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A study on the communication system using Electrooculogram Signals for persons with disabilities

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Abstract: The aim of this study is to present electrooculogram (abbr. EOG) signals that can be used for human computer interface efficiently. Establishing an efficient alternative channel for communication without overt speech and hand movements is important to increase the quality of life for patients suffering from Amyotrophic Lateral Sclerosis or other illnesses that prevent correct limb and facial muscular responses. Using EOG signals, it is possible to improve the communication abilities of those patients who can move their eyes. Investigating possibility of usage of the EOG for human-computer interface, a relation between sight angle and EOG is determined. In other methodology, most famous approaches involve the use of a camera to visually track of the eye. However, this method has problems that the eyes of user must always be open. In this paper, we introduce the mouse cursor control system for Amyotrophic Lateral Sclerosis patients using EOG and electroencephalograph (abbr. EEG). We proposed the algorithm using alternating current and direct current of EOG corresponding to the drift. Therefore, our proposal EOG system did not have the problem of eye blinking artifacts, the displacement of electrode positions and the drift. In addition, we introduce the EEG that the brainwaves can assist us whether the patient control their eye movements consciously. The EEG is not used to control. We are getting the EEG signals used to determine the control state. In order to test the effectiveness of our proposal, we have tried the experiments of the Questionnaire in NO or YES using our system and electroencephalograph device MYNDPLAY[7]. The three experimental subjects are inexperienced persons about this system. In this experiment, we measured 30 states of EEG signals when EOG was done and analyzed the EEG signals. According to the EEG signals changes and the answers of the questionnaire, 26 of the 30 states of the EEG signals were able to correctly determine the control state of EOG. From these results, the EEG signals can be used to adjust the EOG system according to the condition of EOG signals. In addition, it is expected that can be applied to determine whether patients are the way their want answers that can assist caregivers to know the brain handicapped patient's own thinking.

Keywords: Electrooculogram Signal; Mouse Cursor Control System; Electroencephalograph

1 INTRODUCTION

In the eye movements, a potential across the cornea and retina exists, and it is source of EOG. EOG can be modeled by a dipole [1], and these systems can be used in medical systems. There are several EOG-based Human-Computer Interface studies in literature. The eyes movement signals and sensor signals are combined, and both direction and acceleration are controlled [2]. Using horizontal and vertical eyes movements and two and three blinking signal a movable robot is controlled. Because the EOG signals are slightly different for the each subject, a dynamical threshold algorithm was developed [3].

In this approach, the initial threshold is compared with the dynamic range; the thresh-old value is renewed after each difference. According to this threshold the output signal is made 1 or 0 and afterwards it is processed. Investigating possibility of usage of the EOG for human computer interface, a relation between sight angle and EOG is determined. However, in-depth studies evoked that slow changing baseline drift is difficult to estimate in continuous EOG signals. To overcome this issue, previous system was proposed using alternating current of EOG which reduces baseline drift by segmentation of the signal [4].

In this study, we have developed the mouse cursor control system and new idea of EOG Signal for amyotrophic lateral sclerosis patients using EOG signals. Our proposal EOG device did not have the problem of eye blinking artifacts and the displacement of electrode positions. But, the drift was problem. Then, we proposed the algorithm using alternating current (abbr. AC) and direct current (abbr. DC) of EOG corresponding to the drift. In order to test the effectiveness of our proposal system, we tried the experiments of the questionnaire using our proposal system and EEG device MYNDPLAY. The performance of the proposal system and our proposal are very good, we measured 30states of EEG signals when EOG was done and analyzed the EEG signals. According to the EEG signals changes and the answers of the questionnaire, 26 of the 30 states of the EEG signals were able to correctly determine the control state of EOG.

2 MOUSE CURSOR SYSTEM USING EOG SIGNALS

2.1 The EOG Device

In this subsection, novel EOG measurement system design has been proposed. Fig. 1 shows the formal scheme for the acquisition and analysis of the EOG signal and how to control organization flow of information through the system.

Horizontal and vertical eye movements are measured with two passive electrodes. Five Ag/AgCl electrodes are used (two for CH1, two for CH2 and one is for ground). Two channels of EOG signals can be used to recognize the eyes movement. EOG signals can be determined as high as 50Hz. However, the signals which are less than 10Hz are safe and enough for our system. Therefore, we used the low pass filter whose cutoff frequency is 10Hz to remove the more than 10Hz power line signals. In our proposal system, channel 3 and 4that apply high pass filter to channel 1 and 2 are used in order to remove the DC level. The cutoff frequency of high pass filter is 0.175Hz. After filtering and the amplification (about 1000 times) stages, the EOG signals are digitized and then transferred to the personal computer. The sampling frequency of the measurement date is 960Hz.

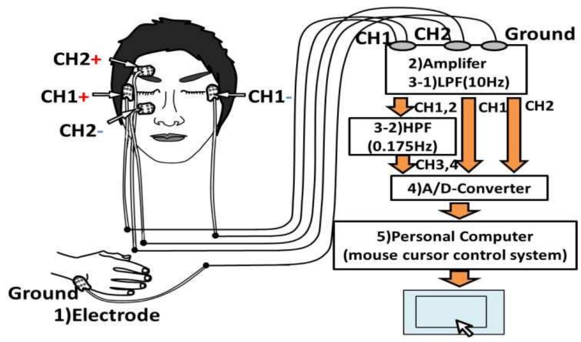

Fig. 1. The mouse cursor control system using EOG

2.2 The EOG signals recording

As seen from the recordings channel 1, 2 and 3 in Fig. 2. (the eyes movements: Right, Left, and intentional Blink), after signal amplitude (about 1000 times) and considering noise reduction measures in designing of the biopotential data acquisition system, the EOG system performance is good. Electronic noise reduction is also successful. Fig. 2 showed that 3 eyes movements are clearly different. Moreover, channel 1 and 2 have the DC level signals, so that the change of the EOG by the eyes movements continues. So, the continuous control for mouse cursor becomes possible. Channel 3 is the AC level signals of the horizontal EOG. Therefore, channel 3 is strongly reacted when eyes moved to right or left. Channel3 and 4signals were removed the DC level by high pass filter. Therefore, channel 3 and 4 signals have the change, only when eyes move. Channel 3 and 4 signals are information that knows the difference between the change by the drift (low frequency) and the change by the eyes movements. When the channel1 or/and channel2 signals change without the channel3 and 4 signal changing, this change is an influence of the drift.

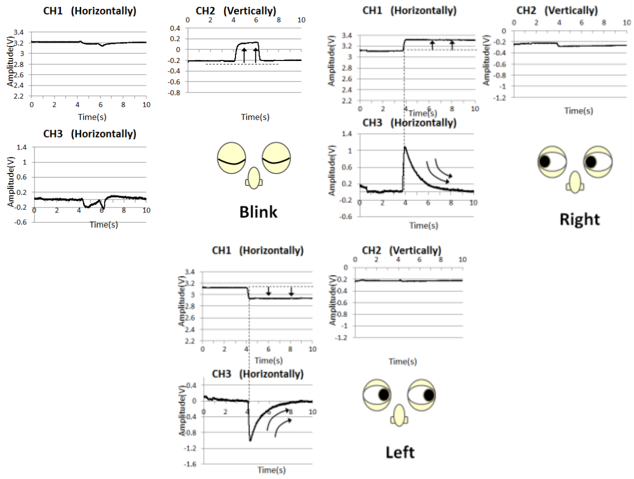

Fig. 2. The EOG signals recording samples in CH 1, 2 and 3 (Blink, Right and Left)

3 PROPOSED METHOD

3.1 Mouse Cursor Control Algorithm

In this section, we introduce our proposal algorithm for the mouse cursor control. The initial thresholds of the eyes movement class (Right, Left, and Voluntary Blink) are set on the user using the initialization screen. 3 eyes movement class (Right, Left, and Blink) are command of the Right movement, Left movement and click processing of the mouse cursor. The values of P_{right}, P_{left}, are defined as the set using the initialization screen. Moreover, the center parameters of the eye (centre) are set. When the experimenter gazes on these points of the initialization screen, the signals change of each channel will be recorded as initial thresholds of the eyes movement class. For example, when the experimenter gazes on the "Centre point", Horizontal centre parameter is set as Cx, and Vertical centre parameter is set as Cy.

At first, in order to remove the more than 60Hz power line noise, we use the moving average method for channel 1 and 2. The moving average method is the unweighted mean of the previous n data points. Because it is the sampling frequency 960Hz, the value of n is 16 (= 960Hz/60Hz). For the reduction of 60Hz power line noise.

Next, the difference between the centre parameter (Cx) and the input of Channel1 is calculated, and it is set to input 1. The input 2 is calculated similarly using difference between the centre parameter (Cy) and the input of Channel2. Our proposal system is judged whether eyes moved by using the input1, 2, channel 3 and channel 4. If eyes do not move, center parameters are updated to correspond to the drift. In this process, Cx and Cy are gradually updated to EOG baseline. I order to keep the security of the system, centre parameters (Cx, Cy) are updated every interval by 30% of the drift.

If eyes move, the eyes movement class is identified using each class thresholds using the rules of Table 1. Here, the value of T_{right}, T_{left}, and T_{blink} are defined as the threshold value of the eyes movement class. Since there is individual difference, it is necessary to update the threshold of T_{right}, T_{left} using the other parameters of P_{right} and P_{left}. And, the threshold of the eyes movement class is updated according to the dynamic threshold method. Therefore, our proposal system can respond to online EOG characteristic changes. The code of the dynamic threshold method of the right threshold is as follows:

```
If 0.64 < input 1/(Pright-Cx) and input
1/(Pright-Cx) < 0.8 Then
  Tright = Tright - 0.01* Tright
Else if input 1/(Pright-Cx) > 0.96 Then
  Tright = Tright + 0.01* Tright
End if
```

Other thresholds are similarly processed. In this process, the threshold is updated to low when the value of input is low, and the threshold is updated to higher when the value of input is high. These processes are repeated. The mouse cursor control interval is 0.2 seconds. The continuous control for mouse cursor can be executed while corresponding to the drift by this proposal algorithm and the proposal EOG device.

Table 1. Pattern classification rules

Command	Right	Left	Blink
Input 1	Input 1>T_{right}	Input 1 <T_{left}	
And input 2	|input 2|<0.3	|input 2|<0.3	Input2 < T_{blink}
And channel 3	CH3>$TCH3_{right}$	CH3<$TCH3_{left}$	CH3 > $TCH3_{blink}$
And channel 4			CH4 > $TCH4_{blink}$

3.2 Electroencephalograph

In this study, we also propose using EEG by MYNDPLAY. EEG is the cording of electrical activity along the scalp, measures voltage fluctuations resulting from ionic current flows within the neurons of the brain. Human brain waves can be divided into at least four states. We determine the activity of the brain by using two categories of low-frequency beta waves and alpha waves in the EEG. Alpha is the frequency range from8 Hz to 13 Hz, seen in the posterior regions of the head on both sides, higher in amplitude on the dominant side. Alpha wave increase during wakeful relaxation with closed eyes. Beta is the frequency range from 13 Hz to about 30 Hz. It is seen usually on both sides in symmetrical distribution and is most evident frontally. Low amplitude beta waves with multiple and varying frequencies are often associated with active, busy, or anxious thinking and active concentration. We use EEG changes that can determine whether the patients using our EOG system in their own meaning. Then, in order to test the effectiveness of our proposal, we have tried the experiments of the Questionnaire in NO or YES using our system and EEG device MYNDPLAY.

4 EXPERIMENTS AND RESULTS

Three inexperience subjects have tried the experiments of the Questionnaire what answer is Yes or No using our EOG system and EEG. But, we cannot run the dynamic threshold method and centre parameters updated method to increase the control misses. The size of the monitor is 23 inches and the distance between the eyes of subject and the monitor is 50cm and use Bluetooth to send the EEG signals.

4.1Experiments method

We have tried the experiments using our proposal system and simple brainwave system MYNDPLAY. The EEG signals of three subjects (S.G, KS.NN and KH.NT) are measured and analyzed 30 states. It is defined as:

$$H(t) = \frac{1}{10}\sum_{i=0}^{9}\frac{A(t-i)}{B(t-i)+C} \qquad (1)$$

A(t) is the frequency from 7Hz to 9Hz of alpha wave of t time power spectrum of Fast Fourier Transform(abb. FFT). *B(t)* is the frequency from 14Hz to 16Hz of the Low-frequency beta waves of t time power spectrum of FFT. *C* is constant, the average of *B(t)*. *H(t)* is the 10 pre moving average.

If the average of *H(t)* is less than 0.5 then the EOG system is uncontrollable of the patient's consciousness. If the average of *H(t)* is greater than 0.5, take 50% of it as the threshold and compared to the *H(t)* whether EOG is controllable. In addition, if the 10 pre moving average value greater than threshold, then the patients according to their own consciousness in using EOG system otherwise not.

4.2Experiments results

Table 2 shows the correct rate of each subject. Fig. 3 shows the correct results for 10 pre moving average of EEG power spectrum and Fig. 4 shows the error one. Fig. 5 and Fig. 6 show the statistical significance less than 1% and the average value of subject KS.NN and S.G, error bar is the standard deviation. The average value of *H(t)*-value of each subject when EOG is controlled by the subject's own thinking or cannot in controlling is calculated, then assessing T-test of each trial. Fig. 7 shows the average of subject KH.NT, although it is no statistical significance, but the correct recognition rate of 80% is a good result. By this analytical method, 30 states of data was measured (one subject for 10 states), 26 states of it can be correct analyzed and the offline correct rate is about 87% and the error is not serious than our previous study (using only EOG system with the dynamic threshold method and centre parameters updated method) that the experimental result of using mouse cursor system and camera is 97%. In addition, as future work, we need online experiment.

Table 2 . Correct rate of each subject

Subjects	S.G	KS.NN	KH.NT
Correct rate	90%	90%	80%

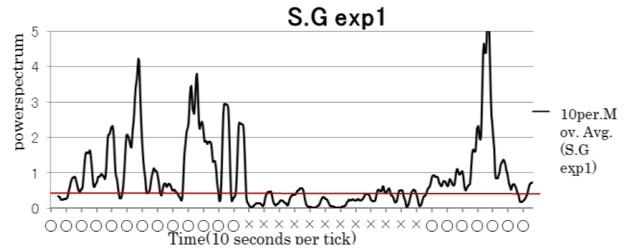

Fig. 3. Correct recognition rate of EEG power spectrum

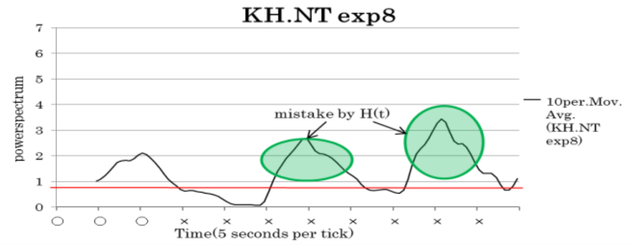

Fig. 4. Error recognition rate of EEG power spectrum

*○ is EOG can be controlled, × is uncontrollable.

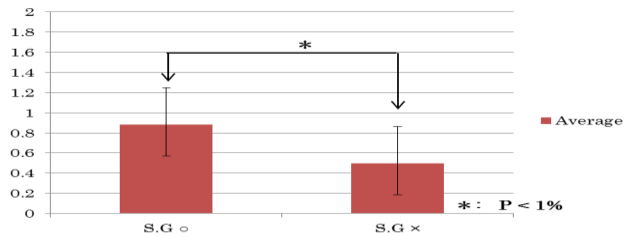

Fig. 5. T-test result of S.G

5 CONCLUSION

In this study, we have developed the mouse cursor control system for amyotrophic lateral sclerosis, by which the amyotrophic lateral sclerosis patients with their own consciousness in control EOG when EOG system was done. The performance of the proposed system was good. According to the EEG signals changes and the answers of the questionnaire, 26 of the 30 states of the EEG signals were able to correctly determine that using Bluetooth to communicate the EOG system and control the EOG. The correct recognition rate of three experimenters is 87%. Two experimenters have the statistical significance less than 1%. From these results, the EEG signals can be used to adjust the EOG system according to the condition of EOG signals. In addition, it is expected that can be applied to determine whether patients are the way their want answers that can assist caregivers to know the brain handicapped patient's own thinking. Our proposed system has one problem that the average time of question increased by wave noise caused by this kind of phenomenon, the whole proposed system should be considered with the properties of electrodes.

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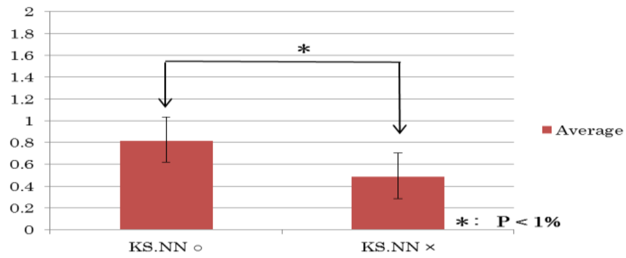

Fig.6. T-test result of KS.NN

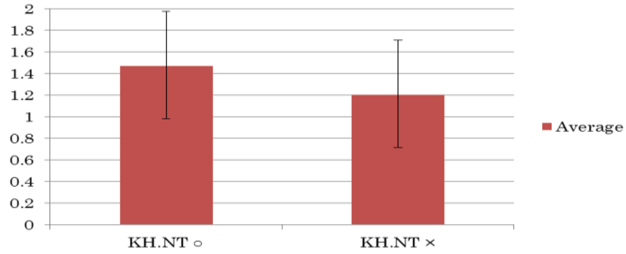

Fig.7. T-test result of KH.NT

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