A Novel Software Solution to Diagnose the Hearing Disabilities In Human Beings

Prithvi B S
Dept of Computer Science & Engineering
SVIT, Bangalore
bsprithvi1992@gmail.com

Sanjay H S
Research Scholar, Jain University &
Asst Professor, Dept of Medical Electronics
MSRIT, Bangalore

Deeksha Hegde
Assistant Professor
Dept of Computer Science & Engineering
SVIT, Bangalore

Bhargavi S
Professor, Dept of Electronics & Communication Engineering
SJCIT, Chikkaballapura

Abstract— Ears are one of the most important sensory organs in human beings. They contribute equally to human beings in acquiring information from around the world. They also help in maintaining a sense of balance in addition to providing the human beings with the ability to hear. Majority of the population are over exposed to sound which significantly leads to hearing loss. A person is said to suffer from hearing loss if he loses the ability to perceive the sound within the normal audible range. In such a scenario, an affordable and reliable testing protocol is required to treat the human fraternity [1]. Therefore, the need of the day is to develop a low cost solution to assess the hearing disabilities in human beings by eliminating the requirement of sound proof environment used in traditional hearing test procedures like audiometry. The auditory function in human beings can be assessed using various parameters of sound such as pitch, intensity, frequency, etc. [2] The current work focuses on developing a simple and an affordable software system which is used to assess the threshold of hearing in human beings. MATLAB platform is used in designing the software system. The software has also been standardised by acquiring the threshold of hearing from 44 healthy individuals of both males and females with age group 20-30 years. The results prove that there is a slight improvement in the hearing perception of males when compared to females.

Keywords- *hearing disabilities, testing protocols, hearing perception, audiometry, threshold of hearing*

*****

I. INTRODUCTION

Hearing loss, also known as hearing impairment is said to happen when a person loses his ability in perceiving the sound. Human ears are sensitive to the range of sound from 20Hz to 20KHz. Hearing losses are found to be from mild to severe. Hearing loss occurs when there is a problem with any part of the ear. People with such hearing loss are able to hear something or not able to hear anything. Hearing loss can be classified as sensory-neural hearing loss and conductive hearing loss. There is a conventional test procedure used to assess the hearing threshold called "Audiometry". Audiometry is a skeletal test used to assess the hearing disabilities in human beings. This test not only helps in assessing the hearing threshold, but also helps in assessing the subject's ability to discriminate between sounds of various intensities and frequencies, pitch and even the ability of an individual in separating purte sounds from background noise. There are different types of audiometrical procedures namely, pure tone audiometry, speech audiometry, immittance audiometry and evoked response audiometry. Pure tone audiometry is used to test both air conduction and bone conduction in human beings. [3]

The results of the mentioned tests are produced in the form of audiograms. Audiogram is a plot of graph with frequency versus intensity, which is obtained as the response from the subject under test. Since, the analysis of the results is done depending upon the response from the subject; audiometry is considered as a subjective test protocol. In order to provide a better, reliable and reachable solution to unaffordable and rural population, the present work proposes a novel software based protocol to assess the hearing perception in human beings by developing an affordable solution to replace the existing setup in the hospitals. [4]

Audiogram is plotted based on the audiometry results which is simply which is a plot of intensity versus frequency obtained based on the response of the subject in the audiometry test and hence, Audiometry is a subjective test protocol wherein subject's response for the test is very much considered for the analysis. This test also needs a trained technician in order to administer various types of sounds to the subject and to obtain their response in order to plot the audiogram. Audiometer is a hardware unit. But latest audiometers have software-hardware combination units in order to facilitate better testing protocol

II. BACKGROUND

Ears form a very important sensory organ in human beings because of which, they can communicate with one another. Proper auditory function in human beings enables them in acquiring the activities performed around the world. Therefore, the people suffering from hearing loss are isolated from the world. Hearing loss may occur due to many reasons such as exposure to high noise, infections present in the middle ear, consumption of various drugs, and finally aeging becomes the natural factor. The inability of an individual to discriminate between different parameters of sound such as pitch, gap, frequency and intensity contribute to hearing loss.

Frequency and intensity are the important parameters of sound which are greatly contributing to hearing loss.
Audiometry is a technique used to assess such hearing disorders in human beings. It provides the threshold of hearing, which is the minimum sound that the human beings can hear.[5] Hearing loss are associated with different parts of the ear as shown in figure 1. There are three major types of hearing loss, as mentioned below

a. Conductive hearing loss: There is a loss in conduction of sound from outer ear till the middle ear.
b. Sensory neural hearing loss: In this case, there is a loss of conduction of sound from middle ear to the inner ear cochlea.
c. Mixed hearing loss: This contributes to both conductive and sensory neural hearing losses.

Subjective audiometer and objective audiometer are the two types of audiometer where subjective audiometer relies on the response from the subject under test and objective audiometer does not depend on the subject's response under the test.
Further, audiometrical procedure is classified into four types as follows:

a. Pure tone audiometry: In this test, sound presented to the user consists of single frequency.
b. Speech audiometry: In this test, sound given to the user consists of complex and different frequencies and intensities.
c. Immittance audiometry: This auditory test checks the structure of the ears offering resistenace to the incoming sound.
d. Evoked response audiometry: This objective test protocol unlike the subjective approach uses electrodes to record the changes in brain or by the ear instead of depending upon the subject's response.

Figure 1: Different areas of human ear related to hearing loss

III. EXISTING SYSTEM

In the conventional audiometry set-up currently used in hospitals, the patient or the subject sits in a sound proof room and is provided with headphones through which he/she is able to hear the incoming sound. This sound is generated by the audiometer, with frequency and intensity modules which are present outside the sound proof room. The operator or technician would be present near the audiometer to vary the parameters of sound (frequency & intensity) in the same depending upon the response given by the subject. The subject is asked to provide a response through some hand actions to the operator outside. Then a plot of frequency versus intensity is made by the operator and the threshold of hearing can thus be found. [6]

Drawbacks of the existing system:

a. Huge cost investment in setting up the sound proof room.
b. Mandatory presence of the operator or the technician at the test spot.
c. Immobile set-up.
d. Subjective test procedure.
e. Tedious user interaction.

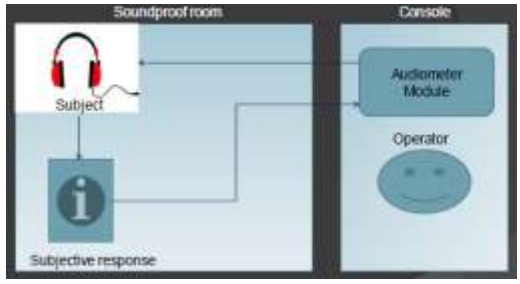


Figure 2: Audiometry set-up currently used in hospitals

IV. PROPOSED SOLUTION

The present work aims at developing a standardized software system to assess the hearing disabilities in human beings which is affordable and also reachable to the rural population. The proposed software solution overcomes the drawbacks exposed by the existing system with the elimination of sound proof environment and also the physical presence of the operator at the test spot. The proposed software system with the aid of MATLAB platform makes the user interaction easy with the system. [7]

A. Implementation

The instrumental setup is very simple and consists of a computer with a windows platform and MATLAB. The stimulus which is a tone with a fixed intensity and varying frequency is given to the subject by means of a noise cancellation headphone to which, the response is picked and the data is stored simultaneously. The use of a battery operated laptop enables recordings at locations remote from AC power sources or when the mains are switched off. [8]
MATLAB is a high performance language used for technical computing. It combines computation, visualization, and programming in a simpler platform using familiar mathematical notations. MATLAB simplifies the analysis of mathematical models and is known for fast computations.

B. Experimental Protocol

The present protocol was designed to test the frequency response of the human ear to determine the threshold of hearing. The test is based on the fundamental principle that the ear has a non-flat frequency response. This means that a set of tones, while keeping the volume constant, when played at different frequency values will sound as if they are being played at different volume levels. This is why individuals hear some tones better or worse than others as each individual's ear has been made differently and hence there is a difference in the response to different frequencies.
The paradigm considers the frequency range to be tested from 0 to 16000 Hz since that is the region of hearing for humans. Especially the high-frequency range from 9000 to 20000 Hz is considered as important for early detection of hearing loss.

Each frequency is played across amplitudes ranging from 10 to near 0. These amplitudes are multiplied by a factor of 0.707 which is an equivalent of 3dB decrement because that is the Just-Noticeable-Difference (JND) for an average human ear. Hence, we get 26 levels for each frequency to be played and tested for the threshold of hearing.

The 26 levels stored in an array rounded off to four decimal points are 10, 7.0794, 5.0118, 3.54813, 2.5118, 1.7782, 1.2589, 0.8912, 0.6309, 0.4466, 0.3162, 0.2238, 0.1584, 0.1122, 0.0794, 0.0562, 0.0398, 0.0281, 0.0199, 0.0141, 0.0100, 0.0070, 0.0050, 0.0035, 0.0025, and 0.0017.

The frequency values considered are from 10 Hz to 16000 Hz in steps of 10 Hz with a total of 1600 values. Each frequency value starting from 10 Hz is used in the tone function of MATLAB with a maximum of 26 levels each, as mentioned prior, depending on the subject's responses to generate tones. It starts from the maximum and goes on decreasing. The sound function of MATLAB is used to play the generated tone.

At each frequency as long as the subject keeps responding positively (tone heard) the level will decrease to the last 26th level and move on to the next frequency and start from the 1st level again. If the subject responds negatively (tone not heard) at a particular level in a frequency value the control moves onto the next frequency level while having set the level back to one. This way the subject's threshold of hearing is determined at every frequency and plotted simultaneously.

So if the result says the subject heard up to level 26 at 3500 Hz, it means levels below 26 are below the threshold of hearing and the level thus obtained corresponds to -4 dB because it would then be the approximate threshold of hearing at 3500 Hz for a subject of normal hearing. Using this convention, the rest of the thresholds are plotted at various frequency values by subtracting the count at each frequency from 3500 Hz and multiplying the difference by 3 and then, adding the result with -4 dB, to get a series of the dB levels to plot the equi-loudness curve that can be, for analysis, compared to the threshold of hearing graph of a normal hearing subject.

For example, if the highest count was 21 for 3500 Hz and for 100 Hz it was counted as 5 audible tone levels and for 1000 Hz, the subject has been able to count 18 audible tone levels. This would then be plotted as -4 dB at 3500 Hz, 3*(21-5)-4=44 dB at 100 Hz and 3*(21-18)-4=5 dB at 1000 Hz. [9] [10]

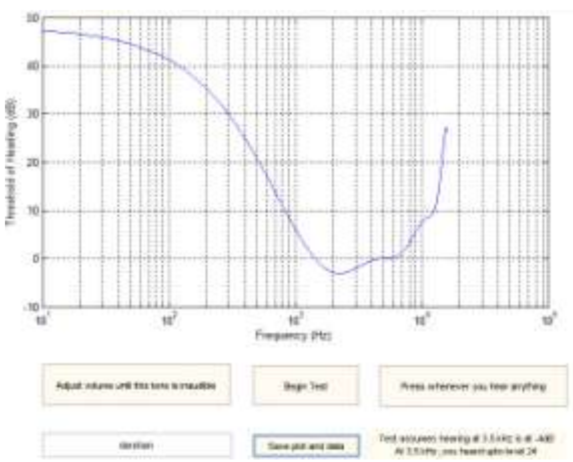


Figure 2: GUI front end for the present protocol- Sample data depiction

C. Algorithm

1. Start.
2. Play the system sound/volume.
3. Adjust the system volume to just audible.
4. Play the actual sound with a particular frequency for a fixed intensity.
5. If the user is able to hear, then decrease the frequency level keeping the intensity constant.
6. Repeat the step 4.
7. If the user is not able to hear, increase the frequency level keeping the intensity constant.
8. Once all the frequency level are varied for a particular fixed intensity, now increment the intensity level.
9. Steps 4, 5, 6 & 7 are repeated.
10. Stop.

V. RESULTS AND DISCUSSIONS

A total of 44 subjects, both males and females of age group 20-30 years all of no known history of auditory pathology were considered for the data acquisition. The experiment was conducted from 8.00 am – 10.00 am thereby minimizing the possible effects of fatigue due to various time bound factors such as stress and work pressure. The intensity response thus obtained is compared for males and females and among the 1600 frequency values, mentioned in the table 1 is a set of response of the subjects at certain important frequency values

Table 1: Intensity threshold power values at important frequency values

	Intensity thresholds (dB)	
	Males	***Females***
Frequency (Hz)		
3000 Hz	***-2.6366***	***-3.5723***
3500 Hz	***-1.3761***	***-3.3820***
4000 Hz	***-1.0284***	***-3.4702***
13500 Hz	***-0.9343***	***-2.3682***

Also an average plot of the intensity responses of males and females is mentioned in figure 3. This graph can be used for further clinical analysis.

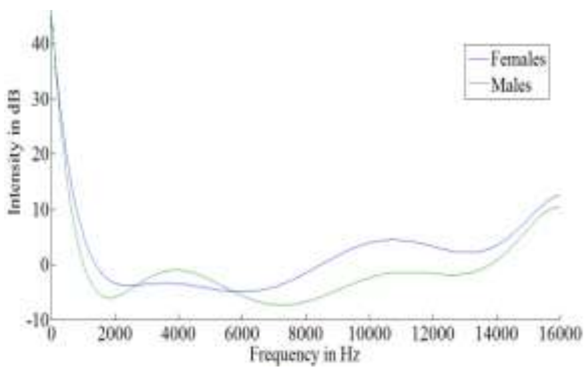
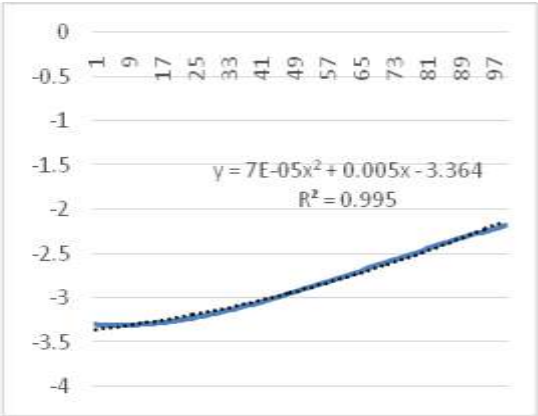


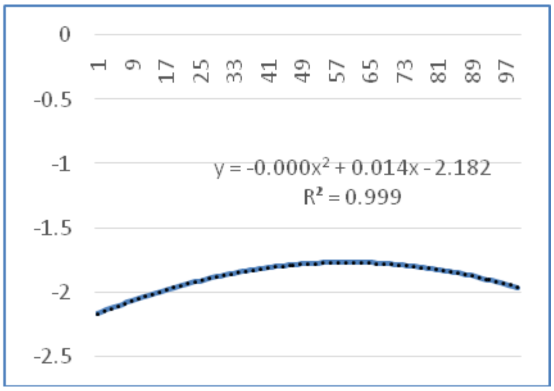
Figure 3: The plot of frequency response portraying the averages of 44 female and 44 male subjects, with the blue line representing the females and green line representing the males.

 ISSN: 2321-8169
593 - 597

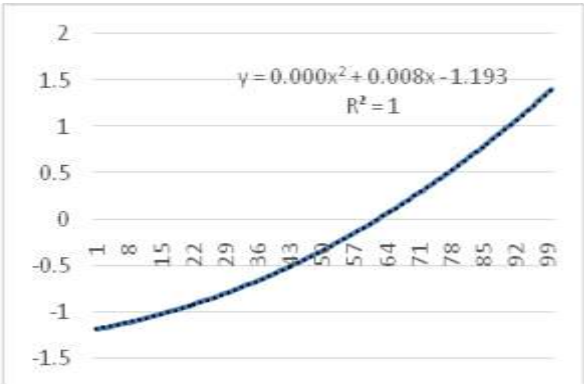
As an extension, a polynomial curve could be fit to the male and female responses and is shown in figure 4 and 5 respectively, for certain important ranges of frequencies



Males 2000 – 3000 Hz



Males 3000 – 4000 Hz

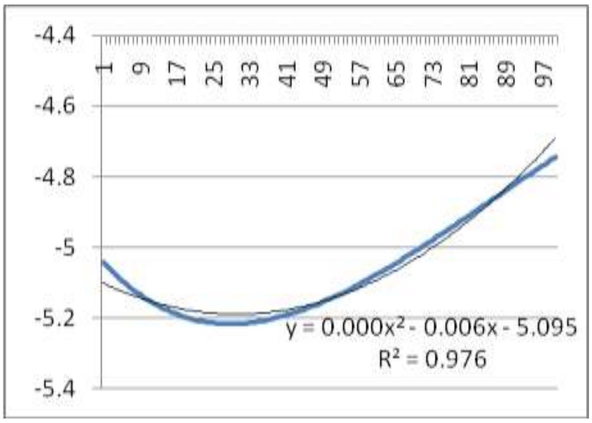


Males 13000 – 14000 Hz

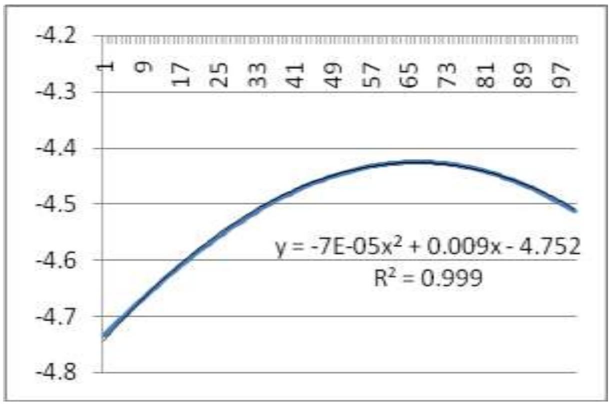
Figure 4: Polynomial fit obtained for males at important frequency ranges

From table 1, it is evident that at 3500 Hz, (the ear is most sensitive at that particular frequency) the average hearing level is better in males than in females. As mentioned in the protocol hearing level can be calculated at any frequency value.

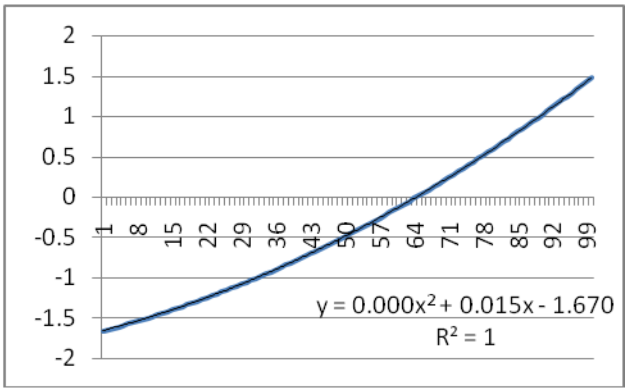
Also from figure 4 and figure 5 which depict a curve fitting to the data acquired, it is observed that the males have a better response than females and a polynomial curve fit at R above 95% proves the strength of the thus obtained fit



Females 2000 – 3000 Hz



Females 3000 – 4000 Hz



Females 13000 – 14000 Hz

Figure 5: Polynomial fir obtained for females at important frequency ranges

VI. CONCLUSIONS AND FUTURE DIRECTIONS

The present work explores an innovative and a novel approach in developing an affordable solution used to assess the hearing loss in human beings with the use of mat lab software and graphical user interface with lesser hardware requirements, making user interaction easy with the system. The proposed solution is also made reachable to all the primary healthcare centers in rural population. MATLAB being a high performance language integrates computation, visualization and programming in an easy to use environment for the users to interact with the system/software in a comfortable manner. As an extension of this work, more focus could be on developing an affordable and easy to use mobile based hearing loss detection paradigm with enhanced parameters facilitating the real-time analysis of the test performed at primary healthcare centers in rural areas

ACKNOWLEDGMENTS

The present work has been carried out at MedNXT Innovative Technologies, Bangalore in association with M S Ramaiah Institute of Technology, Bangalore. The authors wish to express their gratitude for all the support and encouragement provided by these organizations during this work

REFERENCES

[1] Rogers, Susan E. "“Hidden” hearing loss: The search for the origin of common hearing disorders." (2015).

[2] Stamper, Greta C., and Tiffany A. Johnson. "Auditory function in normal-hearing, noise-exposed human ears." *Ear and hearing* 36.2 (2015): 172-184.

[3] Vielsmeier, Veronika, et al. "The Relevance of the High Frequency Audiometry in Tinnitus Patients with Normal Hearing in Conventional Pure-Tone Audiometry." *BioMed research international* 2015 (2015).

[4] Gardner, Jacob, et al. "Bayesian Active Model Selection with an Application to Automated Audiometry." *Advances in Neural Information Processing Systems*. 2015.

[5] Lin, Frank R., et al. "Hearing loss and cognitive decline in older adults."*JAMA internal medicine* 173.4 (2013): 293-299.

[6] Kiessling, Jürgen, et al. "A Comparison of Conventional and In-Situ Audiometry on Participants with Varying Levels of Sensorineural Hearing Loss." *Journal of the American Academy of Audiology* 26.1 (2015): 68-79.

[7] Sanjay H S, Anusha G, et al. “Auditory perception of random gaps in human beings”, International Journal of Biomedical Engineering & Consumer Healthcare Informatics, 4.2, (2012): 29-31.

[8] Sanjay H S, Arundathi, et al. “EEG based GAP perception in human beings”, International Journal of Advanced Engineering 7 Research, 10.2 (2015): 92-101.

[9] Samyuktha, Kruthi, et al. “Design and development of a software based novel paradigm to assess the auditory frequency response in human beings”, M S Ramaiah Journal of Engineering Technology & Research, 4.2 (2016): 10-16

[10] Hirsh, Ira J., and Charles S. Watson. "Auditory psychophysics and perception." *Annual Review of Psychology* 47.1 (1996): 461-484.