ETH ZÜRICH

MASTER OF SCIENCE IN ROBOTICS, SYSTEMS AND CONTROL

Leveraging Deep Learning for Real-time EEG Classification at Cybathlon's BCI-race

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Introduction

Brain Computer Interface (BCI) is a recent field of research that has gained in popularity for the past few decades. It illustrates the need for scientists to get a more complete understanding of the human brain allowing for direct brain-machine communication and the restoration of movements for people with disabilities. Current BCI research heavily relies on Motor Imagery Electroencephalography (MI-EEG) where a patient is asked to perform an action mentally while electrodes placed along the scalp record the superficial neural activity. The ultimate goal of BCI technology is to classify these signals reliably in real-time. However this field has to face many challenges which are far from being solved: noisy and complex signals, brain complexity, variability among subjects, hardware limitations, etc...

In this project, we will focus on the BCI race held at the Cybathlon - an international competition for disabled competitors organized by ETH Zurich. During the competition, pilots from different teams are controlling via MI-EEG a virtual agent that is asked to perform specific tasks in a gamified environment. We choose to leverage deep learning technology as it managed to show for the past few years its superiority w.r.t traditional machine learning approaches in fields such as computer vision & natural language processing. Instead of relying on hand-crafted features, we want the model to be able to learn and target useful features in brain signals that will increase the classification performance.

Our goal in this project is to design an end-to-end architecture that will be capable of classifying multi-channel EEG data in real-time while achieving state-of-the-art results.

Keywords: MI-EEG, real-time classification, deep learning, Cybathlon.

Tasks

The expected pipeline will be coded from scratch using Python and can be split in the following blocks:

- **Data visualization & analysis.** Familiarize with EEG data and the different acquisition, visualization & analysis methods.
- **Preprocessing & Feature extraction.** Format, filter & split dataset and use common feature extraction methods.
- **Model training.** Design new or existing neural network architectures &train them from scratch and/or use a transfer learning strategy.
- **Novelty.** Propose improvements by building upon different existing architectures while integrating recent research novelties (attention mechanism, augmentation, distillation,...).

- **Benchmarking.** Compare traditional machine learning approaches with several state-of-the-art deep learning architectures and our method.
- **Online inference.** Integrate & test the pipeline in real conditions.

Timeline

We propose to distribute the different project components as following:

- **March.** Literature review, data visualization/analysis & writing the preprocessing pipeline.
- **April.** Choosing and reproducing baseline methods & writing the model training pipeline.
- **Mai-July.** Improving upon the baseline, training new models & writing the benchmarking & inference pipeline.
- **August-September.** Finalizing experiments, preparing the final presentation & report.

References

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