Physics-inform attention temporal convolutional network for EEG-based motor imagery classification

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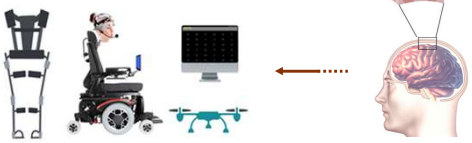
Introduction

The brain-computer interface (BCI) is an emerging technology that has the potential to transform the world. EEG-based Motor imagery (MI) has been used in many BCI applications to assist disabled people and to augment human capabilities. EEG is a non-invasive, low cost, low risk, and portable method that records the electrical activities of the brain. MI Is the activity of thinking about moving a human body part without physically moving it.



Recognizing human intention from EEG signal is challenging due to the low SNR and various sources of artifacts.

Proposed Method

The proposed ATCNet model consists of three main blocks:

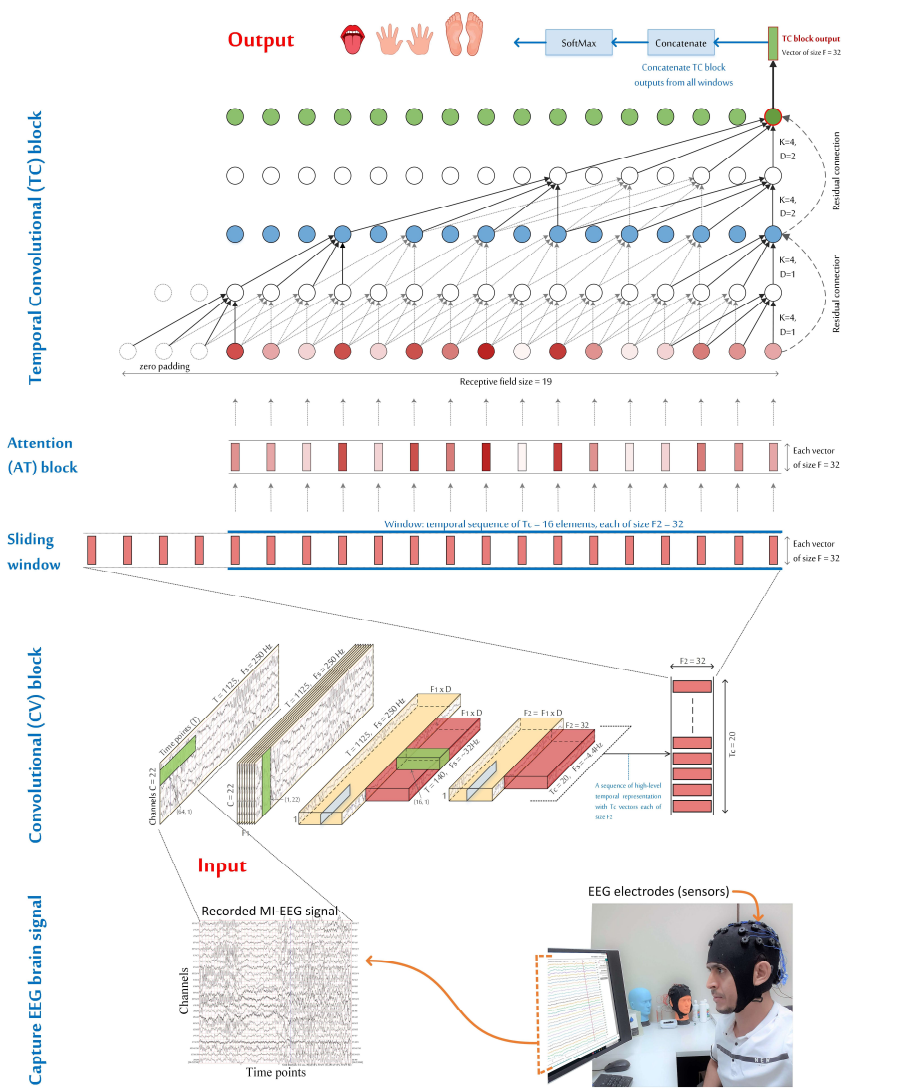
Convolutional (CV) block: encodes low-level spatio-temporal information within the MI-EEG signal into a sequence of high-level temporal representations via three convolutional layers

Attention (AT) block: highlights the most important information in the temporal sequence using a multi-head self-attention, MSA

Temporal convolutional (TC) block: extracts high-level temporal features from the highlighted information using a temporal convolutional layer

The proposed model also utilizes the convolutional-based sliding window to augment MI data and boost the performance of MI classification efficiently.

GitHub
https://github.com/Altaheri/EEG-ATCNet

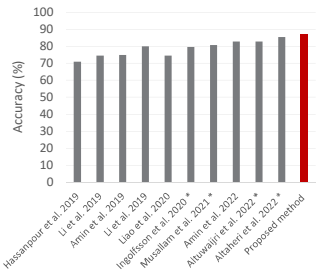


Results

- The proposed ATCNet model achieves a accuracy of 85.38% and a κ-score of 0.81, using the challenging and benchmark BCI Competition IV-2a dataset, which outperforms the state-of-the-art techniques by at least 2.51%.
- Ablation analysis showed that each block adds its contribution: the AT block increased the overall accuracy by 1.54% and SW by 2.28%. The addition of the TC block also increased accuracy by 1.04%.

Removed block	Accuracy %	κ-score
None (ATCNet)	85.38	0.805
AT	83.84	0.784
SW	83.10	0.775
SW + AT	82.75	0.770
TC	79.44	0.726
SW + TC	80.48	0.740
AT + TC	82.60	0.768
SW + AT + TC	81.71	0.756

Ablation analysis: contribution of each block in the ATCNet model. AT: attention, SW: sliding window, TC: temporal convolution.



Performance comparison between the proposed method and recent studies.

* Reproduced Method
Proposed and reproduced methods are available at:
GitHub https://github.com/Altaheri/EEG-ATCNet

Conclusions

This study proposed a novel attention-based temporal convolutional network (ATCNet) for EEG-based motor imagery classification that outperformed state-of-the-art techniques in MI-EEG classification using the BCI-2a dataset with an accuracy of 85.4% and 71% for the subject-dependent and subject-independent modes, respectively. These high results came with a relatively small number of parameters (115.2K), which makes ATCNet applicable to limited devices.

The ablation analysis showed that each block in the ATCNet model made a significant contribution to the performance of the ATCNet model.

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Code shared on GitHub: https://github.com/Altaheri/EEG-ATCNet