Conception of a software pure tone audiometer application

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Abstract— ***The prediction of the hearing thresholds using the pure tone audiometer is an essential part of the hearing test to know the sensitivity of the human hearing. In this paper, we present a pure tone audiometer implemented in MATLAB development environment for a personal computer. A flowchart presents the different steps to facilitate the use of the graphical user interface of pure tone audiometer test . The frequencies of hearing levels graph of the left ear and right ear are displayed together in the same audiogram for comparison. To obtain the audiogram, an accurate and less time consuming procedure called the modified Hughson-Westlake procedure is used. An overview of audiometric calibration is conducted to improve the software audiometer application's results.***

Index Terms— hearing threshold, graphical user interface pure tone audiometer, audiogram, calibration.

I. INTRODUCTION

Human hearing can be influenced by age, noise and hereditary phenomenon[1]. In addition many sickness from viruses and bacteria can deteriorate the organ of the ear and cause hearing loss. The latter is a sever health issue and if undetected, can cause an important negative impact on language development and speech specially for children[2]. Wearing a hearing aids can be the best solution to solve the problem of hearing loss. The hearing impaired persons aren't aware of the damage in the hearing level and delay wearing the hearing aids [3]. To avoid the deterioration of human hearing and to offer better satisfaction to the users of hearing aids, the hearing loss must be detected at the earliest stage.

There are different hearing examination techniques such as the otoscopy, tympanometry with 226 Hz probe tones for adult and 1000 Hz probe tones for children and the otoacoustic emissions which are used to exanimate respectively the outer ear, the middle ear and the status of the cochlea specially the functionality of the inner hair cell[4-5]. For the hearing assessment techniques there are the auditory evoked potential response and the audiometry used to predict the hearing thresholds[6-7]. In medicine, the conventional audiometer is the most electronic instrument used by the audiologist to test the sensitivity of the human hearing. Those audiometers are specific and very high technical. Also, they are costly and present a lack of availability in the clinic. But, because of the existence of a rapid increase in the percentage of the hearing impairments and for the prevention from the hearing loss, audiometric hearing tests must be necessarily done at home or in workplace. The important advantages of the personal computer based audiometer is that it's implemented with automatic screening which contents a simple interface and it not requires a specific training to achieve the screening. In addition, using the computerized methods can facilitate the recording of data and encourage hearing impairment person to periodically conduct hearing test[7-8]. To obtain the audiogram there are different methods which are the method of constant stimuli, method of limits and the method of adjustment[9][10]. The method of limits presents the accurate and less time consuming and the most used method by audiologist to display the audiogram is the modified Hughson- Westlake procedure [10].

In this study, we present pure tone audiometer implemented in MATLAB development environment for a personal computer. This application generates a pure tone signals using MATLAB for different frequencies which start from 125 HZ to 8 HZ with varying the intensity level from 0 dB to110 dB then this signal is fed through the headphone. Then the results are displayed in the audiogram using the modified Hughson-Westlake procedure.

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II. AUDIOGRAM MEASUREMENT

A. Overview of different methods

In this part, the methods of the audiogram measurement are explained. There are three well know procedures could be used to plot the audiogram which are the method of constant stimuli, method of limits and the method of adjustment[9][10]. For the method of the stimuli, a series of pure tones of each frequency and intensity level is played for the patient then the number of responses for each level is recorded. If the number of responses equals to half of the signal level, the later is considered as threshold. With the method of adjustment, the patient could control the signal's level and makes this level to the just-barely heard value. the later is defined as threshold.

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For the limit's method , when the patient is exposed at a signal with certain frequency and intensity level, his responses is recorded. After that, the level's signal is changed and again the response is recorded. The threshold is the lowest intensity level to which the patient' responds present at least fifty percent of the presentation.

When comparing those three methods based on the consuming time and the accuracy of the threshold's determination, the method of constant stimuli presents the most accurate method but it takes long consuming time. In opposite, the method of adjustment consumes less time but it is the most inaccurate method[9]. That leaves the method of limits which is in the middle of accuracy between the other methods and it has less consuming time, the most suited method to perform audiometric test.

B. The modified Hughson-Westlake procedure

In this procedure the signal intensity is presented firstly to the patient at a level at which he can hear clearly. If the patient has normal hearing, the signal intensity should be 40 dB. After, the intensity level is decreased in fixed step size, decrements until the patient could not respond. Then the intensity level is increased in smaller step size then increments until the patient responds again. So whenever the patient responds, the signal intensity is decremented and if the patient could not respond the intensity is incremented. The threshold is considered as the signal level to which the listen could respond two out of three times when the signal level is incremented[10].

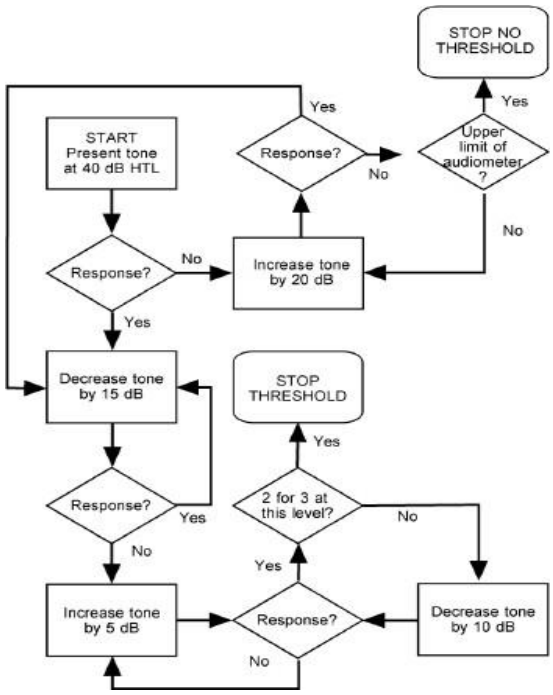

Fig.1 The flowchart of the modified Hughson-Westlake procedure[10]

III. AUDIOMETER

A. GUI implementation

The user interface of the pure tone audiometer being built by GUIDE is in figure 3. This application generates different frequencies, plays a spectrogram of the frequency chose by the user. It also saves the list of frequencies and the hearing level at the selected ear which are played during the test to plot the audiogram. On program execution, the Initialization of the sampling frequency f_s, the sinusoidal frequency f, and the length of the sample N is treat on the GUI initialization. A vector t containing all the time samples is generated by the following equation.

$$t = (2 \times \pi \times [1:N]) \div f_s \tag{1}$$

After the sinusoidal samples is produced using the equation

$$y = A \times \sin(2 \times \pi \times f \times t) \tag{2}$$

A is the amplitude given by the formula:

$$A = 10^{(dB \div 20)} \tag{3}$$

Where dB is the selected decibel level

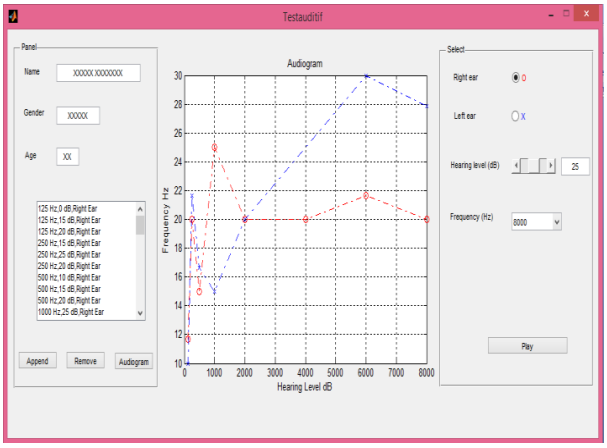

Fig.2. The graphical user interface of the pure tone audiometer

B. The flowchart

The flowchart shown in figure 2, presents the different steps to perform the pure tone audiometer test using the user interface. First, the initialization of sampling frequency fs, the sinusoidal frequency f, the length of the sample N and sample time. Second, the selection of the appropriated ear , the

frequency and the hearing level using respectively ear radio, pop menu and the slider. When the play button is pressed the selected frequency at the set hearing level and at the appropriated ear is played.

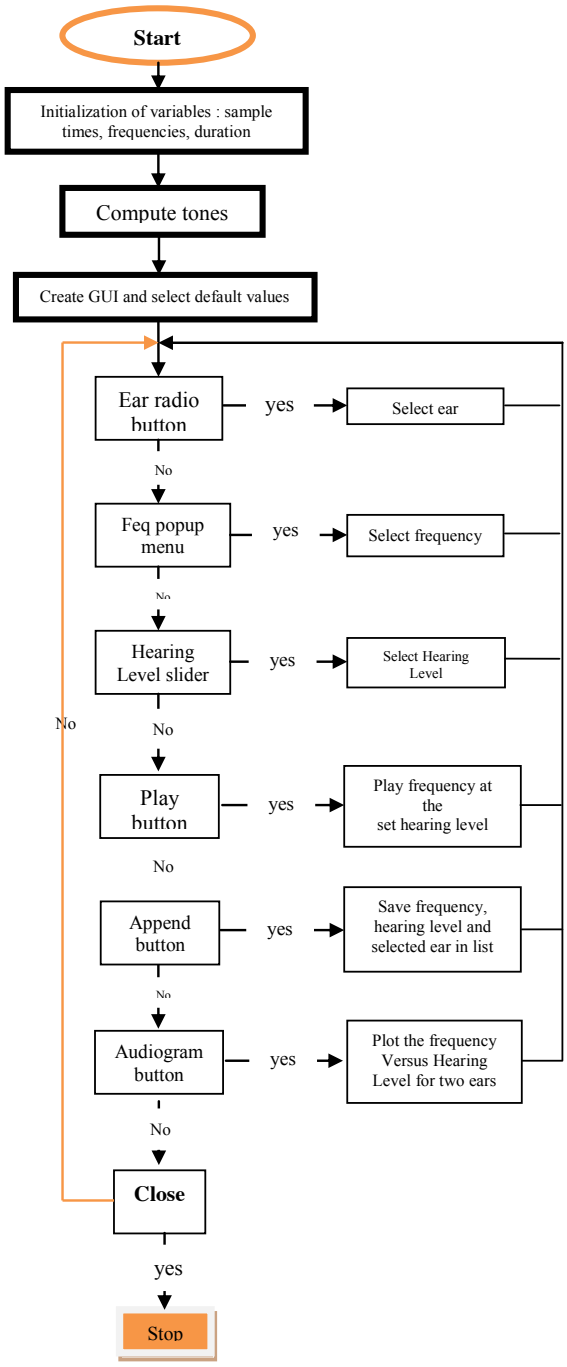

Fig.3 The flowchart of the pure tone audiometer

By selecting the append push button the hearing level, the frequency played and the selected ear are stored in a list box. The remove push button is used to delete the unused data from the list box. When the append button is pressed, the selected frequency at the set hearing level and at the appropriated ear is played. The date are stored into matrix by pressing the push button audiogram. After, the hearing levels are averaged for the same frequency and for each ear. The data for the right and left ear are saved in two separately matrixes. Finally, the graph frequency versus hearing level is plotted for both Right and Left ear simultaneously.

IV. Overview of Audiometric Calibration

The hearing measurement of the pure tone audiometer system consists of computer equipped with MATLAB, transducer and sound card. However, earphones present the most common transducers used to perform audiometric tests. The audiometer generates voltage which drives the earphone, the later results in the output measured in decibels sound pressure level (dB SPL). It exists three types of earphones used to perform audiometric test: circumaural, insert and supra aural earphones[11]. Each audiometer must be calibrated to ensure that the level displayed on the screen is really equal to the simulation to which the subject is exposed. Achieving this correspondence is an indispensable step to have accurate and reliable measurements in characterization and quantification of hearing loss. The calibration must be taken at least once a year.

The acoustic coupler called also ear simulator is the device used for the calibration of the earphone. The later is placed over the coupler which is equipped with a calibrated microphone. After choosing a frequency, the earphone connected to the Audiometer is set to a defined sound level. The coupler's microphone is connected to a measuring amplifier and then to a sound level meter on which the level of sound pressure emitted by the earphone can be read directly. To eliminate noise from the sound environment, a filter is inserted between the microphone and the sound level meter. Then this calibration method is repeated to the next frequencies[11].

The earphone can be calibrated directly with a sound level meter which is equipped with a microphone which permits the measurement of the output level of an earphone. Because of the microphone is very sensitive and it can be influenced by temperature and humidity, the measurement should be conducted in a controlled climate.

V. Conclusion

In this paper, software version of conventional audiometer was implemented under MATLAB. It permits to predict the hearing thresholds using pure tone. The results from the pure tone audiometric tests are displayed in the form of an audiogram which is obtained by an accurate and less consuming time procedure called the modified Hughson- Westlake. This software pure tone audiometer application presents an accessible and friendly interface which can encourage the

hearing impairment people to perform periodically hearing test. For hearing measurement just a computer equipped with sound card , MATLAB development environment and an earphone are needed. In fact, it has low cost implementation comparing to the expensive manual audiometer.

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