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► **To cite this version:**

Mathieu Lefort, Yann Boniface, Bernard Girau. Multi-sensory integration by constrained self-organization. Third EUCogII Members Conference - Multisensory integration, Oct 2010, Palma, Spain. inria-00536933

HAL Id: inria-00536933

<https://hal.inria.fr/inria-00536933>

Submitted on 17 Nov 2010

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Multi-sensory integration by constrained self-organization



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Abstract

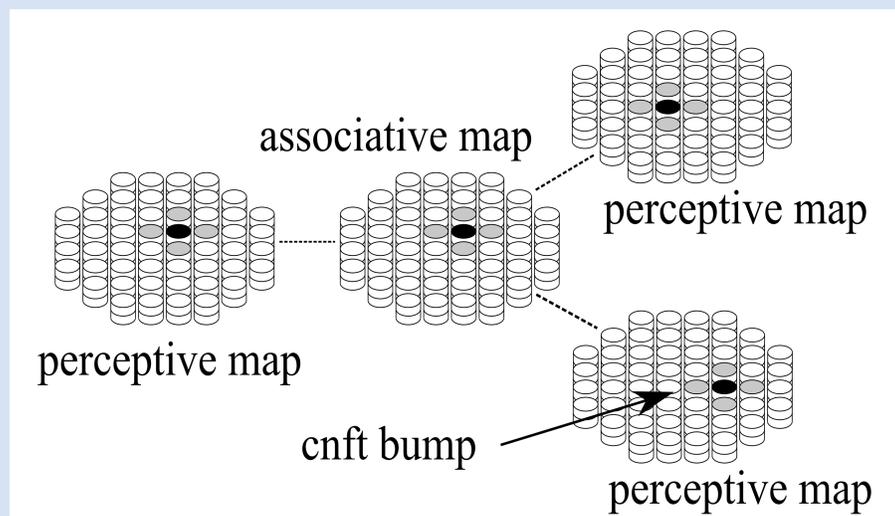
We develop a model for multi-sensory integration to perform sensorimotor tasks. The aim of this model is to provide missing modality recall and generalization using cortically-inspired mechanisms. The architecture consists of several multilevel cortical maps with a generic structure. Each map has to 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 multi-sensory generalization.

Mechanisms of the model

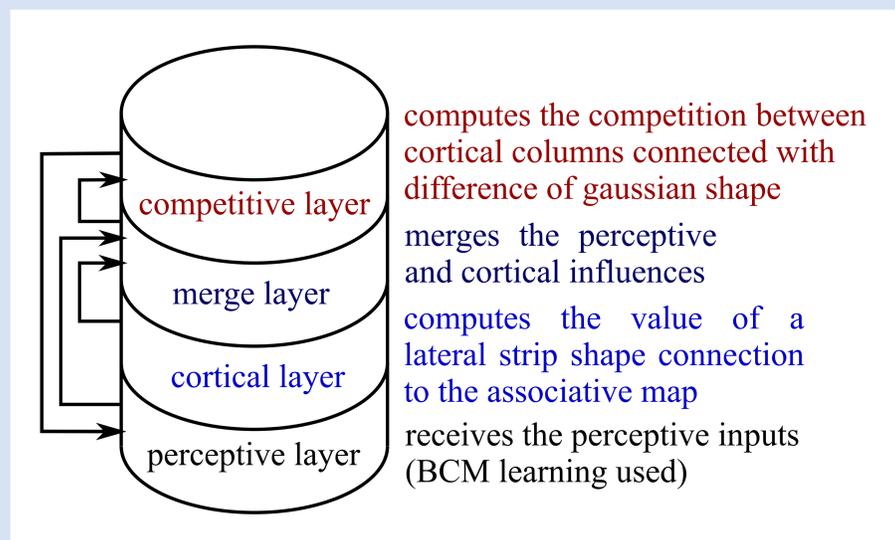
- continuous, decentralized and unsupervised learning
- perception represented by a neural map
- multi-sensory integration through associative map
- emergence of perception by a competitive mechanism (Continuous Neural Field Theory)
- emergence of a multimodal perception thanks to the relaxation of multi-sensory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

Description of the model

Multi-sensory interactions



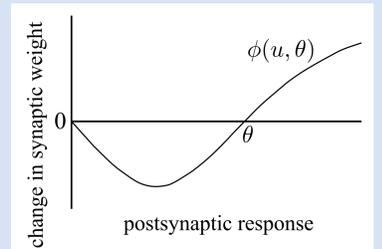
Neural maps: cortical column view



Perceptive layer: BCM's learning rule

BCM's learning rule

$$\begin{aligned}
 u &= w \cdot x \\
 \theta &= E_{\tau}[u^2] \\
 \Delta w &= \eta * x * \phi(u, \theta)
 \end{aligned}$$



BCM's properties

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

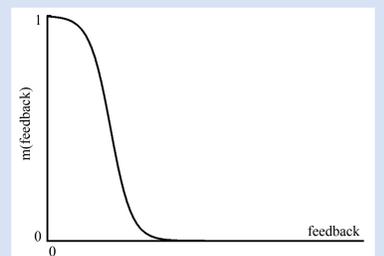
Modification of the BCM's learning rule

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

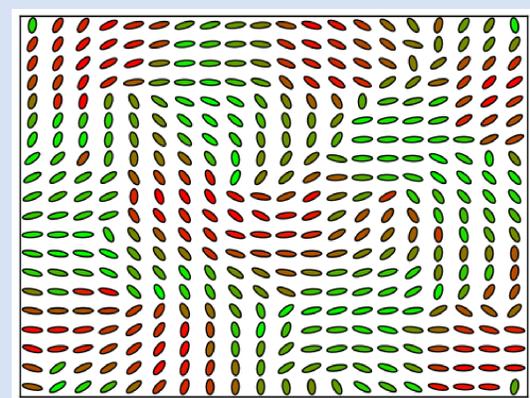
$$\begin{aligned}
 u &= w * x + f(\text{feedback}) \\
 \theta &= E_{\tau}[u^2]
 \end{aligned}$$



$$\Delta w = \eta * x * u * (u - \theta - \alpha * m(\text{feedback}) * \chi * u^2)$$

- 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 a 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.