Proceedings of the 2005 IEEE
Engineering in Medicine and Biology 27th Annual Conference
Shanghai, China, September 1-4, 2005

Development of an EOG (Electro-Oculography) Based Human-Computer Interface

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***Abstract*—We designed an inexpensive user computer interface for helping the disabled persons to communicate with their caretakers, which is based on EOG (electro-oculography) signals rather than the very expensive reflectance based methods. EOG signals of different eye movement patterns are analyzed with the LOS guiding setting constructed ourselves. An effective eye movement pattern is found to control the computer. Testing conducted on 12 subjects show that this system is remarkably accurate, easy to operate and reliable.**

Keywords—**EOG (Electro-Oculography), eye movement, switch on/off, user-computer interface**

I. Introduction

Eye movements are arguably the most frequent of all human movements [1]. Eye movement research is of great interest in the study of neuroscience and psychiatry, as well as ergonomics, advertising and design. Since eye movements can be controlled volitionally, to some degree, and tracked by modern technology with great speed and precision, they can now be used as a powerful input device, and have many practical applications in human-computer interactions.

Many methods had been adopted to test eye movements [2, 3, 4]. Carlos H. et al. compared the characteristics of the traditional eye gazing techniques (Table. 1) [5].

There are challenging cases: the estimated 150,000 disabled persons able to control only the muscles of their eyes [6]. Our main goal is to develop an inexpensive hardware-software system for disabled people who cannot use their hands to control the computer with their eyes.

The EOG is one of the very few methods for recording eye movements that does not require a direct attachment to the eye itself. It is now accepted that the generated electrical potentials arise due to the permanent potential difference of between 10 and 30mV that exists between the cornea and the ocular fundus. This is commonly referred to as the cornea-retinal potential with the cornea being positive. An electrical field is set up in the tissues surrounding the eye and rotation of the eye causes a corresponding rotation of the field vector [7]. For this reason, it is possible to detect eye movement with the appropriate placement of electrodes on the skin surrounding the eyes.

TABLE I
Characteristics of Traditional Eye Tracking Techniques

Technique	Accuracy	Comments
Contact lens	1'	Intrusive, but fast and accurate
EOG	2°	Simple and low cost
IROG	2'	Head mounted, limbus tracking
Pupil tracking	1°	Camera based, hard to detect
Image-based	0.5-2°	Camera based, requires training

Our research has been focusing on finding efficient eye movements patterns to control the scanning picture arrays. Disabled persons can tell what they need to their caretakers clearly and in time by choosing certain pictures which indicate the daily needs of disabled persons, such as watching TV, drinking water and et al.

II. System Design

The whole EOG measurement system (Fig. 1) is consist of the parts as follows: a circuit constructed by ourselves, the A/D converter, the line of sight (LOS) guiding setting (Fig. 2) and the software model.

Design of Hardware

In order to implement an EOG measurement system, a circuit was developed comprising of three major sections. These sections were the three op-amp preamplifier, a 20Hz lowpass filter and the A/D converter and the second stage amplifier with adjustable gain. To gain high common mode rejection ratio (CMMR), a simple three op-amp configuration was implemented to satisfy these important requirements. The differential inputs of the three op-amp amplifier were connected to the left and right lateral electrodes. The ground was connected to the reference electrode that was placed on the bridge of the nose.

Then the differential outputs of the circuit input to the A/D converter. Here we use the NI data acquisition card.

Design of Software

Here, we use the labview as the software development tool. The principal software modules in the system and their functions are:

- Signal smoothing and filtering to eliminate noise.
- Control the the LOS guiding set. This includes controlling the motor rotation velocity, acceleration and direction of the motor that guide the line of eye.

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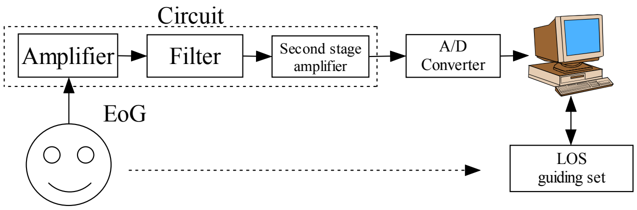

Fig. 1 Diagram of the EOG measurement system

- Extraction certain pattern of eye movements.
- Graphical user interface. This includes the control algorithms to of testing procedure (the flow chart is as Fig. 3).

III. Experiment and Results

Subjects

Twelve healthy students (8 males and 4 females), ranging in age from 23 to 27 (mean age: 24.4, S.D.:1.38 years) were asked to test the system.

Procedures

Three standard ECG electrodes were attached to the subjects. Two electrodes placed to each of the orbits of the eye and a reference electrode to the bridge of the nose.

The test subjects were requested to sit in front of the LOS guiding set, keeping the middle point of two eyes is just above the center of the motor. They were instructed to look at the lighted ball at the top of the bar as the motor moves without head movement. The position of the motor and the related EOG signals were recorded at different rotate velocities and accelerations of the motor. In this experiment, different eye movement patterns were analyzed and compared. Fig.4 shows the EOG signals and its related horizontal angle of gaze. The relationship between the horizontal angle of gaze and the EOG output arcs and the potential amplitude of EOG signal was concluded (Fig. 5).

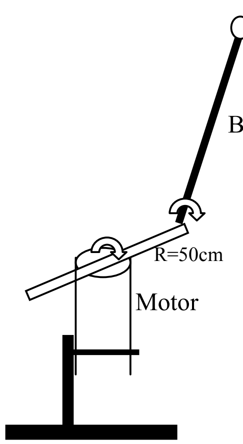

Fig.2 LOS guiding setting

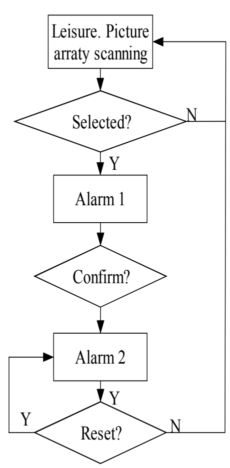

Fig. 3 The flow chart of testing procedure

Testings

According to the data of the 12 subjects, normal eye movement horizontal angle is hardly larger than 45°. Here, the left-center-right eye movement pattern with horizontal angle of gaze larger than 45° is used as a mode to choose certain picture.

Subjects are requested to sit in front of the screen with three electrodes correctly attached. They were asked to finish two groups of testing. One without eye movement and the other they can read or browse websites on the neighboring computer. In each testing, they were asked to choose the picture one by one and the results are recorded. Before the formal testing started, the potential amplitude of 45° horizontal angle of gaze is detected under the guide of the LOS guiding setting. This value is considered as one of the chief parameters to determine the eye movement pattern. Before the formal testing started, they should practice for 10 min.

Results

When a test subject is gazing straight ahead, the corneal-retinal dipole is symmetric between the two electrodes, and measured EOG output is zero. There's a fairly linear relationship between the horizontal angle of gaze and the EOG output. This relationship remains true up to approximately 30 degrees of the arc, which is accordant with the Reference [8]. The amplitude of horizontal EOG signals is dependent on eye movement angle and independent on velocity.

The testing results are show in Table 2 and Table 3. We can find that the error rate is less than 1%.

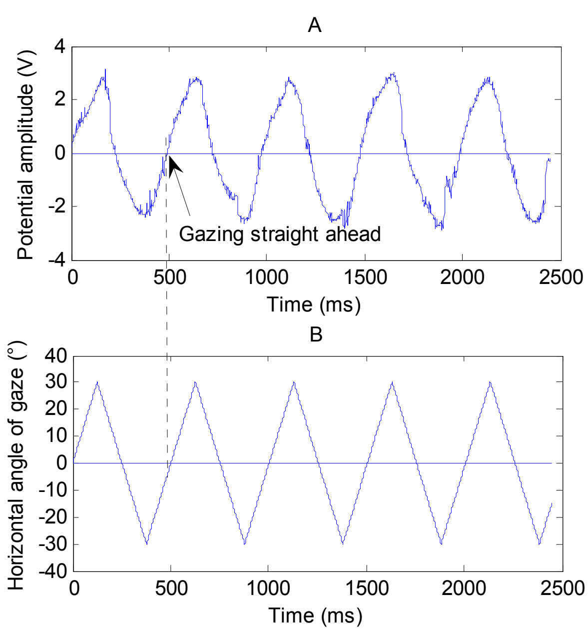

Fig.4 EOG signals of the Left-Right eye movement

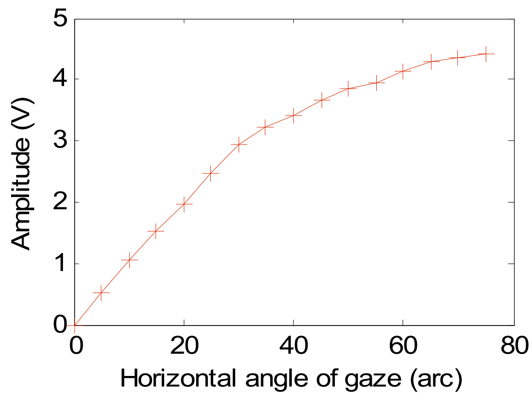

Fig.5 The relationship between the horizontal angle of gaze and the potential amplitude of EOG signal.

TABLE 2 Testing Results Without Head Movement

Choose?	Conform?	Numbers	Percentage
√	√	350	97.2%
√	--	3	0.8%
×	√	0	0
×	--	2	0.6%
--	--	4	1.1%
Total trise		360	100%

TABLE 3 Testing Results

Choose?	Conform?	Numbers	Percentage
√	√	337	93.6%
√	--	2	0.6%
×	√	1	0.3%
×	--	17	4.7%
--	--	3	0.8%
Total tries		360	100%

Here, symbol '√' refers to correct operation
'×' refers to wrong operation
'--' refers to failing to operate

IV. Discussion and Conclusion

In the application of this technology, eye movement replaced the hand operated mouse, allowing users to select icons and menus in a graphical user interface. It takes very little training for naïve users to employ certain eye movement pattern as a means to control the computer interface. According to the testing results, this system works well in the healthy students group without strong head movement. Even the picture is wrongly selected, the user can look straight forwards and not to conform.

There are many ways used to measure the eye movement, some are more accurate than EOG, but most of them are far more expensive and bring much inconvenience and uncomfortable feeling to users. The EOG method is noninvasive, low-cost and easy to use. In this user computer interface, we used an efficient eye movement pattern to select pictures, in some degree, avoided the shortage of low accuracy. Our final goal is to make portable and wireless disabled person assistant system which can help the disabled persons who are able to control only the muscles of their eyes to communicate well with their care takers.

The LOS guider setting designed for finding efficient eye movement pattern can also be used to estimate the ability of eye tracking.

Physiological signals based user computer interface is a challenging and new born field. Compared to EEG, the EOG

Signals are easier to capture, and the mechanism and modes of EOG is much clearer than EEG. Less training is needed compared to brain computer interface [9, 10]. Since eye movements can be controlled volitionally, to some degree, and tracked by modern technology with great speed and precision, they can now be used as a powerful input device, and have many practical applications in human-computer interactions.

Acknowledgement

This work was finished in Jockey Club Rehabilitation Engineering Centre, Hong Kong Polytechnic University. Thanks to Xiaolin Hu, Rong Song, Le Li and Yu Zhang for their help to this work.

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