 DOI: 10.3217/978-3-85125-962-9-12

Virtual Physical Model-based Brain Switch via Periodic SSVEP Modulation for Asynchronous Brain-Computer Interfacing

Songwei Li[1,2], Jianjun Meng[*1,2]

[1] Department of Mechanical Engineering, Shanghai Jiao Tong University, Shanghai, China, [2] State Key Laboratory of Mechanical System and Vibration, Shanghai Jiao Tong University, Shanghai, China

* E-mail: mengjianjunxs008@sjtu.edu.cn

Introduction: Brain switches provide a tangible solution to asynchronized brain-computer interface (aBCI), which decodes user intention without relying on a pre-programmed structure. However, most brain switches based on electroencephalography (EEG) signals have high false positive rates (FPRs) [1], resulting in high frustration and less practicality [2]. Here, we propose a novel virtual physical model-based brain switch that leverages periodic SSVEP modulation to achieve low FPR and robust triggering time.

Material, Methods and Results: EEG data were recorded for eight subjects by a 64 channel Biosemi ActiveTwo system, among which EEG channels over occipital cortex are utilized to be the online control signals. Each subject performed 21 brain-switch triggers to evaluate the triggering time performance. Then, each subject started a one-hour-video-playing task to evaluate the FPR during non-triggering resting state (**Fig. 1a**). The Institutional Review Board of Shanghai Jiao Tong University approved the study protocol. EEG signals from the selected channels were preprocessed and EEG features were extracted via canonical correlation analysis (CCA). The correlation coefficient features (to 15Hz and 20Hz reference signal) are mapped to a virtual force. Then the virtual force (modulated by gazing at different SSVEP stimuli) could periodically drive the virtual physical system to accumulate it's swing amplitude until the switch was triggered (**Fig. 1a**).

(a) (b) (c)

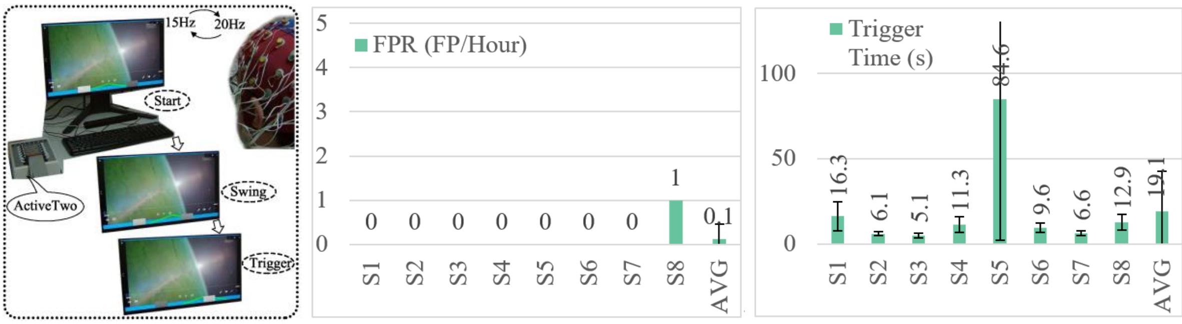

Figure 1. *(a) Experimental paradigm for brain switch evaluation. (b)FPR of each subject during the one-hour-video-playing task . (c) Trigger time of each subject during the active triggering task.*

Figure 1b showed the FPR of each subject during the one-hour-video-playing task. During the one-hour-video-playing, only subject S9 had one false alarm triggering. The average FPR was 0.13±0.33FP/hour during the video-playing. The brain switch's triggering time is given in **Fig. 1c**, demonstrating that most subjects could trigger the brain switch within 16.3s. The best performance was gained by the subject S3, whose triggering time was 5.1s on average, and half of the subjects could trigger the brain switch within 10.5s (the median). The average active-triggering-time (19.1s) was less than one thousandth of the time for a false alarm triggering happened (8h).

Discussion: With the interactive operation mode during the brain switch triggering process, the subjects could modulate the SSVEP feature and drive the virtual physical system to trigger a brain switch when they want. The virtual physical system built up a coding and decoding strategy based on its resonance phenomena, which could be easily understood and accepted by the users. The coherent periodic active modulation would utilize the resonant frequency to trigger the brain switch, while incoherent noise only causes limited swing amplitude.

Significance: This work first time showed that the SSVEP-based BCI was capable to provide high reliability and efficiency for brain switch control. The FPR was as low as 0.13FP/hour while the median triggering time was 10.5s in our pilot evaluation. This is promising for the future development of BCI applications.

References

[1] Lim, Jeong‐Hwan, Yong‐Wook Kim, Jun‐Hak Lee, Kwang‐Ok An, Han‐Jeong Hwang, Ho‐Seung Cha, Chang‐Hee Han, and Chang‐Hwan Im. "An emergency call system for patients in locked‐in state using an SSVEP‐based brain switch." Psychophysiology 54, no. 11 (2017): 1632-1643.

[2] Huggins, Jane E., Patricia A. Wren, and Kirsten L. Gruis. "What would brain-computer interface users want? Opinions and priorities of potential users with amyotrophic lateral sclerosis." Amyotrophic Lateral Sclerosis 12, no. 5 (2011): 318-324.