Classification and Analysis of EEG Signals for Brain-Computer Interface

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This work presents an approach how a small data set of EEG-MI data can be used
to train a Deep Learning model for classification of motor imagery of left and right arm movements for stroke rehabilitation.

Introduction

Stroke Rehabilitation - Why are BCI systems relevant?

Stroke is one of the main causes of long-term disability like motor impairments or limb paralysis [1]. Imagining a movement, called Motor Imagery (MI), activates the same area in the brain (motor cortex) as when the movement is actually performed. Brain-Computer Interface (BCI) is an effective method for motor neurorehabilitation by translating EEG-MI brain signals into motor intentions that can be used to control robotic systems to perform the passive movement [2].

Challenges

EEG signal characteristics:

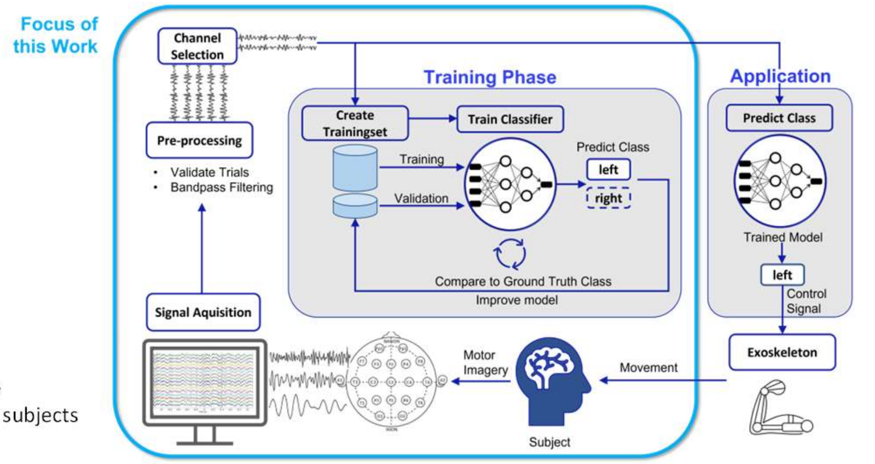
- Low signal-to-noise ratio (SNR)
- Many artefacts (blinking, interference,…)
- Large variability in signal between different subjects/trials

Current Research

Deep Learning (DL) methods attracted attention by combining feature extraction and classification in one model, leading to superior performances [3] → requires a large amount of data

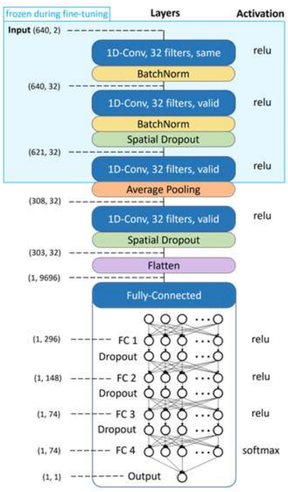
Research Goal

Evaluate methods for training a DL classifier while overcoming the challenges of limited data and variety in EEG-MI data for different subjects

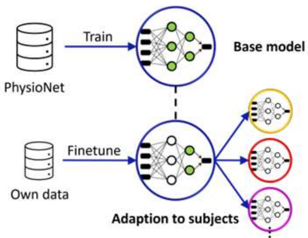


Experimental Setup

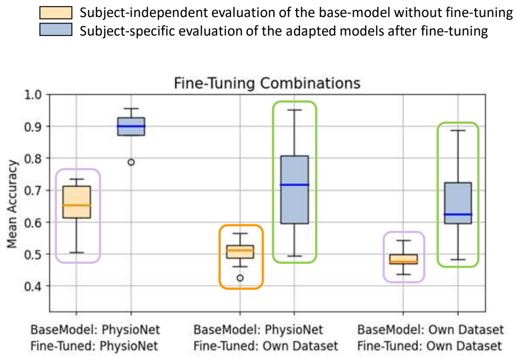
- **Datasets:**
  - Own recordings (11 subjects, 125 Hz, 16 ch)
    → total: **480 trials per class**
  - Open-Source PhysioNet [5] (105 subjects, 160 Hz, 64 ch) → total: **2205 trials per class**
- **Network Architecture** [4]



- **Approach:**
  1. Adapting PhysioNet to our own recording settings (resampling, channel selection)
  2. Train base-model
  3. Fine-tune on individual subjects



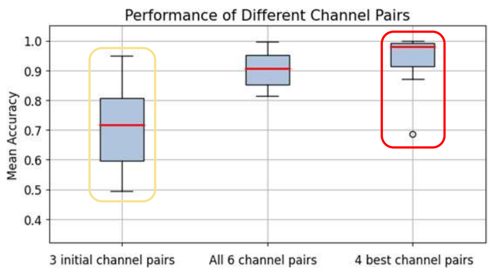
Results



Size of dataset is crucial when classifying unseen subjects

Knowledge of PhysioNet model can't be directly transferred on new data from our dataset

Better results with PhysioNet base-model than training only with own data



High variance with 3 initial channel pairs (bad connectivity, noise)

Choosing 4 channel pairs with the most robust results

→ 98% accuracy after fine-tuning
(averaged over all 11 target subjects)

Summary

- Individualized BCI-system with accurate DL classification, providing a simple and practical solution with only few EEG channels required
- New insights into fine-tuning PhysioNet with subjects from different dataset
- Future Work: - Data variety within a person → record & evaluate multiple sessions
  - Promising architecture: CNNs and Transformer models combined

References

[1] Aekaterini Galimanis et al. "Lifestyle and stroke risk: a review," 2009
[2] Muhammad Ahmed Khan et al. "Review on motor imagery based bci systems for upper limb post-stroke neurorehabilitation: From designing to application," 2020.
[3] Alexander Craik et al. "Deep learning for electroencephalogram (eeg) classification tasks: a review," 2019.
[4] F Mattioli, et al. "A 1dcnn for high accuracy classification and transfer learning in motor imagery eeg-based brain-computer interface," 2022.
[5] A. L. Goldberger et al., "PhysioBank, PhysioToolkit, and PhysioNet: Components of a new research resource for complex physiologic signals," 2000.