 DOI: 10.3217/978-3-85125-467-9-4

Bio-inspired Filter Banks for SSVEP BCIs

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Introduction: Brain-computer interfaces (BCI) have the potential to play a vital role in future healthcare technologies by providing an alternative way of communication and control [1]. More specifically, steady-state visual evoked potential (SSVEP) based BCIs have the advantage of higher accuracy and higher information transfer rate (ITR). In order to fully exploit the capabilities of such devices, it is necessary to understand the features of SSVEP and design the system considering its biological characteristics. This paper introduces bio-inspired filter banks (BIFB) for a novel SSVEP frequency detection method. It is known that SSVEP response to a flickering visual stimulus is frequency selective and essentially gets weaker as the frequency of the stimuli increases. In the proposed approach, the gain and bandwidth of the filters are designed and tuned based on these characteristics while also incorporating harmonic SSVEP responses.

Material, Methods and Results: In order to test the proposed BIFB method, two datasets available online (i.e. AVI [2], RIKEN-LABSP [3]) are used in this study. Initially, higher bandwidth and gain are set to frequencies with low SSVEP response in the BIFB design. Subsequently, these parameters are optimized for individual users in order to counter frequency selective nature of SSVEP response. Fig.1 presents BIFB design for the first dataset and reveals frequency selective nature of the SSVEP response. The second filter bank in Fig. 2 designed for RIKEN-LABSP dataset deals with the weakening of SSVEP response as the frequency increases.

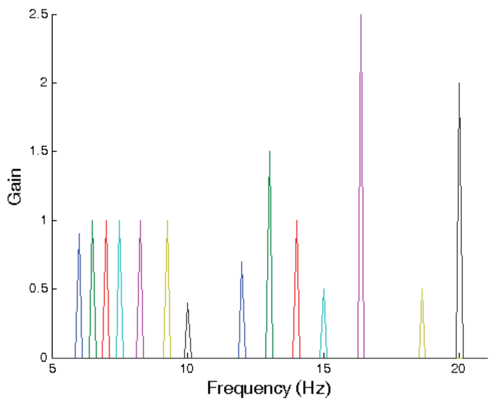

Figure 1. *Sample BIFB design for AVI Dataset.*

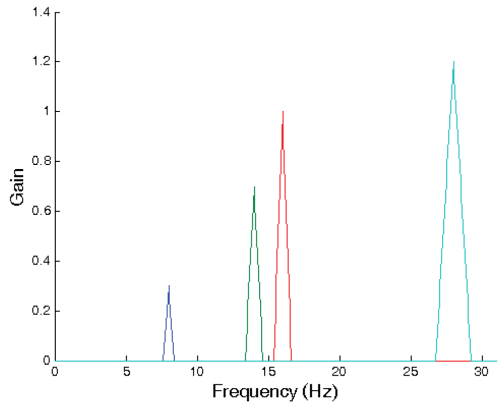

Figure 2. *Sample BIFB design for RIKEN-LABSP Dataset.*

Once the BIFB parameters are trained the EEG signal is preprocessed (filtering, windowing, etc.) and power spectrum is estimated by multiplying each signal's FFT with the BIFB in order to obtain the class value for each target frequency. The SSVEP frequency is labeled as detected when the same class occurs as maximum at least three times in the last four iterations. The BIFB method achieved reliable performance when compared with two well-known SSVEP frequency detection methods, power spectral density analysis (PSDA) and canonical correlation analysis (CCA). For example, BIFB provided %97.8 accuracy, whereas CCA and PSDA provided %89.1 and %83.7 respectively on AVI dataset. Although, the mean detection time was shorther for CCA method (4.9 sec), BIFB (7.4 sec) achived comparable ITR performance due to its higher accuracy [4].

Discussion: The results show that the BIFB method provides both reliable accuracy and sufficient ITR performance which is comparable with CCA due to its bio-inspired design. It is true that BIFB requires a longer training, or calibration process compared to CCA. However, the preliminary results shows that even without any training, using a non-user specific filter bank design, the accuracy of BIFB is still comparable with CCA.

Significance: This method not only improves the accuracy but also increases the available number of commands by allowing use of stimuli frequencies which elicit weak SSVEP responses.

References

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