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Design of novel non-contact multimedia controller for disability by using visual stimulus

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ABSTRACT

The design of a novel non-contact multimedia controller is proposed in this study. Nowadays, multimedia controllers are generally used by patients and nursing assistants in the hospital. Conventional multimedia controllers usually involve in manual operation or other physical movements. However, it is more difficult for the disabled patients to operate the conventional multimedia controller by themselves; they might totally depend on others. Different from other multimedia controllers, the proposed system provides a novel concept of controlling multimedia via visual stimuli, without manual operation. The disabled patients can easily operate the proposed multimedia system by focusing on the control icons of a visual stimulus device, where a commercial tablet is used as the visual stimulus device. Moreover, a wearable and wireless electroencephalogram (EEG) acquisition device is also designed and implemented to easily monitor the user's EEG signals in daily life. Finally, the proposed system has been validated. The experimental result shows that the proposed system can effectively measure and extract the EEG feature related to visual stimuli, and its information transfer rate is also good. Therefore, the proposed non-contact multimedia controller exactly provides a good prototype of novel multimedia controlling scheme.

1. Introduction

With the dramatic development of emerging electronics and digital media publishers, multimedia has exerted a great influence on our daily life. The revolution of multimedia also brings people new approaches to communication, commerce, education, and entertainment [1]. With the development of new multimedia presentation, novel and refreshing multimedia controllers and interaction forms have entailed huge shifts to human life.

A conventional multimedia control mechanism usually involves in manual operation, such as artificial control panels manipulated directly by hands. However, it is inconvenient for the disabled patients to operate the conventional multimedia systems by themselves. Recently, with the noteworthy improvement in studies and techniques related to multimedia control, many more natural and convenient user interfaces,

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such as voice control, hand gesture recognition and eye tracking, have been proposed. In 1998, Bolcioni et al. proposed a novel voice-controlled video decoding system by using an on-chip isolated word speech recognizer [2] for implementing command-oriented and menu-based applications. However, the voice-recognition based media controllers were easily affected by noise interference, and required sample training and back-end database. Gupta et al. proposed a gesture-based interaction and communication scheme using automated classification of hand gesture contours in 2001 [3]. By using nonlinear alignment, they achieved relatively high accuracy in hand gesture classification samples. However, the common drawback of these vision-based hand gesture recognition schemes was that they were easily affected by environmental conditions, such as illumination conditions and misidentified normal hand movements. Recently, eye tracking technique was also applied to the design of multimedia controllers. In 2012, Corcoran et al. proposed a real-time eye-gaze tracking scheme for the applications to game design and consumer electronics systems [4]. Instead of using wearable sensors or enhanced infrared (IR) illumination, they only used video feed from a low-resolution user-facing camera. These eye tracking-based multimedia control systems required eye-gaze or eyeball movements to perform active control commands. However, these eye tracking-based control systems were difficult to discriminate when the user wanted or did not want to perform a control command. Unintentional eyes movements and illumination conditions might cause wrong judgment on the active control commands.

Brain–computer interface (BCI) is a distinctive human–computer interface (HCI), which allows the subject performing control commands with active or passive mental commands without muscles and any physical movements [5]. By using this property of BCI techniques, a neoteric non-contact multimedia controller is proposed in this study. By focusing on the control icons of the visual stimulus device, the user can easily operate this multimedia controller without manual operation. In this study, a commercial tablet is successfully used as the visual stimulus device for the first time. This also effectively improves the convenience and practicability of other system integration applications. Moreover, a wearable and wireless electroencephalogram (EEG) acquisition device is also designed to monitor real-time EEG signals in daily life. Different from other BCI systems which require bulky EEG machines and additional processing units, the advantages of light weight, small volume, and easy setup of the proposed wearable and wireless EEG acquisition device also improves the practicability of applications in daily life.

2. Methods

Steady state visually evoked potentials (SSVEP) are natural physiological feedback signals generated by individual brain as the responses to visual stimuli of specific frequencies [6]. When receiving a visual stimulus, the brain will transform the signals from the excited retina into EEG signal with exactly the same frequency. Recently, SSVEP is frequently used as one of the mental control methods for BCI systems. In this study, the phenomenon of SSVEP is also used as the mental control method of the proposed system.

The procedures of EEG processing and translation in the proposed system are shown in Fig. 1(a) and (b), respectively. The duration between two cues can be viewed as one of translation cycles, which is less than 5 s in this study. In Fig. 1(a), first, the received EEG signal is preprocessed to remove higher frequency interference. Because high-frequent flash may induce epilepsy, the frequency band of visual stimuli is set from 9 Hz to 11.5 Hz in this study. Therefore, a 512-point fast Fourier transform (FFT) with a 384-point overlap is used for obtaining EEG spectra, and the frequency corresponding to the maximum peak in the EEG spectra between 8 Hz and 12 Hz is detected. Let $EEG_{Max}(1, k)$, $EEG_{Max}(2, k)$, and $EEG_{Max}(3, k)$ denote the frequencies corresponding to the maximum peaks in the three consecutive EEG spectra at the kth translation cycle, as shown in Fig. 1 (b). When the three consecutive frequencies are the same $[EEG_{Max}(1, k) = EEG_{Max}(2, k) = EEG_{Max}(1, k)]$, this frequency can be viewed as the specific frequency of the visual stimulus focused. Finally, from the estimated specific frequency, the translation procedure can produce a control command corresponding to the flashing control icon focused.

However, most of BCI systems are usually synchronous which need synchronization cues to hint the beginning of each mental task. Therefore, these BCI systems are difficult to discriminate when the user wants or does not want to perform a control command. This issue also seriously reduces the practicability of these BCI systems. In this study, a specific coding scheme, as shown in Fig. 2, is proposed to provide an operational mode similar to self-paced BCI systems. There are two modes in the specific coding scheme. In mode 1, whenever the user wants to perform a control command, he/she has to first focus on the unlock icon to unlock the system for executing the following control sequence. After finishing the control sequence, he/she can either focus on the lock icon to lock up the system manually or simply do nothing to wait for locking up the system automatically. In mode 2, when the multimedia begins to be played, the system is also locked up automatically. By using the proposed specific coding scheme, the user can effectively avoid mal-operation or other inadvertently behaviors that may cause the system response.

3. System design and implementation

The basic scheme of the proposed non-contact multimedia controller is shown in Fig. 3(a). It mainly consists of a visual stimulus device, a wearable and wireless EEG acquisition device, and a host system. First, the visual stimulus device generates six flashing control icons with different flashing frequencies (9–11.5 Hz) as the sources of visual stimuli. The user can perform control commands by focusing on the wanted flashing control icon on the visual stimulus device. When the user's eyes receive the specific visual stimulus, the user brain would generate the specific EEG rhythm. Next, the wearable and wireless EEG acquisition device is used for measuring and transmitting these specific EEG rhythms to the host system wirelessly via Bluetooth. Finally, the multimedia controlling program built in the host system receives EEG signals continuously and translates them into control commands to