DY 2: Time-delayed feedback and neural networks

Time: Monday 10:30–12:00 Location: H3

DY 2.1 Mon 10:30 H3

Refuting the odd number limitation of time-delayed feedback control — Bernold Fiedler[2], Valentin Flunkert[1], Marc Georgi[2], Philipp Hövel[1], and •Eckehard Schöll[1] — [1]Institut für Theoretische Physik, Technische Universität Ber lin, Hardenbergstr. 36, 10623 Berlin — [2]Institut für Mathematik I, Freie Universität Berlin, Arnimalle 2-6, 14195 Berlin

We refute an often invoked theorem which claims that a periodic orbit with an odd number of real Floquet multipliers greater than unity can never be stabilized by time-delayed feedback control in the form proposed by Pyragas [1]. Using a generic normal form, we demonstrate that the unstable periodic orbit generated by a subcritical Hopf bifurcation, which has a single real unstable Floquet multiplier, can in fact be stabilized. We derive explicit analytical conditions for the control matrix in terms of the amplitude and the phase of the feedback control gain, and present a numerical example. Our results are of relevance for a wide range of systems in physics, chemistry, technology, and life sciences, where subcritical Hopf bifurcations occur.

[1] B. Fiedler, V. Flunkert, M. Georgi, P. Hövel, and E. Schöll: *Refuting the odd number limitation of time-delayed feedback control*, Phys. Rev. Lett. (2006), submitted http://arxiv.org/abs/nlin.CD/0609056

DY 2.2 Mon 10:45 H3

Control of unstable fixed points by extended time-delayed feedback — •Thomas Dahms, Philipp Hövel, and Eckehard Schöll — Institut für Theoretische Physik, TU Berlin, Hardenbergstr. 36, D-10623 Berlin

Time-delayed feedback methods can be used to control unstable periodic orbits as well as unstable steady states. We present an application of extended time delay autosynchornization introduced by Socolar et al. to an unstable focus. This system represents a generic model of an unstable steady state which can be found for instance in a Hopf bifurcation. In addition to the original controler design, we investigate effects of control loop latency and a band pass filter on the domain of control. Furthermore, we consider coupling of the control force to the system via a rotational coupling matrix parametrized by a variable phase. We present an analysis of the domain of control and support our results by numerical calculations.

DY 2.3 Mon 11:00 H3

Controlling the Phase in a Neuronal Feedback Loop Through Asymmetric Temporal Delays — Sebasitan Brandt[1], •Axel Pelster[2], and Ralf Wessel[1] — [1]Department of Physics, Campus Box 1105, Washington University in St. Louis, MO 63130-4899, USA — [2]Fachbereich Physik, Campus Duisburg, Universität Duisburg-Essen, 47048 Duisburg, Germany

We consider the effect of asymmetric temporal delays in a system of two coupled Hopfield neurons. For couplings of opposite signs, a limit cycle emerges via a supercritical Hopf bifurcation when the sum of the delays reaches a critical value. We show that the angular frequency of the limit cycle is independent of an asymmetry in the delays. However, the delay asymmetry determines the phase difference between the periodic activities of the two components. Specifically, when the connection with negative coupling has a delay much larger than the delay for the positive coupling, the system approaches in-phase synchrony between the two components. Employing variational perturbation theory, we achieve an approximate analytical evaluation of the phase shift, in good agreement with numerical results.

DY 2.4 Mon 11:15 H3

Oscillatory associative memory in an electrochemical system — •Robert Hölzel and Katharina Krischer — TU München, Physik Department (E 19), James Franck Str. 85748 Garching

A system of globally coupled Kuramoto oscillators with a weak time-dependent coupling can act as a Hopfield-like neural network with the pattern information stored in the relative phase shifts of the oscillators [Hoppensteadt FC Izhikevich EM, PHYSICAL REVIEW LETTERS 82 (14): 2983-2986 APR 5 1999].

We investigate the Hopfield-like properties of a realistic network of electrochemical oscillators with a time-dependent, weak global coupling through the electric field. Averaged evolution equations for the phase shifts are derived based on phase response curves.

Our results indicate that pattern recognition with two memorized patterns is possible in the realistic system without qualitative modification of constraints compared to the Kuramoto model. However, further refinement of the time-dependent coupling is necessary for general pattern recognition with more than two memorized patterns.

DY 2.5 Mon 11:30 H3

Stable Irregular Dynamics in Complex Neural Networks — •Sven Jahnke, Raoul-Martin Memmesheimer, and Marc Timme — Network Dynamics Group, Max Planck Institute for Dynamics and Self-Organization, and Bernstein Center for Computational Neuroscience (BCCN), Bunsenstrasse 10, 37073 Göttingen

Models mimicking the 'ground state' of neural networks in the cortex exhibit highly irregular spiking dynamics of individual neurons and weak cross-correlations between the neurons. In their mean field study v.Vreeswijk and Sompolinsky (Science, 1996) suggest that this irregular dynamics in general is chaotic.

Here we investigate this irregular dynamics in finite networks keeping track of all individual spike times. For delayed, purely inhibitory interactions we give strong evidence that the irregular dynamics is not chaotic but in fact stable and convergent towards periodic orbits.

Moreover, we show that every generic periodic orbit of these dynamical systems is stable. These results indicate that chaotic and stable dynamics are equally capable of generating irregular neuronal activity. We investigate possible transitions to chaotic dynamics by changing features of the neurons and their interactions.

DY 2.6 Mon 11:45 H3

Dynamics of neural cryptography — •Andreas Ruttor[1], Ido Kanter[2], and Wolfgang Kinzel[1] — [1]Institut für Theoretische Physik, Universität Würzburg, Am Hubland, 97074 Würzburg — [2]Minerva Center and Department of Physics, Bar Ilan University, Ramat Gan 52900, Israel

Synchronization of neural networks has been used for novel public channel protocols in cryptography. In the case of Tree Parity Machines the dynamics of both bidirectional synchronization and unidirectional learning is driven by attractive and repulsive stochastic forces. Thus it can be described well by a random walk model for the overlap between participating neural networks. For that purpose transition probabilities and scaling laws for the step sizes are derived analytically. Both these calculations as well as numerical simulations show that bidirectional interaction leads to full synchronization on average. In contrast, successful learning is only possible by means of fluctuations. Consequently, synchronization is much faster than learning, which is essential for the security of the neural key-exchange protocol.