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Learning spike-timings based representations of sensory stimuli with leaky integrate-and-fire neurons

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Introduction

Stimuli from the environment are sensed by a population of receptor neurons and then carried by spike trains to further processing stages in the brain. Our work deals with the question how, in the early sensory system, rich stimuli from the natural environment can be represented by spike trains. In theoretical approaches to this questions, neural representation is often modeled as an encoder-decoder system: a sensory stimulus is encoded into neural activity and a hypothetical decoder indicated how the neural activity must be read to construct the internal representation of the stimulus.

Previous work

Assuming models for the encoder-decoder pair, in previous work, the free parameters in the models have been learned from natural stimuli, and successfully related to properties of the early sensory system [1]. Much emphasis in previous work has been on the principle that guide the learning process, for example information theoretical [2,3] or energetic principles [4]. Less attention was given to the role of the underlying neuron model. Recently, we have proposed in [5,6] data representation where the encoding happens with a simple spiking neuron model (the Spike Response Model SRM_0 [7]) and the spike timings serve to continuously update the ongoing internal representation.

Results

Here, we first formulate the theory of an encoder-decoder system for leaky integrate-and-fire neurons and then extend the previous models of learning spike timings-based representations. As time is explicitly present in our framework, the internal representation that is constructed from the spike timings can be about the stimulus prior to the spike or an internal prediction of the future stimulus. We present the learning of an encoder-decoder pair where each spike is used both to update the prediction of the future stimulus and to correct the representation of the stimulus before the spike. We present thus the learning of a prediction-and-correction based internal representation of the sensory stimulus.

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