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Electrooculogram Identification from Eye Movement Based on FIR System

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***Abstract*— In this paper, we propose a method for detecting eye movements based on EOG signal. The EOG signal can be process separately through horizontal and vertical channel from the surface muscle around the eye. This method consists of 2 main processes; feature extraction and classification. Feature extraction is implemented from DCT coefficients of the EOG signals and impulse response of FIR system. The FIR system can fully characterize the inherent eye movement by considering the DCT coefficients as the input and output, respectively. The eye movement can be detected by evaluating the Euclidian distance. The minimum Euclidean distance for each eye movement uniquely occurs at a distinct Euclidean distances between reference impulse response and extracted features by FIR system. The experimental results show that the proposed method is useful for identifying eye movements.**

***Keywords*—EOG signal, FIR system.**

I. Introduction

Many papers on Electrooculogram (EOG) have been proposed and practiced for many years. The Electrooculogram is one of biosignals that can be measured and monitored in living beings. The Electrooculogram is a collective electrical signal acquired from the surface muscle around the eye during eye movement. The EOG signal can be process separately through horizontal and vertical channel. However, the use of EOG signals is challenging in both medical and engineering applications. The Eye movements can be used inputs for human computer interface (HCI) systems such as the application for analyzing eye movement patterns [2]. The EOG was applied in the real-time eye-writing recognition by Kwang-Ryeol Lee and et. al [3]. Wijesoma et al. developed an asistive mobile robot controller using saccadic eye movements and eye blinks [4]. Watcharin Tangsuksant et al., applied directional eye movement detection system for virtual keyboard controller [5].

In this paper, we propose a method for detecting six eye movements, upward and downward directions, left and right directions and clockwise and counterclockwise directions. This method consists of 2 main processes; feature extraction and classification. Feature extraction is implemented from DCT coefficients of the EOG signals and impulse response of FIR system.

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II. Experiments and Data Acquisition

The EOG signals measured from the surface muscle around the eye during eye movement. The EOG signal can be process separately through horizontal and vertical channel in Fig. 1. Electrode placement are placed on side of the eye (R-L) and above and below of right the eye (U1-D1).

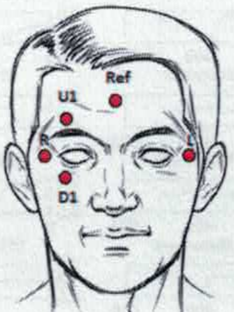

Fig. 1. Electrodes placement.

The EOG signals measured from Narco Bio-Systems Physiograph MK-III-P which is bio-amplifier and filter circuit. In humans the EOG signal bandwidth of eye movement is located in the range of 0.1 Hz to 40 Hz. The EOG signals from two channels are through analog to digital conversion by STM32F4 Discovery microcontroller. All information of EOG is contained in the raw EOG data into the computer via USB port shown as Fig. 2.

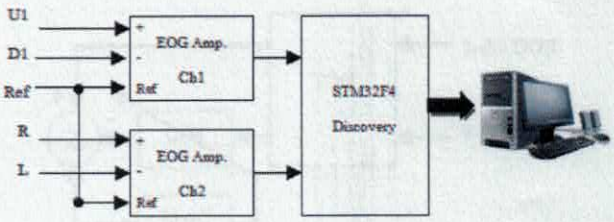

Fig. 2. Block diagram of data acquisition.

There are 6 eye movement consist; upward and downward directions, left and right directions and clockwise and counterclockwise directions as Fig. 3 for calculate feature extraction. The raw EOG signal shows in Fig 4.

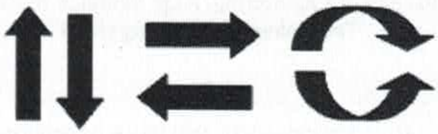

Fig. 3. Pattern of eye movement.

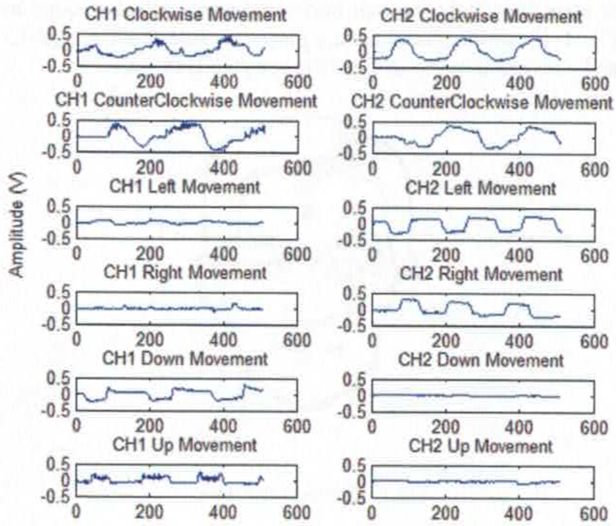

Fig. 4. Raw EOG signal.

III. METHODOLOGY

In this paper, we propose a method for detecting six eye movements, upward and downward directions, left and right directions and clockwise and counterclockwise directions.

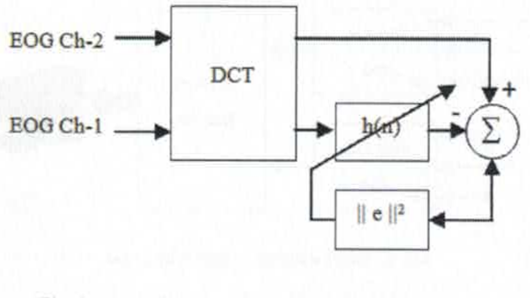

Fig. 5. Block diagram of EOG feature extraction process.

First, the discrete cosine transform (DCT) of EOG signal for eye movement is computed. Secondly, we realize FIR system characterizing eye movement by considering the DCT coefficients as the input and output, respectively. In this case it is considered that the impulse response of the FIR system can fully characterize the inherent eye movement. Thirdly, eye movement can be detected by evaluating the Euclidian distance between the reference impulse responses for the six-eye movements and an impulse response to be detected as shown in Fig.5.

A. Feature extraction

- Discrete cosine transform (DCT)

The EOG signal for each movement is expanded into the discrete cosine transform (DCT) as equation (1)

$$C^{(j)}(k) = \alpha(k)\sum_{x=0}^{N-1} f(k)\cos\left(\frac{(2x+1)k\pi}{2N}\right) \qquad (1)$$

$$\alpha(k) = \begin{cases} \sqrt{\frac{1}{N}} & if \quad k=0 \\ \sqrt{\frac{2}{N}} & otherwise \end{cases}$$

the superscript (j) means the jth channel of EOG signal. The channel 1 is placed on electrode above and below of right the eye (U1-D1) and channel 2 is placed on side of the eye (R-L).

- FIR system

We consider an FIR system having the DCT coefficients $C^{(j)}(k)$, (j=1,2) obtained above as the input and output respectively. The FIR system can be described as.

$$\hat{g}(n) = \sum_{k=0}^{M-1} h(k) f(n-k) \qquad (2)$$

where M is the order of the FIR system
h_k is the impulse response
$g(n)$ is the output of FIR system ($C^{(2)}(k)$)
$f(n)$ is the input of FIR system ($C^{(1)}(k)$)

In this case the impulse response h_k are determined such that

$$c^2 = \sum_{n=0}^{N-1} (g(n) - \hat{g}(n))^2 \rightarrow \min.$$

That is, the optimal impulse response can be obtained as

$$h = Q^{-1} b$$

$$Q(p,k) = \sum_{n=0}^{N-1} f(n-k) f(n-p); (p,k = 0,1,..., M-1)$$

$$b(p) = \sum_{n=0}^{N-1} g(n) f(n-p)$$

The impulse response vector h obtained above is used here as inherent feature of eye movement as Fig 6.

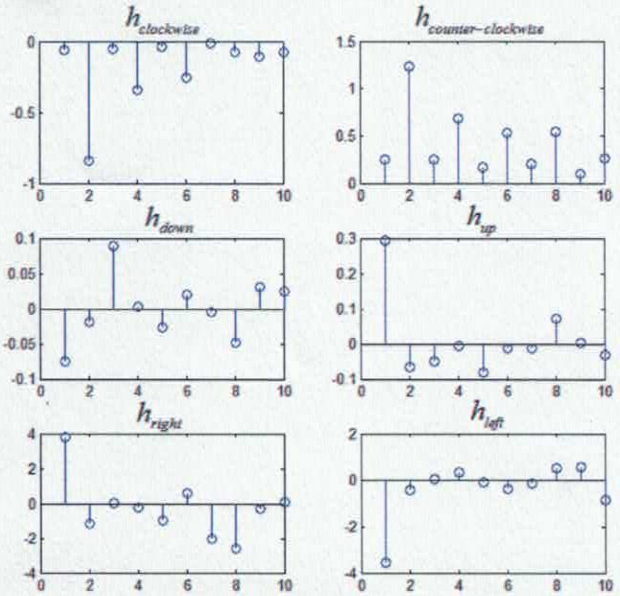

Fig. 6. Impulse response vector of six eye movements.

B. EOG classification

Euclidean distances between reference impulse response vector h_{ref} and extracted features were then calculated and stored for each eye movement, which was defined as clockwise (d1), counter-clockwise (d2), down (d3), up (d4), left (d5) and right (d6). In addition, the eye movement could be identified from the minimum distance by comparing the distance between reference impulse response and extracted feature of all eye movements. The Euclidean distances is given by equation (3)

$$d_k = \sqrt{\sum_{i=0}^{M-1} (h_{ref(i)} - h_{unknown(i)})^2} \quad (3)$$

where k is eye movement (k=1,2,...,6)

IV. Results and Discussion

In the experiment, The total six eye movements were collected which is each eye movement 10 times repeat and then calculate feature extraction by FIR system. The impulse response from FIR system is reference. So, then we will try to detect eye movement using Euclidean distant between h_{ref} and $h_{unknown}$. The minimum Euclidean distant were identified eye movement.

From Table I shows the minimum Euclidean distance for each eye movement uniquely occurs at a distinct Euclidean distances between reference impulse response and extracted features by FIR system of trial-1. The minimum distance as identification of upward and downward directions, left and right directions and clockwise and counterclockwise directions corresponds to d1, d2, d3, d4, d5 and d6. Thus, we can be used to identify the eye movement. The result of Euclidean distances between reference impulse response and extracted features by FIR system of trial-2 shown in Table II.

TABLE I. Euclidean distant between reference and trial-1

Eye Movement	Euclidean distance between reference and trial-1					
	d1	d2	d3	d4	d5	d6
Clockwise	1.1141	2.2236	1.4179	1.3309	4.6092	5.1823
Counter-Clockwise	1.6219	0.7470	0.8383	0.9526	3.9627	4.4471
Down	0.8507	0.9473	0.0737	0.1624	4.0654	4.7232
Up	0.9406	0.9024	0.2208	0.2018	4.2057	4.8531
Left	4.7326	4.9853	4.6811	4.8111	1.3440	2.5207
Right	10.0390	9.7398	9.6097	9.7012	7.6450	7.2238

TABLE II. Euclidean distant between reference and trial-2

Eye Movement	Euclidean distance between reference and trial-2					
	d1	d2	d3	d4	d5	d6
Clockwise	0.8107	2.0856	1.3532	1.3181	5.3507	6.5438
Counter-Clockwise	1.9175	0.3896	0.9035	1.0471	5.0703	6.2038
Down	1.1543	0.8345	0.1327	0.3004	5.0201	6.4745
Up	1.1913	0.8686	0.3205	0.1891	5.1777	6.5783
Left	4.9986	4.4961	4.7759	4.8733	1.3759	5.1142
Right	10.0764	9.1361	9.6769	9.8340	8.6127	8.2701

V. Conclusion

In this paper, we propose a method for detecting six eye movements, upward and downward directions, left and right directions and clockwise and counterclockwise directions. Feature extraction is implemented from DCT coefficients of the EOG signals and impulse response of FIR system. It was found from our experimental results that the proposed method is useful for the identification of eye movements which is the minimum Euclidean distance for each eye movement uniquely occurs at a distinct Euclidean distances between reference impulse response and extracted features by FIR system.

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