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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.

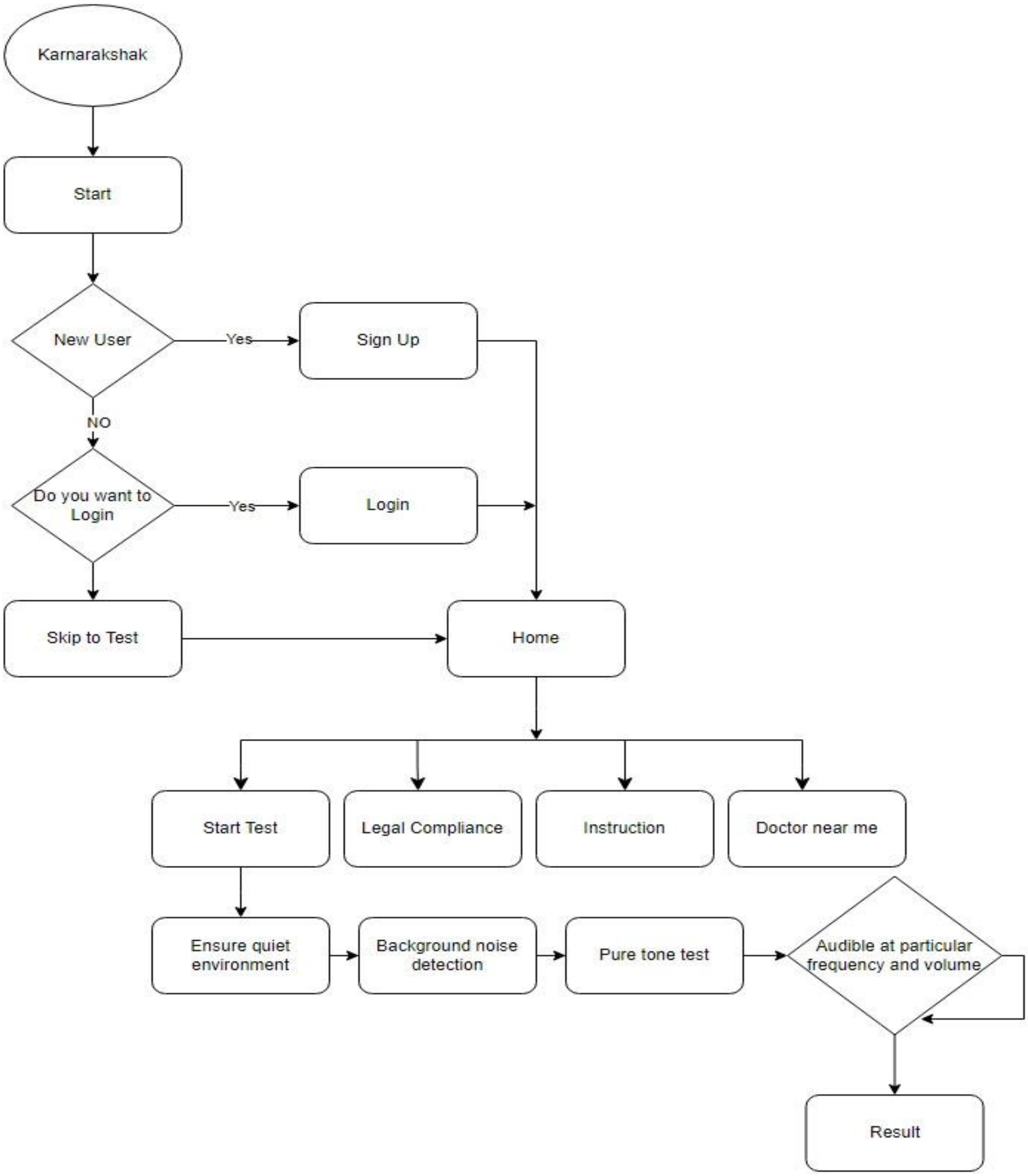

Fig. 1. Dataflow of Karnarakshak Application

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.

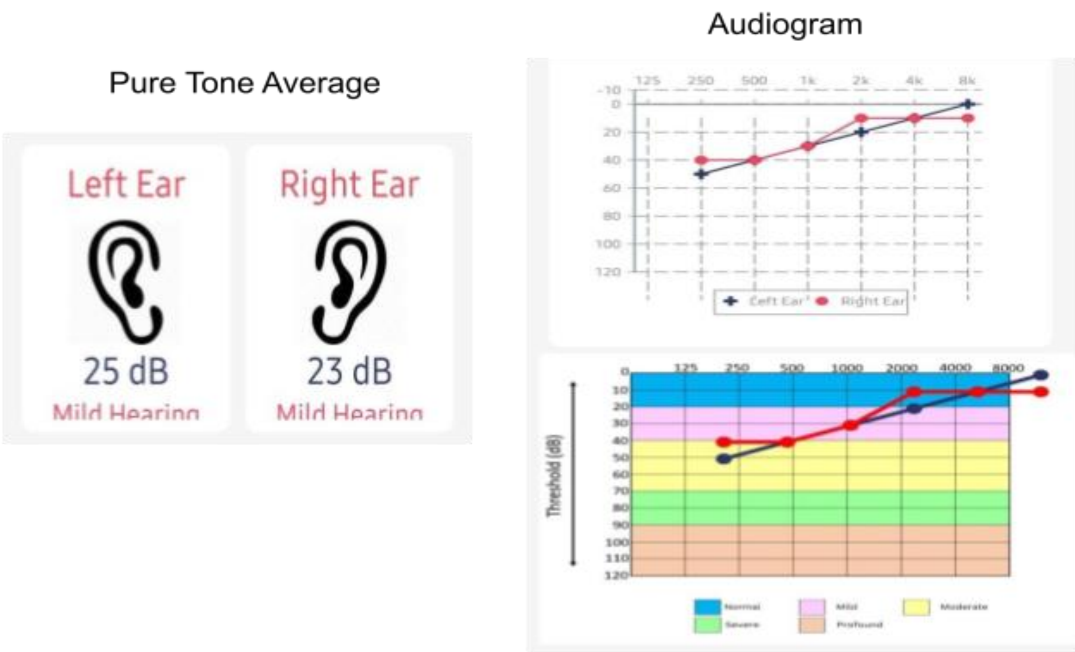

Fig2. Audiogram Output

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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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