Multi-sensory integration by constrained self-organization

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Abstract

We develop a model for multi-sensory integration to perform sensorimotor tasks. The aim of this model is to provide missing modality recall and generalization using cortically-inspired mechanisms. The architecture consists of several multilevel cortical maps with a generic structure. Each map has to self-organize with a continuous, decentralized and unsupervised learning which provides robustness and adaptability. These self-organizations are constrained by the multimodal context to obtain multi-sensory generalization.

Mechanisms of the model

- continuous, decentralized and unsupervised learning
- perception represented by a neural map
- multi-sensory integration through associative map
- emergence of perception by a competitive mechanism (Continuous Neural Field Theory)
- emergence of a multimodal perception thanks to the relaxation of multi-sensory constraints
- neural map self-organization constrained by the multi-sensory context

Description of the model

Multi-sensory interactions

Neural maps: cortical column view

Perceptive layer: BCM's learning rule

BCM's learning rule

\[ u = w \cdot x \]
\[ \theta = E_r [u^2] \]
\[ \Delta w = \eta \cdot x \cdot \phi(u, \theta) \]

BCM's properties

- spatial competition leading to stimulus selectivity
- weights regulation thanks to the sliding threshold

Modification of the BCM's learning rule

Feedback modulation of BCM

- modulation of the neuron activity influences the neuron selectivity
- activity bump is used as feedback modulation signal
- spatial coherence of the bump creates self-organization at the map level

Unlearning mechanism in BCM

\[ u = w \cdot x + f(\text{feedback}) \]
\[ \theta = E_r [u^2] \]
\[ \Delta w = \eta \cdot x \cdot \alpha \cdot m(\text{feedback}) \cdot x \cdot u^2 \]

- decreases weights when an inconsistence is detected (u high and feedback low)
- useful for bootstrapping (neuron selectivity has to develop before feedback can be consistent)
- helps to relax multimodal constraints
- must allow the addition of a new perception in an incremental way

Results

Map self-organization (orientation + colour)

Conclusion

With the modified learning rule, we obtain the self-organization of the map, which can be influenced by the multi-sensory context.