Unsupervised Learning in Multiple Time-Scale Recurrent Neural Networks

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Description: Neural networks of the brain are highly recurrent and learn through unsupervised learning mechanisms implemented via a combination of plasticity rules operating at individual neurons and synapses. Our brains are able to build abstract representations of the world without requiring millions of labeled training examples and can creatively find new solutions to problems. Understanding the mechanisms allowing our brains to form such abstract representations in an unsupervised manner would represent a large step towards understanding brain function and could inspire a new class of artificial neural networks that can form abstract representations and generate complex behaviors. In this internship, we will consider a new class of multiple time scale recurrent neural networks that learn through unsupervised biologically inspired local learning rules such as so-called spike timing dependent plasticity. These networks embody abstract principles of unsupervised learning in the brain, while being suitable for implementation on digital computers (Figure 1). The specific goal of the internship will be to explore the utility of having a hierarchy of time-scales embedded into the network for the prediction and generation of complex sequences. We will study this in one or more application domains such as natural language or music prediction and generation. The specific objectives of the internship are:

- Review literature on unsupervised sequence learning and self-organizing recurrent neural networks
- Design and conduct experiments to test the advantages of embedding a hierarchy of time scales into the recurrent neural nework in one or more problem domains including language and music processing
- Analyse the data and document the results.

Requirements: You are expected to have excellent programming skills, preferably in Python. Prior experience with machine learning, in particular recurrent neural networks is desired. An interest in Computational Neuroscience, e.g. spiking neural networks is a plus.

Figure 1: Schematic depiction of a self-organizing recurrent neural network composed of excitatory (blue triangles) and inhibitory (red circles) neurons learning with different plasticity mechanisms. The network learns to predict future inputs on the basis of past inputs (black arrows). By feeding the network's own predictions as inputs, the network becomes an autonomous dynamical system that can „creatively“ generate novel sequences.