Estimation of Viewpoint Direction and Viewing Angle Using EOG

Minoru Sasaki[a*], Naoya Ozeki[a], Satoshi Ito[a], Harrison Ngetha[b].

[a]Department of Mechanical Engineering, Gifu University, 1-1 Yanagido, Gifu, 501-1193 Japan

[b]Department of Electrical & Electronic Engineering, Dedan Kimathi University of Technology

[*]Department of Mechanical Engineering, Gifu University, 1-1 Yanagido, Gifu, 501-1193 Japan,

Email: sasaki@gifu-u.ac.jp

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Abstract

This paper presents the feasibility study of EOG signal for the input signal of the man-machine system. This research focuses on the relationship between the eye movements and EOG signal. When the trial subjects look right, left, up and down, the EOG signal was measured and compared with the eye movements and later analyzed. We found that there was a linear relationship between the eye movements and EOG signal. The presented method demonstrates the high possibility of using EOG signal for the man-machine interface system.

Keywords: Biomedical, Man-Machine Interface, EOG Signal, Eye Movement, Emotion Spectrum Analyzer, Visual Content Angle Meter.

1. INTRODUCTION

Currently, in Japan, as the aging progresses, elderly persons' dysfunctions and the like are becoming serious problems. In addition, people who have difficulty in their daily lives due to traffic accidents, occupational accidents, etc. are also unavoidable. The people who need nursing care such as elderly people and disabled people are increasing. Support for independence of careers and the reduction of the burden on the caregiver side are huge problems. Recently, research on human-machine interface using biomedical signals that can be handled even by people with disabilities were undertaken for supporting

the self-reliance of elderly people and persons with disabilities and reducing the burden of nursing persons [1-11].

To this end, we focus on electro-oculogram (EOG), especially in the eye potential. This is visually discerned from the EOG waveform that is generated when viewing up, down, left and right directions, thereby associating the eye potential with the viewing angle for the input signal of man-machine interface.

2. EXPERIMENTAL SETUP

Figure 1 shows the experimental system. The target was moved up, down, left and right in four directions on the screen of the PC 3 in steps and the examinees were asked to follow it. The electro-oculogram at that time is acquired with the Emotion Spectrum Analyzer ESA-16 manufactured by Brain Function Laboratory Co., Ltd. The electrode is affixed to the forehead of the subject as shown in Figure 2. Measurement was performed with the sampling frequency set to 100 Hz and the low-pass filter set to 6 Hz. The output of the goggle type viewing angle measuring apparatus in Figure 3 is in two directions of the x axis direction and the y axis direction, that is, $\pm$ 5 V and analog output. The result is analog to digitally converted (ADC) by the digital signal processor (DSP) and compared with the electro-oculogram.
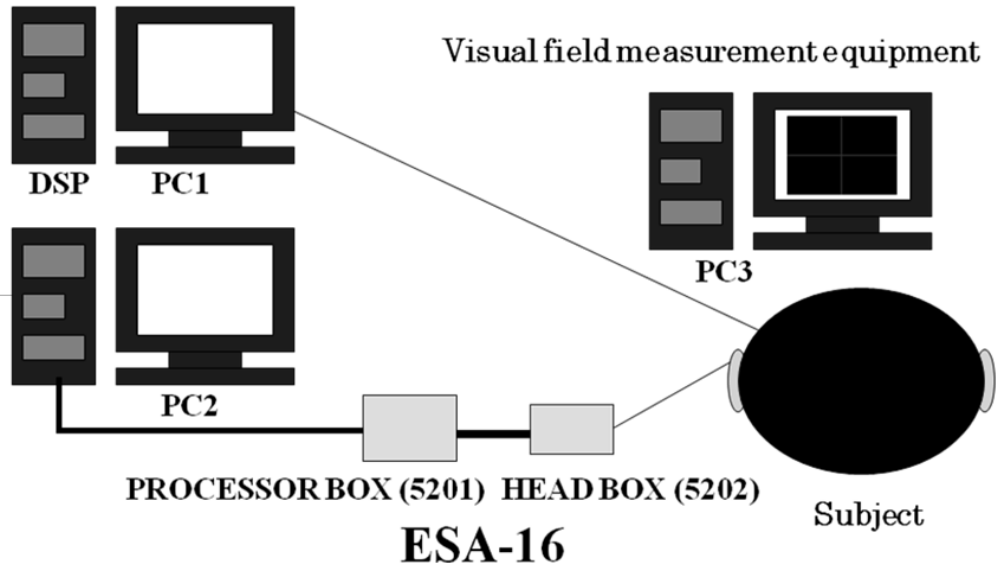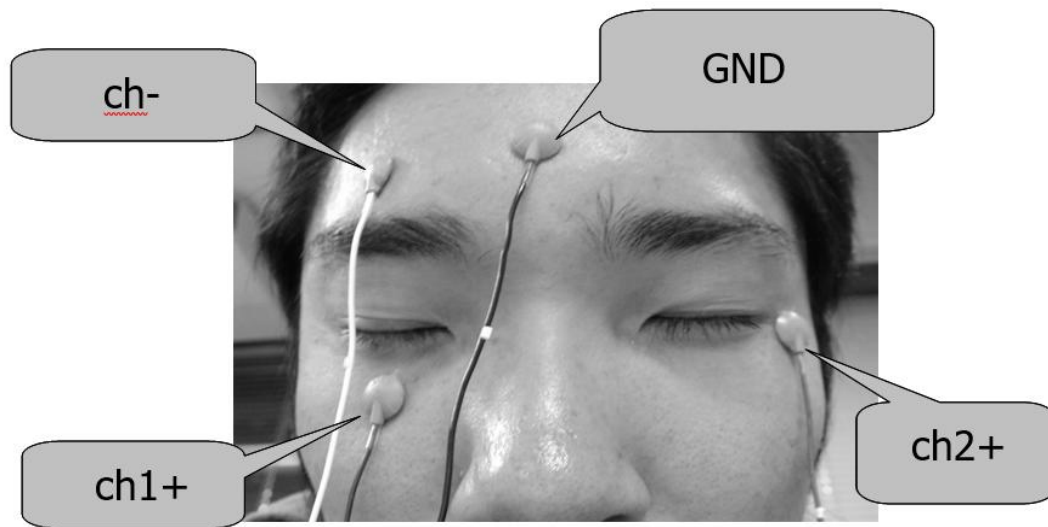
Figure 1: Experiment system

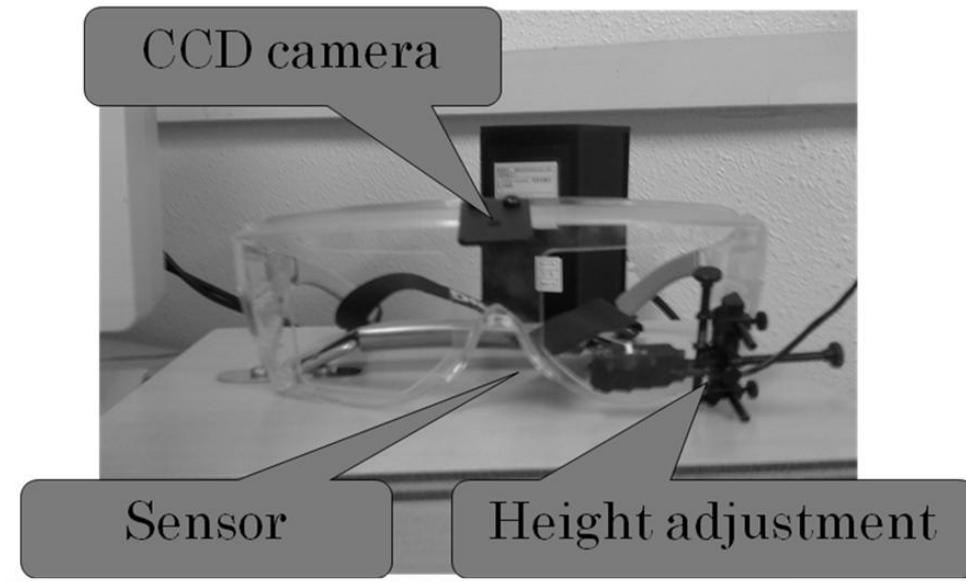Figure 2: Position of the electrodes

Figure 3: Goggle

3. RESULTS AND ANALYSIS

3.1. *Estimation of viewpoint direction*

Figure 4 shows an electro-oculogram waveform when the eyes were moved in order of right, center, left, center, up, center, down, and center. When it turns back to the right from this, it changes in the direction of $(+) \rightarrow (-) \rightarrow (-) \rightarrow (+)$ in ch 1, whereas in ch 2 the opposite $(-) \rightarrow (+) \rightarrow (+) \rightarrow (-)$ direction. Similarly, when looking in the left, up, and down directions, it is possible to distinguish the upward, downward, leftward and rightward directions from the eye potential by combinations of waveforms obtained from ch 1 and ch 2.
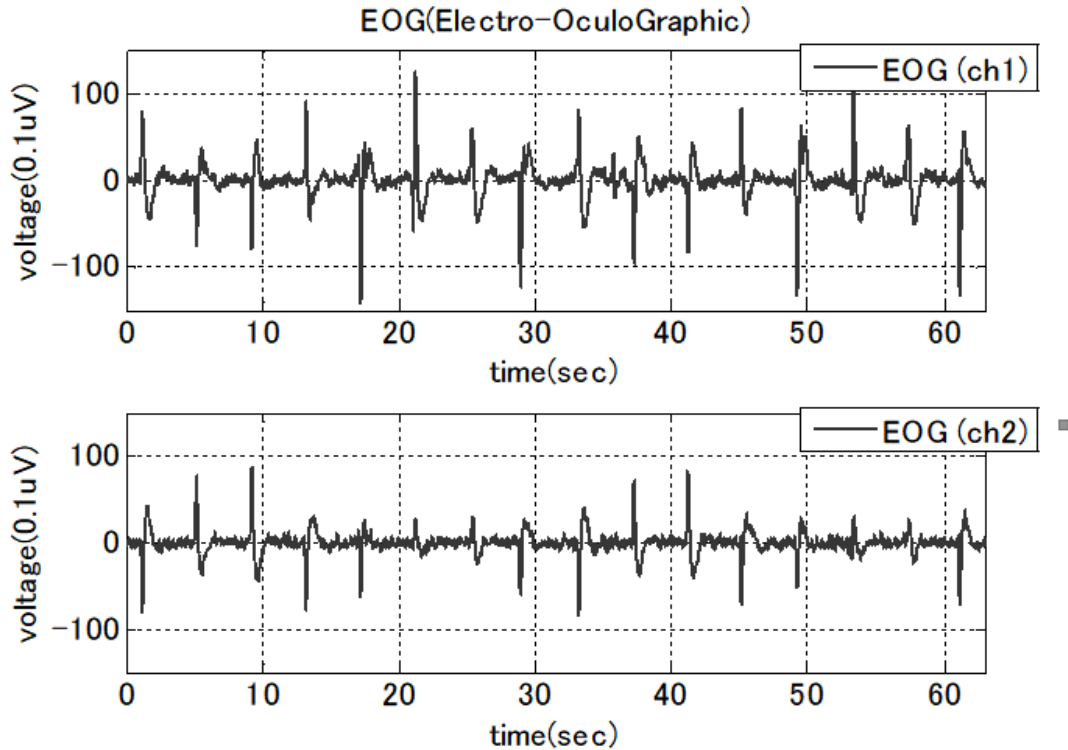
Figure 4: EOG signal (LPF = 6Hz).

3.2. Relationship between EOG and viewing angle

Since the output of the EOG is the amount of change, we plot the difference from the point where the slope changes from plus to minus, or from minus to plus before peak. The result in the upward direction is shown in Figure 5, the result in the downward direction is shown in Figure 6, the result in the right direction is shown in Figure 7, and the result in the left direction is shown in Figure 8.
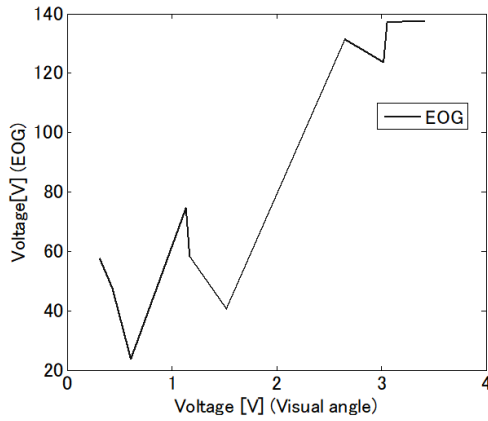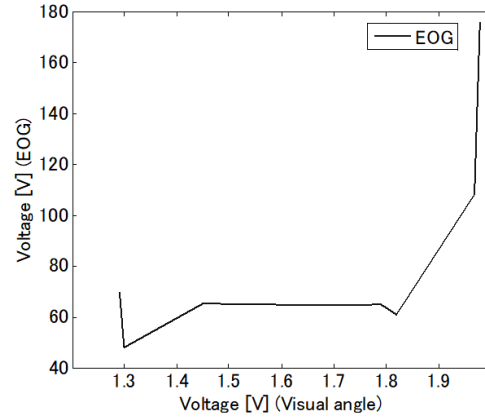
Figure 5: Look at up
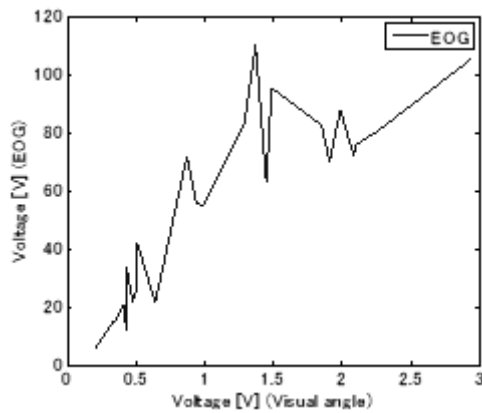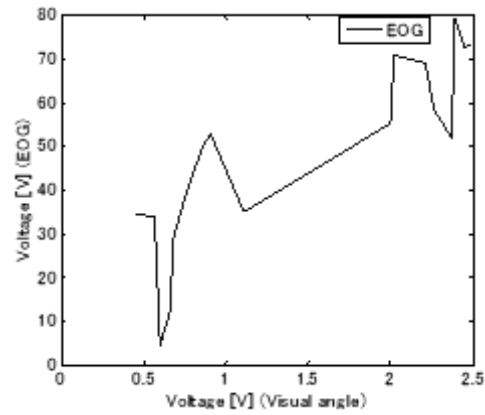

Figure 6: Look at down

Figure 7: Look at right

Figure 8: Look at left

From these results, the eye potential increased as the viewing angle increased, but there was a large variation due to the small amount of data. Also, as shown in Figure 9, it was difficult to associate when the target point could not be seen at one time. Therefore, correspondence was made using the integration result. At the time of visual observation, the difference between the integral value at the point where the sign of the slope of the differential value changes immediately before the eye potential exceeds the threshold and the difference between the peaks of the immediately following integration results are compared.
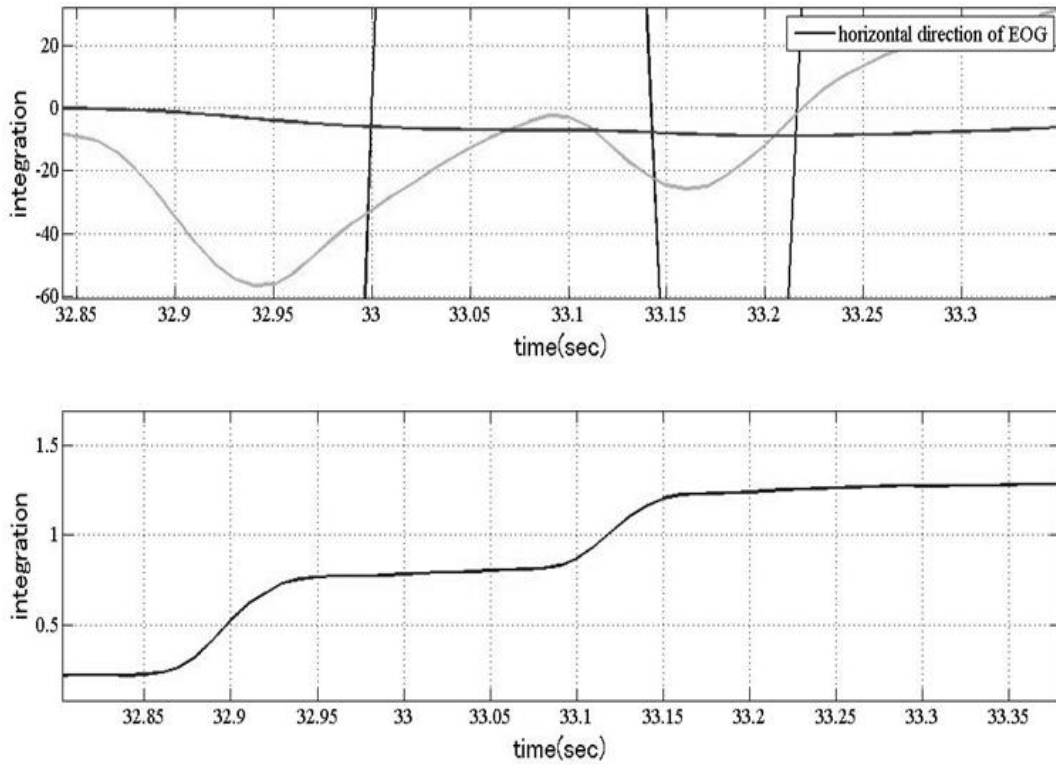
Figure 9: Look at right

The results of visual observation in the upward direction and the linear approximation by the least squares method are shown in Figure 10. Similarly, the result in the downward direction is shown in Figure 11, the result in the right direction is shown in Figure 12, and the result in the left direction is shown in Figure 13.
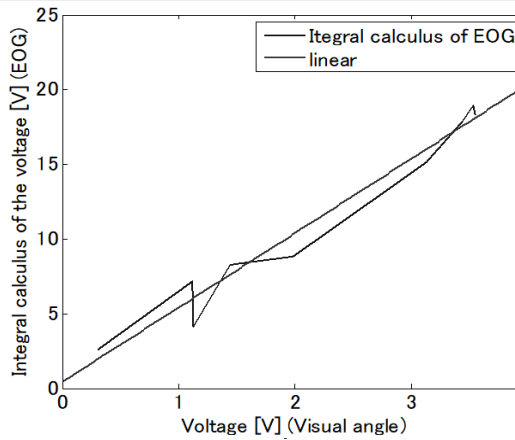
Figure 10: Look at up
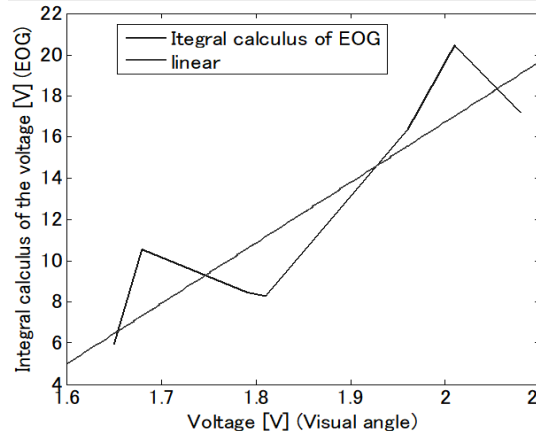
Figure 11: Look at down
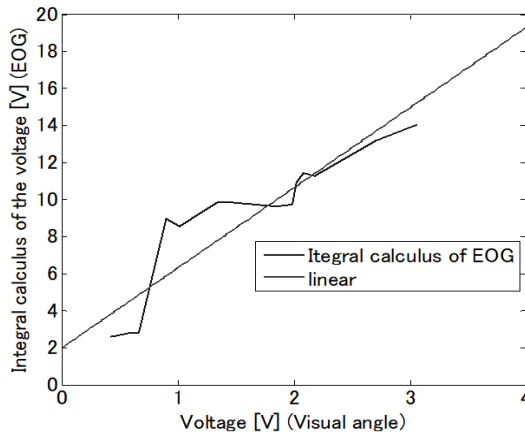
Figure 12: Look at right
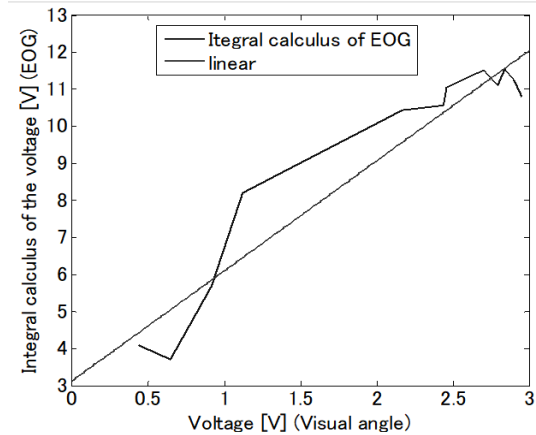
Figure 13: Look at left

As a result, even if linear approximation was performed by the least squares method in all viewing directions, some degree of linearity was observed. The approximate expression now is given by:

Right direction: y = 4.32 x + 2

Left direction: y = 2.98 x + 3.12

Upward direction: y = 4.96x + 0.47

Downward direction: y = 29.37 x - 42.01

Next, experiments are carried out using these results.

3.3.   *Experiment of Direction Estimation from EOG*

Using the experimental system shown in Figure 1, the EOG and viewing angle at the time of viewing the upper, lower, left and right directions were simultaneously measured. The results were then input to an analysis program created in C ++, and the relation between them was examined from the eye recognition potential, visual recognition rate, program output and actual view angle. Also, experimental conditions are set as follows:

1. It is up, down, left, right, and four directions.

2. Do not blink.

3. After visual observation, move on to the next operation after a while.

From past research, we used a region of saccadic motion with visual speed of 100 (deg / sec) or more and a viewing angle of 5 to 45 degrees [1].

3.3.1. Program Specification

The program was specified as follows:

• When the voltage of ch1 and ch2 exceeds the threshold value (± 20 μV) there was visual recognition.

• When the threshold value was exceeded, the time goes back and the integral value of the EOG at the point where the sign of the differential value of the eye potential changes was set as the reference point.

• From the point of exceeding the threshold, the integral value of the point where the sign of the integral value of EOG changed for the first time was the peak.

• Set the dead zone for 1 second from the peak of the integral value.

• Substitute the difference between the peak of the integrated value of EOG and the reference point in the approximate expression.

3.3.2. Visual recognition and direction recognition rates

Right: 13 out of 14 successes → 93%

Left: 12 out of 14 successes → 86%

Top: 11 out of 11 successes → 100%

Down: 10 out of 11 successes → 91%

The visual direction could be recognized 47 times out of 50 times, and it was 94% of the prevalence rate. In addition, even though the visual observation was not performed, the number of times of recognition was 2 times. From this result, it can be said that sufficient direction determination is possible by this method.

3.3.3.   *Relationship between EOG and visual angle*

Figure 14 shows the calculated result of the EOG and the actual visual angle when viewing the upper direction. Similarly, the result in the downward direction is shown in Figure 15, the result in the right direction is shown in Figure 16, and the result in the left direction is shown in Figure 17. Although there are variations, values close to the actual viewing angle were obtained in all the directions of up, down, left, and right.
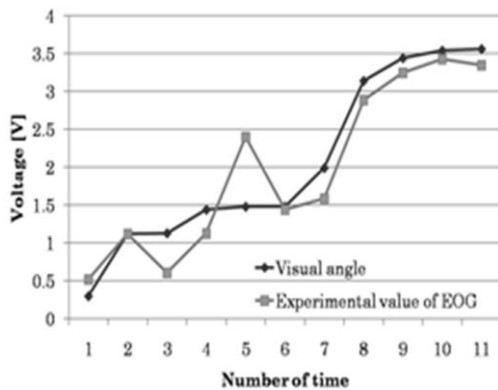
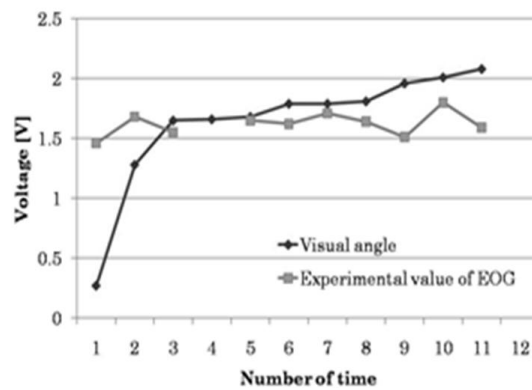Figure 14: Look at up   Figure 15: Look at down
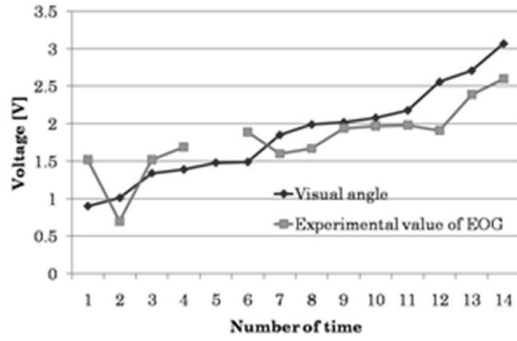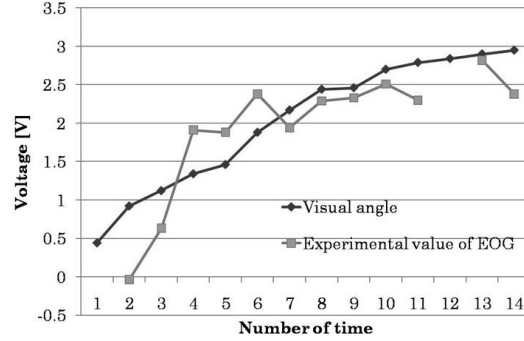
Figure 16: Look at right   Figure 17: Look at left

3.4.   Experiment of Direction Estimation from EOG

Using the program to measure and analyze in real time, we examine whether it is possible to discriminate the direction of the top, bottom, right, and left directions, and to associate the EOG with the visual angle.

In Experiment 1, the EOG low-pass filtered and its differential calculation result are prepared in advance, but in Experiment 2, these calculations need to be performed simultaneously while acquiring data.

First, the transfer function used for the low-pass filter is defined as equation (1).

$$H(s) = \frac{4\pi^2 f^2}{s^2 + 4\pi f \cos\frac{\pi}{4} s + 4\pi^2 f^2}$$

(1)

f = 6 Hz (cutoff frequency)

In addition, the differential is obtained by taking the difference between the current eye potential and the immediately preceding eye potential and using the trapezoidal integral method for integration. Under these conditions, four sets of up, down, left, right and10 vision operations were performed for 10 times in total.

3.4.1.   Relationship between EOG and visual angle

Right: 82 out of 100 successes → 82%

Left: 70out of 100 successes → 70%

Above: 83 out of 100 successes → 83%

Bottom: 48 out of 100 successes → 48%

Although it was easy to recognize in the right direction and the upward direction, it was difficult to recognize the left direction and the downward direction. So, there were variations depending on the direction. For this reason, I would like to consider improvements by not changing all thresholds, but by changing direction, etc. Also, if you did not concentrate then the measurement of electro-encephalopathy did not occur as expected, and the results varied depending on the degree of electrode attachment. In this experiment, data was handled only in the condition of good condition, but a method to always handle the eye potential under the same condition was necessary.

3.4.2. Error in Relationship between EOG and visual angle

Although the cause is still unknown, and yet the loop is fine, calculation is terminated halfway throughout the program, and it was almost impossible to obtain the integration result. It seems that there is a problem with measurement method etc.

3.5. False recognition due to blink

Examine the effect on eye potential when lightly blinked and strongly blinked. If it was weakly blinked, there was no effect on direction determination. However, when we blinked strongly, there was misrecognition in the direction discrimination. The result of false recognition obtained by turning blink 100 strongly is shown in Table 1.

From this result, it was found that in most cases it was erroneously recognized as the upward direction. This was because, as shown in Figure 18, the eye potential when viewing in the upward direction and the eye potential when blinking was similar.

Table 1 Direction of blinking versus number of blink times

Direction	Number of times
Rightward	7
Leftward	6
Upward	79
Downward	8

Since everyday unconscious blinking blinks are weak, so it is unlikely that it affects the eye potential. To reduce the false recognition more, it may be necessary to respond by measuring the myoelectric potential at the same time unknown.
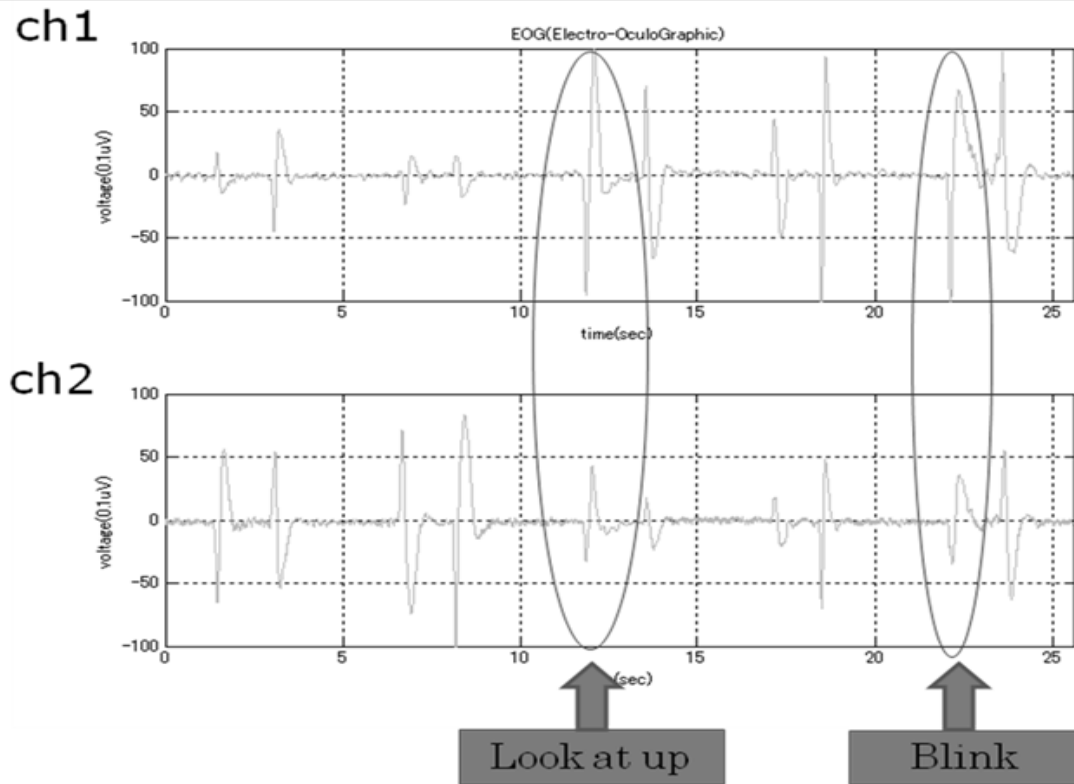
Figure 18: Misrecognition of EOG

4. CONCLUSION

In this study, attention was focused on the electro-oculogram for the biomedical signal. The electro-oculogram generated when viewing the up-down and left-right directions was correlated with the visual angle measured by using the view angle measuring apparatus, and the electro-oculogram signal was input as the position.

Basic studies on the feasibility of the man-machine interface to be used were made, and the following knowledge was obtained: First, because of experiments in the up, down, left, and right directions, the visual direction was judged to be a precise value of 94%. Also, by using the integration result, it was impossible to point the target point at once, and even if it reached the target point by going through the saccade movement more than once, it could respond. We further observed that the relationship between

the EOG and the visual angle could be associated to some extent by linearly approximating the integration result of the electro-oculogram, and the EOG can be used as the position signal. In the case of direction discrimination in real time, it was 82% in the right direction, 70% in the left direction, 83% in the upward direction and 48% in the downward direction. Lastly, regarding misrecognition due to blinking, we made a conclusion that there was a possibility that eye EOG will be generated and blindly recognized when blinking strongly. However, there was no problem because there was no misrecognition at normal blinking.

The possibility of man-machine interface development with position input of electro-oculogram signal was investigated. Based on the findings obtained in this research, we will promote the development of a man / machine interface such as a mouse pointer.

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