Comparison of EWT and OVMD Techniques for Left and Right Hand Motor Imagery Classification in EEG Signals

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Extended Abstract

Neuroengineering advancements in non-invasive brain-computer interfaces (BCIs) offer transformative potential for stroke-related neurorehabilitation by leveraging event-related desynchronization/synchronization (ERD/ERS) to provide closed-loop neurofeedback to patients [1]–[5]. A critical challenge in these systems is the non-stationary nature of EEG signals, which necessitates adaptive signal decomposition to isolate task-relevant rhythms effectively. This study evaluates the empirical wavelet transform (EWT) [6] against the recently developed orthogonalized variational mode decomposition (OVMD) [7] using the BCI Competition IV Dataset 2b. Two distinct processing pipelines were implemented: a spatial-spectral framework using filter bank common spatial pattern (FBCSP) and an instantaneous features extraction. In the first pipeline, signals are decomposed into 10 adaptive modes to define a filter bank, followed by spatial filtering and feature selection via mutual information-based best individual feature (MIBIF) [8]. In the second pipeline, the Hilbert Transform (HT) is applied to the highest-power mode to extract instantaneous amplitude (IA) and frequency (IF), along with standard and higher-order statistics (HOS) [9].

The results, detailed in Table I, demonstrate a significant performance split based on the chosen decomposition technique and feature domain. EWT shows superior synergy with spatial filtering, achieving a cross-validation (CV) accuracy of 0.718 and a test accuracy of 0.776. Conversely, OVMD provides more stable results for instantaneous signal analysis, outperforming EWT in the HT pipeline. Individual variability remains a significant factor, for instance, subject B04 reached 95.6% accuracy with EWT, whereas subject B05 performed notably better under the OVMD-HT approach. While linear classifiers like SVM and LDA confirm that the feature spaces are generally linearly separable, the high inter-subject variance emphasizes that the choice of decomposition must be tailored to the specific user's neurophysiological profile. Ultimately, EWT remains the standard for spatial-spectral discrimination, while OVMD is a powerful alternative for tracking phase and amplitude dynamics in localized event waves.

TABLE I
CV and test performance (accuracy / F1-Score)

Pipeline - Method	CV (ACC / F1)	Test (ACC / F1)
FBCSP - EWT	0.718 / 0.716	0.776 / 0.773
FBCSP - OVMD	0.621 / 0.619	0.600 / 0.579
HT - EWT	0.660 / 0.658	0.614 / 0.578
HT - OVMD	0.648 / 0.643	0.653 / 0.626

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