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Design of virtual keyboard using blink control method for the severely disabled

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ABSTRACT

In this paper, a human–machine interface with the concept of "blink control" is proposed. The human–machine interface is applied to an assistive device, namely "blink scanning keyboard", which is designed specifically for the severely physical disabled and people suffering from motor neuron diseases or severe cerebral palsy. The pseudo electromyography (EMG) signal of blinking eyes could be acquired by wearing a Bluetooth headset with one sensor on the forehead and the other three on the left ear of the user. Through a conscious blink, a clear and immediate variation will be formed in the pseudo EMG signal from the users' forehead. The occurrence of this variation in pseudo EMG signal could be detected and filtered by the algorithms proposed in this paper, acting like a trigger to activate the functions integrated in the scanning keyboard. The severely physical and visual disabled then can operate the proposed design by simply blinking their eyes, thus communicating with outside world.

1. Introduction

The functionality and practicability of technological products have been perfected; however, for the users with disabled limbs, even paralyzed, these products are very difficult to use, or are even unusable. Therefore, methods using image processing or physiological signals for detecting human eye movement and blinks have been proposed [1–3], and these methods have been applied to the research and development of various computer interfaces for the physical and mental disabled. The former is referred to as the eye movement based control method and is also called "eye-tracking system" or "eye mouse" [4–10]. The other method is based on eye blink detection [11–14], using eye blinks and a special interface to communicate with others and control software.

Lin et al. proposed an eye-tracking system with one video CCD camera and a frame grabber to analyze a series of images taken of the human pupil when gazing at a screen. In the proposed design the computer will produce speech according to the location of where the eyes are gazing [15]. Usakli and Gurkan designed an electrooculography (EOG) based system using a virtual interface to notify in writing the needs of the disabled. Considering the bio-potential measurement pitfalls, the EOG-based system allows users to achieve environment control with only the eye movements [16]. Lewandowski and Augustyniak implemented a system controlled by moving eyeballs to allow users with upper limb dysfunction to use computer. The eyeball movements are detected by the proposed system, which sent transmitting diodes according to the measurements of reflected infrared radiation collected by detectors placed in the goggles worn by the users [17].

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Bala et al. presented an algorithm to analyze the features of the face and eyes in video image sequences. They used skin color information to improve the system speed [18]. Kirbiš and Kramberger proposed a mobile device for disable people, which can perform different operations through left eye gaze and right eye gaze separately by analyzing the EOG potentials [19].

Although the various kinds of assistive tools have been developed for several years with many of these products tested by the disabled, some of them are still not very popular. For example, the eye-tracking system needs to be adjusted before using, the process of adjusting is too difficult to operate for both healthy people and the disabled, and the cost is still very high. Hence, a virtual scanning keyboard based on the blink control method is proposed in this paper with improving the above disadvantages, and is designed specifically for the severely physical disabled and people suffering from motor neuron diseases or severe cerebral palsy.

Since the blink control cannot be considered only as a unilateral control, more functions can be assigned to conscious left eye blink, right eye blink and simultaneous left/right eye blink [19], and it would make the scanning keyboard more practical and friendly. While considering the main user of proposed keyboard is the people suffering from motor neuron diseases or severe cerebral palsy, they cannot only blink the right eye or left eye nimbly. Hence, the scanning keyboard is designed to be controlled by blinking left eye and right eye simultaneously. The pseudo electromyography (EMG) signal generated from a user's blink is acquired by a Bluetooth headset and transmitted to a PC through wireless transmission, and the noise is eliminated by a self-derived algorithm. The transient variation of a pseudo EMG signal of a "conscious blink" is observed and used for controlling the scanning keyboard. Moreover, the intelligent character selection function is added in the scanning keyboard for promoting the typing speed. Fig. 1 illustrates the system framework of the proposed human–machine interface using blink control method.

The severely disabled can select phonetic symbols on the scanning keyboard through blinking their eyes simultaneously, and repeat this step to type Chinese characters on the screen for communications with others. In such a communication mode, the user's needs can be known, and misunderstandings resulted from difficult communication with nursing personnel can be reduced effectively.

2. Methods of scanning keyboard using eye blink control

2.1. *The algorithm of pseudo EMG signal filtering and eye blink control*

The forehead sensor, or called reference sensor, is used to create a reference potential to reduce the influences of outer electrical fields and disturbances that are created by facial activities. The reference sensor serves as a reference feedback in the automatic gain loop of Bluetooth headset. The difference between the left earlap against to the forehead reference is measured by the headset, and the signal gain becomes stable when no muscular activity is detected. While blinking eyes, this stable condition will be broken due to the disturbances from the forehead muscle, and the output signal will vary with the strength of blinking. Hence, the output signal is defined as a pseudo EMG signal of the forehead in this paper for blink control.

When the forehead pseudo EMG signal is successfully read, the amplitude of pseudo EMG signal would hold as a constant value without blinking as shown in Fig. 2(a). While it would change significantly during a "conscious blink", as it is enlarged or greatly reduced, compared with a relaxed state (including unconscious blinks) as shown in Fig. 2(b). It is observed that the pseudo EMG signal amplitude increases as the strength of blink increases. Therefore, a threshold T could be obtained, and the functions of scanning keyboard are triggered according to the relation of pseudo EMG signal amplitude and threshold T. More specifically, the blink control could be realized by conscious blink.

The threshold T could be determined through the automatic mode. In the automatic mode, the users would be asked to blink purposely within a period of time, and the corresponding data will be recorded, and the threshold T could be obtained by applying Nearest Mean Reclassification Method as follows:

Step 1: Sorting the acquired pseudo EMG signal with the absolute value of amplitude, and forms an increasing sequence from small value to large value. The difference of two neighboring amplitude is denoted as d_1, $d_2, \ldots, d_{n-1}$, where n is the data number of acquired pseudo EMG signal.

Step 2: Let M denote the average value of the above differences as an initial guess, and could be illustrated as below:

$$M = \frac{\sum_{i=1}^{n-1} d_i}{n-1} \tag{1}$$

These differences could be separated into two groups according to M, that is, the differences which are equal or greater than M forms one group, and the corresponding average value of this group is M_1. The differences that are smaller than M forms the other group, and the corresponding average value of this group is M_2.

Step 3: The new clustering threshold M' could be illustrated as below:

$$M' = \frac{M_1 + M_2}{2} \tag{2}$$

If M is equal to M', then the process is ended, and the threshold $T = M'$. Otherwise, let $M = M'$ and repeat steps 2 and 3 until M' is converged to M.

The threshold T of conscious blink could be determined precisely and automatically through above algorithm. In other words, the conscious and unconscious blink could be recognized by the relation:

$$\begin{cases} \text{conscious blink} & \text{if } |F_t| \geq T \\ \text{uncinscious blink} & \text{else } |F_t| < T \end{cases} \tag{3}$$