AN EOG BASED HUMAN COMPUTER INTERFACE SYSTEM FOR ONLINE CONTROL

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Abstract

Human to machine interfaces have received more and more attention of researchers in recent years. Electrooculography (EOG) is a new technology to sense eye signals and can be used as an efficient bio-based human computer interface (HCI). The paper is concerned with the design and implementation of an eye movement detection system for biomedical research. The described system includes several electronic units for acquisition, conditioning, amplification and noise filtering of measured voltage signals. Analog to digital conversion of such biopotentials is achieved with an Arduino BT board. With its built-in Bluetooth module, it allows for wireless communication to personal computers for further signal processing and analysis. Experimental results based on real-life EOG signals show that the developed system is efficient in terms of accuracy and applicability. The proposed solution is a low-cost general purpose EOG-based HCI system that can be used by patients with disabilities for communication.

1. INTRODUCTION

Traditional methods of control or communication between humans and machines, e.g. mouse and keyboard, require a certain control motor on the part of the users. However, many people with severe disabilities only retain their control capacity over the oculomotor system. Therefore, the focus on the development of new human computer interface (HCI) and communication systems based on the detection of eye position has increased in the last years.

Electrooculography (EOG) is a new technology of recording both horizontal and vertical eye movements, by measuring, in real time, very small electrical potentials that exist across the cornea and the retina. Such signals are easily detected by placing electrodes on user's forehead around the eyes. Also, the relationship between EOG waveforms and eye movements is almost linear.

EOG based HCI is becoming the hotspot of bio-based HCI research in recent years, since it provides users with a degree of independence in the environment. This method was used as the guidance strategy in assistive devices for controlling wheelchairs for disabled people [1]. It also represents an efficient computer interface to improve communication abilities of those patients [2, 3, 6]. EOG has also been used as a measurement device used in psychophysiological tests as research equipment for recording facial expressions during human emotion studies [4]. Furthermore, applications can be extended to normal persons as well, in robotics and entertainment.

As a contribution in this area of biomedical research, we present a general purpose EOG based HCI system for online control. The proposed approach includes several electronic modules for acquiring and filtering EOG waveforms, generated from different eye movements such as looking up/down, right/left and eye blinking. The system also provides wireless data transmission to a personal computer (PC) for further signal processing and analysis.

The paper is organized as follows: Section 2 introduces the fundamental principles of detecting and acquiring EOG signals. Section 3 describes the design of the proposed HCI system in detail. Experimental results of several eye movements and blinking are illustrated in Section 4 and the conclusion is given in Section 5.

2. EOG DETECTION PRINCIPLES

EOG is a method for sensing eye movement and is based on recording the standing corneal-retinal potential arising from hyperpolarizations and depolarizations existing between the cornea and the retina [1]. Such biopotential, commonly known as an electrooculogram, is captured by five surface electrodes placed around the eyes, as shown in Figure 1.

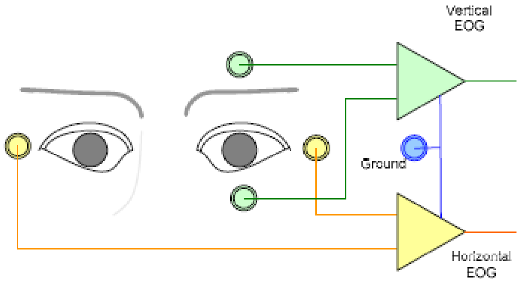

Fig. 1. Electrodes placement [2, 5]

Independent measurements can be obtained: two electrodes are placed on the temples to detect horizontal movements, while another pair above and below the eye is used to detect vertical motion and eye blinking. A reference electrode (ground) is placed on the forehead or at the mastoid [6].

The corneal-retinal potential is roughly aligned with the optic axis and hence rotates with the direction of gaze. When the gaze is shifted, positive or negative pulses will be generated when the eyes are rolling, e.g. upward or downward. The amplitude of EOG pulses will be increased with the increment of rolling angle, and their width is proportional to the duration of the eyeball rolling process.

EOG values vary from tens to hundreds of μV, with a frequency range of about DC-100 Hz. The EOG signal changes approximately 20 μV for each degree of eye movement and is practically linear for gaze angles up to 30º [1]. Therefore, with proper calibration, EOG can be used to accurately specify the angular position of the eyeball in both vertical and horizontal channels.

3. HCI SYSTEM DESIGN

The block diagram of the proposed HCI system is shown in Figure 2. The system is microcontroller (μC) based, battery powered, and is composed of four main parts or units: signal pre-amplification, signal filtering, analog to digital conversion (ADC) and data transmission to PC.

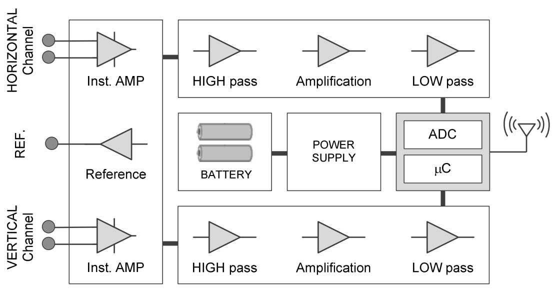

Fig. 2. EOG based HCI system block diagram

Five Ag/AgCl electrodes (two for each channel and one for ground) are used to acquire EOG signals. The pre-amplification circuit is intended to amplify the signals to appropriate amplitude. The EOG signal filtering unit includes a band-pass analog filter (a combination of high-pass and low-pass filter) to remove the baseline and higher frequency interference. The total gain of the system is achieved by implementing signal amplification into two stages, each having a fixed gain. Analog to digital conversion is then performed, and horizontal and vertical EOG signals are finally transmitted to the PC serial port over Bluetooth wireless technology. Free open source is used to program the microcontroller and display EOG waveforms in real-time.

3.1. Power Supply

The whole circuit is operated from a single +5 V power supply, by using a 7805 voltage regulator. The chip ICL7660 was used to perform supply voltage conversion, resulting in complementary output voltage –5 V. The circuit has been powered with a simple +9 V battery.

3.2. Pre-amplification

According to the characteristics of EOG signals, the differential amplifier chip INA126P was selected for the acquisition and pre-amplification step, as it can handle EOG signals in μV range. The INA126P is a precision instrumentation amplifier for accurate, low noise differential signal acquisition. The gain of the INA126P is set by simply adjusting the value of a single external resistor R_G:

$$G_1 = 5 + (80\ \text{k}\Omega / R_G) \qquad (1)$$

A protection system in the form of an RC low-pass filter was also implemented at the INA126P's inputs, in order to remove electro-static discharge and radio frequency interference [2].

3.3. Reference Electrode

To improve the INA126P's common mode rejection ratio (~94 dB), a driven-right leg circuit was implemented. Here, a low-noise high-precision OPA2227 dual amplifier was used. This circuit reads what it believes to be noise and transfers a minute signal back to the body through reference electrode to negate its effect. This technique is normally used in medical operations when reading a very small electrical potential from the body.

3.4. Signal Filtering

A critical issue in accurately acquiring and amplifying the EOG potential, is overcoming a substantial DC offset generated by the potential difference between the reference electrode and each of the active electrodes. For reducing DC offset and some other shifting resting potentials, an active high-pass filter is employed with cutoff frequency at 0.20 Hz. Once DC component is removed, an OPA227 amplifier circuit is designed to complement the entire magnification required. The formula for gain depends on two resistors R_A and R_B:

$$G_2 = 1 + (R_B / R_A) \qquad (2)$$

The power line noise and high frequency components of EOG signals are then greatly reduced with low-pass filtering. A cutoff at 32 Hz was selected due to bandwidth of EOG signals. A single OPA4227 was used to implement both 4^{th} order Bessel filters.

3.5. Data Acquisition

After all amplifications and filtrations, EOG signals are digitized and transferred to PC. Analog to digital conversion with 10 bits of resolution is done using a microcontroller board *Arduino* BT [7]. Since it supports wireless serial communication over Bluetooth, software was written in *Processing* [8] to read incoming data from the PC serial port and display the measured signals on the screen saved real-time.

4. EXPERIMENTAL RESULTS

In building the whole circuit, number of components was tried and final component selection was based on optimal performance. Therefore, the two-stage signal amplification was implemented by using R_G = 806 Ω, R_A = 994 Ω and R_B = 55.8 kΩ. From equations 1 and 2, G_1 = 104 and G_2 = 57. Thus, for each EOG channel, the total gain of the system was set to $G = G_1 * G_2 = 5928$. Some examples of EOG waveforms acquired from horizontal and vertical eye movements and eye blinking are shown in Figure 3.

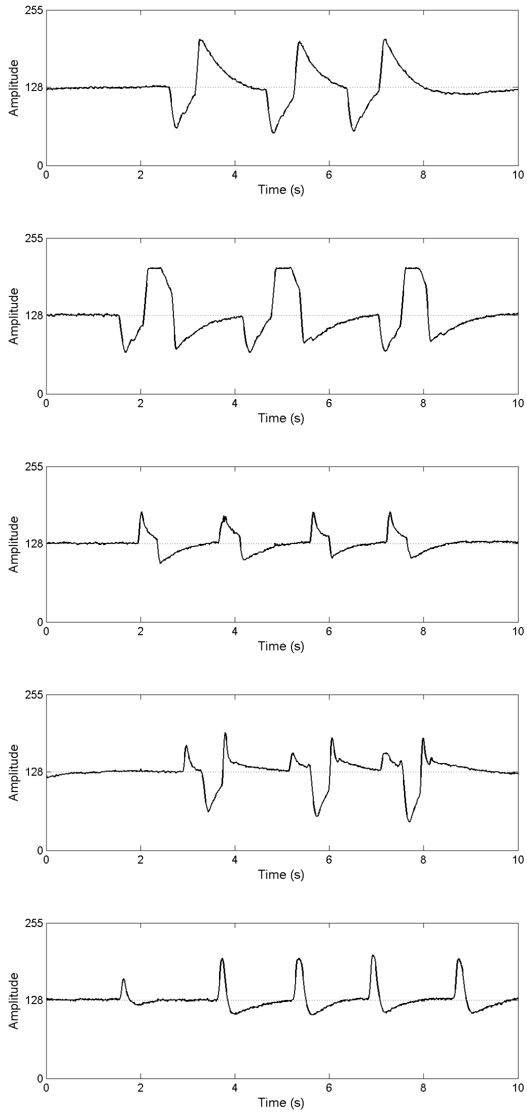

Fig. 3. EOG waveforms. From top to bottom: Center–RIGHT, Center–RIGHT–LEFT, Center–UP, Center–UP–DOWN and eye blinking

All signals were sampled at 100 Hz (10 ms per sample), which rightly follows the Nyquist rate. Experiments with higher sampling frequency (500 Hz and 1 kHz) were also performed. In all cases, similar results were obtained.

5. CONCLUSION

A general purpose EOG based HCI system for eye movement detection was presented. With a simple design, the system is μC-based, battery powered and supports wireless data transmission to PC. The results show that the proposed system has stable performance and can be used as an effective low-cost solution for online control applications.

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