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An EEG Artifact Removal Neural Network for BCI Applications with EEG-ViTNet

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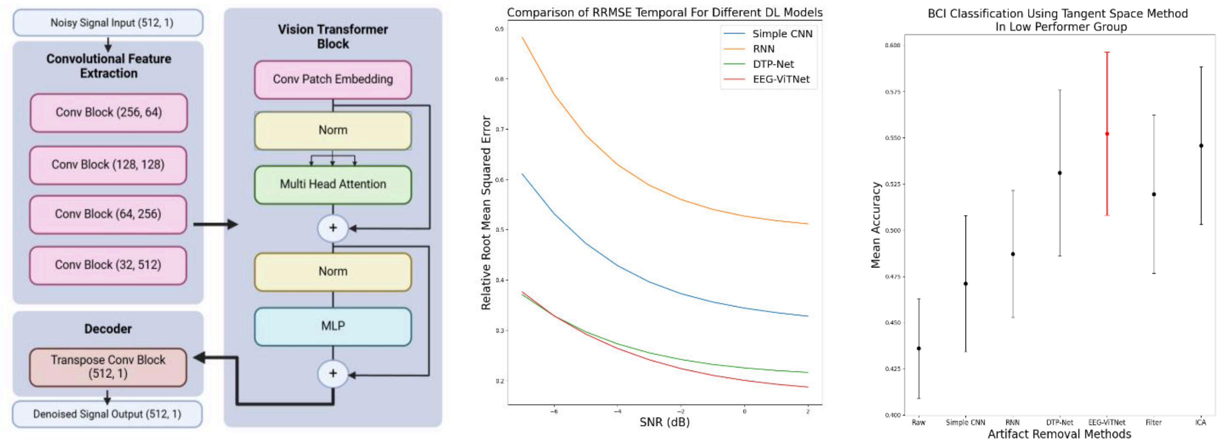
Introduction: Brain-computer interfaces (BCIs) are systems that translate brain activity into commands to control external devices, replacing motor pathways in individuals with disabilities. However, artifacts from eye movements (EOG) [1] and muscle activations (EMG) [2] often contaminate neural signals (EEG) and obfuscate meaningful physiological information. Effectively removing these artifacts from EEG with minimal distortion can enhance signal quality and improve downstream BCI tasks [3]. Traditional blind source separation methods, such as independent component analysis (ICA), are limited in their ability to efficiently denoise EEG in real-time. In contrast, deep learning (DL) techniques, which have shown success in computer vision and medical image segmentation, offer a promising approach for EEG artifact removal, potentially leading to more effective denoising and thus more accurate BCI control.

Methods & Results: An open-access dataset (*EEGDenoiseNet)* was used to train and test the DL models [4]. The dataset consists of 4514 EEG, 3400 EOG, and 5998 EMG segments. Clean and contaminated segments were linearly combined at varying SNR levels (-7 to 2dB) to generate semi-synthetic data, which was then split into training (80%), validation (10%), and testing set (10%). A novel 1D vision transformer-based model (EEG-ViTNet) was proposed and compared with existing state-of-the-art models from literature using metrics such as relative root mean squared error (RRMSE) and correlation coefficient (CC) (Fig A). A second open-access dataset (*PhysioNet EEG Motor Imagery Dataset)* was used to validate the DL models on a real-world BCI task [5]. Data from 80 participants were selected to assess accuracy of a 2-class motor imagery task (hands and feet) using the Riemannian tangent space method and a logistic regression classifier [6]. The novel EEG-ViTNet was used to pre-process the motor imagery data in the classification pipeline, and resulting accuracies were benchmarked against traditional methods, including bandpass filtering, ICA, and other DL models. The novel model achieved a RRMSE of 0.252 (temporal) and 0.272 (spectral), and a CC of 0.955, outperforming the current state-of-the-art model (0.266/0.309/0.950) (Fig B). Furthermore, it achieved the highest classification accuracy (55.2±4.3%) on the validation motor imagery dataset, boosting accuracy for the lowest performers and surpassing the raw baseline (43.6±4.3%), bandpass filter (51.9±4.3%), and other DL models (53.1±4.5%), while displaying comparable performance with the state-of-the-art ICA (54.6±4.3%) (Fig C).



(A) EEG-ViTNet Architecture (B) DL Model Error Comparison (C) BCI Task Accuracy

Discussion & Significance: The preliminary results show strong potential of EEG-ViTNet for artifact removal in BCI tasks. However, the substantial interparticipant performance variability in the motor imagery task suggests the need for larger sample validation. Future work will explore additional BCI tasks (i.e., P300 event-related potential) and consider challenges like single-channel limitations, reliance on semi-synthetic data, and individual EEG variability. Overall, the EEG-ViTNet could be a promising pre-processing step to improve BCI control for people with disabilities.

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