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Wavelet Scattering-based EEG Channel Reduction for Motor Imagery Classification

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Introduction: EEG-based motor imagery (MI) classification has been widely used for movement brain-computer interfaces (BCIs) to enable intuitive control of external devices. A key challenge in MI-BCIs is reducing the number of EEG channels to minimize computational burden and improve user comfort, while maintaining robust classification performance [1]. Wavelet scattering, a method that captures hierarchical time-frequency features, has shown promise for robust feature extraction from EEG signals [2]. Here, we investigate wavelet scattering-based channel selection for MI classification and evaluate its performance.

Methods and Results: This study utilized the publicly available Shu EEG dataset [3], consisting of motor imagery (MI) data from 25 subjects across five sessions, recorded during left- and right-hand MI tasks using 32 EEG channels. Wavelet scattering was used to process the raw EEG signals, which involves wavelet filter convolution, modulus transformation, and low-pass filter averaging. Scattering coefficients for each channel were ranked by their mutual information with MI class labels, and the top 15, 9, 7, 5, and 3 channels were selected. A simple convolutional neural network (CNN) consisting of three convolutional layers was used for 10-fold cross validation classification. The classification accuracy was 79.24% when all channels were used, and showed the highest of 79.81% with 9 selected channels. A performance of 77.44% was reported when only 3 channels were used. Statistical analysis using the Friedman test followed by the Wilcoxon signed-rank test with Bonferroni correction showed no significant differences in accuracy across all channel counts. We also examined the differences in selected channels between a high and low performer. The high performer showed a consistent selection of channels on the motor and prefrontal cortex, while the low performer displayed a more dispersed selection pattern.

Conclusion: This study demonstrates the effectiveness of wavelet scattering as a robust feature extraction method for EEG-based motor imagery classification. We achieved comparable classification performance with significantly reduced channel sets, underlining the potential for efficient BCIs without compromising performance.

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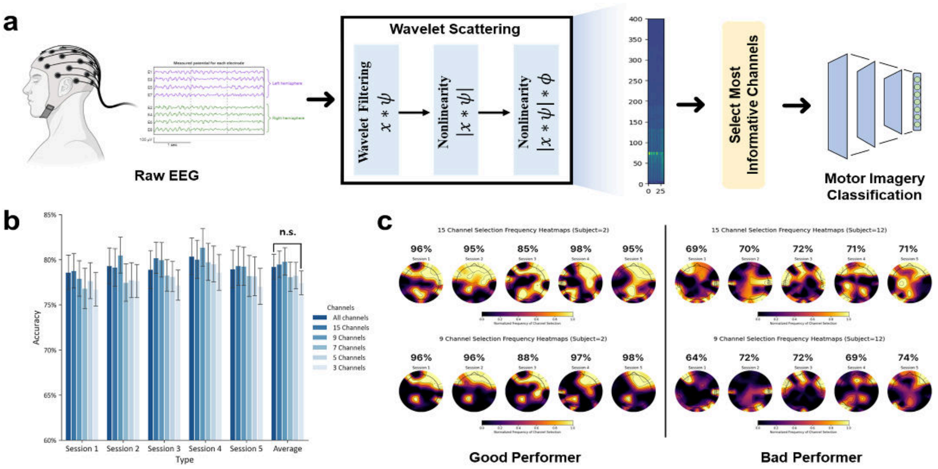

Figure 1. ***a*** *Schematic of wavelet scattering-based channel selection using mutual information.* ***b*** *Classification accuracies across all sessions according to the number of selected channels showed no significant differences.* ***c*** *Heatmap of selected channels. The good performer consistently selected motor and prefrontal cortex electrodes unlike the bad performer (top: 15 channels, bottom: 9 channels).*

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