ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Distributed Computing

Prof. R. Wattenhofer

EEG, Eye Tracking and BCI

Deep Learning is inspired by the brain structure. But can deep learning help us to advance our understanding of brain functions?

The collection of eye gaze information provides a window into many critical aspects of human cognition, health and behavior. Brain-computer interfaces can for example be used to decode locked-in patients' brain signals in order to facilitate communication.

The eyenet group has recently developed a neural network framework for event detection for time series. DETRtime achieves state-of-the-art performance in ocular event detection across diverse eye-tracking experiment paradigms. In addition to that, they provided evidence that the model generalizes well in the task of EEG sleep stage segmentation.

Done within the eyenet group, the purpose of the thesis is multifold: The focus lies in predicting whether participants intend to press yes or no during certain experiment settings. The experiment settings need to be understood and defined in a meaningful but to the thesis proportional effort.

As a starting point, one focuses on the prediction using Electroencephalography (EEG) data, involving the understanding of brain measurement data, common methods for binary prediction based on that data type, and state-of-the-art models with research in how these models could be improved and where difficulties lie. For sure, one wants to include a part on DETRtime which currently achieves state-of-the-art performance in ocular event detection across diverse eye-tracking experiment paradigms.

A second focus could then be laid on the prediction using eye tracker coordinates and EEG data. This involves the understanding of eye tracker coordinates data, standard methods for binary prediction based on that data type, and state-of-the-art models, respectively their improvement and weak points. When combining EEG data and eye tracker coordinates data, one is looking for a hybrid modeling approach. This approach is also based on results of two other students that are doing their semester project on the hybrid modeling approach.

In general, the goal lies on one side in finding questions and fields that should be explored or pose problems. This should be done in the process of reading introductions and building background knowledge. On the other hand, the practical part of the thesis should be focused on the improvement of existing models. This happens in discussion with the advising PhD students.

The choice of a concrete model depends on the identified problem areas. Problems could, for instance, arise from a data shift and therefore a possible direction could go in the field of domain adaptation, domain generalization and causality. Another area can be seen as understanding uncertainty behind model predictions and therefore introducing more probabilistic modeling approaches.

From a mathematical perspective, we want to lay out the theoretical background on which the thesis is based. This includes the mathematics behind the structure and components of neural networks, theoretical consequences, and properties of different architectures which are being considered. It is important that the subjects being worked on, in practice, are embedded in a mathematical framework. This could, for example, when treating domain generalization, lie in statistical learning theory, i.p empirical risk minimization. For probabilistic models, one would likely want to include Bayesian statistics and discuss distributions from a theoretical point of view. The actual choice of mathematical topics depends on the different focuses.

A general question accompanying the thesis is a more philosophical one, whether attention or focus is measurable. This question can be discussed in the experiment approaches but also when seeing the results of measurements. It is something to be reflected on until the end of the thesis.

Requirements:
Knowledge in Deep Learning, or solid background in Machine Learning.
Implementation experience with TensorFlow or PyTorch is an advantage.

Interested? Please contact us for more details!

Contact

- Ard Kastrati: kard@ethz.ch, ETZ G61.3
- Martyna Plomecka: martyna.plomecka@uzh.ch, AND 4.90
- Anh Duong Vo: anhduong.vo@inf.ethz.ch, CAB E 71.1