Music Auditory Aided System for Hearing Impairment

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Abstract

Middle or heavy hearing impairments lack of sound perceived capability. Therefore, a music learning system for hearing impairment (MLSHI) has been implemented to help hearing impairments to practice the musical melody play. This system can be an auditory monitor tool for hearing impairments to help them understand what are the pitch, tempo, and song to increase their interest of musical class and also to increase their listening performance.

Keywords: auditory training, hearing impairment aide tool, voice frequency, speech hindrance

1. Introduction

With the advance in computer technology and the ever decreasing cost dramatically of computer, the computers have been pervasively used in education for the past decades [20, 22]. The high quality of computer-aided learning (CAL) material has been seeing the emergence to support both for the teachers and for the students.

For hearing impaired people, the musical treatment or the training may strengthen their auditory capability as well as widen their residual auditory capability. Auditory training should make hearing impaired people to understand the sound or voice through the brain analysis and the penetration sense of hearing. Ended with the training to make hearing impaired people understand the significance of the sound or the voice, it is also widen the scope of the sense of hearing and further increase their social communication capability. Therefore, the auditory training should try to increase the residual auditory capability for hearing impaired people as far as possible expansion to be biggest. The reason is that the speech or the pronunciation training process surely is very tedious and dull. Thus the musical note does for the auditory training can become the effective and interesting method.

The pronunciation and musical note have many common features, such as tone range, duration, intensities, and timbres and so on. When these sounds continually change, the listeners rely on these features to recognize the sound [9, 11, 12, 23] and understand the sound. From these features of musical note to train the auditory, it may give people feel happy and may also use to assist the insufficient of the traditional auditory training [15]. The musical treatment process can effectively help auditory training in many aspects, for instance, the sound attention, the sound difference, the different object sound and the distance of pronunciation and so on [15]. Moreover, Robbins & Robbins [18] discovered that the suitable music is easier than the pronunciation sound to simulate the auditory to the hearing impairment. Amir & Schuchman [19] used a set of music treatment curriculum to strengthen hearing impairment understanding music, which includes the tempo of music (the bat), the rhythm, the intensity, the phrase and so on. The research and experiment found that there were many hearing impairments significantly improve their residual auditory capability through the musical treatment curriculum. The residual auditory has revealed the improvement. Generally speaking, the music class is one kind of the auditory training curriculum that is more interesting than the tedious pronunciation class. Students study not only the tempo of the music but also the pitch with the characteristic of durations, intensities, and timbres.

Darrow & Starker [17] in their spoken language training research found that hearing impairments have higher base frequency than the people without any hearing impairment, however the high tones in hearing impaired people are dramatically lower than the people without any hearing impairment. Therefore, it is difficult for people to understand their spoken language. Darrow & Starker [17] thus suggested that choosing the lower melody in the spoken language or the musical training would help hearing impaired people widen their auditory of the sound or tone frequency. Darrow [16] applied musical treatment for hearing impaired people to adjust their language understanding to improve the pronunciation intonation and the pronunciation fluency. Darrow [16] also emphasized the importance of feedback mechanism for hearing impaired people while pronunciation, namely, therapist should help the hearing impaired people to correct their pronunciation.

In order to enhance the language spoken ability, besides the spoken language training in Deaf School, cultivating the auditory capability is also a necessary training for hearing impaired people[1, 3, 8, 14, 24]. However, hearing impaired people lost most hearing ability. Hence, they do not have the self-monitoring mechanism to study speech, not even to learn music. This study is to implement an automatic music auditory training system for hearing impaired people. Thus the main purpose of this research is to implement a music learning system for hearing impaired people (MLSHI) with the combination of computer system and application program including spectral analysis, software design, and C++ software [2, 10] for hearing impaired people to learn music more efficient. The software of MLSHI includes the student auditory measurement module, the tone tuning module and the computer musical learning module.

2. Methods

2.1 The spectrum of a voice signal

Fourier series can represent cyclic wave into the summation of infinite sin-wave series and those sin-waves are the harmonic of the fundamental frequency. For instance, a symmetry square wave can be denoted by

$$v(t) = \frac{4V}{\pi}\left(\sin \omega_0 t + \frac{1}{3}\sin 3\omega_0 t + \frac{1}{5}\sin 5\omega_0 t + \ldots\right) \quad (1)$$

where v is the intensity of square wave, $\omega_0 = 2\pi/T$ (T is the cycle of square wave) called the fundamental frequency. We noticed that the intensity of the harmonic wave gradually decreases. Thus the infinite series can be truncated to obtain the approximate progression of square wave. In equation (1), all sine-wave components composed of the spectrum of square signal. The spectrum graph is also called line spectrum [4, 5, 13, 21].

Fourier transformation can process a non-cyclical sound function signal as Fig. 1, and its frequency spectrum is a continuous of frequency function, shown in Fig. 2. Fig. 1 is not a frequency spectrum of cyclic function and only contains the distributed frequencies (w_0 and its harmonic waves). Non-cyclic signal frequency spectrum includes all possible frequencies. No matter, an actual signal frequency spectrum is usually limited in the small range of frequencies, which are extremely useful in the signal process. For instance, the sound frequency spectrum, such as voice or music, is audio band from 20 Hz to probably the 20 kHz. Although there are still many tones are over 20 kHz, the human's ear cannot receive the frequency for surpassing above 20 kHz. Therefore, a time-domain signal can be denoted by voltage signal $v(t)$ in Fig. 1 and its wave shape is changing along with the time. Also it may express the frequency spectrum form, shown in Fig. 2. These two different expression ways are called the time-domain method and the frequency-domain method respectively. The frequency-domain of $v(t)$ is denoted by $v(\omega)$.

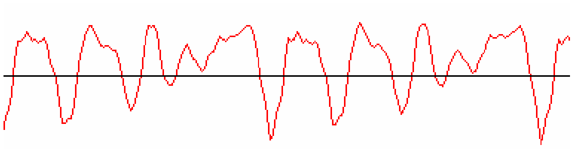

Fig. 1 A non-cyclic voice signal $v(t)$

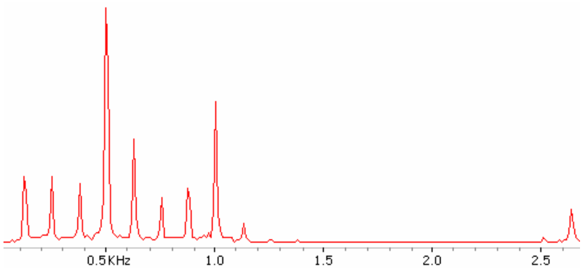

Fig. 2 The frequency spectrum of Fig. 1

2.2 Fast Fourier transform and discrete Fourier transform

Sound signal after the A/D transformation and sampled by the specific frame has become a discrete signal. Then, a Discrete Fourier Transformation was used to transfer the signal from time-domain to frequency-domain. Discrete Fourier Transformation is the application of Fast Fourier Transformation. Its supposition has N signals Xn as the transformation of equation (2).

$$X_n = \frac{1}{N}\sum_{k=0}^{N-1} x_k e^{-2\pi jkn/N}, n = 0,1,2\ldots N-1 \qquad (2)$$

Through Discrete Fourier Transformation, the spectrum components were obtained from the sound frame signal frequency spectrum parameter, also called the Periodogram. It is the transformation of the signal from time-domain to frequency-domain [25].

3. System Framework and Function

The components of MLSHI system include personal computer, video card, microphone as input device, earphone to monitor the input sound data, shown in Fig. 3. Three software functions in the MLSHI system include the student auditory measurement module, tone tuning module and the computer musical learning module written in Borland C++ Builder [2, 10].

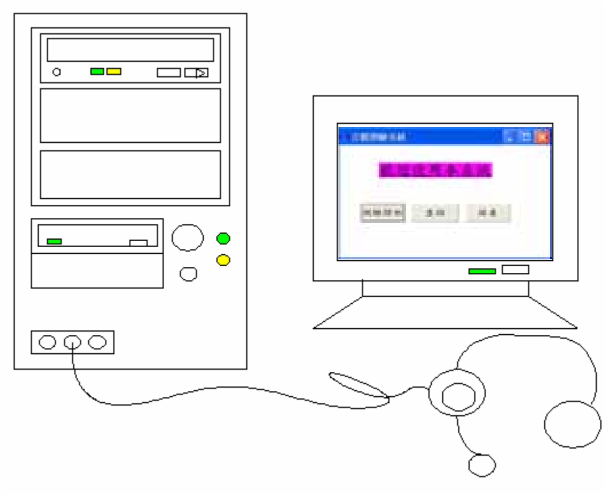

Fig. 3 The framework of MLSHI system

3.1 Student auditory measurement module

In order to understand the reaction of tone range (pitch response) on hearing impairments, an auditory measurement software module was designed and shown in Fig. 4(a) and (b).

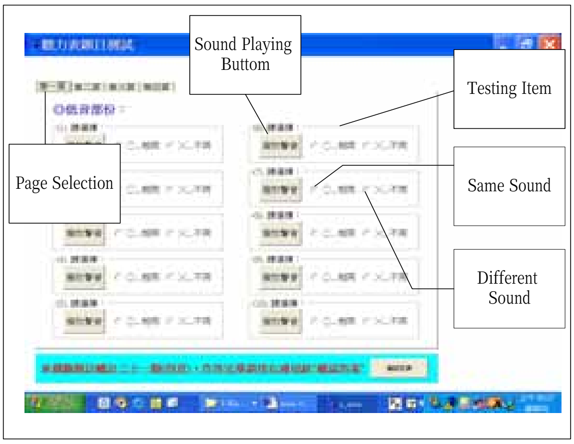

Fig. 4(a) The testing screen of tone auditory measurement

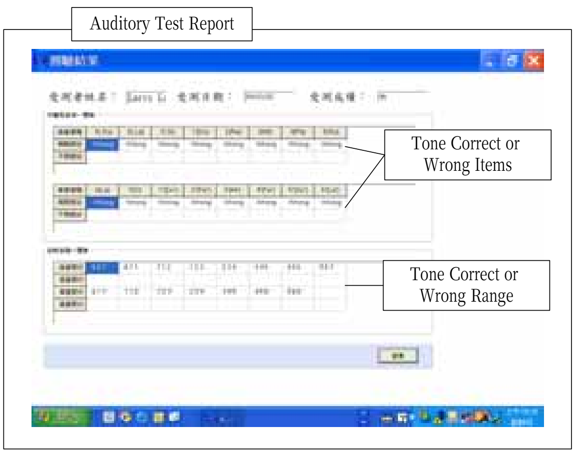

Fig. 4 (b) The testing results of tone auditory measurement

The system with a test bank randomly broadcasts the tone frequency to hearing impaired people. The testing range of tone is from A4 (440Hz) to B6 (1979Hz) by a D note flute transcribing as shown in Fig. 4(a). When the students press the "play" key of each test, the system will send out three major tones, for instance Do Do Do or Ro Re Mi and so on. If these three sounds, for example Do Do Do, are the same, student should choose circle (correct) ; If these three sounds, for example Ro Re Mi, are different, student should choose X (wrong). If these three sounds have same Do sound, then the different test sounds start from Do and its following two high pitch sounds, Re and Mi to compose into three sounds. If these three sounds have the same Re sound, then its different test sound starts from Re and its following two high pitch sounds, Me and Fa to compose into three sounds. The rest can be done in the same manner. After students doing the test, the system may list the results to show student's perceptions about the sound. The right and error answer will be listed, shown in Fig. 4(b) [6, 7].

3.2 Musical tone tuning module

Hearing impaired people use flute to utter a tone with a specific frequency. System will get the tone from the instrument. After the calculation of the tuning module, hearing-impaired people can be indicated by the supportive tools with complete sound frequency data and tone shift by the moving needle. It can help hearing impaired people self-corrected its tone accuracy to reach the aim of expanding its auditory learning performance and more the accurate of tone playing.

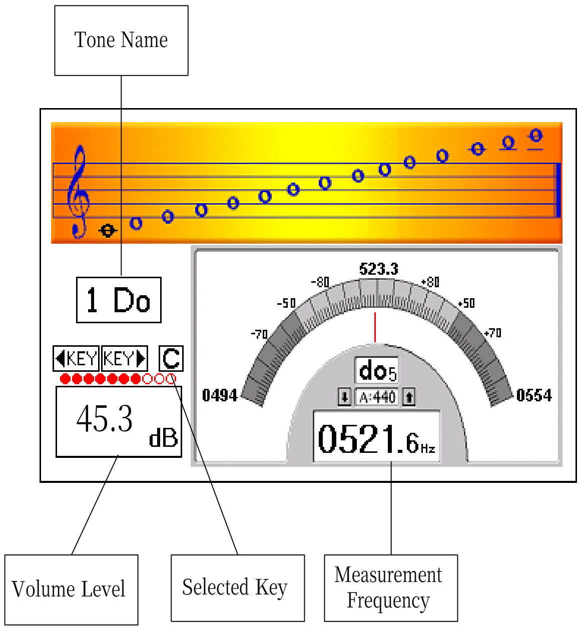

Fig. 5 Musical tone tuning module

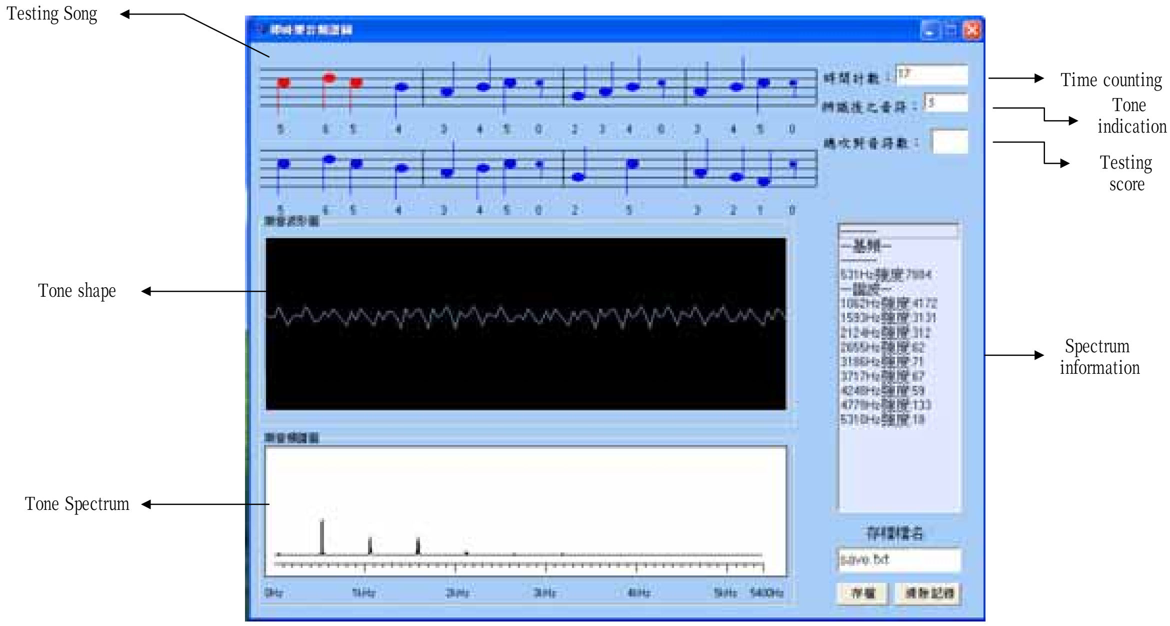

Fig. 6 The computer musical learning module

The system picture shown in Fig. 5, the users must establish the good tone mark (termed as key) in advance. In the picture it refers to choose C tone. The major tone approaches standard frequency 523.3 Hz and this major tone is 521.6 Hz. Five spectra displayed the tone range indicated by bold black circle. The sound scale is denoted by “1” and “Do” and also displayed the volume 76.3db by red dot expression on volume intensity.

3.3 Computer musical learning module

This module displayed a song on the screen, shown in Fig. 6. Student relies on the instruction of the red musical note to play the sound they should. Red note will be based on the length of rhythm to change to next musical note. When student plays musical note, the microphone receives the tone and then transmits to computer to calculate the fundamental frequency correct or not based on the spectral analysis software. If the playing is correct (positive and negative 30 sound minute to be called correctly), then the musical note will slowly twinkle 4 times per second. If the blowing is not correct, the musical note will quickly twinkle 8 times per second to remind the student the pronunciation sound is not correct. Thus, the student will do their best pronounce the correct sound. After the song performance, the system would automatically calculate the score the student got. The way to calculate the score depends on the correct blowing time divided by the time of the song.

4. Experiments

There are three steps for computer-aided group in this experiment process. The first step is that student auditory measurement module was used to test the reaction of tone range on hearing impaired students in the whole training periods. The second step is that participants use a musical tone tuning module to help hearing impaired people self-corrected its tone accuracy for expanding its auditory learning performance and the accuracy of the tone playing. The third step was applied the computer musical learning module to train the hearing impaired students playing a song.

4.1 Testing Procedure

The testing procedure was supported by two teachers who teach in National Taichung Deaf School. One is for a music teacher and the other is for a computer system support. They have over ten-year teaching experience for hearing impaired students. This music training course was processed in music classes for one semester to train the students playing the recorder as the main goal. The training period was lasted for one semester about five months with two hours a week. Initially, when the semester starts, the *auditory measurement module* (Fig. 4a) was used to examine student’s tone range distribution as an auditory comparison for pre-training and post-training. The auditory test was done once of two weeks and lasted one semester to detect the change of tone range. Initial six weeks use *musical tone tuning module* (Fig. 5) to train students blowing the musical scale such as Do, Re, Mi, Fa, So and so on. The tuning module was used to monitor whether the tone is accurate or not while students playing the recorder. With repeatedly practicing to make the musical scale blowing being proficient or skillful, the musical scale training is completed. Finally, ten weeks was used to train a song. In this study, the training song is a nationwide folk song, called "London Bridge is Falling Down". Students were instructed by the *computer musical learning module* (Fig. 6) to play the song. At the end of the song, the system will show the score on the screen based on the accuracy of playing. We can rely on these scores to monitor and evaluate the progress of students who use the supportive system to learn the song. The scores were then recorded by time to see the student's leaning performance. In order to stimulate student's learning motivation. The scores were counted as a reference for teacher to judge their final grade of the course. The learning performance for each student is the sum of the score of music scale and song play.

4.2 Experiment Results

The testing group used the MLSHI system, 13 students where 7 males and 6 females, to support the teacher's teaching and student's learning on how to blow the tone scale and then the song. The final score is graded by the teacher with the two scores where one is tone score and the other is song score. The learning performance is the sum of tone score and song score.

From Table 1 shown, the test score on final exam is better than the mid-term exam. The result displayed that the computer supported teaching method did help hearing impaired student's learning on music.

In order to understand whether the computer-aided group student's auditory improvement affected by the music tone tuning module and computer musical learning module or not, an auditory measurement module was processed once of two weeks and generated eight times' scores to detect the improvement of auditory capability for computer-aided group students. Fig. 7 showed the auditory test score. From the figure shown, there was no significantly improvement on student's auditory ability. The curve was smooth without a specific slope. Consequently, we can not conclude MLSHI system did really help to expand student's auditory ability.

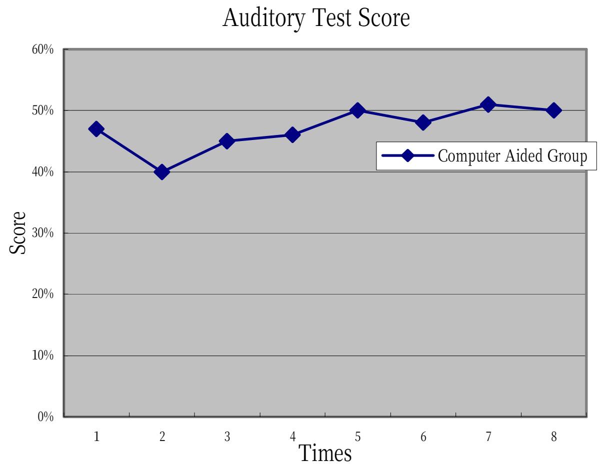

Fig. 7 Auditory Test Results

5. Conclusion

This study proposes a MLSHI system for helping hearing impaired students to learn music more efficient and invoke more interest in music class. The MLSHI system presents an instant feedback mechanism to hearing impaired students in the form of automatic assessment of their learning performance. This allows the hearing impaired students not only to tailor their learning condition, but also to provide comprehensive information about the learning performance. Based on the proposed system, three modules were included in this system. Initially, in order to test student's pre and post performance of recorder and see whether the tone auditory change or not, an auditory measurement module was implemented. Next, the tone tuning module was used to help students understand the pitch of an instrument such as the frequency, the key, the volume with note number, rotate meter scale, music staff, the level indicator and so on. Finally, the computer musical learning module was used to help the hearing-impaired students to learn a popular folk song. To evaluate the performance of aforesaid modules, an experiment involving 13 junior high school students with middle and heavy hearing disability were performed. The experiment results revealed that the students who received the learning guidance by MLSHI system made a significant progress as Table 1 shown. Consequently, we conclude that the computer-

Table 1 Test scores of mid-term and final

Students	1	2	3	4	5	6	7	8	9	10	11	12	13
Mid-term score	97	102	106	99	105	104	90	102	97	99	93	106	89
Final score	124	112	118	112	111	119	113	120	115	123	107	111	117

aided system did help students to improve their music learning.

Although the experiment achieved positive results in a cross-section period, a longitudinal study would be interesting to know the usability of this system. A longitudinal investigation is necessary to apply for an advanced study. Additionally, the learning performance is graded by one teacher. This would cause the subjective bias. Thus, a further study should overcome this problem. One possible solution is that at least two teachers join the grading process to avoid the subjective bias. Additionally, the testing samples are only 13 participants. The results may not generalize to all hearing impaired students. A further study can implemented with more samples to increase its internal and external validity.

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