HyenaFormer: The Long-Range Brain Signal Modeling for the Vigilance Estimation

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Abstract

Driver vigilance estimation is essential for preventing fatigue-related traffic accidents, yet existing multimodal EEG–EOG models often neglect personalized neural variability and incur high costs for long-sequence modeling. We propose HyenaFormer, a personalized vigilance estimation framework that combines Transformer-based multimodal spatial encoding with a frequency-aware long convolutional sequence learner derived from Hyena. EEG and EOG signals are first processed by a lightweight Transformer to capture cross-modal spatial dependencies, followed by a personalized channel attention module that incorporates demographic priors to enable subject-aware representation learning. The resulting features are modeled by a Hyena-based temporal module employing structured implicit long convolutions, allowing efficient modeling of both slow fatigue accumulation and short-term vigilance fluctuations. This hybrid architecture achieves sub-quadratic complexity while preserving long-range temporal reasoning. Experiments on the SEED-VIG and SADT datasets demonstrate that HyenaFormer consistently outperforms Transformer-, LSTM-, and Mamba-based baselines in RMSE, MAE, and PCC under cross-subject and zero-shot settings.

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