Available online at www.sciencedirect.com

ScienceDirect

Procedia Computer Science 107 (2017) 389 – 394

Procedia Computer Science

International Congress of Information and Communication Technology (ICICT 2017)

The distribution of classification accuracy over the whole head for a steady state visual evoked potential based brain-computer interface

Gaopeng Sun, Yuankui Yang, Yue Leng, Haixian Wang, Sheng Ge *

Key Laboratory of Child Development and Learning Science of Ministry of Education,
Research Center for Learning Science, Southeast University, 2 Sipailou, Nanjing 210096, China.
**Corresponding authors: shengge@seu.edu.cn*

Abstract

Brain–computer interfaces (BCIs) system designed using the steady-state visual evoked potential (SSVEP) signal have been widely studied because of their high accuracy of classification and high rates of the information transfer. However, the SSVEP is typically measured over the occipital scalp region (channels O1, O2, and Oz), which makes this type of BCI unsuitable for some patients. We investigated the classification accuracy of SSVEP over the whole scalp, to evaluate the feasibility of building SSVEP-based BCIs that use additional channels. The classification accuracy distribution of the whole scalp increased with the electrode positions closer to the occipital region, and the classification accuracy increased with an increasing number of electroencephalogram data channels.

Keywords: Steady-state visual evoked potential(SSVEP); Brain–computer interface(BCIs); Electroencephalogram; Classification accuracy

1. Introduction

The designment of the brain–computer interface (BCI) systems have included a lot of electroencephalogram (EEG) signals, like the event-related desynchronization/ synchronization(ERD/ERS), P300, slow cortical potential (SCP), and the steady-state visual evoked potential (SSVEP). Among the different kinds of the BCI systems, the BCIs system based on the SSVEP signal provide the highest accuracy of the classification and rates of the information transfer. The SSVEP [1] is visual stimulus generated response that typically occurs in the occipital scalp region, and the canonical correlation analysis (CCA) method could be used to detect the kind of the signal effectively [2].

Although the advantages of the SSVEP, such as easy detection, high rate of the information transfer, and use-friendly to users, have been reported widely [3], the high-quality SSVEP signal can generally be acquired over the occipital areas of the scalp. This limits the use of the BCIs based on the SSVEP signal for certain subjects, such as stroke patients who may be bedridden. Thus, it is important to develop SSVEP-based BCIs that are suitable for use

Peer-review under responsibility of the scientific committee of the 7th International Congress of Information and Communication Technology
doi:10.1016/j.procs.2017.03.123

in these types of patients.

A number of SSVEP studies have been performed using other areas of the head and brain. For example, Wang et al. studied the signal-to-noise ratio of the SSVEP over regions with less hair (including the face, the region behind the ear, forehead, and neck), and showed that the signal-to-noise ratio of SSVEP signals was highest in the occipital region, followed by behind the ear, the neck, and the face [4]. Thus, SSVEP signals recorded from low hair-bearing areas can be used for discrimination of brain responses. Hao-Teng Hsu et al. also examined the characteristics of the amplitude and frequency of the frontal SSVEPs signal for design of a BCI system. In their study, they found that the accuracy of the two-class classification was over 80% in elderly, young, and ALS subjects [5].

In the present study, because of the limitations of current SSVEP-based BCIs and suggestive published data, we assessed the classification accuracy of SSVEPs using channels selected from over the entire scalp, to evaluate the feasibility of building an SSVEP-based BCI that uses additional channels.

2. Materials and methods

2.1. Data collection

EEG signals were recorded at 1000 samples/s using a SynAmps2 system (NeuroScan Inc., USA). The electrodes were placed in an electrode cap, and were located according to the international 10–20 placement standard. The ground was set as the electrode between FPz and Fz. All electrodes over the scalp, with the linked mastoid electrode as the reference, were recorded. Electrooculography was recorded to eliminate movement artefacts in the recorded data. Electrode impedances were kept below 10 kΩ during EEG data collection.

2.2. Visual stimulus

The study group included three healthy right-handed volunteers (one man, two women, average age of 23 years) whose vision was normal or corrected-to-normal. The subjects sat on a chair located about 70 cm in front of an LCD display.

A 3 × 3 stimulation matrix consisting of nine visual stimuli was shown on the display (screen refresh rate, 60 Hz), with the numbers 1–9 located in the center of each square (Figure 1). The visual angle of each visual stimuli was approximately 1.15°.

In order to make the visual stimulus flicked at different frequencies, we used the sampled sinusoidal method [6]. The sequence of the stimulus which was expressed as the $s(f,\phi,i)$ was created by modulating the luminance of the screen using the sampled sinusoidal method (see Eq. (1)).

$$s(f,\phi,i) = \frac{1}{2}\{1+\sin[2\pi f(i/R)+\phi]\}\,, \tag{1}$$

in the equation above, the f represented the frequency and the ϕ represented the phase of each stimuli, R which was 60Hz in our experiment, means the rate of the refresh of the screen, and i represents the sequence number of the frame.

The frequency and the phase of the visual stimuli (from 1 to 9) were set at 11.4 Hz (0.1π), 8 Hz (1.5π), 13.6 Hz (0.5π), 9.2 Hz (1.7π), 12.6 Hz (0.3π), 15.8 Hz (0.9π), 14.6 Hz (0.7π), 16.8 Hz (1.1π), and 10.2 Hz (1.9π),guaranteeing that the visual stimuli would generate different electrophysiological responses.