DYNAMICS DAYS EUROPE
3-7 SEPTEMBER 2018

MS20: Linking the dynamics of oscillator models to real-world networks
Titles and Abstracts

Speaker: Alex Roxin, CRM Centre for Mathematical Research, Barcelona, Spain

Title: Network Mechanisms Underlying the Role of Oscillations in Cognitive Tasks

Abstract: Oscillatory activity robustly correlates with task demands during many cognitive tasks. However, not only are the network mechanisms underlying the generation of these rhythms poorly understood, but it is also still unknown to what extent they may play a functional role, as opposed to being a mere epiphenomenon. Here we study the mechanisms underlying the influence of oscillatory drive on network dynamics related to cognitive processing in simple working memory (WM), and memory recall tasks. Specifically, we investigate how the frequency of oscillatory input interacts with the intrinsic dynamics in networks of recurrently coupled spiking neurons to cause changes of state: the neuronal correlates of the corresponding cognitive process. We find that slow oscillations, in the delta and theta band, are effective in activating network states associated with memory recall by virtue of the hysteresis in sweeping through a saddle-node bifurcation. On the other hand, faster oscillations, in the beta range, can serve to clear memory states by resonantly driving transient bouts of spike synchrony which destabilize the activity. We leverage a recently derived set of exact mean-field equations for networks of quadratic integrate-and-fire neurons to systematically study the bifurcation structure in the periodically forced spiking network. Interestingly, we find that the oscillatory signals which are most effective in allowing flexible switching between network states are not smooth, pure sinusoids, but rather burst-like, with a sharp onset. We show that such periodic bursts themselves readily arise spontaneously in networks of excitatory and inhibitory neurons, and that the burst frequency can be tuned via changes in tonic drive. Finally, we show that oscillations in the gamma range can actually stabilize WM states which otherwise would not persist.

Speaker: Helge Dietert, Université Paris Diderot, Sorbonne Paris Cité, France

Title: Continuum approximation around stable states

Abstract: The continuum limit is a valuable approximation in order to explain the stability of configurations with many oscillators (Landau damping, phase mixing). For short times, the approximation can be justified by the classical Dobrushin and Neunzert estimate. In this talk, I will discuss how the approximation can hold for longer times near stable configurations.

Speaker: Kyle Wedgwood, University of Exeter, Exeter, UK

Title: Bumps and waves - interface approaches in spiking neural networks

Abstract: Neural networks perform computations through the coordinated activity of large populations of electrically and chemically coupled cells. Through advances in electrophysiological and imaging techniques, we are able to simultaneously record from an increasing number of neurons. Understanding the combined dynamical activity of such large networks represents a significant computational and analytical challenge.

In spite of their large size, certain systems exhibit coherent activity at meso- or macro-scopic scales, that can be attributed to functional responses. For example, bumps in cortical tissue have been linked to working memory, periodic tilings are associated with retinotopic maps and travelling waves with switching in binocular rivalry tasks. Neural field theory has provided insight into how such macroscopic patterns are formed across neural networks, but does not account for important properties of individual neurons, that may, for example be responsible for transitions between bump and wave states.

In this talk, we will present analysis of synaptically coupled integrate-and-fire type neural networks and show how interface approaches, which track level sets of spatiotemporal patterns, can be used to study the formation of waves and bumps, as well as bifurcations between them. We will also discuss how the same techniques can be applied to smooth neural models and how the analysis can be used to predict emergent dynamics under conditions of parameter uncertainty.

Speaker: Bastian Pietras, Andreas Daffertshofer, Vrije Universiteit Amsterdam, Amsterdam, Netherlands

Title: Phase description of coupled neural oscillators

Abstract: Rhythms and oscillatory behavior are abundant on all different scales of the human brain. Meso- and macroscopic models as well as instrumental devices and recording techniques have been developed to describe and trace these, typically large-scale brain dynamics. However, linking recordings of brain activity to the underlying neuronal mechanisms is one of the major challenges in neuroscience. A promising idea is to recover the macroscopic behavior by simulating neural network models. Such modeling is often simplified to the phase dynamics of cortical activity, which is believed to play a crucial role in information processing and inter-cortical communication. Time series analysis techniques can often be applied to extract the phase dynamics of the model which render the comparison between experimental and simulated data feasible. But does the phase dynamics really represent the underlying neural network? We compared the outcome of several mathematically sound phase reduction techniques applied to networks of weakly coupled Wilson-Cowan neural masses. While some reduction techniques only differ quantitatively, others yield qualitatively different phase models. By qualitatively different we mean that the modelsdisplay distinct stability properties. We highlight caveats and sensitive issues in the analytic derivation of phase models that may contribute to these dichotomies. We also illustrate the effects using numerical simulations. It appears phase reduction techniques have to be tailored to the targeted macroscopic observable and the parameter regime under study. More importantly, though, we have to conclude that using heuristic phase models as guidelines for inferring neural network dynamics from data is challenging, if at all possible.