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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](image)

Neural maps: cortical column view

- competitive layer
  - computes the competition between cortical columns connected with difference of gaussian shape
  - merges the perceptive and cortical influences

- merge layer
  - computes the value of a lateral strip shape connection to the associative map

- cortical layer
  - receives the perceptive inputs (BCM learning used)

- perceptive layer
  - computes the perceptive map

**Perceptive layer: BCM's learning rule**

### BCM's learning rule

\[
\begin{align*}
  u &= w \cdot x \\
  \theta &= E_r [u^2] \\
  \Delta w &= \eta \cdot x \cdot \phi(u, \theta)
\end{align*}
\]

### 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**

\[
\begin{align*}
  u &= w \cdot x + f(feedback) \\
  \theta &= E_r [u^2] \\
  \Delta w &= \eta \cdot x \cdot u \cdot \left( u - \theta - \alpha \cdot m(feedback) \cdot \chi \cdot u^2 \right)
\end{align*}
\]

- 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.