Extraction of Eye Movements for a Communication System by EOG Signal Using DC Amplifier

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Abstract

Electrooculographic (EOG) signal reflects the eye movement. This paper proposes the detection of eye movements by EOG signal for a communication of people with movement disabilities. The system consists of a computer, analogue-to-digital converter, digital-to-analogue converter, a direct current (DC) amplifier and a monitor. The monitor is used to display a target for acquiring the eye-gaze position. For adjusting the DC amplifier, the eye-gaze position can be acquired. The target position on the monitor is changed at constant interval, and then the user looks at the target, relation of eye-gaze position and eye potential is derived. From the above, it was verified whether the DC amplifier can be adjusted and horizontal eye movements are detected. Then, the proposed system was used to normal healthy subjects. The result, eye movements is detected, and it can be expected to be used for the development of future communication aid system.

1 Introduction

The symptom of movement disorders caused from neurodegenerative diseases such as amyotrophic lateral serious (ALS), multiple system atrophy (MSA) etc, changes according to the progression of those diseases. Available input for communication according to the progression of the disease is difference. If it is mild movement disorders, he/she can use residual muscle for communication input. Then, he/she will be unable to move his/her muscle according to the progression of the disease. After that, he/she will be able to use only eye movements or electroencephalogram (EEG). In addition, finally locked in state and he/she will be only able to use EEG. Communication tool will become necessary of for improving the quality of life. In case of progressive neurodegenerative diseases, eye movement is often usable for a long period. Hence, a communication system using EOG signal has been developed [1-3].

In our previous research, a communication system using EOG signal for people with movement disabilities has been developed [4]. EOG signal is acquired by magnified using AC amplifier. However, the system could only judge left or right direction of eye movement, and flexibility of operation of input interface was low due to be incapable of acquired accurate eye movement. Thus, it is considered to use a DC amplifier to acquire EOG signal. There are several researches describing the possibility of DC amplifier [5-6]. Using DC amplifier, eye movement can be correctly extracted, and the aim can be increasing flexibility of operation of input interface of communication system. Therefore, EOG signal was acquired using the DC amplifier, and horizontal eye movement was extracted from EOG signal.

2 Method

2.1 Subjects

Two normal healthy subjects (males, 22 - 23 years old) were involved in this study. The data of normal healthy subjects were used for developing the eye movement extraction system. Oral and written informed consent was obtained for normal healthy subjects.

2.2 System configuration

The system configuration of this research is shown in Fig.1. The system consists of a computer, the analogue-to-digital converter, the digital-to-analogue converter, the DC amplifier and a monitor.

First, the EOG signal (V_{eog}) was measured by disposable electrodes attached to a user’s face with every 5 ms (sampling frequency of 200 Hz). Electrodes were attached at left and right outer canthus, and upper and lower portions of the left eye. Finally, the EOG signal (V_{eog}) is analyzed by a computer, and eye movements
are derived. DC amplifier requires to adjust the baseline voltage in order to avoid the saturation by the offset of the circuit and the slow changes of the capacitance in human body. Compensation signal ($V_{DA}$) was calculated and was added to the DC amplifier for maintaining the baseline of the measurement signal.

Also, a monitor is used to present a target. A target has role displaying eye-gaze position and it is used to verification of eye-gaze position.

![Diagram of system eye movements structure for extracting by EOG signal using DC amplifier](image)

**Fig. 1:** System eye movements structure for extracting by EOG signal using DC amplifier

### 2.3 Baseline compensation of DC amplifier

Measurement signal ($V_0$) may not be possible to acquire, because it can’t be adjusted within conversion range of the A/D converter by the offset of the circuit and the slow changes of the capacitance in human body. By considering this bias, measurement signal ($V_0$) can be completely extracted. The circuit of DC amplifier is shown in Fig.2. $V_1$ and $V_2$ correspond to the voltages of two electrodes attached to the subject. Compensation signal $V_{DA}$ was added to the latter part of the circuit. Then, the measurement signal $V_0$ can be derived as follows

$$V_0 = 10,000/3(V_1 - V_2) + 100V_{DA} \quad (1)$$

In this study, compensation signal was calculated by combining two components. One was to reduce the large amplitude of constant bias component. The other was the drift component that gradually changed in the long-time use. The equation for generating the compensation signal $V_{DA}(t)$ was expressed as

$$V_{DA}(t) = V_f(t) + V_v(t) \quad (2)$$

Where $V_f(t)$ was for compensating the large amplitude of constant bias component, and $V_v(t)$ was that for the drift component. Here, $V_f(t)$ was obtained by equation (3) as

$$V_f(t_n) = \begin{cases} V_f(t_{n-1}) + \frac{V_v}{100} & (\text{if } V_0(t_n) > 9.5[V]) \\ V_f(t_{n-1}) - \frac{V_v}{100} & (\text{if } V_0(t_n) < -9.5[V]) \\ V_f(t_{n-1}) & (\text{otherwise}) \end{cases} \quad (3)$$

Hence, $V_v$ was the step width for compensating in one time period, and was set at 19 (=9.5+9.5) V. Adjustment of slow drift component was compensated by using a PID controller. Actually, only I element was used as

$$V_v(t) = \frac{K_p}{T_i} \int_{t_0}^{t} e(\tau) d\tau \quad (4)$$

Parameters $K_p$ and $T_i$ were determined as 5 and 0.001 respectively. $t_0$ was time that decided constant bias component, $t$ was current time and $e (=0-V_0)$ was subtraction of baseline voltage (0V) and measurement signal ($V_0$).

### 2.4 Estimation of eye-gaze position

Horizontal eye movement is extracted from acquired EOG signal using the DC amplifier. In order to estimate the eye-gaze position from the measurement EOG signal, the following data was acquired.

A monitor shown in Fig.3 was placed in front of a subject’s face with a distance of 40 cm. Three targets were expressed in a monitor with the distance $l$ (=9cm) and a subject gazed them for a while. Mean value of EOG signal during gazing each target position was obtained.

![Circuit of DC amplifier for canceling bias by operational amplifier or living body](image)

**Fig. 2:** Circuit of DC amplifier for canceling bias by operational amplifier or living body
In this study, relationship between eye-gaze position and EOG signal was assumed to be proportional. Accordingly, equation for estimating the eye-gaze position was obtained by using the above data

\[ d_g(t) = d_t \frac{V_{eog}(t) - V_b}{V_{tr} - V_b} \]  \tag{5}

Where \( d_g \) and \( d_t \) were eye-gaze position and target position, respectively. \( V_{eog} \) was EOG signal, \( V_b \) was eye potential for center target gazing and \( V_{tr} \) was eye potential for right target gazing.

3 Result and discussion

3.1 Zero point adjustment of DC amplifier

Figure 4 shows an example of EOG signal measurement for evaluating the effect of baseline compensation. Figure 4 (a), (b) and (c) represent the compensation signals of large amplitude of constant bias component \( V_f \), slow drift component \( V_v \) and their combined signal \( V_{DA} \). Figure 4 (d) and (e) were measurement signal by DC amplifier and calculated EOG signal \( V_{eog} \).

In order to verify the effectiveness of the compensation of slow drift component, experiment was done for continuous 600 seconds. The subject had kept his eyes at central position during the experiment. \( V_v \) was gradually changed thought the experiment, and \( V_{eog} \) was almost in constant. \( V_f \) was fixed within a short time, so the earlier part of Fig.4 was displayed in Fig.5. The value of \( V_f \) was adjusted constant in about 0.2 seconds. Then after, the value of \( V_0 \) became within the range of A/D converter. Slight time difference was seen between \( V_f \) and \( V_{DA} \). This was caused from the time delay of USB in the A/D converter.

![Target points displayed in monitor](image)

**Fig. 3: Target points displayed in monitor**

![Graphs showing result of each signal](image)

**Fig. 4: Result of each signal by zero point adjustment**
3.2 Relation of eye-gaze position and eye potential

Figure 6 shows an example for estimating the eye-gaze position from the EOG signal. Figure 6 (a) represents the EOG signal and (b) corresponds to the estimated eye-gaze position and target position.

During the experiment, a subject gazed a target position displayed in the monitor. A target position moved with saccadic pattern. Estimated eye-gaze position was well similar motion for the target. Result of eye-gaze position estimation by another subject was also in a satisfactory level.

4 Conclusion

Adjustment of the output signal of the DC amplifier was derived and horizontal eye movement was extracted by the DC amplifier. Then, eye movement pattern was extracted from EOG signal. Proposed method can be applied to operate a communication tool.

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