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:

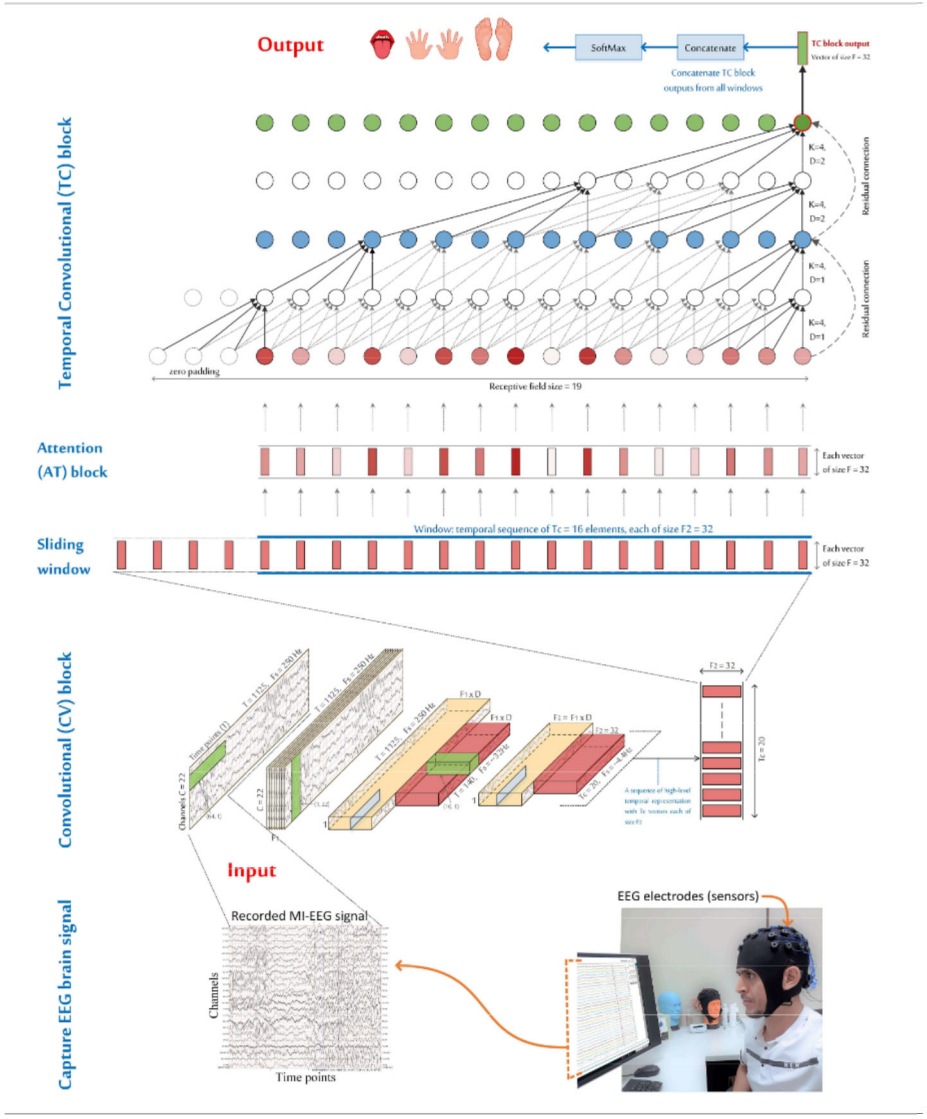
Convolutional (CV) block: encodes low-level spatio-temporal information within the MI-EEG signal into a sequence of high-level temporal representations via three convolutional layers

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

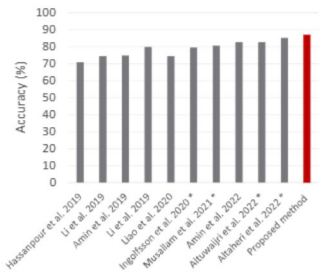


Results

- 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:
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

基于 EEG 运动想象分类的物理信息注意时间卷积网络

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介绍

脑机接口 (BCI) 是一项新兴技术，有望改变世界。基于脑电图 (EEG) 的运动想象 (MI) 已在许多 BCI 应用中得到应用，以协助残疾人士并增强人类能力。脑电图是一种非侵入性、低成本、低风险且便携的记录脑电活动的方法。MI

是指在不实际移动人体某个部位的情况下想象移动该部位的活动。

由于信噪比低和各种伪影来源，从脑电信号中识别人类意图具有挑战性。

提出的方法

所提出的 ATCNet 模型由三个主要模块组成：卷积（CV）模块：通过三个卷积层将 MI-EEG 信号中的低级时空信息编码为高级时间表示序列；注意（AT）模块：使用多头自注意力 (MSA) 突出显示时间序列中最重要的信息

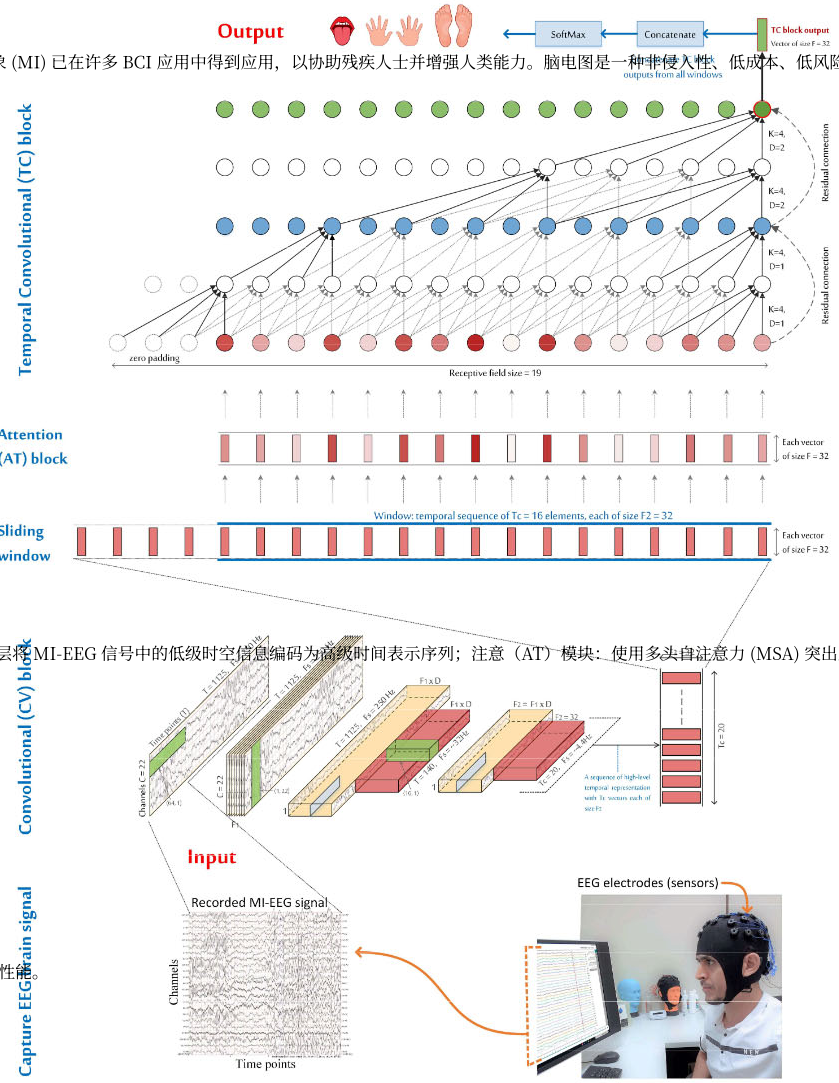
时间卷积（TC）块：提取高级时间

使用时间卷积层从突出显示的信息中提取特征

所提出的模型还利用基于卷积的滑动窗口来增强 MI 数据并有效提高 MI 分类的性能。

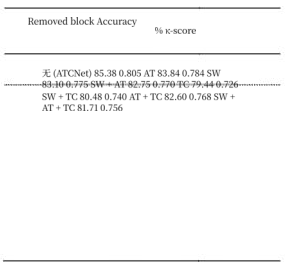
GitHub

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

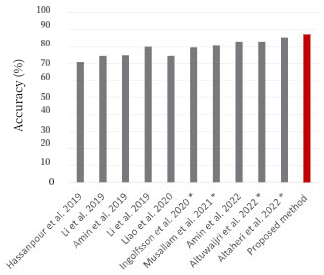


结果

- 所提出的 ATCNet 模型使用具有挑战性的基准 BCI 竞赛 IV-2a 数据集实现了 85.38% 的准确率和 0.81 的 κ 分数，比最先进的技术表现高出 5.1%。
- 消融分析表明，每个模块都增加了其贡献：AT 模块使整体准确率提高了 1.54%，SW 模块提高了 2.28%。TC 模块的加入也使准确率提高了剩余的 85.4% 和 71%。



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

结论

本研究提出了一种新的基于注意力的时间卷积网络 (ATCNet)，用于基于 EEG 的运动想象分类，其在使用 BCI-2a 数据集进行 MI-EEG 分类时优于最先进的技术，在受试者相关和受试者无关模式下的准确率分别为 85.4% 和 71%。

这些较高的结果来自于相对较少的参数数量（115.2K），这使得 ATCNet 适用于有限的设备。

消融分析表明，ATCNet 模型中的每个块都对 ATCNet 模型的性能做出了显著的贡献。

由 IEEE Transactions on Industrial Informatics 发布：https://ieeexplore.ieee.org/document/9852687 在 GitHub 上共享的代码：https://github.com/Altaheri/EEG-ATCNet