AUTOMATED IDENTIFICATION AND INTERPRETATION OF AUDITORY BRAINSTEM EVOKED POTENTIALS

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Abstract: In this paper, a novel algorithm is proposed in which the exact locations of I, III and V peaks in ABR signal are determined. Considering the effects of many factors such as age, gender, body temperature, state of arousal muscular artefact, and drug effects on the fuzzy logic inputs, more reliable diagnosis is achievable. First of all, the peaks detections are performed and their latencies are then used for clustering. The criteria for ABR interpretation is based on latency, morphology and amplitude of waveform. The diagnosis algorithm is based on least MSE with corresponding norm waveform. To distinguish the neural (retro cochlear) from sensory (cochlear) hearing losses in sensor neural hearing loss, time domain features (absolute and relative latencies) are used for clustering in fuzzy logic. Then the effects of various factors on the fuzzy system inputs are studied. Although the evaluation of an expert system is a complicated problem, the results show that in some cases the automated interpreter was very helpful if the proper rules selected and suitable membership function considered and parameters were properly tuned the performance will significantly increase.

Introduction

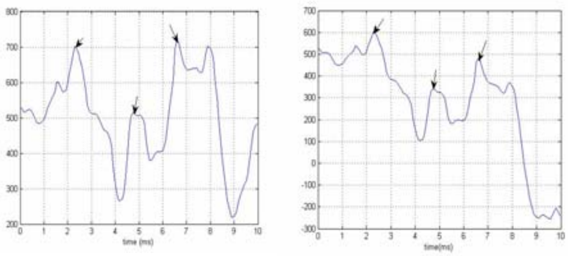
An Auditory Evoked Response (AER) is activity within the auditory system that is produced or stimulated by sounds. The clinical analysis of auditory evoked response signal is an important medical problem, because it is one of the important techniques of the auditory function evaluation and provides an objective way to determine the actual level of sound perception. The response is recognized by five to seven peaks. The latency and amplitude analysis of these waveforms consist of very useful information about peripheral hearing status. The auditory evoked response has become a useful and practical clinical procedure in audiology otolaryngology and neurology during last decade. The criteria for ABR interpretation is based on latency, morphology and amplitude of waveform. However, accurate reliable and clinically meaningful AER depend on appreciation and understanding of how these factors affect the response.

Many other factors are important in auditory evoked response interpretation such as age, gender, body temperature, state of arousal muscular artefact, and drug effects. There may be important variations as effects of these factors on different ABR waveforms. The effects of each parameter were clinically measured and most of the human experts know these clinical rules for wave correction but they can not consider all of them during interpretation. Therefore, a computer based automatic identifier and interpreter which considers all the factors is very helpful tool for the specialists.

Materials and Methods

ABR signals should be obtained from both ears under the similar conditions. To enhance the detection of the main peaks which have high frequency components, the signal is passed through a highpass Butterworth filter to eliminate low frequencies. Figure 1 indicate signal before and after filtering [1].

After this stage, the signal is differentiated twice and peaks are marked at the points which have negative second derivative within range of 1.2 to 7.5 millisecond (location range of I to V peaks).



a) b)

Figure 1: Signal a) before b) after filtering

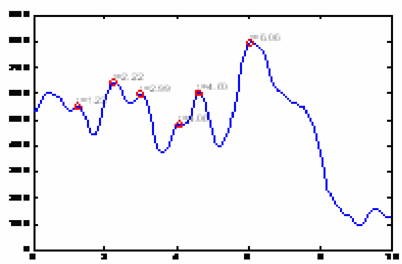


Figure 2: Detected peaks of signal

As shown in figure 2, many peaks have been indicated in the specified time range, I is 1.7-2.5, III is 3.5-5.1 and V is 5.8-7.3 ms. The primary detected peaks of

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right and left ears ABR signals are divided into three batches, I, III and V, according to their corresponding peaks time ranges, as shown in figure 3. [2],[3].

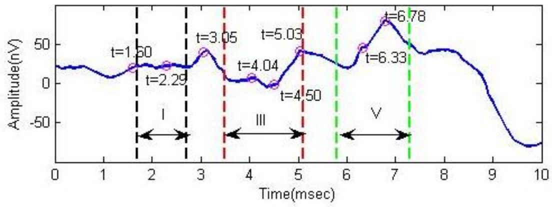


Figure 3: Time range of each peak

For the precise detections of I, III and V peaks, various algorithms can be used. After indicating location of peaks in each signal and extracting latency of three peaks I, III and V for both ear signals some algorithms can be used to select signals that has best peaks. [1],[3].

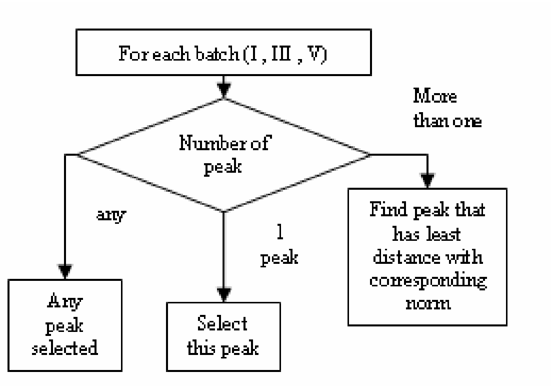
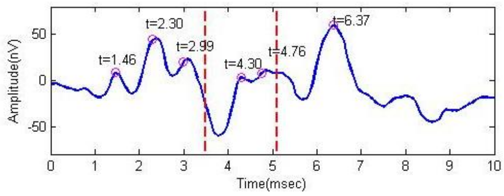
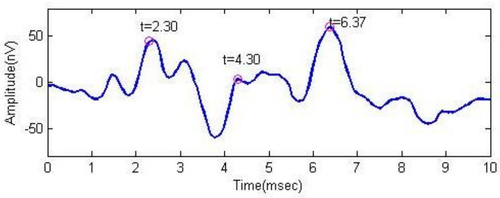


Figure 4: Flowchart of peak selection



a)



b)

Figure 5: a) detection of peaks b) select best peak for each wave based on algorithm mentioned at figure 4.

Peak selection algorithm

Having three batches of I, III, and V, in each batch, the peak that has least difference to corresponding norm, is identified as the mail peak in that batch. Figure 4 shows this peak detection flowchart. Implementation of the peak detection algorithm is illustrated in figure 5.[4].

Signal selection algorithm

In cases that the numbers of obtained ABR signals are more than one, the best signal should be selected. Few algorithms can be used to perform the best selection. In all of these, a decision is made according to the number of peaks which are detected. Therefore, the signal that has three peaks has the highest priority then the one with two peaks and finally the one with one peak. In other word, at first decision is made based on the number of peaks and then the main criterion for each method is implemented. The best algorithm takes into consideration both ear together. In this case the ABR signals from both ears must include the same number of peaks. In this algorithm, the signal which has least mean square error (MSE) from all the signals from both ears is taken as the reference. Then, a signal that has the same number of peaks and least MSE with respect to the reference signal is selected from the ear that the reference is not chosen from that.
If three peaks are not found in the signal, ABRs with two numbers of peaks are considered. The signal that the appeared two peaks are repeated and has the east MSE with corresponding norm value is then selected. Finally, for the single peak signals, if peak has repeated, signal that has least distance with corresponding norm is selected. In case none of these states happen, no peak takes into consideration. These algorithms are shown in figure 6. [7], [9]

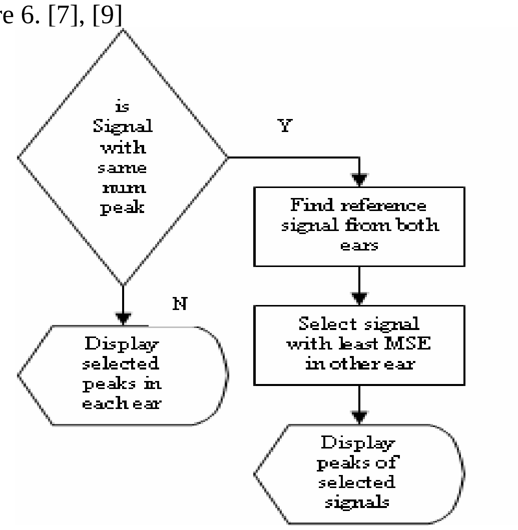


Figure 6: Peak detection algorithm for signals with more than one peak for each wave.

Automatic Interpretation

One of the main aims is to take into consideration all the effective parameters and decrease diagnosis error resulting from variety of effective factors on latency. Therefore after extracting the absolute and the relative peaks latencies and then correcting these latencies with applying the correction factors, an expert system such as fuzzy logic, are used to make an accurate decision. The reason for use of the expert rule-base fuzzy system is the fact this is flexible and based on natural language.

Since fuzzy logic is built a top the structures of qualitative description used in everyday language, fuzzy logic is suitable to diagnosis auditory damages. [3], [6].

To use fuzzy system, inputs and outputs have been fuzzyfied. Then first, if the antecedent of a given rule has more than one part, the fuzzy operator is applied to obtain one number that represents the result of the antecedent for that rule. Second that result applied to the consequent. Inputs have been fuzzyfied in base of five outputs cluster that audiologist diagnoses patient's damage. With considering data in various dimensions and to take into consideration effect of each point in the input space on various outputs, six variable fuzzy inputs with five membership functions with triangular and trapezoidal forms are defined. Fuzzy variable for wave V showed in figure 7. [9].

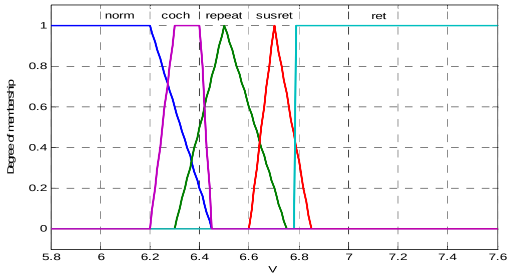


Figure 7: Membership functions for wave V

As shown in figure 8, the outputs with five triangular membership functions are defined.

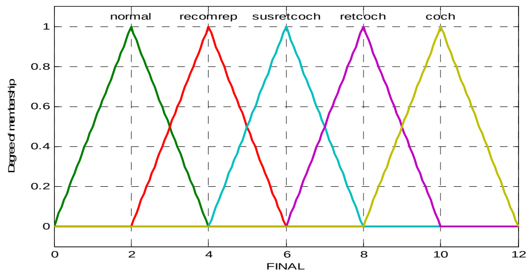


Figure 8: Membership functions of output

To get sufficient If-then rule that used to map the input space to the output space, with attention to two and three dimensions graph, each effective input on outputs are considered. Then fuzzy operators (AND/OR) with sufficient weight for each rule are used by Rule editor in fuzzy logic toolbox of MATLAB. At last, using mom (middle of maximum), one of the defuzzification methods the final desired output is obtained.

Results

The automatic peaks detections were performed on 116 ABR signals and compared to audiologist peaks detections. In 95% of cases the automatic detection agreed exactly with human detection. The fuzzy analysis was performed on signals from 58 cases with confirmed MRI diagnosis, achieved 65% accuracy for five diseases set and 83% accuracy for only normal and cochlear sets of uncorrected inputs.

Discussion

At the first phase, the Peak detection Algorithms based on time features (absolute and relative peaks latencies) used to find latencies of three main peaks of ABR signals (I, III and V). These were used for clustering in fuzzy system in the second phase. Triangular and trapezoidal membership functions are used for clustering five set of input (cochlear, retro cochlear, normal, repeated test and doubt to retro cochlear) and mom used to defuzzification. Peak detection Algorithms, mostly have true result but because of variations of the norm values and dependency of the latencies values to instrument used and the condition that the test is performed, it is appropriate to replace time and amplitude features with features that have a less variations such as frequency or find some rules to compensate effect of these changes. Also at the second phase, input sets have time overlap that only could be separated with time-frequency features by using proper methods like wavelet.

Conclusions

Non-invasive electrophysiology and the measurement of evoked sensory potentials have assumed increasing importance in clinical audiology. Helping modern technology, the necessary instrumentation has become cost-effective and time-beneficial, and ABR evaluations have become a part of the services offered routinely by audiologists. Although the evaluation of an expert system is a complicated problem, the results show that in some cases the automated interpreter was very helpful if the proper rules selected and suitable membership function considered and parameters were properly tuned, the performance will significantly increase.

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