M.Sc. Florian Walter

Contact Data

Institute
Informatics

Affiliation
Computer Science, Robotics and Embedded Systems

Address
Boltzmannstraße 3
85738 Garching bei München
Germany

Office
03.07.037

E-mail
florian.walter@tum.de

Web
Homepage

Research at a Glance

Project:
Brain-Derived Modular Neural Networks

Supervisors:
Prof. Dr.-Ing. habil. Alois Knoll (TUM)
Prof. Henry Markram (EPFL)

Start of doctoral project at GSB:
May 2016
**Project Description:**

The brain is the most versatile, flexible, energy-efficient, and robust information processing system known to date. It derives its computational power from a complex system of billions of neurons that are interconnected in a continuously changing network. Researchers have early conceived simplified mathematical models of this network both to understand how the brain works and at the same time to apply this knowledge in technical systems. In recent years, massive parallel processing power and large storage capacities have enabled the simulation of neural network models at large scale.

Currently, there are two main classes of neural network models. In computational neuroscience, the focus is on models that predict and reproduce findings from neuroscientific experiments on different levels of biological detail. This requires neuron models and network topologies that closely capture the specific properties of biological systems. By contrast, neural networks in machine learning and artificial intelligence are primarily optimized for application performance. Therefore, only some basic structural properties are loosely inspired by the brain. Nevertheless, deep artificial neural networks with many processing layers currently set the benchmark in many applications ranging from image classification to robot control.

Even though artificial neural networks have even achieved superhuman performance in several machine learning tasks, the underlying mechanisms of information processing are still considerably different from those in the brain, which has a modular structure where different tasks are processed in different brain regions. Artificial neural networks have a monolithic black box-architecture and a highly regular network topology. In most models, training is performed offline and requires statistically independent data samples. Recent results have shown that already small perturbations to the input data that are invisible to humans can lead to erroneous output. These issues clearly show that current neural network models in machine learning neglect essential architectural properties of biological brains. At the same time, neuroscientific models are too complex for applications in machine learning. Moreover, both types of models completely neglect embodiment, the embedding of the brain in a body and an environment.

The goal of this doctoral thesis project is to develop a novel neural network architecture that implements two of the most important features that are missing in current models. First, the architecture will implement a modular structure with functional subnetworks that – similarly to brain regions – process modality-specific input data. Hub networks fuse these segregated information streams into a coherent percept based on the current task through multisensory integration. The second contribution is a learning mechanism for this novel architecture that is based on training protocols. These training protocols mimic the developmental processes of living creatures where development undergoes different stages that are closely coupled to body growth. The implementation of the training protocols will therefore be based on neurorobotics, which means that the network model will be trained through interaction with the environment inside a simulated or physical robot body. Learning will be based on a closed perception-action-loop where actions of the robot have direct influence on the sensory input processed by the neural network model and thereby also on the next action that will be executed. The statistical regularities induced by this process through the specific morphology of the robot body and the properties of the environment drive the learning of the connectivity between the different component networks.

The contributions of the proposed novel network architecture will be twofold. First, compared to current monolithic architectures, the organization of the network into different functional modules will make the information processing within the network transparent and make the system more robust. Second, the implementation of embodied training protocols based on developmental neurorobotics will enable the training of large and complex networks with brain-like connectivity. The learning of the connectivity between component networks and hub networks will in particular yield a new approach for multisensory integration.
Selected Publications


Feldotto, Benedikt; **Walter, Florian;** Röhrbein, Florian; Knoll, Alois: Hebbian learning for online prediction, neural recall and classical conditioning of anthropomimetic robot arm motions. Bioinspiration & Biomimetics 13 (6), 2018, 066009.


Akl, Mahmoud; **Walter, Florian;** Röhrbein, Florian: Learning Spiking Neural Controllers for In-silico Navigation Experiments. TUM Chair of Robotics, Artificial Intelligence and Real-Time Systems, 2015


Research Projects

The Human Brain Project
EU
SP 10 Neurorobotics
Web I www.humanbrainproject.eu
Web I www.neurorobotics.net