Target spectral band canonical correlation analysis enhancing target frequency feature extraction in SSVEP-based BCI

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***Abstract*— Due to its high performance, filter-bank canonical correlation analysis (FBCCA) is widely used in steady-state visual evoked potential (SSVEP)-based brain-computer interfaces (BCIs). The FBCCA has a broad subband bandwidth for detecting harmonic components. Nevertheless, the SSVEP signal responds most strongly at fundamental frequency. This study proposed a target spectral band canonical correlation analysis(TSB-CCA) that focuses on the target frequency(which is assumed to have a high fundamental frequency component). Using existing low- and high-frequency SSVEP dataset, we assessed the accuracy of the canonical correlation analysis (CCA), the FBCCA, and the proposed TSB-CCA. Consequently, it was determined that FBCCA performed better with the low frequency dataset, while TSB-CCA performed better with the high frequency dataset.**

I. INTRODUCTION

Traditional steady-state visual evoked potential (SSVEP) detection methods have typically focused on low/medium frequency bands (e.g., 4–25 Hz) that induce a greater amplitude response than stimuli with a higher frequency. However, low frequency visual stimulation causes excessive visual fatigue(4-15 Hz), and medium frequency visual stimulation easily induces photosensitive epileptic seizures(15-25 Hz), so subjects cannot use it for an extended period of time. On the other hand, it has been confirmed that brain-computer interfaces (BCIs) based on high frequency SSVEP are less sensitive to visual fatigue[1]. In this paper, we propose target spectral band canonical correlation analysis (TSB-CCA), which focuses on target frequencies, and evaluate its performance using low frequency (frequency range: 6-14.9Hz, interval: 0.3Hz) and high frequency (frequency range: 26-34.7Hz, interval: 0.3Hz) SSVEP datasets (target: 30, subject: 26). Fifteen occipital channels (P5, P3, P1, Pz, P2, P4, P6, PO7, PO3, POz, PO4, PO8, O1, Oz, O2) were used for analysis. The performance of canonical correlation analysis (CCA), filter-bank canonical correlation analysis (FBCCA)[2], and the proposed TSB-CCA was evaluated.

II. METHOD

A. Target Spectral Band Canonical Correlation Analysis

This study proposed TSB-CCA focusing on the target frequency. To extract the target frequency, each EEG signal(trial) is subjected to a band-pass filter with a target frequency ± 1 Hz range. Standard CCA was applied to the EEG signal that passed through the band pass at the target frequency.

III. RESULTS

At data length 5s, the average accuracy of CCA, FBCCA, and TSB-CCA for low frequency was 62.37%, 78.04%, and 78.59%, and for high frequency was 64.04%, 77.15%, and 87.72%, respectively. In particular, in all data lengths of the high frequency dataset, TSB-CCA performed better than other methods.

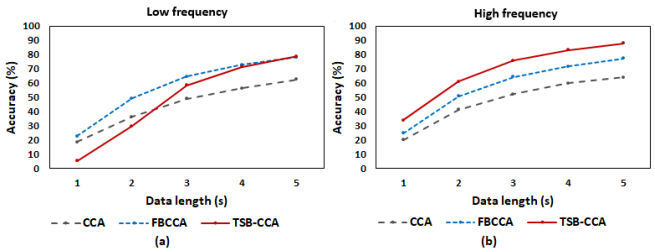

Fig. 1. Accuracy comparison of three methods using SSVEP dataset. (a) Low frequency, (b) High frequency

IV. CONCLUSIONS

We proposed TSB-CCA with an emphasis on the target frequency band. On the low frequency and high frequency SSVEP datasets, we evaluated the performance of CCA, FBCCA, and the proposed TSB-CCA. In all data lengths of high frequency SSVEP, TSB-CCA performed better than other methods. These results suggest the applicability of high frequency in a practical SSVEP-based speller system.

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REFERENCES

[1] Won, Dong-Ok, et al. "Effect of higher frequency on the classification of steady-state visual evoked potentials." Journal of neural engineering, vol. 13, no. 1, 016014, 2015.

[2] Chen, Xiaogang, et al. "Filter bank canonical correlation analysis for implementing a high-speed SSVEP-based brain–computer interface." Journal of neural engineering, vol. 12, no. 4, 046008, 2015.