TITLE : Multiclass Motor Imagery EEG Classification Pipeline Using a Spiking Neural Network

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Brain-computer interface (BCI), electroencephalography (EEG), motor imagery, neuromorphic computing, spiking neural networks (SNN).

Abstracts:

Brain–Computer Interfaces (BCIs) enable direct communication between the brain and external devices, offering transformative opportunities for assistive technologies and clinical neuroengineering. Electroencephalography (EEG), a non-invasive and widely used biomedical signal, is central to many BCI applications. Yet, practical adoption remains limited because state-of-the-art methods often depend on deep learning models that are computationally intensive and power-hungry, making them unsuitable for portable or embedded biomedical systems. To address this challenge, we propose a fully neuromorphic BCI pipeline that avoids frame-based digital computations and instead leverages sparse, event-driven processing inspired by the brain. The system integrates a filter bank for spectral decomposition with Common Spatial Patterns (CSP) for spatial feature extraction and introduces an adaptive delta coding scheme to convert continuous EEG features into sparse spike trains. These are processed by a Spiking Neural Network (SNN) trained with a spike time–dependent Van Rossum loss. Evaluation on the BCI Competition IV-2a motor imagery EEG dataset, with training and testing performed within each subject, demonstrates competitive classification accuracy and supports low-power, real-time operation. This work provides a proof of concept for fully neuromorphic EEG-based pipelines as a viable path toward energy-efficient, edge-deployable BCI systems in biomedical engineering and healthcare.