Telemedical System in Evaluation of Auditory Brainsteam Responses and Support of Diagnosis

Piotr Strzelczyk, Ireneusz Wochlik, Ryszard Tadeusiewicz, Andrzej Izworski, and Jarosław Bułka

AGH University of Science and Technology, Department of Automatics,
Al. Mickiewicza 30, 30-073 Krakow, Poland
pit@student.agh.edu.pl, wolo@agh.edu.pl, rtad@agh.edu.pl,
izwa@agh.edu.pl, bulek@agh.edu.pl

Abstract. The paper presents the use of telemedicine in intelligent supporting of otorhinolaryngologist in the diagnosis of auditory brainsteam responses. This test is easy to visualize but difficult to diagnose. The presented software system uses advanced methods of signal processing and an author's algorithm supporting the doctor by setting the characteristic points of the examination and reach the diagnosis. This paper describes the capabilities of the system and underline the benefits which are result of the nature of this application. It also highlights the benefits and opportunities introduced to this field of medicine by the described intelligent software system.

Keywords: Auditory brainsteam responses, telemedicine, intelligent software systems, diagnosis support systems.

1 Introduction

Nowadays, the progress of medicine is significant in the early detection of health defects. Recently audiology, the branch of medicine dedicated to the research field of hearing, experienced a rapid development. At the moment it is tend to reach a diagnose in disorder of sound reception as early as possible. Clearly visible is the desire to standardize the hearing testing and introducing them as obligatory for the whole country. Therefore, the hearing screening tests are going to be a norm by children in the preschool and school age. The detection of potential hearing failures by a patient at a such young age, has a significant impact on his psychological and intellectual development.

One of the most popular methods of hearing screening tests are the auditory brainsteam responses. Their results are not easy to interpret. For an unexperienced doctor it is not easy to reach a diagnose. A mojor diagnostic problem is a situation when the ABR (Auditory Brainsteam Responses) results are from a patient that has hearing

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disorder or the quality of the measurement is not good. The results are in this case very hard to diagnose. Audiologist, who is not sure of the final interpretation, does not reach a diagnosis without consultation with a person witch is an authority in this field.

In today's world of medicine, the problem of high-class specialist is visible, which are not much in the whole country. They are working in medical centers which are known as units specialized in the brunch of medicine. In the case of audiology such center in Poland is the International Center of Hearing and Speech in Kajetany near Warsaw. This means that in most cases, most consultations must be carried remotely.

Modern technology offer many opportunities for communication, but they are not sufficient for the needs of medicine. A physician, to remotely terminate its opinion, needs to see the results. In ABR the results are presented in graphs. They occupy a fairly large volume of memory. They lossy compression to a file of smaller size is not allowed, because there is a risk of losing important data. This loss may result in a completely incorrect diagnose. Sending a few results of a large capacity may take a long time. Another solution is to send data as a sequence of numbers obtained from the measurement equipment. This approach avoids the problem described about with the capacity of the files to be send. The disadvantage of this method is that the receiving side needs to have a tool to convert the numerical data to charts. In both approaches have significant discomfort. Doctors are forced to be involved in the process of initial data exchange, rather than take up the appropriate discussion about the results of the examination.

2 Auditory Brainsteam Responses

One of the most objective methods of hearing test are the auditory brainsteam responses. They are measuring the bioelectrical activity of the brain, forced by sound given into the tested ear. For this purpose the surface electrodes are placed in fixed points on the head. Then, using headphones a noise or short sound is made with a certain frequency. The end result is a chart that shows the stimulation of different hearing centers. At the moment it is used as a screening hearing test by newborns and infants. This method is also used in the differential diagnosis and in monitoring the function of the auditory nerve and brain stem during neurosurgical procedurs. The disadvantage of this test is the need that the patient is sleeping during it. This results from the fact that the brain registers various signals associated not only with hearing but for example with freedom thinking, work of muscles, work of eyes. This signals are disorders that prevent the execution of the test.

The test procedure consists of two main stages: the registration of a number of responses known as “intensity series” and analysis of recorded responses to determine the hearing threshold. The intensity series is created in the following way: in the first phase the ear is stimulated by a sound with high intensity for example 90 or 100 dB nHL, and in subsequences phases – responses for ever-lower levels of sound. The intensity of the stimulus is reduced in steps by usually by 20, 10 or 5 dB. For intensities near the hearing threshold the registration is reapeted two or three times. Then the results are listed on the screen in such a way that they are as to be closest to each other. Waveforms recorded for the same intensity are placed one after another.

A doctor or a trained technician can on this examination result mark characteristic waves, which are numbered in Roman. Peaks of every wave kind represents the place in anatomical structure which are responsible for their generation. Wave I is generated in the distal part of the auditory nerve, wave II in the proximal part, wave III mainly in the cochlear nucleus, wave IV mainly in the upper band olives, and wave V mainly in the nuclei sideband. Any pathology of the ear may change the morphology, time parameters and the amplitude of individual waves in the result. Only waves I, III and V are determined in clinical practice, which forms the basic for the diagnosis. The presence of wave V for an intensity means that the patient is hearing on this sound level. In this way, using the ABR test, the doctor sets the hearing threshold.

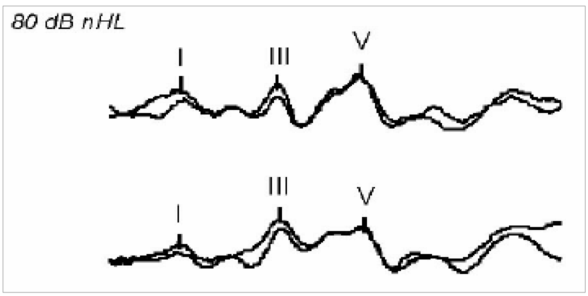

Fig. 1. An example measurement of ABR signal for the intensity of 80 dB. The upper chart is for the right ear and the other for the left ear. The measurement was made for every ear on this level two times.

3 Telemedical Application

In the last years internet technologies have been developing very fast. They become an internal part of success in business and projects undertaken by the people, institutions and companies. The main advantage of these solutions is the minimal requirements posted to the user.

Today, thanks to the web technologies, the only requirement is that the user have a web browser. To use the more advanced capabilities of these technologies, there is only the need to install the appropriate software which is free. It is often supplied as a plug-in to a concrete web browser.

Diversity and capabilities of these technologies were not yet found there use in many fields of medicine. At present there is in Poland no common online platform that allows the use of modern web technologies to support medical diagnosis of auditory brainsteam responses.

The platform presented here is an integrated telemedical system that supports the diagnosis of auditory brainsteam responses. This platform contains personal data of patients and connected with them hearing tests. The most important functions are: addition of examination, review of historical examinations with diagnosis, review of undiagnosed examinations, interactive presentation of the results and the ability to analysis them by many doctors at the same time, reaching a diagnosis. The reaching of diagnosis requires to analysis the intensity series. This means that data are presented in interactive charts. They allow to mark characteristic points of the hearing test and adding description to them. The working wave detection algorithm in the background make it easier to reach a diagnose.

From the technical point of view the architecture of the application is three layer technology. In the view layer is embedded an interactive application used to present the results of ABR and analysis them. Characteristic for the system is: high level of security, easy and transparent operation, high interactive functionality for analyzing examinations, minimizing the work done by the doctor.

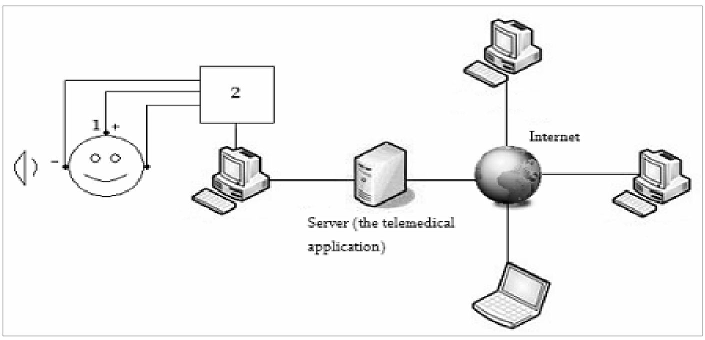

Fig. 2. The Flowchart of the telemedical application. Measurement electrodes (1), send the signal to the equipment (2) that filters out the ABR signal. The user can connect a computer to the measurement equipment and send the data to the telemedical application. Other doctors can via the internet watch, analysis and diagnose the hearing test results.

3.1 Interactive Presentation of ABR Results

The heart of the entire application is the page which presents the results of the tests. RIA (Rich Internet Application) were used to create this page which allows direct interaction with the user without refreshing the page. The communication between the page and the server is based on Web Service technology.

The interactive application is from the visual side divided in two parts: a chart and a option panel. The first part is used to present the data and allows the physician a comfortable and easy review of the hearing test. The second part provides options to perform a detailed analysis. Operations such as zooming or displaying selected measurements helps the doctor to reach a diagnosis.

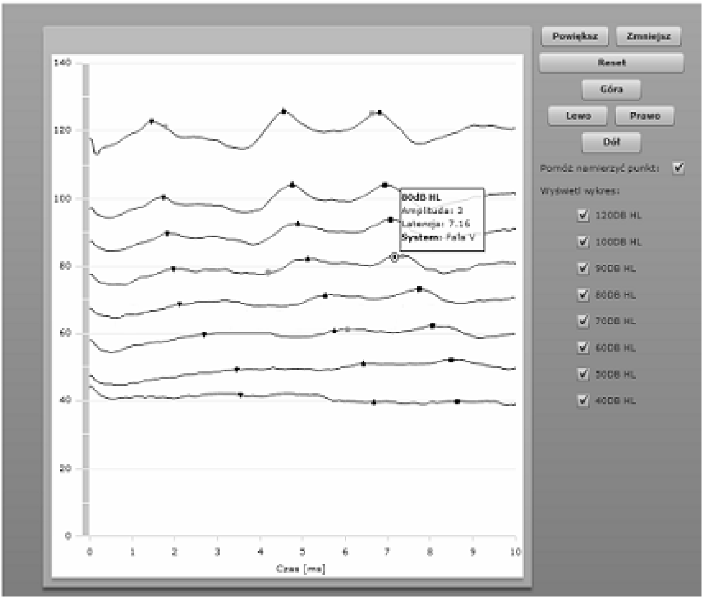

Fig. 3. The interactive application presenting the results of ABR. On the horizontal axis there is the latency of the signal and on the vertical axis the intensity level. On the right side of the chart there are buttons and checkbox that provides different options.

3.2 Preprocessing of ABR Signal

The ABR signal itself contains noise, which means that it is sometimes difficult to interpret by the physician. To improve the quality of the ABR signal there is used a few step preprocessing [1], which is performed before sending data to the interactive application that presents the results. The output from these operations is a smoother and more readable ABR signal.

The use of such a preprocessing algorithm cause that doctors can faster identify individual waves I, III and V. This element of the application is a next improvement, which make the diagnosis easier for a doctor.

The ABR signal converted by the preprocessing algorithm is the input data for the detection algorithm of wave I, III and V.

3.3 Detection Algorism of Wave I, III and V

Another improvement which is used in the application is the detection algorithm of wave I, III and V. He is mostly based on the stock indicator SMA (Simple Moving Average). This is one of the fundamental and first indicator used to determine the trend of shares. He is based on the arithmetic average of stock prices from a number of sessions. This indicator was slightly modified to fit the auditory brainsteam responses. He is basically used to assess the quality of the detected local maximums. Its value to decide if the found maximum can be a wave. This algorithm takes into account the delays in measurements for lower intensities.

The most important part of the algorithm, on which is based the effectiveness, is the detection of wave I, III and V for the highest intensity in the intensity series. From the set of the maximums, it is designated that point which is the wave V, using the characteristic of the chart.

The detected waves by the algorithm are shown in the interactive application described in chapter 3.1. The are always marked with a reserved color.

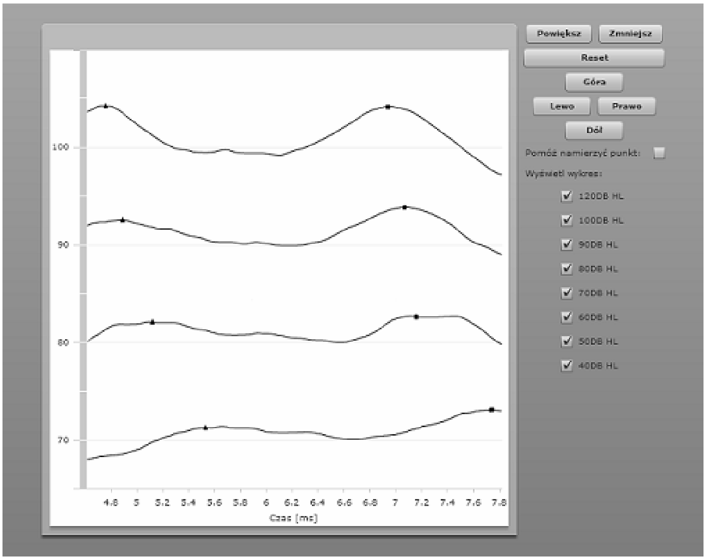

Fig. 4. The interactive application presenting the ABR result with the zoom effect on the chart component. The visible black points are waves detected by the system. In this case there are only visible wave III and V.

In the case of correct detection of the waves by the system the doctor accepts the proposal of the computer and proceed to the description of diagnosis. In this way the time used to analysis one examination is minimized.

A doctor is supported additional by the diagnosis with the highlighted information about the selected points. The exact value of the latency and amplitude of individual waves in the form of a table reduces errors that may result from the diagnosis based only on the analysis of the chart. These values also allows to specify the exact value of the intervals, which are one of the basic parameters important for the diagnosis.

The effectiveness of this algorithm is 87,4%. It has been tested on actual medical hearing tests, obtained from the International Institute Of Physiology And Pathology of Hearing in Kajetany near Warsaw. So a good result means that the waves marked by the system can often provide valuable suggestion to the physician and reduce the amount of work connected with marking of this waves.

4 The Benefits of the Application

The web based platform brings many opportunities in the field of otorhinolaryngology in the case of ABR. The platform was constructed in such a way that it is able to expand and extend it with new options. This possibility is very important because of the high dynamic of development of the ABR test and the possibility of need to extend the functionality of the application.

At present, diagnostic systems allows to mark only the wave V. This cause that every assessment of the measurement is an activity that is important for the health of the patient. The option of marking points on charts and adding comments to them, makes the application a place, where doctors can justify there decision. Such a examination cares not only value for the health condition of hearing, but is a source of information for doctors which needs additional training in this field.

Implementation of the preprocessing algorithm gives the user a better view in higher quality of the test results. The biggest advantage of it is the exposure of places suspected of occurrence of waves and the removal of small noise from the chart. This can have significant impact during the reaching of diagnosis, especially by an unexperienced otorhinolaryngologist.

The implemented wave detection algorithm of wave I, III and V is an innovative solution that combines mathematical and medical knowledge. The high performance of this algorithm, reaching more than 87%, can support the work done by the doctor.

The web platform allows to review hearing tests already diagnosed. This gives incredible possibilities. In first order it may be a source of training materials for young doctors. High functionality allows to leave a lot of information in each test, provides significantly more knowledge then the standard description of the diagnosis which is used at present. Another advantage is the possibilty of remote trainings for doctors. They need only access to the system resources to study and analysis the test on their own. This allows to save costs and reach in a short time a large group of people requiring training.

Another benefit of the historical examinations is the ability to verify the quality of the wave detection algorithm. On this basis it is possible to make statistics and find the cause of potential common errors. This will allow in future to propose amendments to it, making it even more effective. In case of confirmation of its effectiveness on a large number of samples, it may give a basis to create an algorithm to automatize the diagnosis.

The hearing test of auditory brainsteam responses are characterized by certain common attributes. After reviewing the appropriate number of measurements there is visible the occurrence of some regularities. At the moment there is no research on certain statistical regularity. Analysis of ABR results suggest that such dependencies exist. The absence of such information is mainly caused by the absence of a system collecting such data. This platform provides such a possibility. This may be a source in future to create another algorithm of wave detection and automatic diagnosis based on tools connected with probability and statistic. Statistical information can also make a major contribution to otorhinolaryngology introducing new theories related with diagnosis of ABR.

The most important feature of this system is the possibility of remote consultations. Such a solution can significantly minimize the mistakes made in clinics which have doctors with insufficient experience in difficult results of ABR.

The developed online platform will not replace a doctor in his work, but it provides tools that can improve the effectiveness of the diagnosis. It may also be a source, which opens up new perspectives in the field of otorhinolaryngology in the field of auditory brainsteam responses.

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