Detection and Removal of Non-responsive Channels and Trials in Evoked Potentials using Median test

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ABSTRACT

The primary goal of this research work is to detect and remove non responsive channels and trials in evoked potentials by tracing out the signals with very low energy. This is done by calculating the energy of the average evoked potential of each channel, and the energy of the average evoked potential of each trial. Then channel wise and trial wise median test is conducted to detect and remove non-responsive channels and trials. An attempt has been made to apply these techniques to 14-channel visual evoked potentials (VEPs) obtained from four different subjects.

KEYWORDS

evoked potentials, energy, median..

1. INTRODUCTION

Evoked potentials (EPs) are usually considered as the time locked and synchronized activity of a group of neurons that add to the background electro-encephalogram (EEG). Evoked Potentials indicate how well the brain is processing stimuli from the sense organs (eg. eyes, ears or skin) and can help diagnose illnesses. An evoked potential (EP) is a signal that is generated as a result of the transmission of information induced by the application of a sensory stimulus to a sensory pathway. Examples of such stimuli are electric stimuli, visual stimuli, and auditory stimuli [1]. The application of a stimulus invokes a sequence of action potentials that is transmitted via a nervous pathway to the central nervous system (CNS).

The activation of different parts in the nervous pathway leads to variations in the electromagnetic field that can be recorded on the scalp. Using surface electrodes a sequence of positive and

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negative peaks can be recorded; such a sequence is called a sensory evoked potential. These peaks are characterized by their amplitude and time after the stimulus, at which they occur the (post stimulus) latency. Evoked potentials are simultaneously recorded on the scalp with the spontaneous EEG. The EEG signal has much larger amplitude than the evoked potential. Averaging techniques are used to extract the signal related to the stimulus and reduce the amplitude of the ongoing EEG signal, which is treated as back ground noise while recording evoked potentials [2]-[4].

Evoked potentials are used extensively in the study of human brain functions and in clinical investigations to study normal and abnormal brain functions. They are used to test conduction in the visual, auditory, and somatosensory systems. During surgery they can be used to monitor the condition of structures at the operative site. Sensory evoked potentials can also be used for monitoring effects of anesthetics on the central nervous system (CNS). The choice of stimulus type to be used depends on the part of the nervous system to be investigated and the circumstances under which measurements are to be made.

Visual evoked potentials are very useful in detecting blindness in patients those cannot communicate, such as babies or animals. If repeated stimulation of the visual field causes no changes in EEG potentials then the subject's brain is probably not receiving any signals from his/her eyes. Other applications include the diagnosis of optic neuritis, which causes the signal to be delayed. Artifacts in EP waveform recordings typically result from voltage changes due to eye blinks, eye movements, muscle activities, and power line noise. Fig.1(a) shows visual evoked potential recording setup where pattern reversal method is used as stimulus, and Fig.1(b) shows a typical visual evoked potential.

A class of stimuli such as visual, auditory or somatosensory signal affects a particular group of neurons that can be detected by respective channel sensors placed on the scalp. Evoked potential response to each trial of the stimuli depends on the concentration of the subject on the applied stimuli at that particular time.

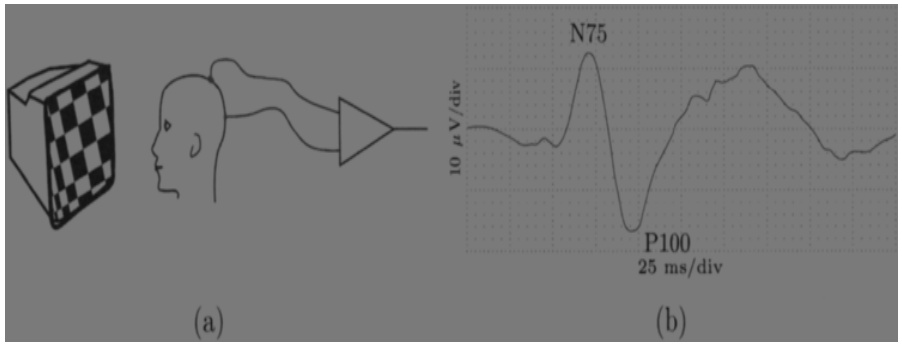

Fig.1. Visual evoked potentials. (a) Recording setup using pattern reversal method as stimulation.
(b) Typical VEP morphology.

2. RELATED WORK

Several researches are going on to improve the quality of bio-medical signals. Errors in averaging of small signal samples can be reduced more efficiently by using median rather than mean [6]-[8]. Artifacts in visual evoked potentials caused by eye movement, eye blink, external noise, internal noise of recording instruments, etc., are removed by using different techniques such as blind

component separation, multichannel median test , standard deviation and kurtosis tests, etc., [14]-[16].

3. MEDIAN TEST

This work proposes median test to detect and remove non-responsive channels and trials in evoked potentials.

3.1. Removal of Non Responsive Channels

If a channel has stuck at fault, the EPs of that channel are discarded from further analysis. Some of the channels may not respond to a particular class of stimulus. In such cases, the non responsive channels may be detected as follows. k^{th} sample of N – trial average evoked potential of each of the M channels is

$$Z_{m/c}(k) = \frac{1}{N}\sum_{n=1}^{N} Z_{m/c;n}(k), \quad \begin{matrix} m = 1,2,...,M \\ k = 1,2,...,K \end{matrix} \tag{1}$$

Where $Z_{m/c;n}(k)$ is the k^{th} sample of n^{th} trial of m^{th} channel evoked potential in response to stimulus c. Energy E_{Z_m} of N – trial average of each channel m is calculated as

$$E_{Z_{m/c}} = \sum_{k=1}^{K} Z_{m/c}^2(k) \qquad m = 1,2,...,M \tag{2}$$

Let $\overline{E}_{Z_{ch/c}}$ be the median, $E_{Z_{ch/c}\max}$ be the maximum value and $E_{Z_{ch/c}\min}$ be the minimum value of $E_{Z_{1/c}}, E_{Z_{2/c}}, ..., E_{Z_{M/c}}$.

Define $d_{ch/c} = E_{Z_{ch/c}\max} - \overline{E}_{Z_{ch/c}}$ as the distance between the median and maximum value of energy of M – channels.

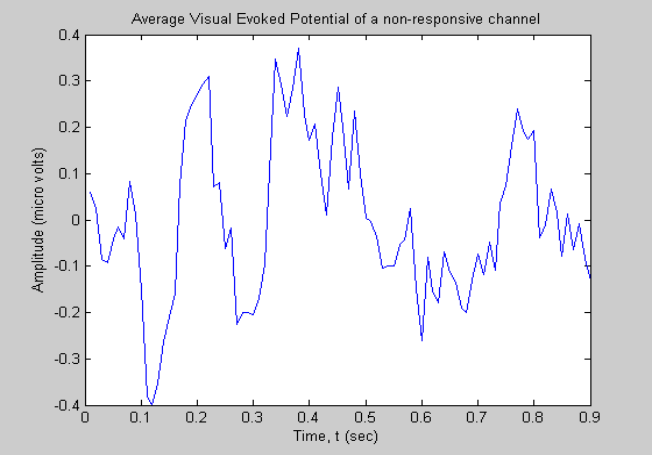

Fig. 2. Fig. Average VEP of a non-responsive channel.

The channels providing average evoked potentials with energy less than $\overline{E}_{Z_{ch/c}} - d_{ch/c}$ are detected as non responsive channels, and removed from the channel averaging process. This will improve the peaks average EP responses. Fig.2 shows an example of average VEP of a non responsive channel, whereas Fig.3 shows that of a channel with good response to the applied stimulus *c*. Fig.4 shows a comparison of average VEPs including and excluding non responsive channels.

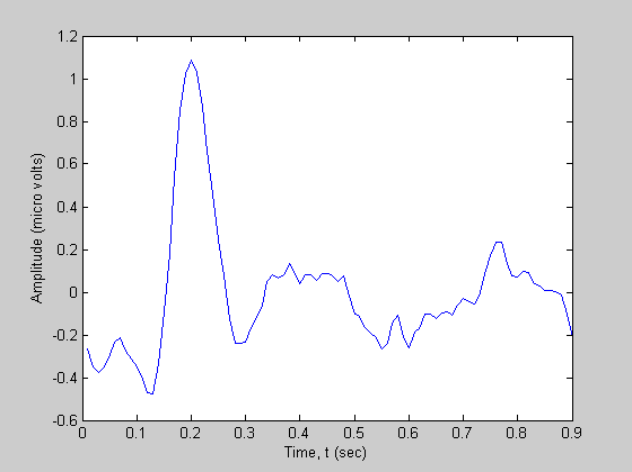

Fig. 3. Average VEP of a channel with good response

3.2. Removal of Non Responsive Trials

If the subject is not ready, or diverted from the stimulus, then evoked potentials of some trials may be non responsive. In such cases, the non responsive trials may be detected as follows. k^{th} sample of M – channel average evoked potential of each of the N trials is

$$Z_{c;n}(k) = \frac{1}{M}\sum_{m=1}^{M} Z_{m/c;n}(k), \quad \begin{matrix} n = 1,2,...,N \\ k = 1,2,...,K \end{matrix} \tag{3}$$

Where $Z_{m/c;n}(k)$ is the k^{th} sample of n^{th} trial of m^{th} channel evoked potential in response to stimulus *c*. Energy E_{Z_n} of M – channel average of each trial *n* is calculated as

$$E_{Z_{c;n}} = \sum_{k=1}^{K} Z_{c;n}^2(k) \qquad n = 1,2,...,N \tag{4}$$

Let $\overline{E}_{Z_{tr/c}}$ be the median, $E_{Z_{tr/c}\max}$ be the maximum value and $E_{Z_{tr/c}\min}$ be the minimum value of $E_{Z_{c;1}}, E_{Z_{c;2}}, ..., E_{Z_{c;N}}$.

Define $d_{tr/c} = E_{Z_{tr/c}\max} - \overline{E}_{Z_{tr/c}}$ as the distance between the median and maximum value of energy of N – trials.

The trials providing average evoked potentials with energy less than $\overline{E}_{Z_{c,tr}} - d_{tr/c}$ are detected as non responsive trials, and removed from the trial averaging process.

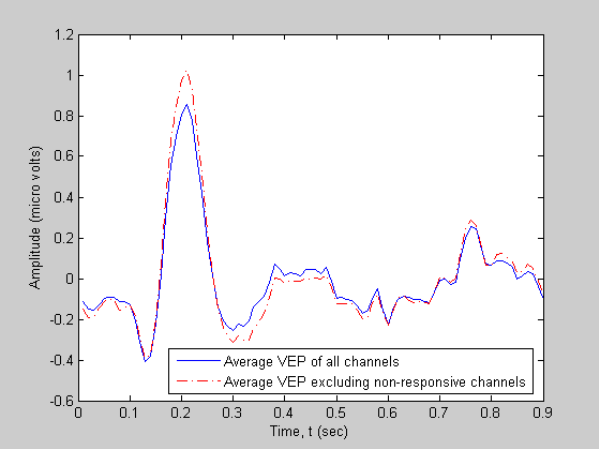

Fig.4. Comparison of VEPs with and without non responsive channels

Fig.5 shows an example of average EP of a non responsive trial. Removal of such trials will improve the peaks of average VEP responses, on addition to that provided by removing non responsive channels. Fig.6 shows average VEP of a non responsive trail after the removal of non responsive channels. Fig.7 shows a comparison of average VEPs including and excluding non responsive trials. A comparison of average VEPs with and without both non responsive channels and trials is shown in Fig.8.

Quality factor (Q-factor), $\theta = 1 - \hat{\theta}$

Where $\hat{\theta} = \frac{a}{N}$

a = No. of non-responsive channels (trials)

N = No. of tested channels (trilas)

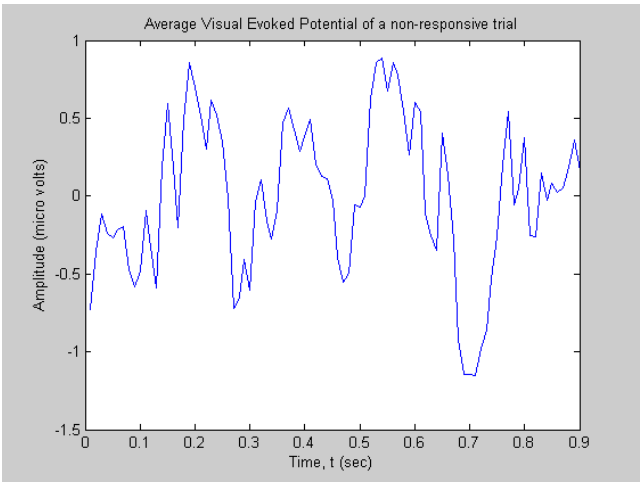

Fig.5. Average VEP of a non-responsive trial.

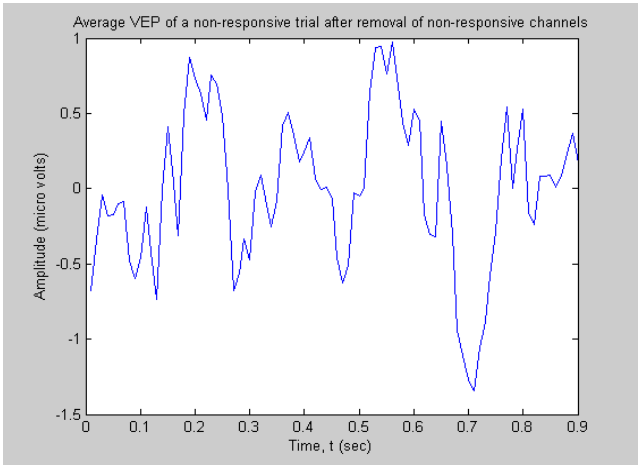

Fig.6. Average VEP of a non-responsive trial after removal of non responsive channels.

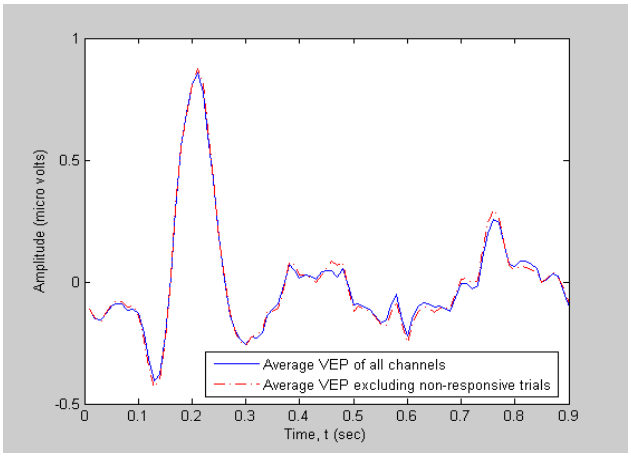

Fig.7. Comparison of VEPs with and without non responsive trials

4. SIMULATION AND RESULTS

The median test was applied to 14-channel 71-trial VEP ensembles acquired from four different subjects. Channel wise and trial wise average EPs having low energies were detected and removed while classifying the EPs. The following table shows no. of non-responsive channels and trials and quality factors related to visual evoked potentials of a typical subject.

No. of non-responsive channels detected	2
No. of non-responsive trials detected	4
No. of non-responsive trials detected after removal of non responsive channels	3
Channel wise Q - factor before removal of non-responsive channels	85.71%
Trial wise Q - factor before removal of non-responsive trials	94.37%
Over all Q - factor before removal of non-responsive channels and trials	80.89%
Trial wise Q - factor after removal of non-responsive channels but before removal of non-responsive trials	95.78%
Over all Q - factor after removal of non-responsive channels and trials	100%

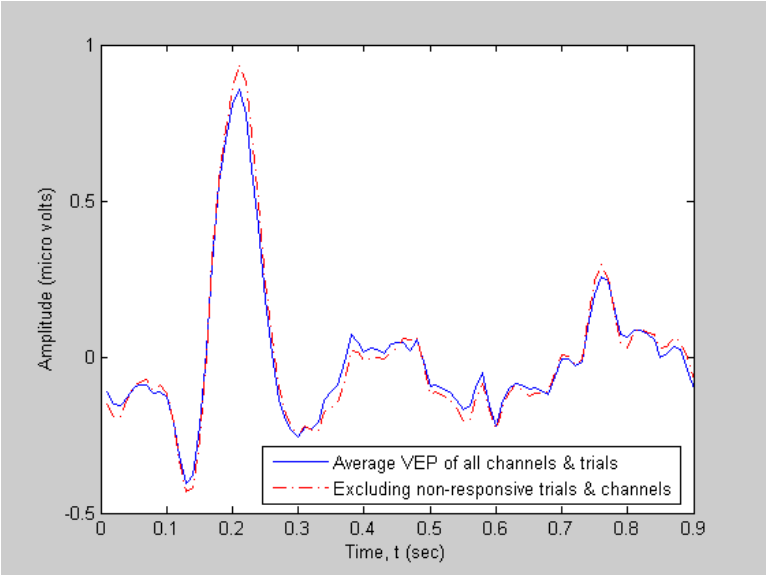

Fig.8. Comparison of VEPs with and without nonresponsive channels & Trials.

5. CONCLUSIONS

The primary objective of this work is to identify and reject non responsive channels and trials in the acquisition of evoked potentials. The proposed method is applied to visual evoked potentials. Energy of average VEP of each channel, and of each trial is obtained. Then non responsive channels and trials are detected and removed by using channel wise and trial wise median test respectively. This improves the peaks of average VEPs and hence classifier performance.

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