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Frequency Decomposition Approach for Sub-Band Common Spatial Pattern Methods for Motor Imagery Based Brain-Computer Interface

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Abstract : Motor imagery (MI) based brain-computer interfaces (BCI) uses event-related (de)synchronization (ERS/ ERD), typically recorded using electroencephalography (EEG), to translate brain electrical activity into control commands. To mitigate undesirable artifacts and noise measurements on EEG signals, methods based on band-pass filters defined by a specific frequency band (i.e., 8 – 30Hz), such as the Infinity Impulse Response (IIR) filters, are typically used. Spatial techniques, such as Common Spatial Patterns (CSP), are also used to estimate the variations of the filtered signal and extract features that define the imagined motion. The CSP effectiveness depends on the subject's discriminative frequency, and approaches based on the decomposition of the band of interest into sub-bands with smaller frequency ranges (SBCSP) have been suggested to EEG signals classification. However, despite providing good results, the SBCSP approach generally increases the computational cost of the filtering step in IM-based BCI systems. This paper proposes the use of the Fast Fourier Transform (FFT) algorithm in the IM-based BCI filtering stage that implements SBCSP. The goal is to apply the FFT algorithm to reduce the computational cost of the processing step of these systems and to make them more efficient without compromising classification accuracy. The proposal is based on the representation of EEG signals in a matrix of coefficients resulting from the frequency decomposition performed by the FFT, which is then submitted to the SBCSP process. The structure of the SBCSP contemplates dividing the band of interest, initially defined between 0 and 40Hz, into a set of 33 sub-bands spanning specific frequency bands which are processed in parallel each by a CSP filter and an LDA classifier. A Bayesian meta-classifier is then used to represent the LDA outputs of each sub-band as scores and organize them into a single vector, and then used as a training vector of an SVM global classifier. Initially, the public EEG data set IIa of the BCI Competition IV is used to validate the approach. The first contribution of the proposed method is that, in addition to being more compact, because it has a 68% smaller dimension than the original signal, the resulting FFT matrix maintains the signal information relevant to class discrimination. In addition, the results showed an average reduction of 31.6% in the computational cost in relation to the application of filtering methods based on IIR filters, suggesting FFT efficiency when applied in the filtering step. Finally, the frequency decomposition approach improves the overall system classification rate significantly compared to the commonly used filtering, going from 73.7% using IIR to 84.2% using FFT. The accuracy improvement above 10% and the computational cost reduction denote the potential of FFT in EEG signal filtering applied to the context of IM-based BCI implementing SBCSP. Tests with other data sets are currently being performed to reinforce such conclusions.

Keywords : brain-computer interfaces, fast Fourier transform algorithm, motor imagery, sub-band common spatial patterns
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