Benchmarking and Analysis of Deep Learning methods to classify EEG Motor Movement / Imagery signals

CSCI-566 - Deep Learning Project - Group 18

Objective

- **Compare** and **benchmark** the performance of current Deep Learning methods to **classify EEG** signals for Motor Movement / Imagery.
- Analyze **robustness** of models to **noise**

- The study aims to offer insights to optimize EEG data classification for **BCI** applications.

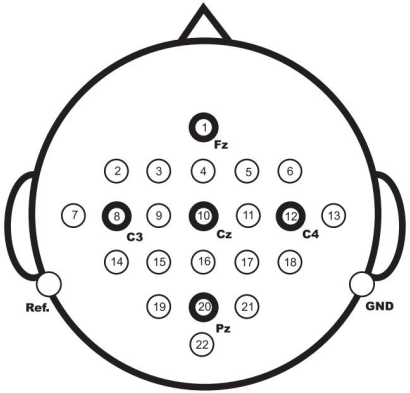
Dataset - BCI-Competition-IV-2a

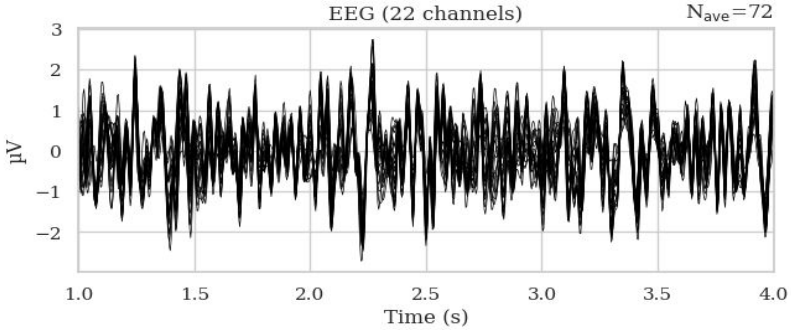
Dataset description

- Subjects: 9
- Trials: 288 x 18 = 5184
- Channels: 22 EEG + 3 EOG
- Sampling frequency: 250 Hz
- Frequency range: 0.5 to 100 Hz
- Format: GDF

Target classes

- Left hand
- Right hand
- Feet
- Tongue





Approach

- **Preprocessing**
  - Bandpass filtering: 4 - 38 Hz
  - Exponential moving standardization
  - Split into windows: 5184

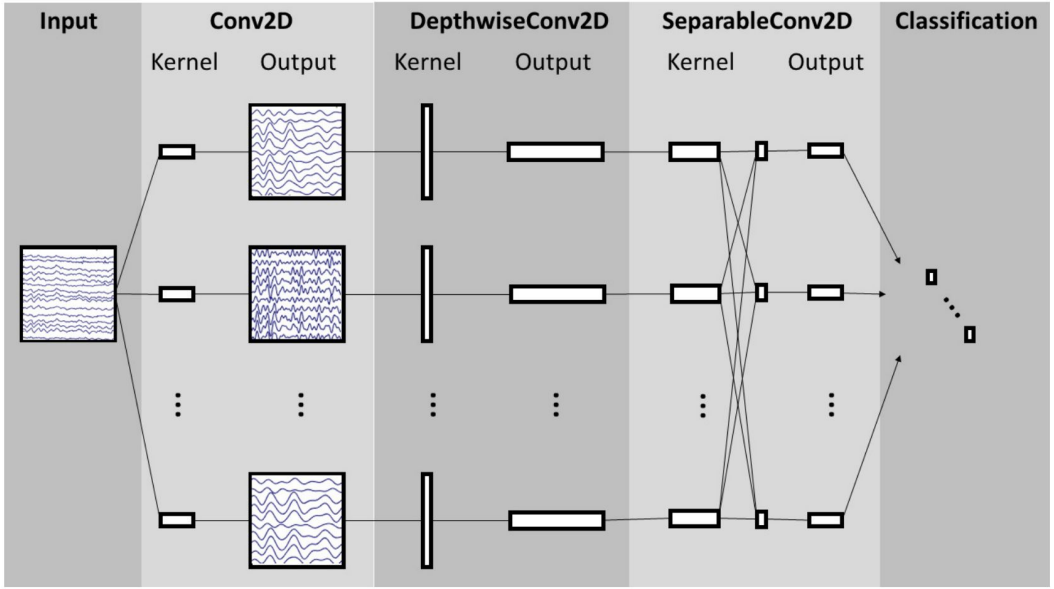
- **Feature Extraction**
  - Wavelet Packet Decomposition
  - Common Spatial Pattern
  - Graph Embedding

- **Train - Test split**
- **Model Training**
- **Robustness to noise -** SNR 15

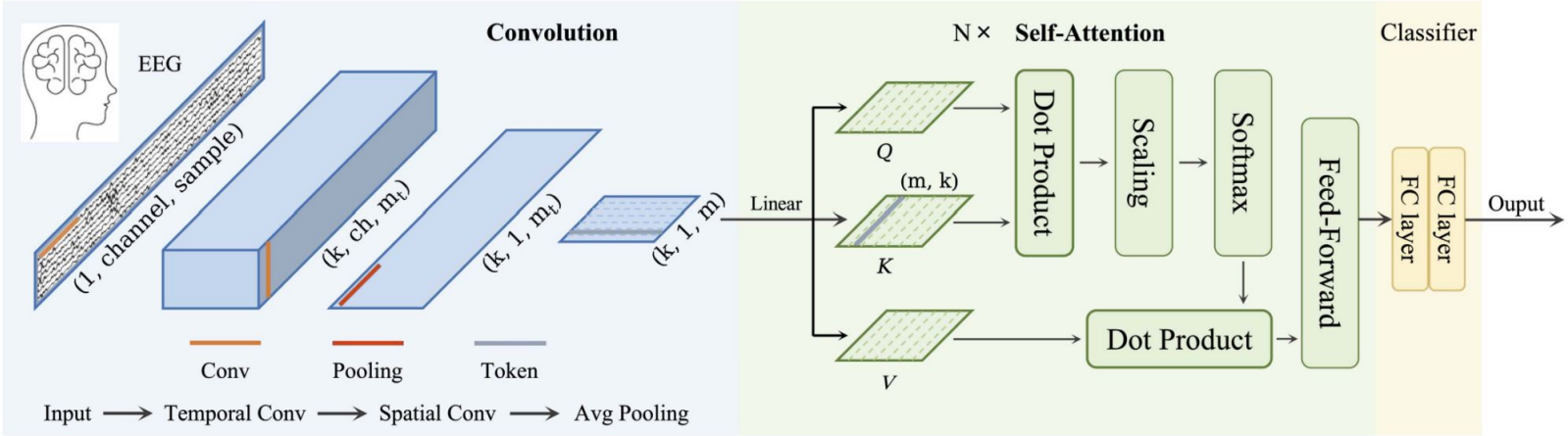
Models

- Raw Dataset
  - MLP
  - Shallow ConvNet
  - Deep ConvNet
  - EEGNet
  - EEGConformer
  - ATCNet
  - EEGITNet
- WPD CSP
  - MLP
  - CNN
  - ConvLSTM
  - ShallowFBCSP

Models - EEGNet

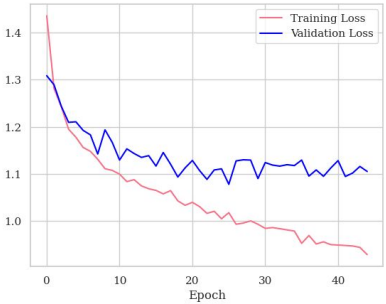


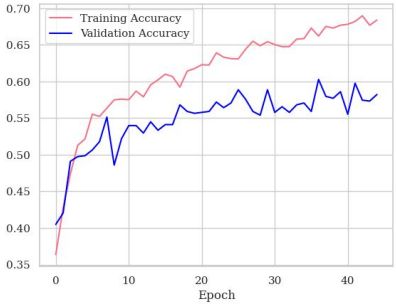
Models - EEGConformer



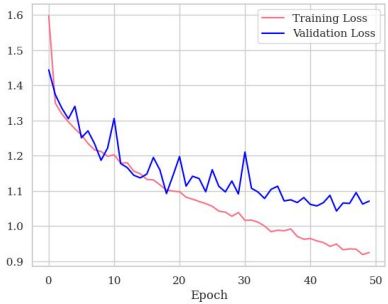
Training curves

MLP Classifier

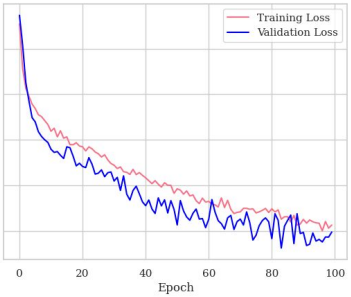


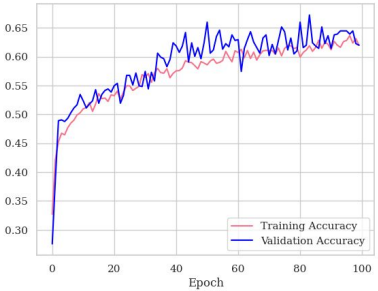


Conv LSTM

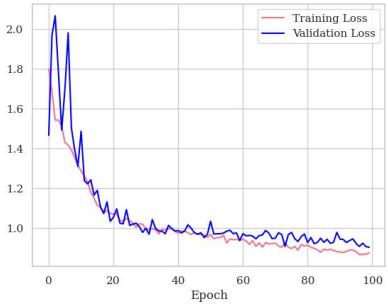


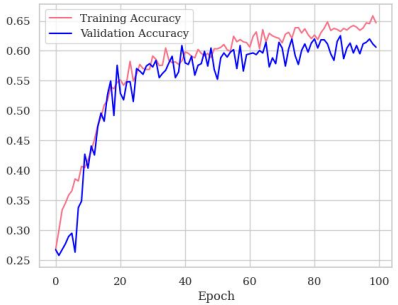
EEGNet





Deep ConvNet





Preliminary Results

Models	Feature Extraction	Accuracy	F1	Acc-Noise	F1-Noise
MLP	Raw-filtered	0.2390	0.0922	0.2307	0.0865
EEGNet	Raw-filtered	0.6073	0.6040	0.5449	0.5365
Shallow ConvNet	Raw-filtered	0.5617	0.5632	0.5296	0.5317
Deep ConvNet	Raw-filtered	0.5990	0.5934	0.5764	0.5741
ATCNet	Raw-filtered	0.6658	0.6643	0.6034	0.6021
EEGConformer	Raw-filtered	0.4949	0.4922	0.4916	0.4901
ShallowFBCSPNet	FBCSP	0.5893	0.5885	0.5893	0.5879

Preliminary Results

Models	Feature Extraction	Accuracy	F1	Acc-Noise	F1-Noise
EEGNet-v1	Raw-filtered	0.5450	0.5420	0.5536	0.5416
Deep4Net	Raw-filtered	0.5347	0.5223	0.5302	0.5221
EEGITNet	Raw-filtered	0.5964	0.5842	0.5597	0.5508
MLP	CSP	0.3689	0.3285	0.2734	0.2564
CNN	CSP	0.3281	0.3177	0.2647	0.2556
Conv-LSTM	CSP	0.3463	0.3294	0.2960	0.2799

Future Steps

- Fine-tuning the models
- Other datasets - Physionet
- Other models - HybridConvNet, FusionNet
- Robustness Testing - Synthetic Data, Saliency map attack, DeepFool attack

References

- D. Milanés Hermosilla et al., "Shallow Convolutional Network Excel for Classifying Motor Imagery EEG in BCI Applications," IEEE Access, vol. 9, June 2021, doi: 10.1109/ACCESS.2021.3091399.

- N. Shajil, M. Sasikala, and A. M. Arunagiri, "Deep Learning Classification of two-class Motor Imagery EEG signals using Transfer Learning," in Proc. 8th IEEE International Conference on E-Health and Bio engineering (EHB), Grigore T. Popa University of Medicine and Pharmacy, Romania, Oct. 2020.

- D. Avola, M. Cascio, L. Cinque, A. Fagioli, G. L. Foresti, M. R. Marini, and D. Pannone, "Analyzing EEG Data with Machine and Deep Learning: A Benchmark," arXiv:2203.10009v1 [cs.LG], Mar. 2022.

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