SSVEP Brain-computer Interface using Green and Blue Lights

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Abstract **A novel approach to steady-state visual evoked potentials (SSVEP) based brain-computer interface (BCI) is reported in this abstract. To minimize possible side effects of the monochromatic light SSVEP we propose to utilize color information in form of the green and blue interlaced flicker. The feasibility of the proposed method is evaluated in a comparison of the classical monochromatic versus the proposed colorful SSVEP responses.**

Keywords **Brain-computer interface; SSVEP.**

I. INTRODUCTION

The brain-computer interface (BCI) is a technology that utilizes human neurophysiological signals for a direct communication of a brain with external devices without any muscle activities [1]. Particularly, in the case of users suffering from locked-in-syndrome (LIS) [2], such technology could allow them to communicate. In this abstract, we propose a novel BCI paradigm using the colorful SSVEP. We compare our proposal with the classical monochromatic method [1].

SSVEP is a natural response for visual stimulations with specific frequencies. This response's feature can be used for detecting at which stimulator the user gazes. While SSVEPs have been known for many years already [1] the SSVEP-BCIs have been not popular due to several limitations.

The major reason why SSVEP-BCI has not been used is a danger of generation of an epileptic seizure called the photosensitive epilepsy. Moreover, the light flashing with lower frequencies might cause user's exhaustion when used for longer time periods.

Based on the above limitations of the conventional SSVEP devices, we propose a safer option for BCI using the green and blue colorful light combinations delivered by light-emitting diodes (LEDs).

II. MATERIALS AND METHODS

The experiments reported in this abstract were performed in the Life Science Center of TARA, University of Tsukuba, Japan. The experimental procedures were approved and designed in agreement with the ethical committee guidelines of the Faculty of Engineering, Information and Systems at University of Tsukuba, Tsukuba, Japan (experimental permission no. 2013R7). The visual stimuli were flashed using small white or RGB LEDs as square waves generated by ARDUINO UNO microcontroller board. In this study we used 7, 18, 25, 39 Hz flashing frequency patterns to create four commands SSVEP-BCI paradigm. During experiments the LEDs continued to flash simultaneously with the above frequencies. In the training phase, to let the user to gaze at specific LED, the spoken experiment instructions were delivered from OpenViBE software environment. The experiment settings have been summarized in Table I. The EEG electrodes were placed on the user's head close to the visual cortex [1]. Spoken instructions were given to let the user to execute saccades and to focus at the target LEDs. The spoken instructions were delivered as a recorded human voice (for Japanese speakers) or a synthesized MacOS X system speech (Serena's voice for English speakers). In a single BCI EEG experimental run there were 40 trials to gaze at each LED (ten trials for each target frequency).

For SSVEP responses classification a linear soft margin support vector machine (C-SVM) [3] was chosen. The features were calculated as power spectral densities based on Welch's method [4]. The feature vector used for linear C-SVM training was constructed by 10×96 matrix for each target frequency. A test data used for classification was constructed as a concatenated of all EG channels 1×96 feature vector in each single trial.

Table 1. EEG experiment details

Number of users	3
Recording length	5000 ms for each trial
EEG recording system	g.USBamp with active wet EEG electrodes system
Electrode locations	O1, O2, Po3, Po4, P1, P2, Oz and Poz
Reference and ground electrode	Left earlobe and FPz
Notch filter	Butterworth 4th order with rejection band of 48 ~ 52 Hz
High-pass filter	Butterworth 8th order at 5 Hz
Number of runs	4 for each LED display colors

III. RESULTS

The results obtained from offline BCI EEG classification accuracy improvement with the soft margin support vector machine [4] together with questionnaire given to the users' analysis are presented in this section. Figure 1 summarizes the SSVEP-BCI experiment with results calculated by a multi-class linear C-SVM classifier. The mean classification accuracies based on various time windows are depicted in a form of box-plots with pairwise t-test statistical significances ($p < 0.05$) marked with "*" symbols. The results have shown that the longer the recorded time the higher accuracy except for the user #2. The accuracies of users #1 and #3 formed monotonic increase for each stimulus' color type. Moreover the proposed method scored with higher accuracies comparing to the monochromatic SSVEP. Results of user #1 showed also statistically significant differences (conventional vs. proposed) in the time window ranges of 2 to 5 seconds.
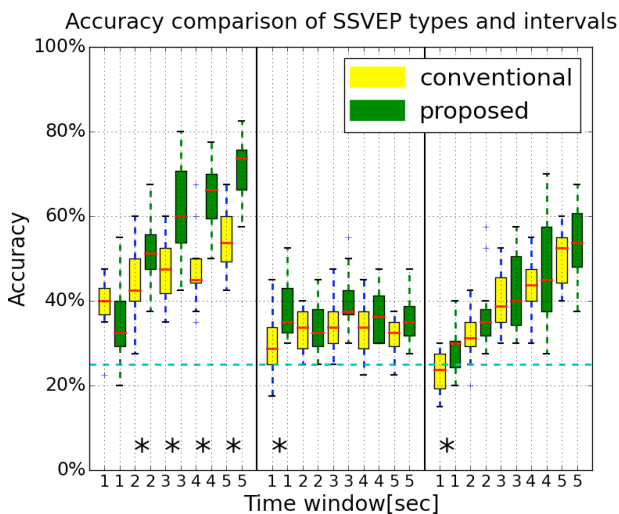

Figure 1. SSVEP EEG classification results of every user in various signal analysis time windows. The horizontal axis represents each time window. The cyan doted horizontal line depicts the chance level of 25%.

On the other hand, results of the user #3 did not contain significant differences except for the result of one second long interval. Results of questionnaires given have been summarized in Table II. There were two questions as follows: (1) Which stimulus did you prefer monochromatic versus colorful (response range -5 ~ +5)? (2) Please evaluate experiment difficulty from tiring to relaxing (response range -5 ~ +5). When the preference response was positive, the user preferred colorful flashing comparing to the monochromatic. Similarly, the difficulty positive scores reflected the users' lower tiredness with the colorful LEDs. Except for preference report of the user #3, all the others reported that the proposed method was better from the point of view of preference and difficulty.

Table 2. Questionnaire results

User number	Preference	Tiredness
#1	3	1
#2	5	3
#3	-1	4
Average	2.33	2.67

IV. CONCLUSIONS

This paper reported a successful implementation of the four command-based colorful SSVEP BCI in offline signal analysis scenario. We conducted experiments to verify the feasibility and user experience of the proposed method. According to the results obtained from three users, classification accuracies were as good or even better as of the conventional monochromatic stimuli. In addition to these results, the majority of the users preferred the proposed green-blue LED flashing. For future research, we aim to validate the prototype colorful SSVEP-based BCI with more users to further proof the results.

REFERENCES

[1] J. Walpaw and E. W. Wolpaw, Eds, Brain-Computer Interfaces: Principles and Practice, Oxford University Press 2012.

[2] F. Plum and J. B. Posner, The Diagnosis of Stupor and Coma. Philadelphia, PA, USA: FA Davis, 1966.

[3] C. Cortes and V. Vapink, "Support-vector networks," Machine Learning, vol. 20, no. 3, pp. 273-297, Sep. 1995

[4] P. D. Welch, "The use of fast Fourier transform for the estimation of power spectra: a method based on time averaging over short, modified periodograms," IEEE Transactions on Audio and Electroacoustics, vol. 15, no. 2, pp. 70-73, 1967.