

Bachelor Thesis overview

Aim:

The aim of this study is to gain insight into the fundamental learning rules underlying intelligence as we know it from our own brain and modern deep learning systems. By better understanding these underlying principles, we might discover alternative ways to build, train and deploy systems that learn from data in more efficient ways.

Background:

In the recent years, deep learning has shown impressive results due to the availability of massive parallel compute and huge amounts of data. From the biological inspiration of the neuron to the perceptron where data inputs are weighted, summed together and thresholded, several new modern architectures, like recurrent, residual and transformer neural networks have pushed the limits and achieved state of the art results in speech recognition, computer vision and natural language understanding. Despite of these networks being originally inspired by the brain, the backpropagation (backprop) algorithm for learning the weights and deep learning in general has been criticized for being biologically *implausible*.¹ In their 2015 paper, Bengio et al. lists several reasons as to why that is. This project will primarily be dealing with one of them: *The weight transport problem* which arises from the way backprop uses the connection weights in both the forward pass (inference) and the backwards pass (calculating the gradients), requiring that both forward and backward connections have symmetric weights.

Content:

This bachelor thesis will discuss the biological plausibility of modern deep learning. It will compare backpropagation to biologically constrained learning algorithms from the literature such as Predictive Coding (and a derivative hereof called Z-IL)² and make connections to the learning process in the brain, variational bayesian methods and active inference³. At last it will include a discussion on what possible benefits deep learning can gain from studying the brain and how this might be used in practice.

Research questions:

The project will address the following three research questions:

- According to the current literature, what are the biological constraints of biological learning?
- To what extend can predictive coding be used to approximate backpropagation under the above mentioned biological constraints?
- In what ways can modern deep learning benefit from biological plausible learning algorithms?

¹ Bengio, Y., Lee, D.-H., Bornschein, J., & Lin, Z. (2015). Towards Biologically Plausible Deep Learning. arXiv: [arXiv:1502.04156](https://arxiv.org/abs/1502.04156)

² Song, Y., Lukasiewicz, T., Xu, Z., & Bogacz, R. (2020). Can the Brain Do Backpropagation? -Exact Implementation of Backpropagation in Predictive Coding Networks. Advances in neural information processing systems, 33, 22566–22579.

³ Friston, K., FitzGerald, T., Rigoli, F., Schwartenbeck, P., O'Doherty, J., Pezzulo, G., Active inference and learning, Neuroscience & Biobehavioral Reviews, Volume 68, 2016, Pages 862–879, (<https://www.sciencedirect.com/science/article/pii/S0149763416301336>).

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