Fundamentals of Computational Neuroscience

Chapter 10: The cognitive brain

Hierarchical maps and attentive vision

A. Ventral visual pathway

B. Layered cortical maps

A. Ventral visual pathway

B. Layered cortical maps
Attention in visual search and object recognition

Model
Example results

A. "Parallel search"

- Time
- Activity
- Number of items

B. "Serial search"

- Time
- Activity
- Number of items

The interconnecting workspace hypothesis

Stanislas Dehaene, M. Kergsberg, and J.P. Changeux, PNAS 1998
Stroop task modelling

1) The brain can develop a model of the world, which can be used to anticipate or predict the environment.

2) The inverse of the model can be used to recognize causes by evoking internal concepts.

3) Hierarchical representations are essential to capture the richness of the world.

4) Internal concepts are learned through matching the brain’s hypotheses with input from the world.

5) An agent can learn actively by testing hypothesis through actions.

6) The temporal domain is an important degree of freedom.

The anticipating brain
Recurrent networks with hidden nodes

The Boltzmann machine:

Energy: \( H^{nm} = \frac{1}{2} \sum_{ij} w_{ij} s_i^n s_j^m \)

Probabilistic update: \( \rho(s_i^n = +1) = \frac{1}{1 + \exp(-p \sum_j w_{ij} s_j^m)} \)

Boltzmann-Gibbs distribution: \( \rho(s^{vn}; w) = \frac{1}{Z} \sum_{s^{hn}} \exp(\beta H^{vn}) \)
Training Boltzmann machines

**Kulbach-Leibler divergence**

\[
KL(p(s'), p(s'; w)) = \sum_s p(s') \log \frac{p(s')}{p(s'; w)} = \sum_s p(s') \log p(s') - \sum_s p(s') \log p(s'; w)
\]

Minimizing KL is equivalent to maximizing the average log-likelihood function

\[
l(w) = \sum_s p(s') \log p(s'; w) = \langle \log p(s'; w) \rangle.
\]

Gradient descent → **Boltzmann Learning**

\[
\Delta w_i = \eta \frac{\partial l}{\partial w_i} = \eta \frac{\partial}{\partial w_i} \left( \langle s_i s_j \rangle_{\text{clamped}} - \langle s_i s_j \rangle_{\text{free}} \right).
\]

The restricted Boltzmann machine

Contrastive Hebbian learning: Alternating Gibbs sampling
Deep generative models

Adaptive resonance theory (ART)
Further readings


Jeff Hawkins with Sandra Blakeslee (2004), On Intelligence, Henry Holt and Company.


