Journal of Multidisciplinary Engineering Science and Technology (JMEST)
ISSN: 3159-0040
Vol. 1 Issue 4, November - 2014

Online EEG eye state detection in time domain by using local amplitude increase

Selahaddin Batuhan AKBEN
Osmaniye Korkut Ata University, Bahce Vocational School
Osmaniye, Turkey

***Abstract* — In this study, online eye state detection method have been proposed by using EEG signals. The proposed method is related to the amplitude increase in small periods. Attribute used for proposed method is EEG artifacts caused by eye lid movements. So, eye lid opening and closing moments have been detected by continuous amplitude increase in artifacts. As a result, eye state was determined at same time with recoding.**

Keywords—EEG Artifact; EEG Eye state; EEG Eye blink;

I. INTRODUCTION

Electrical signals from human brain can be detected along the scalp by an EEG. The EEG signals are divided into bands by frequency [1]. These frequency bands determine the brain activity. For example, if the eye is closed, brain resting signals are in 4-14 Hz band. By this attribute, the state of the eye can be determined [2]. But frequency bands are usually extracted using spectral methods and spectral methods are used for recorded signals because the use of spectral methods for ongoing signals is not possible (Spectral methods are available for offline signals) [3]. Spectral methods can be used for recorded sections of ongoing signal to overcome this problem. But recorded time required for spectral methods should not be too short. Therefore eye state detection will not still be online [4, 5]. Now then the eye state detection must be implemented in time domain.

Amplitude of the EEG signal is very low. So the EEG data is contaminated by many artifacts. Artifacts are non-cerebral signals. Artifacts can be observed in time domain. Artifacts are noise signal. The removal of artifacts is required for observation of original EEG signal. Therefore researchers have developed several methods to remove eye blink artifacts [6, 7, 8]. However, artifacts can be used to detect eye state because the eye blink is the most observed physiological artifacts in EEG. Eye blink artifact is related to eye lid movement. EEG amplitude increases with the movement of the eye lids. Thus eye lid movement can be detected by EEG amplitude increase. Likewise, eyelid opening and closing moments can be detected by local amplitude increase in EEG signals [9, 10]. Local EEG amplitude increase caused by eyelid movement can be seen in figure 1.

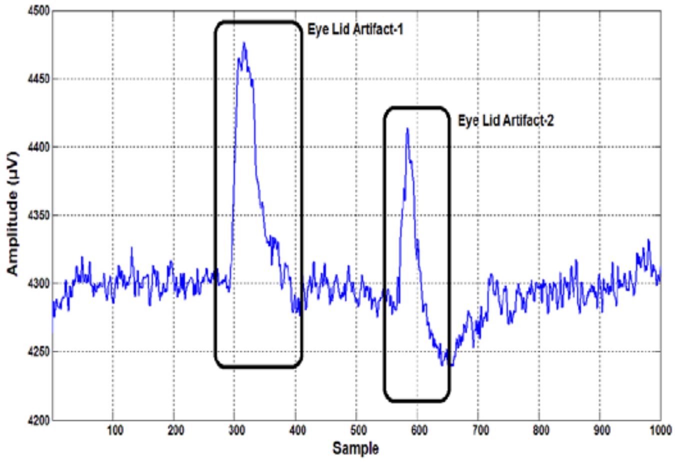

Fig. 1. Amplitude increase caused by eyelid movement

In this study, EEG amplitude variations occurring in a small time period have been identified. Then continuous amplitude increase moments have been determined. As a result, eye state have been detected by eye opening and closing moments.

II. MATERIALS

In this study, EEG_eyestate Data Set from UCI Machine Learning Repository Database was used. Data set is consisting of continuous 14 EEG measurements. The duration of the measurement is 117 seconds (each measurement has14980 sample). Sampling frequency is 128 Hz. The eye states were marked as "1" or "0". “1” indicates the eye-closed and “0” the eye-open state. Thus, data set has class labels. Characteristics of the data set can be seen in table 1.

TABLE I. CHARACTESITIC OF DATA SET

Name	*Samples*	*Attribute*
EEG_eyestate Data Set	14980	14

Each attribute contains an EEG record

Also eye blink moments of data set can be seen in table 2.

TABLE II. CHARACTESITIC OF DATA SET

Name	***Eye Blink Moments (Second)***					
EEG_eyestate Data Set	1,5	6,8	10,4	12,8	17,0	20,6
	22,7	22,9	26,1	34,0	40,9	46,3
	52,0	70,7	86,8	94,4	99,4	99,8
	101,4	101,8	111,1	111,6	116,9	---

Each record has 23 eye lid movement moments

III. METHOD

In this study, primarily used method is related to the diagnostic algorithm of the eyelid moments. Then, the same method was used with some modifications to the eye state detection. Finally, the success rate of the proposed method was compared with the success rate of the clustering method applied to the raw data.

To understand the logic of the proposed method it must first examine the EEG time series. Sometimes, sign of difference between consecutive EEG voltages changes continuously. But sometimes, sign of this difference may also be stationary in short period. Furthermore, sign of amplitude difference doesn't change in a long time at eye blink period [11, 12].

So, it can be said that main characteristic of artifacts caused by eyelid movement is sign of amplitude difference that remains stationary for a long time. As shown in figure 1, the amplitude increases for a long time from the start of eye lid movement. So the start point of eyelid movement can be detected by determination of long timed amplitude increase.

For this aim, time window need to determine first. Aim of this window is to identify signs of difference between samples in specific time period. There is a start of artifact if all signs are same in window. As result, artifact start time can also be determined, If window is shifted by one sample at each iteration. Algorithm of proposed method is below:

1. Suppose that X_n is an EEG time series and ω is a window length. Also Y_n is another vector all elements are same with X_n.

2. Signs of difference between samples from 1 to ω are controlled.

3. If all signs are same Y_1 is set to 1. Otherwise Y_1 is set 0.

4. Sign control is done for samples between 2 and $\omega + 1$ in second iteration.

5. Same 0 or 1 assignment operation is done for vector Y_n.

6. The same process continues in all iterations. Thus, affected samples by artifacts can be determined by elements of 1 in Y_n. vector.

7. Also 0-1 transitions in Y_1 are determined as start of eye lid artifacts.

Moreover, open or closed moments of eyes can be determined if consecutive two 0-1 transitions is assigned as 1 in Y_n. In this study, class labels have been created by determining the 0-1 transition intervals in Y_n.vector. Determined labels were used for eye state detection. Success rate of proposed method for eye state detection was determined by ROC analysis.

In this method, window size is very critical. In addition, the window size must be selected at least two to create difference between samples. If window size is too small, some small amplitude changes may be evaluated as artifact. If window size is too large, some artifacts will not be evaluated as artifact. Therefore, the optimal window size should be selected.

This problem can be solved by difference between amplitude of EEG amplitude and artifacts. An eye blink can be 10 times larger in amplitude than electrical signals originating from cerebral cortex [13]. Accordingly, eyelid artifacts start at the beginning of approximately 10 samples having consecutive amplitude increase. If so, window size must be selected as 10. Therefore, In this study, the window size is selected as 10.

Also algorithm can be seen in figure 2.

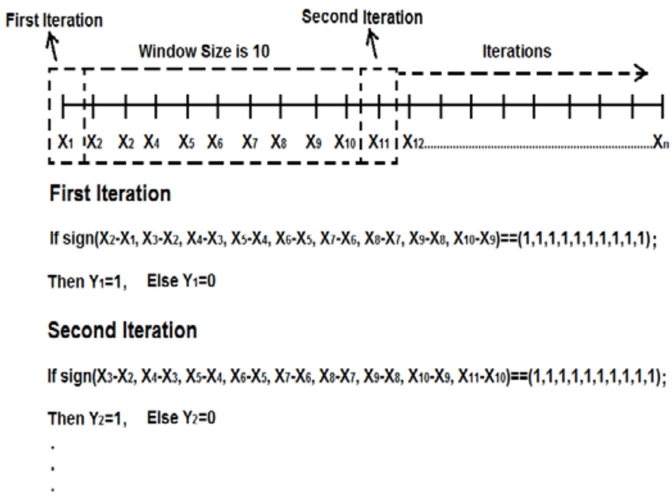

Fig. 2. Proposed detection algorithm

ROC (Receiver operating characteristic) analysis was used to determine eye state in this study. ROC analysis is related to ratio of four values (True Positive, False Positive, True Negative and False Negative). These values can be defined as:

If prediction is positive and the known value is also positive, then it is called a true positive (TP)

However if the known value is negative while predicted value is positive, then it is said to be a false positive (FP).

Conversely, a true negative (TN) has occurred when both the prediction and known value are negative.

False negative (FN) is when the prediction is negative while the known value is positive.

Furthermore, success rate (accuracy) is calculated as follows according to ROC analysis:

Accuracy: (TP+TN)/(P+N)

While TP is true positive, TN is true negative, P is positive and N is negative [14].

IV. EXPERIMENTAL RESULTS

In this study, class labels determined by proposed method were compared with known class labels. Result of proposed method can be seen as moments of eye state changes in figure 3. In figure 3, also known class labels are shown as eye state change moments.

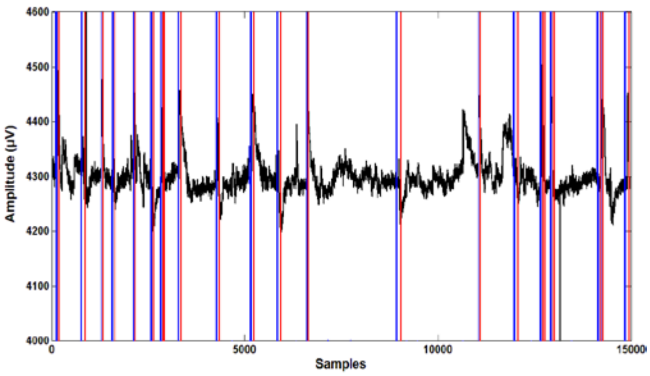

Fig. 3. Eye state change moments created by proposed method (Blue lines are eyelid movement moments detected by proposed method, red lines are known eyelid movement moments).

As shown in figure 3, most of eyelid movements have been determined by the proposed method. Also detected moments are very close to known moments. Furthermore, figure 1 pointed out failure of proposed method in case of eye blink repeatedly. In such eye blink moments, method has detected two movements as a single movement. Reason for this is continuous amplitude increase in consecutive eye blink moments. Also, difference between known eye blink moments and detected eye blink moments may be explained by camera recording delay. Again, the reason of moment difference can be explained by early detection of proposed method. Figure-3 belongs to one of 14 records. So, the rate of success in other records should be determined. Success rate of proposed method for all records can be seen in table-3.

TABLE III. SUCCESS RATE OF PROPOSED METHOD IN EYE BLINK DETECTION

Records	***Number of Detected Eye Blink Moments***	***Number of Known Eye Blink Moments***	***Success Rate***
1	21	23	%91
2	21	23	%91
3	19	23	%83
4	20	23	%87
5	19	23	%83
6	19	23	%83
7	20	23	%87
8	21	23	%91
9	20	23	%87
10	21	23	%91
11	18	23	%78
12	21	23	%91
13	20	23	%87
14	20	23	%87
Mean	20	23	%87

As can be seen in table 3, the proposed method has an average of %87 success rate for all records.

In next stage of study, eyes are open and closed periods were tried to determine. In other words, the time between eye blink moments have been studied to detect. For this aim, eye states were detected by period between eye blink moments. Namely, a vector that each element has assigned as 0 first has been created. After, when eyes blinked the elements of vector have been assigned as 1. From the moment of next blink, elements have been assigned as 0 again. This element assign procedure was repeated continuously. Thus, detected class labels were created for each record. Finally, detected class labels were compared with known class labels. Comparison results can be seen in table-4 for all records and can be seen in figure 4 for one record.

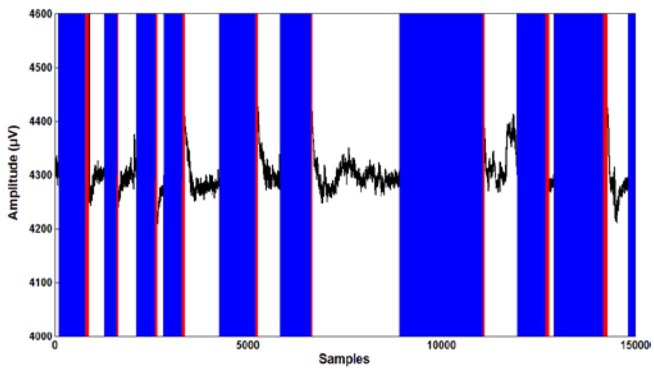

Fig. 4. Eye states (Filled areas mean eyes are closed. Blue fills have been created by proposed method. Red fill means eyes are really closed)

TABLE IV. SUCCESS RATE OF PROPOSED METHOD IN EYE STATE DETECTION

Records	***Accuracy Rate***
1	%98,3
2	%97,9
3	%89,9
4	%94,7
5	%88,1
6	%88,7
7	%95,1
8	%98,1
9	%94,8
10	%97,8
11	%86,6
12	%98,2
13	%94,9
14	%94,9
Mean	%94,1

As can be seen in table 4, the proposed method has an average of %94,1 success rate for all records. This success rate means that the proposed method is to be useful for eye state detection. Also raw data were clustered by well-known k-means method to better understand these success rates. The success rate of K-means method is 50% for raw data. If so, it can be said that proposed method makes the raw data meaningful for EEG eye state detection.

V. CONCLUSIION

Raw EEG data consists of continuously voltage fluctuates. Depending on eyelid movement a momentary increase may occur in the EEG signals. These instantaneous amplitude increase called as artifact can be used for determining eye lid movement moment. An algorithm was proposed for this purpose in this study. Thus, the start of the eyelid movement moment has been detected. Thus, the start of the eyelid motion has been detected at the same time with EEG recording. Therefore, eye lid movement warning software algorithm is proposed. In addition, EEG eye state was determined simultaneously with recording moment by the same method. Thus, sleep transition of patients can be detected simultaneously with recording at an early stage. Furthermore the proposed method can also be used in artifact detection. Moreover, because the proposed method has simple algorithm the applicability to real life is very easy.

REFERENCES

[1] E. Niedermeyer, and F.L. Da Silva, “Electroencephalography: Basic Principles, Clinical Applications, and Related Fields,”. Lippincot Williams & Wilkin, 2005, pp. 161-193.

[2] H. Laufs, K. Krakow, P. Sterzer, E. Eger, A. Beyerle, A. S. Haddadi, and A. Kleinschmidt, “Electroencephalographic signatures of attentional and cognitive default modes in spontaneous brain activity fluctuations at rest,” National Acad Sciences, 2003, pp 1153-1158.

[3] A. Delorme, T. Sejnowski and S. Makeig, “Enhanced detection of artifacts in EEG data using higher-order statistics and independent component analysis,” Neuroimage, vol. 34(4), pp. 1443–1449, 2007.

[4] S. Valipour, A. D. Shaligram, G. R.Kulkarni, “Spectral analysis of EEG signal for detection of alpha rhythm with open and closed eyes,” International Journal of Engineering and Innovative Technology (IJEIT), vol. 3(6), pp. 1-4, 2013.

[5] R. N. Vigario, "Extraction of ocular artefacts from EEG using independent component analysis," Electroencephalogr. Clin. Neurophysiol., vol. 103, pp. 395-404, 1997.

[6] G. Gratton, M. G. Coles and E. Donchin, "A new method for off-line removal of ocular artifact," Electroencephalogr. Clin. Neurophysiol., vol. 55, pp. 468-484, 1983.

[7] L. Shoker, S. Sanei and M. A. Latif, "Removal of eye blinking artifacts from EEG incorporating a new constrained BSS algorithm," Conf. Proc. IEEE Eng. Med. Biol. Soc., vol. 2, pp. 909-912, 2004.

[8] V. Krishnaveni, S. Jayaraman, L. Anitha and K. Ramadoss, "Removal of ocular artifacts from EEG using adaptive thresholding of wavelet coefficients," J. Neural Eng., vol. 3, pp. 338-346, Dec. 2006.

[9] T. P. Jung, S. Makeig, M. Westerfield, J. Townsend, E. Courchesne and T. J. Sejnowski, "Removal of eye activity artifacts from visual event-related potentials in normal and clinical subjects," Clinical Neurophysiology, vol. 111, pp. 1745-1758, 2000.

[10] W. Zhou and J. Gotman, "Removing Eye-movement Artifacts from the EEG during the Intracarotid Amobarbital Procedure," Epilepsia, vol. 46, pp. 409-414, 2005.

[11] B. J. Fisch and R. Spehlmann, “Fisch and Spehlmann's EEG Primer: Basic Principles of Digital and Analog EEG.,” 3rd ed. Elsevier, 1999.

[12] G. Gratton, M. G. Coles and E. Donchin, "A new method for off-line removal of ocular artifact," Electroencephalogr. Clin. Neurophysiol., vol. 55, pp. 468-484, Apr. 1983.

[13] L. Shoker, S. Sanei and M. A. Latif, "Removal of eye blinking artifacts from EEG incorporating a new constrained BSS algorithm," Conf. Proc. IEEE Eng. Med. Biol. Soc., vol. 2, pp. 909-912, 2004.

[14] T. Fawcett, "An Introduction to ROC Analysis," Pattern Recognition Letters, vol. 27(8), pp. 861–874, 2006.