 DOI:10.3217/978-3-85125-378-8-98

Detection of Eyes Closing Activities through Alpha Wave by Variability Analysis

Denis Delisle-Rodriguez[1,2*], Javier F. Castillo-Garcia[1], Teodiano Bastos-Filho[1], Anselmo Frizeira-Neto[1], Alberto López-Delis[2]

[1]Post-Graduate Program of Electrical Engineering, Federal University of Espirito Santo, Brazil

[2] Center of Medical Biophysics, University of Oriente, Santiago de Cuba, Cuba

delisle05@gmail.com, javier.castillo@correounivalle.edu.co, teodiano@ele.ufes.br, anselmo@ele.ufes.br, alberto.lopez@cbiomed.cu

Abstract

This work presents an alternative method to detect events correlated to eyes opening and closing, based on electroencephalography (EEG) measured from the occipital lobe. The goal is to propose a method based on variance and variability analysis of alpha wave to classify segments of EEG signals that contain activities originated by eyes closing. The peak values of alpha waves are determined to obtaining the variability series, which are used to compute the power spectrum through Welch periodogram. The combination of alpha wave variance and their variability, were used to obtain a coefficient that allows discriminating between events of eyes opening and closing. This approach can be used to control the switching of a brain computer interface (BCI).

1 Introduction

Several technologies have been developed to assist and improve the communication of people with paralysis and severe motor disability. BCI is a communication system that does not depend on the brain's normal output pathways of peripheral nerves and muscles. At UFES/Brazil we are developing a BCI system for an autonomous car based on evoked visual stimulus (Castillo *et al* 2013), which can cause visual fatigue. A good alternative is switching the BCI through a user command, that can be performed by eyes closing. This way, electroencephalography signals (EEG) have been employed, which contain information that allows the eyes closure detection. Eyes opening and eyes closing activities can be sensed on the occipital lobe through alpha wave analysis in a frequency range of 8 Hz to 13 Hz. A high energy of the alpha wave corresponds to closed eyes on awake subjects (in 90% of healthy and people with disabilities) (Alaraj and Fukami 2013). Alpha waves have been applied to operate electrical devices, however, the automatic recognition associated to eyes opened (EO) and closed (EC) is not a trivial task, because the bandwidth of alpha wave is affected by natural variation and electrical noise, and muscle artefacts. Several methods have been developed to automatic detection of alpha wave, such as: analogue filtering and smoothing (AFS), peak detection and counting, power spectrum analysis, fractal dimension, KM2O-Langevin and approximated entropy (Kirkup *et al* 1998, Craig *et al* 2005, Sakai *et al* 2010, Alaraj and Fukami 2013). All aforementioned methods use a threshold value as a reference that depends on each subject and experiment conditions. The aim of this work is to propose one automatic method based on the variability information of alpha wave of EEG for recognition of eyes closing events in awake subjects, in order to activate a BCI.

 DOI:10.3217/978-3-85125-378-8-98

2 Material and methods

The proposed method allows the online automatic detection of the opening and closing eyes activity from alpha wave by variability analysis in time and frequency domains. Figure 1 presents a block diagram of the proposed method.

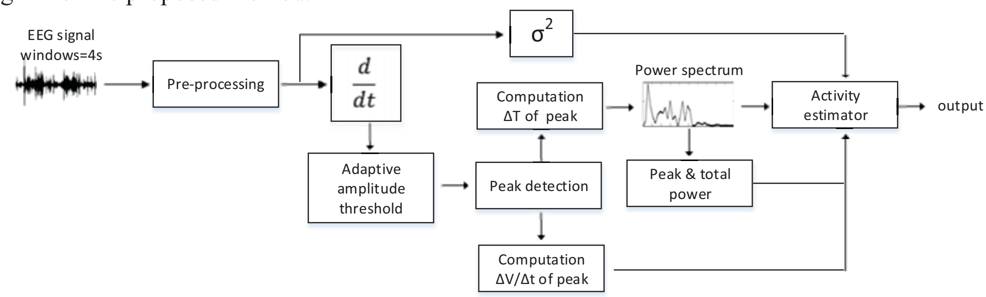

Figure 1: Representation of the proposed method to detect eyes opening or eyes closing.

The electroencephalographic (EEG) signals are captured and analyzed in sliding windows of 4s, shifted for 1s. First, EEG signals are pre-processed by a Common Average Reference (CAR) filter and a bandpass elliptic filter (bandwidth: 8-13 Hz, 5nd order), to reduce the common interference and select the principal information of the alpha wave, respectively. Second, the variance and first derivative of alpha wave are computed, and adaptive amplitude thresholds are calculated on the first derivative signal to detect local peak values. The thresholds are computed on windows of 78 ms with overlapping 90% using the equations (1) and (2). The local peak values higher than a threshold are taken as reference to detect the peak values of the alpha wave, which are employed to obtain the temporal series of the variability. After, these peak values are used to compute the transition velocity ($\Delta V/\Delta t$) and power spectrum (by Welch periodogram, overlapping of 50%, and Blackman window) to determine the peak and total power of the variability. Finally, the variance and variability information of the alpha wave are employed to compute a coefficient to detect the events (eyes opening or eyes closing). This coefficient can be calculated by equation (3).

$$RMS_k = \frac{1}{N}\sum_{i=1}^{N} {y_i}^2 \quad (1)$$

$$AT_k = RMS_k - 0.4 \times \sigma_k \quad , \quad (2)$$

where RMS is the root mean square of the window of 4 s, y is the first derivative of alpha wave, N is the total samples, σ is the standard deviation of the first derivative, AT is the amplitude threshold, $0 < k < W$-1, and W is the total windows.

$$coefficient = \frac{P_{max}}{\left(V_t \times \frac{1}{f_{max}}\right)^2} + \frac{P_{total}}{\sigma^2} \quad , \quad (3)$$

where P_{max} and P_{total} are the peak and total value of power spectrum of the variability series, f_{max} is the frequency that correspond to P_{max}, σ^2 and V_t are the variance and transition velocity between peak values (from minimum to maximum value) of the alpha wave, respectively.

2.1 Experimental protocol

The experimental protocol allows the acquisition of EEG signals in two events: opened eyes and closed eyes. Eight healthy subjects participated in the experiment and provided written informed consent. Each subject is sit near to a visual (virtual animated eye) and auditory (tone) synchronized stimuli that guide the oscillation period necessary to open (remaining 10 seconds) and close (remaining 10 seconds) the eyes during 100 seconds. Five records of EEG signals were acquired to each subject. EEG signals

 DOI:10.3217/978-3-85125-378-8-98

were acquired from Emotiv EPOC neuroheadset using fourteen electrodes on the scalp, placed according to the international 10/20 system: AF3, AF4, F3, F4, F7, F8, FC5, FC6, P7, P8, T7, T8, O1, O2. However, only the data from occipital alpha waves (8-13Hz) on O1 and O2 sites were used. The occipital locations O1 and O2 were chosen for two reasons: (1) alpha activity is larger in the occipital region as it is directly linked to the visual perception; and (2) there is less artefact in this region, such as ocular muscle activity, compared to the frontal scalp regions. EEG channels were sampled with 128 Hz at 1.95μV, the least significant bit voltage resolution.

3 Results and discussion

Table 1 shows the behavior of the variables considered to estimate the possible event of eyes in the analyzed segment of the eight subjects.

Events	Transition velocity (u.a/s)	Variance	Total power (s^2)	Peak power (PP) (s^2)	Frequency of PP (Hz)
Eyes opening	161.07 ± 73.42	14.72 ± 17.95	20.66 ± 8.40	305.64 ± 117.77	1.59 ± 1.25
	114.81 ± 40.38	5.72 ± 6.41	16.36 ± 8.71	237.05 ± 110.6	1.59 ± 1.20
	257.62 ± 64.08	26.59 ± 13.31	16.07 ± 7.29	258.40 ± 116.4	1.64 ± 1.08
	109.94 ± 50.17	5.83 ± 6.96	17.28 ± 10.63	261.05 ± 121.84	1.29 ± 0.98
	127.37 ± 38.56	6.38 ± 7.85	17.45 ± 6.93	265.23 ± 108.82	1.81 ± 1.14
	172.23 ± 51.75	11.73 ± 7.98	17.59 ± 12.69	259.76 ± 128.14	1.64 ± 1.18
	133.76 ± 41.35	8.73 ± 4.55	19.62 ± 8.80	302.89 ± 128.07	1.75 ± 1.25
	60.65 ± 17.59	1.63 ± 1.46	21.13 ± 8.39	316.54 ± 141.63	1.68 ± 0.98
Eyes closing	536.56 ± 171.53	101.33 ± 52.16	4.50 ± 2.31	64.23 ± 30.72	1.37 ± 1.09
	453.54 ± 145.30	70.63 ± 33.87	4.80 ± 3.16	71.42 ± 45.04	1.35 ± 0.96
	539.61 ± 190.13	110.66 ± 66.42	6.26 ± 3.88	88.48 ± 51.88	1.55 ± 0.92
	364.95 ± 90.74	46.94 ± 19.14	3.98 ± 2.69	60.52 ± 41.72	1.71 ± 1.08
	186.69 ± 64.81	12.98 ± 9.59	9.40 ± 5.15	129.27 ± 60.59	1.64 ± 1.38
	269.64 ± 106.80	27.76 ± 22.58	8.25 ± 5.01	117.60 ± 75.87	1.55 ± 1.14
	276.07 ± 78.28	32.15± 15.20	9.92 ± 4.91	141.21 ± 68.00	1.68 ± 1.10
	114.24 ± 37.43	4.93± 2.99	8.49 ± 4.53	116.40 ± 62.74	1.73 ± 1.16
p-value	0.0078	0.0078	0.0078	0.0078	0.2343
d effect	1.68	1.43	5.25	5.91	0.34

Table 1: Performance of the variables (mean ± standard deviation) for the proposed method to detect eyes opening and eyes closing.

Wilcoxon Signed-Ranks test for paired samples and effect size methods were employed to evaluate the performance of the proposed method (Haidous *et al* 2013). For each event of eyes (eyes opening or eyes closing), it can be observed that there are statistical significance (p-value<0.05) and high effect size (d effect>0.8) in the variables that contain information of the variability (transition velocity, variance, total power, peak power), as well as the variance. It is worth to connect that the last subject presented a low difference in the variance. Figure 2 shows the coefficient computed throughout the signal. In these figures it can be seen that artefacts present during segments of open eyes do not affect the coefficient value.

 DOI:10.3217/978-3-85125-378-8-98

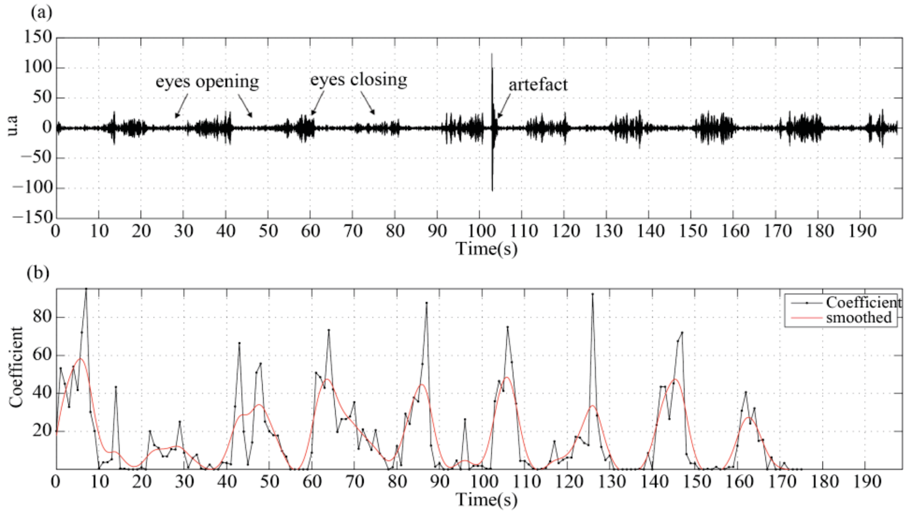

Figure 2: Representation of the coefficient computed to detect eyes opening or eyes closing.

4 Conclusion

The preliminary results suggest that the combination of the variance and information variability can be used to detect events of eyes opening and eyes closing through EEG signals measured on the occipital lobe. Several works have reported that power spectral analysis of alpha wave is not a good option to detect events of eyes closing and eyes opening. Thus, this work presents the possibility of using the power spectral technique to analyze the variability information of the alpha wave. As future works, the proposed method should be improved to detect the peak values detection on the alpha wave. This approach here proposed can be also used to control the switching of BCI systems.

References

Kirkup L, Searle A, Craig A, McIsaac P and Moses P. (1997) *EEG based system for rapid on-of switching without prior learning*, Med. Biol. Eng. Comput., pp. 504–9.

Kirkup L, Searle A, Craig A, McIsaac P and Larsen G. (1998). *Three methods compared for detecting the onset of alpha wave synchronization following eye closure*, Physiol. Meas., vol. 19, 213–224.

Craig A, Tran Y, Craig D and Thuraisingham R. (2005). *Improving correct switching rates in a hands free environmental control system*, Journal of Neural Engineering, pp. L9-L13.

Sakai M, Wei D, Kong W, Dai G, and Hu H. (2010). *Detection of change in alpha wave following eyes closure based on KM2O-Langevin equation*, International Journal of Bioelectromagnetism, 12(2), 89–93.

Alaraj M and Fukami T (2013) *Quantification of subject wakefulness state during routine EEG examination,* International Journal of Innovative Computing, Information and Control, 9 (8), 3211–3223.

Castillo J, Muller S, Caicedo E, Ferreira A and Bastos T (2014) *Proposal of a Brain Computer Interface to Command an Autonomous Car*, In: 5th IEEE Biosignals and Biorobotics Conference (BRC 2014), Salvador. Proc. of the 5th IEEE Biosignals and Biorobotics Conference, pp. 6.

Haidous, N (2013) Robustness and Power of the Kornbrot Rank Difference, Signed Ranks, and Dependent Samples T-test. American Journal of Applied Mathematics and Statistics 1(5), 99–102