6th Neural Coding Workshop, Marburg, Germany, 23–28 August 2005

Stochastic Interaction in Neural Systems

Thomas Wennekers[1], Nihat Ay[2], and Peter Andras[3]

[1] Centre for Theoretical and Computational Neuroscience,
University of Plymouth, PL4 8AA Plymouth, United Kingdom
thomas.wennekers@plymouth.ac.uk

[2] Mathematics Intitute, Friedrich Alexander University Erlangen-Nuremberg,
Bismarck-Straße 1 1/2, 91054 Erlangen, Germany
ay@mi.uni-erlangen.de

[3] School of Computing Science, University of Newcastle,
NE1 7RU Newcastle upon Tyne, United Kingdom
peter.andras@ncl.ac.uk

Brains are information processing systems evolutionary adapted since millions of years. It seems plausible therefore that they follow information theoretic optimization principles. In the early visual system *mutual information maximization (Infomax)* is one such widely accepted principle which claims that neurons represent as much information as possible in their output about the ensemble of stimuli at their input. The principle minimizes coding redundancy in feedforward pathways thereby efficiently coupling the brain to its environment, and it supports self-organization of fairly realistic receptive fields.

Independent information channels seem useful for early stimulus coding under a bottleneck constraint, but brain activity is more complex in that cortical neurons get dynamically engaged into functional networks. They interact massively within and between areas in order to integrate distributed information into functional ensembles as tentatively expressed by highly dynamic correlation patterns in their activity. Synchronized oscillations and synfire-chain-like spatio-temporal firing patterns are the two best known correlation patterns suggested to serve cortical integration.

The *maximization of spatio-temporal stochastic interactions* (called TIM for *temporal Infomax*) has been proposed as an information-theoretic organizing principle in neural systems which supports complex correlation patterns and a high cooperativity among cells. Instead of information transfer between input and output units it maximizes information exchange between all units in a system thereby emphasizing dynamic cooperation in recurrent networks in favor of static feedforward encoding systems only.

In the present work we show

- similarities between Infomax and TIM in so far as Infomax maximizes the global flow through a (feedforward) system and TIM the sum of local flows [1]
- typical properties of strongly interacting systems, in especially an almost deterministic global dynamic, nonetheless accompanied by almost random local firing patterns, similar as in synfire chains [2]
- that attractor networks have low, but synfire chain networks an almost maximal spatio-temporal interaction [3]
- that TIM leads to context dependent receptive fields, input dependent internal transitions, and rule-like behavior [4]
- that timing dependent learning rules induce a high (though not always maximal) stochastic interaction in Markov chains and probabilistic neural networks [4,5]
- that interaction in multiple electrode data from cat primary auditory cortex is fairly high.

Taken these results together we hypothesize that cortical neural systems may maximize spatio-temporal stochastic interaction and that activation-based local temporal learning rules support this.

References

[1] N. Ay (2002) Locality of Global Stochastic Interaction in Directed Acyclic Networks, Neural Computation 14, 2959–2980.

[2] N. Ay and T. Wennekers (2003a) Dynamical properties of strongly interacting Markov chains. Neural Networks 16, 1483–1497.

[3] T. Wennekers and N. Ay (2003b) Spatial and Temporal Stochastic Interaction in Neuronal Assemblies. Theory in Biosciences 122, 5–18.

[4] T. Wennekers and N. Ay (2005a) Finite state automata resulting from temporal information maximization and a temporal learning rule. Neural Computation, in press.

[5] T. Wennekers and N. Ay (2005b) A temporal learning rule in recurrent systems supports high spatio-temporal stochastic interactions. Submitted.