring hearing thresholds via smartphones, demonstrates high accuracy akin to traditional audiometers in testing on individuals with normal hearing. However, it's underscored that HearTest isn't a substitute for professional audiologist evaluation, necessitating further refinement and validation, especially for those with hearing impairment and in diverse settings.

De Wet Swanepoel., [2] According to the study, automated audiometry offers adults with normal hearing and hearing impairments fast, accurate, and dependable hearing evaluations. It also has a lot of promise for reaching underprivileged communities without access to hearing health specialists.

Levent Renda., [3]Studies that Smartphone hearing test applications demonstrate strong validity compared to traditional pure-tone audiograms, with results consistently exceeding 0.75 for each ear and frequency. Moreover, the mean absolute difference between smartphone test results and audiograms is less than 8.8 dB. These findings indicate the potential for smartphone-based audiometric tests to provide cost-effective solutions and alleviate the demand for audiological services, particularly in underserved areas.

Marcin Masalski., [4] High compatibility with pure-tone audiometry is demonstrated by research on the hearing self-test method, which can be used for screening tests, hearing monitoring, or large-scale epidemiological studies. The test is conducted on mobile devices that come with headphones.

Lekha V. Yesantharao BS., [5] The study evaluated smartphone apps Mimi and uHear for audiometric testing accuracy compared to in-clinic tests, indicating potential for virtual hearing loss detection using mobile applications.

Hung Thai-Vana., [6]Online digital audiometry has been demonstrated as a clinically accurate method for hearing assessment and showed that the mean difference between the two audiometric test results remained for both the air and bone conduction thresholds at all frequencies examined, within 5 dB HL.

Ravneet Ravinder Verma., [7]A large-scale multicentric study to identify the degree and type of HL, social awareness campaigns, widespread neonatal screening, strengthening treatment facilities and well-funded rehabilitation initiatives can combat India's growing rate of hearing impairment. The prevalence of hearing loss in India varies, with rates ranging from 1.59 to 8.8 per 1000 births in neonates, 6.6% to 16.47% in children, and 6% to 26.9% in the community.

Alexandria L Irace., [8]The paper reviews smartphone apps for hearing assessment, highlighting their potential in remotely screening age-related hearing loss, despite varying features and limited validation studies,smartphone-based hearing test applications may make it easier to screen for hearing loss remotely, but there are still issues that need to be resolved with regard to data security, equipment calibration, app validation, and usability.

III. METHODOLOGY

A. System Architecture

1) *Frontend:*

The frontend of the digital audiometer system comprises the user interface (UI) components essential for user interaction throughout the audiometry testing process. Developed using React.js, this interface facilitates seamless engagement with various functionalities. Users can input test parameters such as frequency and loudness levels through intuitive user input forms. During the testing process, interactive elements provide immediate user feedback, including buttons to indicate whether the tone is heard. Additionally, the front end offers a graphical representation of audiogram results, enhancing the comprehension and analysis of test outcomes. This comprehensive front-end design ensures a user-friendly and efficient audiometry testing experience.

2) *Backend:*

The backend of the digital audiometer system is responsible for managing the logic and processing necessary to conduct audiometry tests effectively. Developed using Python with Django, this backend system incorporates various components to facilitate seamless test administration. It includes an advanced audiometry algorithm designed to generate pure tones and accurately calculate hearing thresholds based on user responses. Additionally, the backend features API endpoints dedicated to handling user requests and responses, ensuring smooth communication between the frontend and backend

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components. Database interaction is also integral, providing robust storage and retrieval capabilities for user data and test results. Together, these components form a cohesive backend infrastructure essential for delivering reliable and comprehensive audiometry testing services.

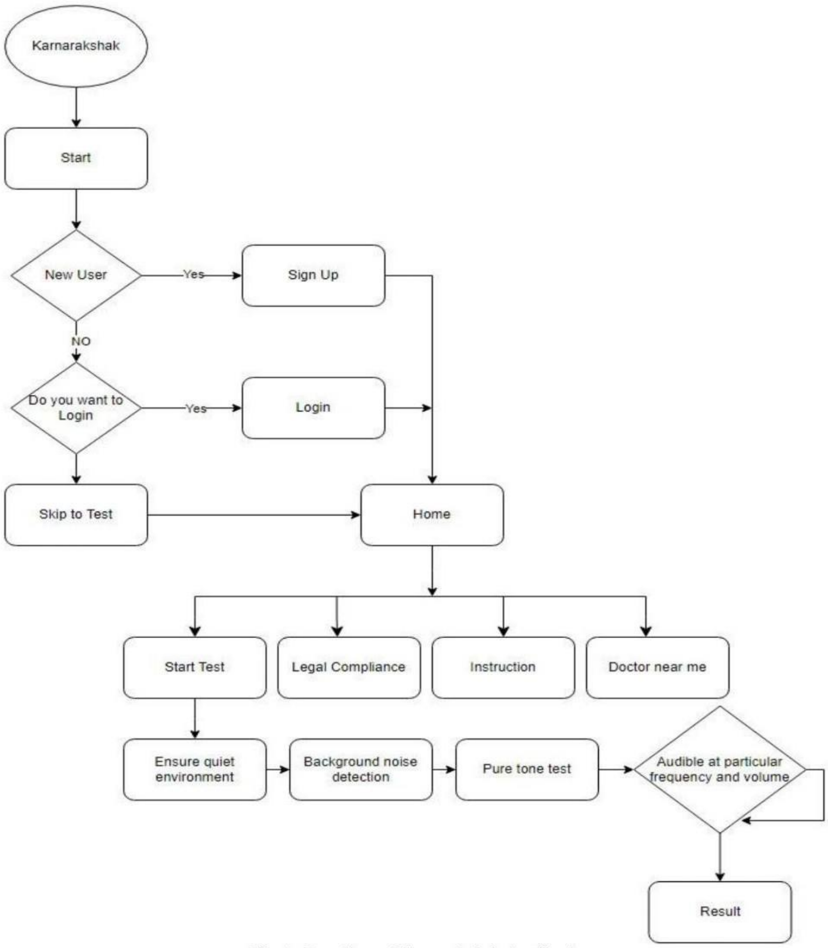

Fig. 1. Dataflow of Karnarakshak Application

3) Database:

The database utilized for the digital audiometer system plays a crucial role in storing and managing essential data related to user profiles, test configurations, and audiometry test results. Employing SQLite technology, this database offers reliability and efficiency for handling the system's data requirements. It encompasses various components, starting with user profiles containing demographic information crucial for personalized testing experiences. Additionally, the database stores test configuration settings, including parameters such as frequency range and step size, ensuring consistency and flexibility in test administration. Moreover, it maintains comprehensive audiometry test results, capturing crucial data such as hearing thresholds for each frequency tested alongside metadata like test timestamps, facilitating analysis and

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tracking of user progress over time. Through these components, the database serves as a robust repository, integral to the functionality and effectiveness of the digital audiometer system.

B. Audiometry Algorithm

1. *Generating Pure Tones with Varying Frequencies and Loudness Levels*:

   Algorithm Name: Tone Generation Algorithm
   This step involves generating pure tones at varying frequencies and loudness levels to be presented to the user during the audiometry test.

2. *Presenting Tones to the User in a Controlled Manner:*

   Algorithm Name: Tone Presentation Algorithm
   This step entails presenting the generated tones to the user in a controlled manner through the user interface of the audiometry test.

3. *Recording User Responses (whether they can hear the tone or not):*

   Algorithm Name: Response Recording Algorithm
   This step involves recording the user's responses indicating whether they can hear each presented tone or not during the audiometry test.

4. *Calculating Hearing Thresholds Based on User Responses*:

   Algorithm Name: Hearing Threshold Calculation Algorithm (MLE)
   This step employs Maximum Likelihood Estimation (MLE) to calculate hearing thresholds based on the user's responses to the presented tones during the audiometry test. MLE aims to find the intensity level at which the observed responses (i.e., whether the subject hears the stimulus or not) would occur with the highest likelihood.

IV. Results & Discussion

The output of the audiometry test comprises two main components: the Pure Tone Average (PTA) and the audiogram of the left and right ears.

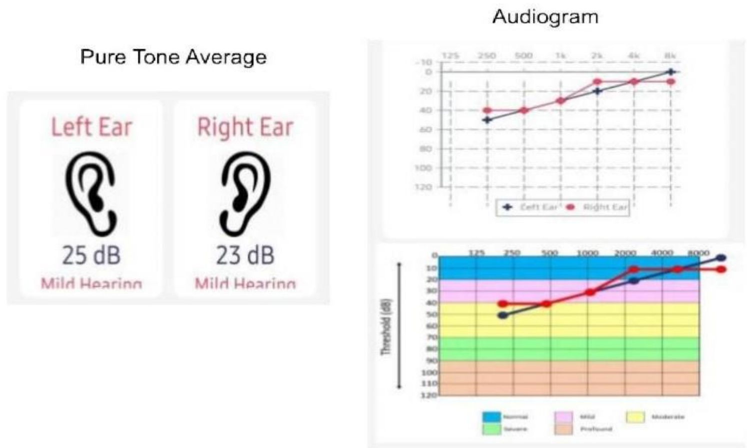

Fig2. Audiogram Output

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a) Pure Tone Average (PTA)

The PTA stands for Pure Tone Average serves as a summary measure of hearing sensitivity across a subset of frequencies commonly associated with speech perception. In our study, the PTA is calculated as the arithmetic mean of the thresholds measured at select frequencies, usually chosen between 1,000, 2,000, 4,000, and 500 Hz. By averaging the thresholds at these frequencies, we obtain a single value that represents the overall hearing sensitivity of the individual within the speech frequency range.

b) Audiogram

The audiogram provides a graphical representation of an individual's hearing thresholds across a range of frequencies, typically from 125 Hz to 8,000 Hz, for both the left and right ears. Each point on the audiogram represents the minimum sound intensity (in decibels Hearing Level, dB HL) required for the individual to detect pure tones at a specific frequency. The audiogram allows visual assessment of the pattern and severity of hearing loss, if present, across different frequencies and ears.

The graph illustrates the average frequency thresholds of 50 students across a range of frequencies. Each data point on the graph represents the average hearing threshold measured for a specific frequency, with frequencies ranging from 250 Hz to 8000 Hz.

Fig3. The average frequency thresholds of 50 students

The graph provides valuable insights into the hearing sensitivity of the student population across different frequencies. A higher threshold value indicates poorer hearing sensitivity, while a lower threshold value suggests better hearing acuity at that frequency.
Significance:
Understanding the average frequency thresholds of the student population is essential for identifying any potential hearing impairments or areas of concern. This information can inform interventions and support strategies to promote optimal hearing health and academic success among students.

V. CONCLUSION

The hearing self-test method conducted on mobile devices with included headphones shows good compatibility with pure-tone audiometry, confirming its possible use in large-scale epidemiological investigations, screening tests, or hearing monitoring. The combination of the Pure Tone Average and audiogram output provides comprehensive information about an individual's hearing status, facilitating diagnostic assessment, monitoring of hearing health over time, and formulation of tailored interventions to address any identified hearing deficits.

VI. FUTURE SCOPE

Future research endeavors could focus on the following areas to enhance the effectiveness and robustness of systems:

1. Obstacle Detection
2. Multi-lingual support

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