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To cite this version:

HAL Id: inria-00536933
https://inria.hal.science/inria-00536933
Submitted on 17 Nov 2010

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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 multisensory 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*

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

*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*

\[
\begin{align*}
\Delta w &= \eta \ast x \ast u \ast (u - \theta - \alpha \ast m(feedback) \ast \chi \ast u^2)
\end{align*}
\]
- decreases weights when an inconsistency 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.