UNIVERSITÄT OSNABRÜCK

Institute of Cognitive Science

confirmed speakers:
Sophie Denève
József Fiser
Claus Hilgetag
Herbert Jaeger
James Kilner
Konrad Körding
Frank Pasemann
Peggy Seriès
Fritz Sommer
Shimon Ullman
Paul Verschure
Angela Yu

discussants:
Tim Kietzmann
Johannes Schumacher
Niklas Wilming

poster session

group work

organizing committee:
Frank Jäkel
Peter König
Gordon Pipa

venue:

workshop:
Industrie- und Handelskammer
Osnabrück-Emsland-Grafschaft Bentheim
www.osnabrueck.ihk24.de

public talk:
Universität Osnabrück, Schloss, Aula
www.uos.de

email:
occam2011@cogsci.uni-osnabrueck.de

internet:
www.occam-os.de

OCCAM 2011

Osnabrück Computational Cognition Alliance Meeting
on „Natural Computation in Hierarchies“

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Bifurcation Analysis of Multiplicatively Interacting Populations of Spiking Neurons

Fereshteh Lagzi, Stefano Cardanobile, Stefan Rotter

Bernstein Center Freiburg & Faculty of Biology, University of Freiburg

Hansastraße 9a, Freiburg, Germany

http://www.bcf.uni-freiburg.de

fereshteh.lagzi@bcf.uni-freiburg.de

We study the behavior of a sparsely connected network of excitatory and inhibitory neurons described by multiplicatively interacting point processes. In our analysis, the excitatory and inhibitory subpopulations are compactly described by two populations which interact with each other according to the parameters of the synaptic couplings in the network. Using an exponential activation function to derive the expected value of the dynamic firing rates of the two populations, two mutually coupled nonlinear differential equations reflect the large scale dynamics of the network.

Depending on the network parameters, we find three different types of stationary state in our system, corresponding to synchronous regular (SR), asynchronous regular (AR), and asynchronous irregular (AI) network activity. The relative strength of recurrent inhibition plays the role of a bifurcation parameter, which changes the excitation-inhibition balance. Another bifurcation parameter is the intensity of external input, which is effective in the emergence of the AR state for short synaptic delays. In our model, the transition between these states is described by a Hopf bifurcation. In fact, the bifurcation diagram for multiplicatively interacting neurons matches reasonably well with the results from a similar analysis of sparsely connected random networks of leaky integrate-and-fire neurons for short synaptic time delays (N Brunel, J Comput Neurosci 2000).

Our analysis represents only a first step toward analyzing the dynamics of more general “networks of networks” that are implicated in various cognitive abilities of the brain.

Hierarchically clustered network topologies: The relevance of robustness in reservoir networks and neuronal cultures

Sarah Jarvis[1,2], Stefan Rotter[1,3], Ulrich Egert[1,2]

[1] Bernstein Center Freiburg, University of Freiburg, Hansastrasse 9A, Freiburg im Breisgau, Germany www.bcf.uni-freiburg.de jarvis@bcf.uni-freiburg.de

The inclusion of hierarchy in an information processing system has been demonstrated to lead to the several interesting properties, such as improved propagation of activity, that cannot be obtained if using comparable but non-hierarchically organized networks. Here, we present the findings of our work on two separate but related models, both of which highlight the importance of hierarchy in clustered networks.

The first is Echo State Networks, a type of artificial network in which a reservoir of analogue units are connected in a manner that is random, sparse and fixed. They have been demonstrated to have excellent performance in the prediction of non-linear sequences; however, due to their recurrent structure, a key issue in their use is that of ensuring reservoir stability. We have previously demonstrated (Jarvis et al., 2010) that while the inclusion of hierarchical clusters within the reservoir slightly impedes the optimal performance in the network, their presence greatly increases the robustness of the network with respect to stability. By examining the location of connections between clusters, we also established that this effect is present but far diminished in the instance where the reservoir is non-hierarchically clustered.

We relate these findings to our second example: dissociated cortical cultures, in which neurons are no longer constrained by cortical architecture but instead self-organize to form their own network structure on a 2D surface. Present in their dynamics are periods of strongly synchronized spiking by the network, termed `bursting', in which activity propagates faster than can be accounted for by purely local connectivity. Using a network model of spiking neurons, we demonstrate how the presence of clusters is a necessary condition for bursting and investigate the importance of hierarchy in facilitating activity propagation throughout the network.

Jarvis, Rotter, Egert (2010) “Extending Stability Through Hierarchical Clusters in Echo State Networks” Front Neuroinformatics. 2010; 4: 11.