ADAPTIVE FUZZY-LOGIC FOR PROCESSING VISUAL EVOKED POTENTIALS IN OBJECTIVE PERIMATRICAL EXAMINATIONS

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Abstract: Visual evoked Potentials (VEP) extracted during a perimetrical examination are affected by many fluctuations and differ individually. Because of these variations expertise and adaptivity are needed for an effective identification and conditioning of characteristics of signals. The adaptive fuzzy logic (AFL) is able to combine the expertise and variations of the signals. Results of the processing show that the AFL generates a selective averaging, which show VEPs significantly earlier recognizable than after stimulus related averaging during the same time of measurement.

Introduction

Objective perimetrical examinations are needed to indicate pathological cases like glaucoma or demyelising diseases during a diagnosis of the field of vision with a minimum of support by the patient. In order to treat the patient with care, one intention is to maintain the time for an objective perimetrical examination as short as possible.

The visual evoked potentials (VEP), gained in such an objective perimetrical examination, differ throughout the individuals and during each examination. Therefore variations appear which are well known for the experienced ophthalmologist, who diagnoses the patient. The adaptive fuzzy logic (AFL) is an approach for combining this expertise with these variations [1] in order to create an algorithm, which emulates the experience of the doctor. The expertise is gained by signal analysis of the VEP in order to generate characteristics which are uncorrelated to the form of the signal. These characteristics allow the algorithm to generate a selective averaging.

Results of this algorithm shortens the time of diagnosis by presenting contained VEP in an EEG faster than stimulus related averaging method and presents us a helpful tool in biosignal analysis and finally supports the doctor.

Materials and Methods

To prove the faster processing, AFL method is compared to stimulus related averaging like the Averaging method. The comparison is made at a set of data, which is generated by measurements of healthy probands[1]. Their retina were periodically monofocally stimulated with white LEDs flashes and produced a VEP in their mastoid EEG [2]. Their mastoid EEG is bipolar occipital derived, amplified and the spectrum is filtered for eliminating undesirable noise and artefacts.

The Averaging method is used for examining the VEP of large sets of EEG samples, where the probands have seen 1200 trigger impulses. These VEPs are taken as basis for the extraction of verbal formulated properties, which describe the VEP. These properties are used for fuzzy rules, included in the AFL.

The following procedure descibes the signal processing of the AFL algorithm: The series of measurement is examined for each proband and channel of the EEG. The channel of the EEG is divided into segments, where each trigger impulse gives the beginning for each segment and produces the basis for the Averaging and the AFL method.

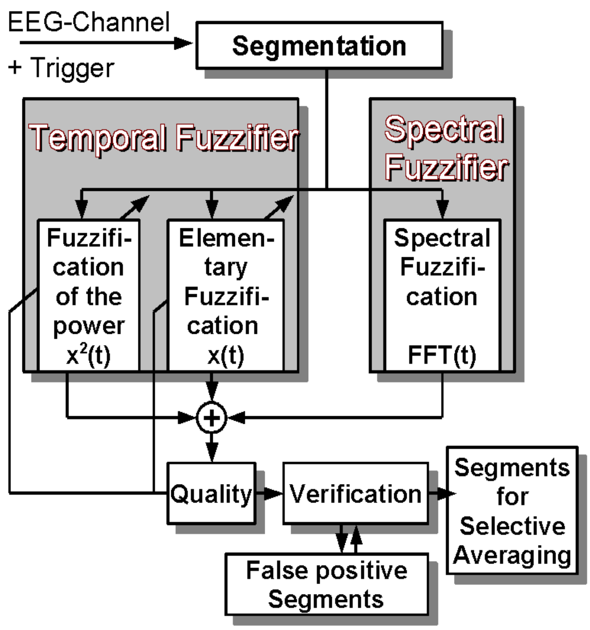

Figure 1: Block diagram which represents the structure of the adaptive fuzzy logic (AFL), which produces a quality rating for each trigger impulse.

Within the AFL, each segment is examined for properties in three independend fuzzy systems, which is

1 Unfortunatly patient data has not been available.

illustrated in the block diagram (Figure 1). Each fuzzy systems produces a quality rating for every segment. The fuzzy systems examines time, power, and spectral relevant properties. These three systems produce an overall rating, which is used as an indicator for the adaption of the threshold. The adjusted threshold located at the AFL input determines the amount of properties being examined. The threshold with the best quality rating for each segment, enables a selective averaging. This method of adaptation leans on the Wiener filtering [3]. Only these segments, which pass a certain rating value are selected. Additionally information about latencies are gained by the detected properties and are passed through for further examinations.

Finally the included verification, based on a fuzzy system, checks the quality of the selected segments, to ensure that false positive detections can be excluded by a certain security. False positive detections may occur by randomly matching certain properties of the VEPs. Therefore the verification depends on properties, which are independent to those of the three fuzzy systems. According to the properties of the verification security is given to ensure the results given by the AFL. The quality of the verification is being tested on an artificial EEG and resting EEG, where the existences of VEPs are excluded.

The verified final results of the selective averaging given by the AFL method are compared to the results of the Averaging, which is a commonly used method for detecting VEPs in a series of measurements.

The AFL method has been tested on probands, whose retinas were periodically mono-focally stimulated with white LEDs flashes, with a luminance of 5000 cd/m². The eye of the proband is been stimulated separately centrally and peripherally. The interstimulus interval (isi) differed randomly between 800 ms and 1200 ms to avoid adaptation to the trigger impulse. A CCD camera has been included in the perimeter, in order to monitor the eye of the proband during the measurement. The supervisor is able to see the attention and the wakefulness of the proband.

A group of probands contains 13 healthy volunteers. Measurements are taken at one group with 400 trigger impulses, which were first centrally stimulated and secondly stimulated peripherally. A long term series of measurement contains 1350 trigger impulses, which were taken on another group of probands in order to verify the found results in before.

To prove that the result has not been adulterated by tight fuzzy rules, the signals were tested with following procedure. The long term series of measurements were investigated carefully for undesired artefacts and other noise or interferences. These interferences were cleared before the AFL is been tested with this resultant series. The amount of the selected segments by the AFL has been the basis for a randomly Averaging. The selected segments, which is the result of the AFL, is been compared to the result of the random Averaging.

The AFL is written in Matlab® and the processing of the signals has been tested offline with Matlab®. Online measurements can be made with a few changes to the source code.

Results

Results are gained by the series of measurement of 400 segments and of 1350 segments. In order to show the early recognisability it will suffice to show samples that represent results, where a VEP structure can be seen after 128s of measurement. The samples cover the results of the latest measurements. On certain probands an identification of VEP structure was possible after 43s.

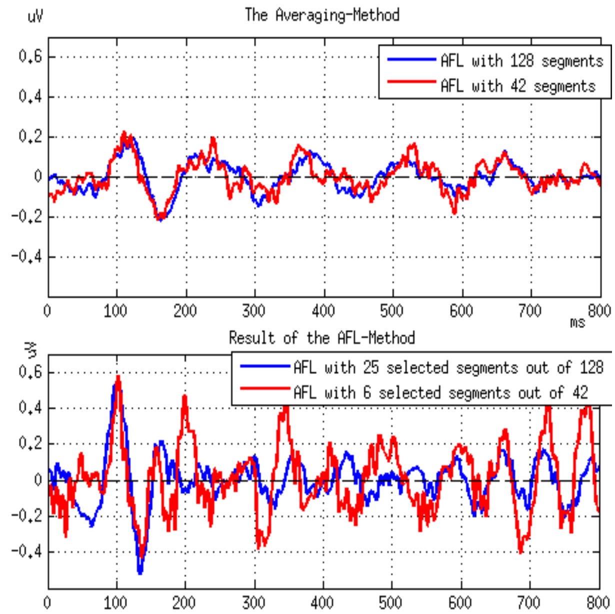

Figure 2: Comparison of the AFL method (graphic below) with the Averaging method (graphic above). A VEP structure can be seen after 42s of measurement time in the graphic below (red line), while a sure statement cannot be made with the Averaging method (graphic above).

The comparison of the results between the AFL method and the Averaging method shows an earlier recognizability VEP, which is demonstrated in the figure 2. A typical VEP-structure [4], which is defined by the peaks N2, P2, and N3, are recognizable after 42 segments, of which 6 segments were selected for averaging (red line, graphic below). Even though noise versus signal is quite high, the structure of the VEP is identifiable.

The graphic above shows the results of the same series of measurement, where neither the result after the averaging of 42 segments (red line) nor the result after 128 segments shows a well defined VEP-structure. The blue line in the graphic below ensures the result of the first found VEP-structure.

Occasionally artefacts may discard a measurement like theta or alphas waves with low signal to noise ratio (SNR). Filtering these waves would even reject the desired VEP. The figure 3 shows such an example, where alpha waves with a low amplitude would have

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discarded a measurement. The graphic above shows an EEG of a proband who has produced primarily alpha waves.

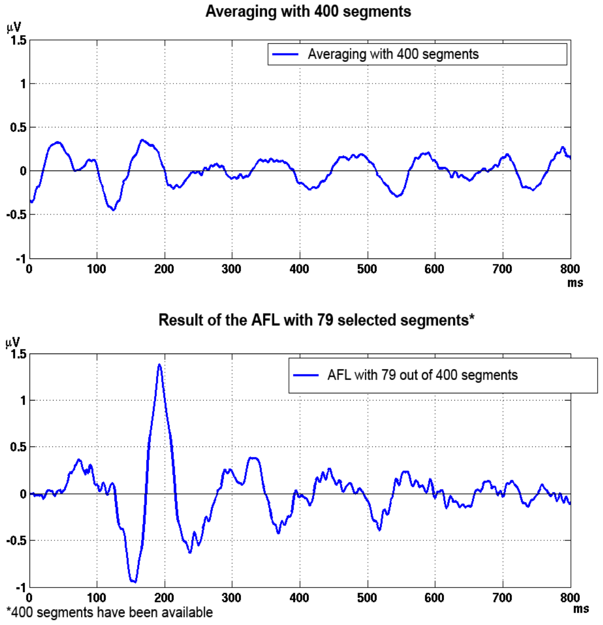

Figure 3: Averaging of an EEG which includes alpha waves with a low SNR. The graphic below shows the extraction of the AFL method with 79 out 400 segments.

The Averaging method is not able to extract VEPs, while the AFL selected these segments of high quality and therefore a VEP structure can be recognized in the graphic below.

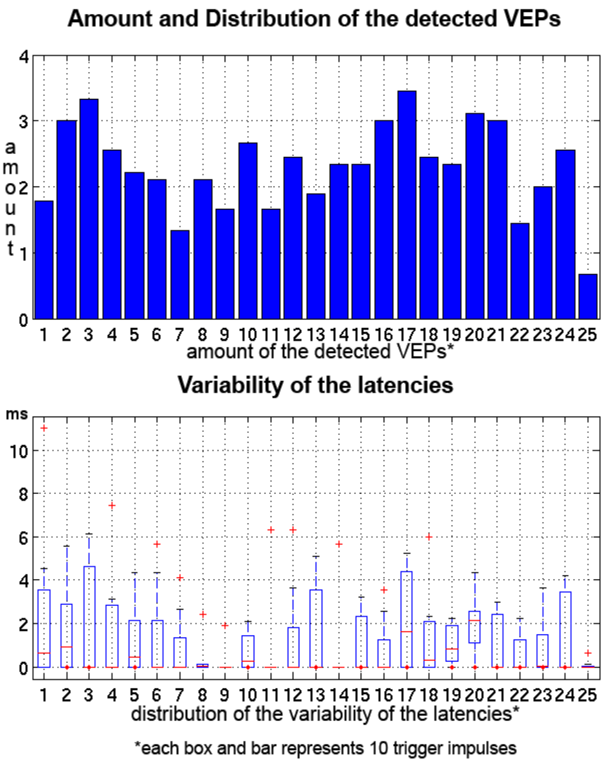

Figure 4: Typically detection rate is shown in the block diagram (above), where each block is a mean of 10 stimuli. The box plot below shows the distribution of the variability of the latencies.

Although low detection rate the recognizability is given after 42 seconds in this case. A typical distribution of the detections is shown in the above block diagram of the figure 3. Each block illustrates the detection means of 10 stimuli.

The detections here differ between 2 and 3 detections. This rate can be taken additionally to the CCD camera during the measurement in order to have a criterion of the attention of the proband. The box plot given in figure 4 shows the distribution of the variability of the latency for these 10 stimuli.

It can be seen that the variation of the latencies average 1.6ms, measured on a healthy proband. These distributions can be seen online during the measurement.

Without the included verification the detection rates averages 49% throughout all measurements. Verification reduces the detection rate to 23%, which is represented in the figure 4 (graphic above). The verification ensures that false positive detection can be excluded with a security of 9.4%. This security has been tested on an artificial EEG, which does not contain VEPs.

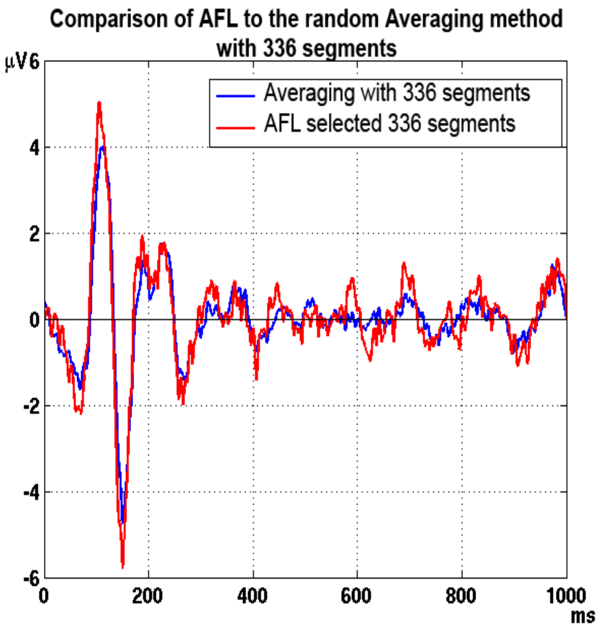

Figure 5: Result of the test, whether adulteration occurs. The VEPs of the AFL method are identically to these of the Averaging method with randomly chosen segments.

Adulteration can be excepted due to the result of the test shown in the figure 5. The results of the random Averaging (blue line) are identically to those of the AFL method (red line). Even though the AFL is uncorrelated to the form of the signal the VEPs are identical. This test shows the reliability of the AFL, which is necessary to find degenerated VEPs. Degenerated VEPs are needed to indicate pathological changes of the visual system. Comparing the figure 3 and 5 it can be seen that the algorithm is able to detect VEPs of electrodes with reversed polarity.

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Configuration	BogoMips	Computing time /segment [ms]
A	2244	**1056,3**
B	2572	**960,2**
C	4719	**620,9**

Configuration of the Computers	
A	Intel Celeron 1.3GHz, 512MB SDRAM
B	AMD-Duron 1.3GHz, 768MB SDRAM
C	Intel P4 2.4GHz, 1GB DDRAM

Table 1: Test for real-time capabilities of the AFL algorithm. The configuration C is a current computer system (July 2005), which allows online diagnoses with Matlab®.

To view the results during a diagnosis the algorithm has been test for real-time processing capabilities. The following table (Table 1) shows the computing time of the AFL method on three different computer systems. The algorithm is written in Matlab® and has been tested with offline data. The table 1 shows that real-time processing capabilities are given with current computer systems. A current computer system (Configuration C on July 2005) would be able to present the results in real-time. A further processing can be achieved by implementing this algorithm close to the hardware.

Discussion

The AFL and the Averaging method belong to the group of algorithms that are uncorrelated to a form of a signal. Neither the AFL nor the Averaging methods seek for a reference signal. Because of the capability to combine expertise and adaptation recognisability of VEPs is much earlier given with the AFL. Averaging a few selected segments with high quality does result in shorter time of measurement. Results show that an early diagnosis can be made. In some cases the VEP is even recognisable after less than 60 segments. A statement of the existence of a VEP can therefore be made after less than a minute total time of measurement. The time of the measurement could be furthermore decreased by adapting the algorithm to multifocal stimulation.

To rely on these diagnoses the security should have been increased. The insecurity of the verification should not be greater than 5% before the algorithm can be integrated in an application like a perimeter [5]. To reach this security level further investigations on the form of the signal of VEPs are needed. These investigations are needed in order to find properties which are independent to properties of the three used fuzzy systems.

Although security does not yet allow application on patients the AFL is a promising challenge for further researches. For example the information about latencies passed through the AFL method give valuable information about the state of the visual system. Another close field of application would be the research on acoustical evoked potentials (AEP), where few adaptations of extracted verbal formulated properties might be needed.

Conclusions

The AFL method is a highly dynamically adjustable tool for biosignal analysis. Adjustments can be made to each individual task. In the ophthalmology we are interested in shortening the time to detect VEPs in favour of the patient. This has been achieved by gathering expertise about the VEPs and adjusting the AFL to this expertise. Additionally the adaptation allows the AFL to adjust to variability during an examination.

To treat patients with care we intent to maintain the time for an objective perimetrical examination as short as possible. The results show that one promising approach is the AFL method. In comparison to the Averaging method recognisability of a VEP structure is given even in cases where examination would have been discarded. This algorithm profits due to few high quality segments that enhances the SNR and due to the ability to ignore segments with a poor quality. A short examination prevents eyestrain, and after all a fatigue patient.

A clearly recognisable VEP structure helps the doctor to determine a diagnosis. Additionally valuable information is gained by the ability of displaying the time of latencies, which allows conclusions about the visual system and especially about the visual cortex.

References

[1] WANG, L.(1994): 'Adaptive Fuzzy Systems and Control', (Prentice Hall, London u.a.)

[2] NUNEZ, P. L.(1981): 'Electric Fields of the Brain', (Oxford University Press, New York, Oxford)

[3] DOYLE, D.J.(1975): 'Some comments on the use of Wiener filtering for the estimation of evoked potentials', Electroencephalogr. Clin. Neurophysiol. 38, p. 533-534

[4] LOWITZSCH, K. (1983): 'Visuell evozierte Potentiale',. in LOWITZSCH, K., MAURER, K., HOPF, H. C.: 'Evozierte Potentiale in der klinischen Diagnostik, visuell, akustisch, somatosensibel', (Georg ThiemeVerlag Stuttgart – New York.), p. 32-33

[5] SCHUMACHER M., SCHULGEN G. (2002): 'Methodik klinischer Studien, Methodische Grundlagen und Auswertung', (Springer-Verlag Berlin Heidelberg New York), p. 161