Prediction of Hearing Loss Based on Auditory Perception: A Preliminary Study

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Abstract. The major cause of deafness and hearing impairment around the globe is hearing loss. Hearing loss has become very common among young adults and kids due to the genetic disorder, temporary or permanent hearing impairments, aging, and exposure to noise. Meanwhile, the possibilities of treating hearing loss are very limited. It can be reduced by taking proper precautionary measures if diagnosed on time. In this paper, we study the possibility of preventing hearing loss based on the auditory system responses. The auditory perception is highly correlated with the human age. Consequently, predicting a big gap between the real age and the perceived one can be an indicator of hearing loss. Our predictive model of human age is very robust with an RMSE value of 4.1 years and an EER value of 4%, indicating the applicability of our proposed method for predicting the hearing loss.

Keywords: Computer-aided · Healthcare technology
Predictive model · Hearing loss · Auditory perception

1 Introduction

Since many decades, research aims to study and analyze the reasons for the human hearing loss. Military and occupational physicians declared an index to decide for an individual to be at risk of hearing loss in the early age due to exposure to noise [11].

Hearing loss is the fifth leading reason for living with disability according to the World Health Organization [1]. It may lead to several diseases if not treated on time, such as cognitive decline [2], inclined incidence of dementia [3], social isolation [4], depression [5] and including falls [6]. Cognitive decline and hearing loss indicate a common cause on the brain and auditory pathway. Likewise, cognitive competence reduces cognitive resources for the auditory perception that increases the effect of hearing loss which is directly proportional to increasing age. In 2012 it was reported that at the age of 65 years and above, 164.5 million people suffered from hearing loss [7] and the number of individuals are increasing with a high ratio than the younger age [8]. Bringing this into account,

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experts concern about the precautionary measures for hearing loss [9,10]. In fact, hearing loss related to age has multi-factorial pathogenesis. Some pathogenetic elements are identified in microvascular disorders like hypertension, diabetes, and atherosclerosis. Hearing loss reduces the efficiency of cognitive skills related to age. To investigate the hearing loss, it requires a proper arrangement and cannot be possible for a subject to conduct by him/herself such as tympanometry, Audiogram, Auditory Brain Stem Response (ABR), Otoacoustic Emission (OE), and Auditory Steady State Response (ASSR). In tympanometry, a doctor inspects visually the ear with the help of otoscope, then a probe is placed in the ear. The probe generates an air pressure on the ear canal, changing pressures effects the eardrums and could be recorded for further processing. Audiogram also helps a physician to predict the hearing loss and the patient should physically appear for the test in the hospital. ABR measures the response along the auditory pathway by taking measurements from electrodes on the head. OE consist of measuring low-intensity sounds, generated by the cochlea. It can be measured with or without acoustic stimulation using a microphone. ASSR is often done in combination with the ABR test. This test also measures the brain response to sound. All the proposed test needs to be done in the hospital and is not possible to achieve without a physician. In this paper, we study the correlation between hearing loss and auditory perception. Thus, we present for the first time a new approach for predicting hearing loss based on auditory perception [11].

2 Related Work

A variety of research work explored the causes of hearing loss which are subdivided into two main categories:

Nonmodifiable risk factors comprise genetics, age, race, and gender. Among all these aspects, age plays a vital role. Hearing loss is directly proportional to increasing age. As the age increases, the value of hearing loss also increases. Nearly 23% of the population is suffering from partial or full hearing loss between the age of 65 and 75 years. The value of hearing loss increased to 40% for the age above 75 years and resulted in deafness and hearing impairment [12]. Recent studies show that hearing impairment and temporary threshold shift are increasing among children and teenagers. Around 12% of children from 6 to 12-years-old are suffering from hearing loss [13]. In parallel to that, the teenager and young adults are suffering from hearing impairment and tinnitus [14]. Studies have also shown that right and left ear respond separately to hearing loss. It is a proof of the genetic variance to respond to a sound [15]. The chances of hearing loss and impairment increase with individuals having blood group O. Research proves that boys have more chances of hearing loss as compared to females due to more involvement of activities [b]. There is a correlation between the higher level of noise and hearing loss, such that maximum noise exposure results in a severe hearing loss.

Modifiable Risk Components. Many modifiable components are related to hearing loss such as non-use of hearing protection, lack of exercise, smoking, unbalanced diet, diabetes.

Protection of ear can reduce the chances of hearing loss which is related to noise exposure. Most of the people, mainly teenagers do not take measures when required. Lack of knowledge, discomfort, safety measures and design pushes an individual to face hearing loss [16]. Smoking is also a cause of many health issues including hearing loss. Smokers are exposed to many toxic substances which efficiently effect hearing with loud noises. Nearly 3700 adults are reported to have hearing loss due to smoking. Nonsmoker sitting in the environment of smokers may also suffer from hearing loss [17]. Physical fitness and nutrition are also related to hearing loss. Having proper exercise teenagers and young adults can improve hearing capability and cardiovascular fitness [18]. Physical fitness and exercises can reduce temporary hearing loss which results because of noise exposure. Researchers suggest that with physical fitness, the inner ear gets more oxygen-rich blood, which reduces hearing loss and strengthens hearing [19]. Cognitive impairment related to hearing loss mesmerized researchers in the past decade. Evidence shows that hearing loss results in dementia. To assess and understand hearing is a tough job. Some clinical outlines can refer and indicate the assessment of hearing loss. There is very few web-based application for hearing loss detection [20,21] and all of them are complicated and time-consuming. As compared to the existing approaches, our approach is providing an alert system to predict and prevent hearing loss. It can help to reduce the cost, labor work, and time for early prediction of hearing loss.

3 Motivations

Auditory perception is the ability to interpret and identify the information that reaches the ears. Auditory perception plays a vital role in our daily life, being used almost in every task. It creates a link to interact with the outer environment, make us enjoy and responsive to probable threats.

The capabilities of the auditory system decrease with age. At 16 years old, the highest audible frequency is around 18000 Hz, while at 30 years old, it decreases to around 15000 Hz. Thus, there is a correlation between the auditory perception and the human age. Predicting the human age based on the auditory system responses provides a perceived age. When the perceived age is not close to the real age of the person, there is probably a hearing loss problem. It is, for this reason, we considered that there is a correlation between age and hearing loss. Thus, considering this as a factor, we proposed a computer-aided prediction of hearing loss based on the auditory perception.

The rest of the paper is organized as follows. In Sect. 4, we proposed auditory perception based prediction of hearing loss method. In the Sect. 5, the results and the evaluations of the proposed approach are discussed. Finally, in the last Sect. 6, we conclude this work and we deliver a set of perspectives and paths for our future works.

4 Proposed Approach

The proposed approach presents three main steps. First, the auditory system is stimulated using a dynamic frequency sound. Later on, the set of auditory system, responses are fed to the predictive model for age estimation. In case of a significant positive difference between the estimated age and the actual age, it will be considered that the test person may have a hearing loss. The flow diagram of our proposed approach as shown in Fig. 1. The protocol of the stimulation of the auditory system is presented in Sect. 4.1. The predictive model of Human age is presented in Sect. 4.2.

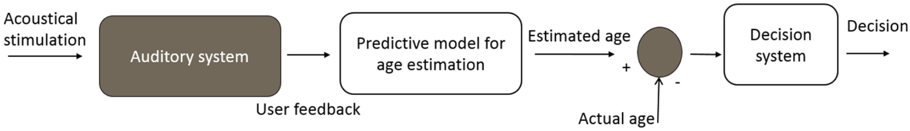

Fig. 1. Flow diagram of our proposed approach

4.1 Acoustical Simulation

The human auditory system is stimulated by generating a dynamic sound. The used protocol present a bilateral stimulation with the speaker. Our system required real-time interaction. Thus, the user should interact and respond to the system. For better accuracy, two tests are to be conducted:

- **First test:** the sound is generated from lower frequency to higher frequency (20 Hz to 20,000 Hz), and the user has to respond through keyboard action when he/she stops hearing. The correspondent audible frequency F1 is saved.
- **Second test:** the sound is generated from a higher frequency to lower frequency (20,000 to 20 Hz), and the user has to respond when he/she starts hearing. The correspondent audible frequency F2 is saved.

The human auditory system is stimulated by generating dynamic sound waves as shown in Fig. 2 according to the following model:

$$x(t) = A_0.sin(2\pi.\phi(t).t) \tag{1}$$

where $\phi(t) = \alpha.t + \phi_0$, A_0 stands for sound amplitude, t stands for time, ϕ_0 is the initialization frequency, and α stands for the increasing/decreasing frequency speed.

The two audible frequencies F1, F2 and the mean of both of them are saved and fed to the predictive model for age estimation.

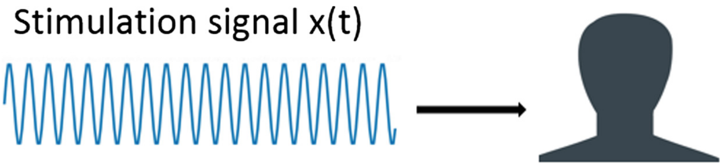

Fig. 2. Protocol of stimulation

4.2 Predictive Model of Human Age Based on Auditory Perception

The predictive model for age estimation is a regression model. Different regression models are compared to find the best one for age estimation using the auditory system responses. They are the Regression Forest (RF), the Support Vector Regression (SVR), the Adaboost regression and the Neural Network (NN) regression. For all the proposed regression models, we considered 10-fold cross-validation technique.

RF generates a forest of decision trees and uses average or majority voting to aggregate results over the set of trees. It is based on kernel functions by applying nonparametric algorithms for classification and regression. SVR minimize the error and increase the margin by finding the optimal hyperplanes. For AdaBoost, the experiments are done with backpropagation as “weak” learning algorithm. Adaboost techniques enhance the performances of machine learning algorithms for both classification (binary class, or multiclass) and regression. Neural Networks (NN) are used most of the time for classification and regression in both supervised and unsupervised learning.

5 Experiments

5.1 Dataset Collection

In this experiment, 156 healthy subjects participated to conduct the test as shown in Fig. 3. The dataset is balanced and which included subjects within a range of 6 to 64 years old. The ratio of males was more than females where 87 males and 69 females successfully conducted the test. The proposed protocol requires 2–3 min for a volunteer to conduct, successfully the test.

5.2 Correlation Between Auditory Perception and Hearing Loss

The performances of age estimation using machine learning techniques such as RF, SVR, Adaboost, and Neural network are shown in Table 1.

10-fold cross validation using RF shows the highest accuracy among the stated regression models. RF has a Root Mean Square Error value of 4.1 years and standard deviation of 2.98 years. That proves that our prediction model is very robust and shows a very a low error. Therefore, one can predict the hearing

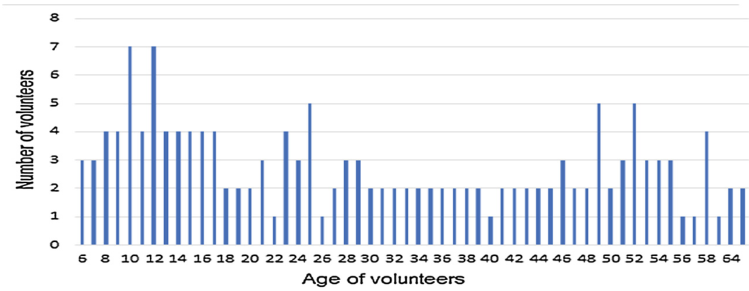

Fig. 3. Age distribution of the subjects

loss if the difference between the estimated age and the actual age $\triangle t$ is greater to n years (Eq. 2).

$$\triangle t = (\sigma_1 - \sigma_2) > n(years) \tag{2}$$

with n $= \triangle + \epsilon$ and $\epsilon =$ the minimum auditory distrust for subjects suffering with hearing loss presented by a number of years.

where σ_1 is actual age, σ_2 is estimated age, and $\triangle$ is the error rate of the system. The greater error rate indicates higher hearing loss.

Table 1. Age estimation regression models performances

Model	Root mean square error (years)	Standard deviation (years)
Random forest	4.1	2.98
SVR	5.9	4.01
Adaboost	12.3	10.9
Neural network	13.3	11.2

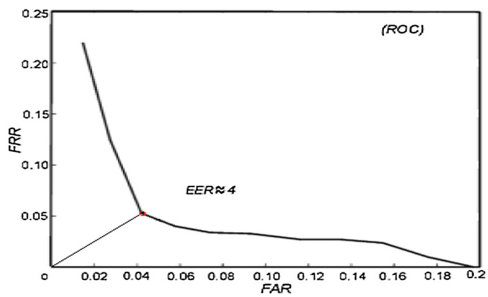

Fig. 4. ROC curve

Performance Evaluation. To evaluate our approach, we considered the False Acceptance Rate (FAR) and False Rejection Rate (FRR). We cannot evaluate a system by just the values of FAR and FRR such that a lower FRR and higher FAR performs better than a system having higher FRR and Lower FAR value. Hence, we need the Equal Error Rate (EER) to be used to evaluate the performance of a system. The lower is the EER, the higher is the performance of the system. In Fig. 4 shows Receiver Operating Characteristic (ROC). It can be noticed that the value of EER is 4% for 156 samples. Hence, this proves that our system is robust by providing a minimum error value.

6 Conclusion and Future Work

In our work, we studied the possibility of predicting hearing loss based on auditory perception. We demonstrate that auditory system responses are highly correlated with the age. Consequently, we built an accurate RF model that could estimate the age of a person with an RMSE value of 4.1 years and the EER value equal to 4%.

We are planning for future work to develop a computer-aided system to predict and prevent hearing loss. We are planned to test the system with subjects suffering from hearing loss to find the minimum auditory distrust. Our System can provide economic, health-care and well-being benefits.

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