論文の内容の要旨

Learning Rules for Data Representation with Dynamical Neural Systems
(動的ニューラルシステムによるデータ表現のための学習法則)

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Neural integration, and the neural representation of sensory input, remains an incompletely understood topic in neuroscience. We show here first that the theoretical approach of modeling neural integration by means of data representation allowed to gain some insight into the principles and mechanisms of neural integration. Data representation is a mathematical method to find a change of basis for the input which matches the structure of the data.

The encoding transforms which are in existing data representation methods used to calculate the new representation of the input with respect to the new basis did however either not include a time structure, or they were acausal. If neural integration is modeled by means of data representation, the input should be encoded into neural activity by means of a valid neuron model. We point then out that the encoding transforms of existing data representation methods correspond to rather abstract neuron models, and that the modeling of neural integration by means of data representation could be improved by using dynamical neural systems for the encoding.

We derive then learning rules for data representation with dynamical neural systems. We focus on neural systems which are composed of integrators. The integrators signal by means of spikes. We use two models for the integrators. In a first model, the neuron model is a formal spiking neuron in the sense that the action potentials are not modeled. In a second model, the neuron model is a real spiking neuron in the sense that the upstroke of the action potential is also modeled. The derived learning rules are for data representation with a single neuron, and in the case of the formal spiking neuron, also for data representation with a population of neurons. In that case, the neurons may have lateral connections.

The application of the learning rules to represent an input signal by means of a population of neurons illustrates the usefulness of the derived learning rules for the study of neural integration and representation: After learning, the input was accurately represented by the population of neurons, and the learning rules led to self-organized neural differentiation.