Effects of a Modulatory Feedback upon the BCM learning rule

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Thomas Girod[1], Frédéric Alexandre[1]

[1] INRIA-Lorraine, Nancy, France
E-mail: thomas.girod@loria.fr

Background

In 1982, Bienenstock, Cooper and Munro introduced the BCM rule [1]. The background hypothesis is that the threshold between long-term potentiation (LTP) and long-term depression (LTD) is be dynamic and function of the neurons' history. The resulting learning rule is local, unsupervised and can reproduce phenomena such as the acquisition of orientation selectivity and occular dominance in the primary visual cortex. Later, the BCM rule was applied to a map of cortical "units" having inhibitory interactions. This mechanism was proved to create a competition among the population, thus spreading the individual selectivities of units over the input space [2]. Using lateral connectivity patterns inspired by local center-surround connectivity in V1, they were able to obtain self-organized maps of orientation selectivity [3].

Information arriving at one location of the cortex is often schematically represented as the composition of three flows. The *feedforward flow*, coming from extra-cortical structures, the *lateral flow*, representing short distance interactions between neurons within an area, and the *feedback flow* representing influence from distant areas. Obviously, previous works on BCM introduced the feedforward and lateral flows. Our intent is to introduce the feedback flow in the model.

Approach

Feedback stimulation is usually seen as having a modulatory influence over the activity rather than a driving influence [4]. This modulation generally comes from higher areas of the brain, such as MT modulation over V1.

To reflect this, we introduce feedback as a multiplicative term applied to postsynaptic activity. This shift of activity alters the behaviour of the learning rule, as it can cause a switch from LTD to LTP (and reciprocally). Thus, the modulatory feedback allows us to influence the overall learning process occuring on the feedforward connectivity.

Experiment

We tested the influence of feedback modulation over feedforward learning process by running a learning task on a population of units sharing the same receptive field, with a training set composed of normalized stimuli. During the learning process, one stimulus of the training set was always presented coincidentally with a facilitatory feedback. We ran the same learning task with feedback signals of various strength. The experiment clearly showed a bias in favor of the coincident stimulus, correlated with the strength of the feedback signal.
In a second experiment with the same setup, we varied the probability of coincident apparition of a chosen stimulus and the feedback signal. Again, this experiment shows a bias in favor of the chosen stimulus, correlated with the probability of appearance of the feedback signal.

Perspectives

Feedback controlled modulation allows us to orient BCM learning occuring on the feedforward flow. We are currently working on an application of this principle to introduce constraints on the self-organization of a cortical map representing V1. With this work, our goal is to learn in parallel orientation selectivity on LGN → V1 layer IV, and cortico-cortical, iso-oriented, co-aligned connectivity within layer II/III.

References

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