DY 7: Time-delayed feedback and neural networks

Time: Monday 16:30–18:15 Location: A 053

DY 7.1 Mon 16:30 A 053

Stabilizing continuous-wave output in semiconductor lasers by time-delayed feedback methods — •Thomas Dahms, Philipp Hövel, and Eckehard Schöll — Institut f. Theor. Physik, Sekr. EW 7-1, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany

Time-delayed feedback methods have been widely used to control unstable dynamics in a huge variety of different fields ranging from chemical to optical systems. In the latter case, the time-delayed feedback can be realized experimentally by an optical resonator [1]. We present an application of a multiple time-delayed feedback scheme to a semiconductor laser system with undamped relaxation oscillations implemented as a model of Lang-Kobayashi type. We show that the control method is able to enhance the range of local stability of the lasing fixed point leading to continuous-wave operation by suppression of unwanted intensity pulsations. This local enhancement matches our findings on a generic normal-form model [2], but due to the self-feedback, multistable behavior can also occur in the form of delay-induced limit cycles and fixed points for certain choices of the control parameters.

[1] S. Schikora, P. Hövel, H. J. Wünsche, E. Schöll, and F. Henneberger: *All-optical noninvasive control of unstable steady states in a semiconductor laser*, Phys. Rev. Lett. **97**, 213902 (2006).
[2] T. Dahms, P. Hövel, and E. Schöll: *Control of unstable steady states by extended time-delayed feedback*, Phys. Rev. E **76**, 056201 (2007).

DY 7.2 Mon 16:45 A 053

Controlling noise–induced oscillations by time–delayed feedback — •Clemens von Loewenich and Hartmut Benner — Institut für Festkörperphysik, Technische Universität Darmstadt, Germany

Noise-induced oscillations have been observed in an electronic van der Pol oscillator just below the Hopf bifurcation, where the noisefree system still has a stable fixed point. In previous investigations it was shown both analytically and numerically that these oscillations can be controlled by time-delayed feedback, which allows to maximize their correlation time on variation of delay time, feedback strength and noise intensity [1,2].
The experimental implementation of this model turned out to be a rather delicate problem, in particular, to achieve a variation of the noise level over several orders of magnitude. Nevertheless we were able to confirm the main theoretical predictions: Correlation time and power spectrum were measured for different delay times and feedback strengths over a noise intensity range of about 30 dB. The power spectrum of the delayed-feedback circuit exhibits the typical multi-peak structure predicted. The correlation time, in fact, shows a dramatic feedback-induced increase which fits the theory even quantitatively.

[1] N. B. Janson et al., Phys. Rev. Lett. **93**, 010601 (2004)
[2] J. Pomplun et al., Europhys. Lett. **71**, 366 (2005)

DY 7.3 Mon 17:00 A 053

Suppression of pulses in excitable media by delayed nonlocal coupling — •Felix M. Schneider, Markus A. Dahlem, and Eckehard Schöll — Institut f. Theor. Physik, Sekr. EW 7-1, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany

We investigate a FitzHugh-Nagumo system with diffusion in 1D close to the excitation limit. This serves a model of spatio-temporal neural excitation patterns in the cortex emerging from pathological pathways, e.g. during migraine, seizure, or stroke. We apply a range of control algorithms based on time-delayed feedback transmitted spatially along nonlocal connectivity patterns. We show through simulations that for different control schemes activity can be restricted to the pathological part of the network. Some control schemes reflect the nature of interneuronal cortical connections, where on short distances connections from inhibitory interneurons dominate, while on an intermediate range excitatory, lateral connections prevail.

DY 7.4 Mon 17:15 A 053

Observing global properties of time-delayed feedback control with an unstable controller — •Hiroyuki Shirahama[1,2], Klaus Höhne[1], Hartmut Benner[1], and Wolfram Just[3] — [1]Institut für Festkörperphysik, TU Darmstadt,, 64289 Darmstadt, Germany — [2]Faculty of Education, Ehime University, Matsuyama 790-8577, Japan — [3]Queen Mary/University of London, School of Mathematical Sciences, London E1 4NS, UK

Time-delayed feedback control is a simple, robust and efficient tool to stabilize unstable periodic orbits embedded in strange attractors of chaotic systems. Early analytical investigations indicated that unstable orbits with an odd number of real unstable modes cannot be stabilized by this method [1]. To overcome this limitation the counterintuitive idea of an unstable control loop has been proposed [2]. By including an additional unstable mode into the control loop one artificially enlarges the set of real multipliers greater than unity to an even number. We demonstrate the feasibility of an unstable control loop to stabilize such torsion-free orbits in an electronic circuit experiment. Analytical normal form calculations and numerical simulations reveal a severe dependence of the control performance on the coupling scheme of the control force. These predictions are confirmed by the experiment and emphasize the importance of the coupling scheme for the global control performance [3].

[1] H. Nagajima, Phys. Lett. A **232**, 207 (1997)
[2] K. Pyragas, Phys. Rev. Lett. **86**, 2265 (2001)
[3] K. Höhne et al., Phys. Rev. Lett. **98**, 214102 (2007)

DY 7.5 Mon 17:30 A 053

Control of neural dynamics by extended time-delayed feedback — •Philipp Hövel, Markus A. Dahlem, and Eckehard Schöll — Institut f. Theo. Physik, Sekr. EW 7-1, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany

We investigate the cooperative dynamics of two muually coupled neural populations represented by two FitzHugh-Nagumo systems. Both populations are prepared at parameter values at which no self-sustained oscillations occur, and both are subject to independent sources of Gaussian white noise. In order to influence the cooperative dynamics measured, for instance, by quantities like the coherence, ratio of average interspike intervals, and synchronization, we apply a local, external stimulation modelled as extended time-delayed feedback. This method was originally proposed to stabilize unstable periodic orbits of deterministic systems and generates a feedback signal from the differences of multiple time delays. Depending on the control parameters such as time delay, feedback strength, and memory parameter, we expect stronger effects on the coherence, time scales, and synchronization of coupled neural oscillators compared to control schemes with only a single time delay.

DY 7.6 Mon 17:45 A 053

Delay sustained pattern formation in subexcitable media — •Martin Gassel, Erik Glatt, and Friedemann Kaiser — Institute of Applied Physics, TU Darmstadt, Germany

In the last decades a lot of investigations on the dynamics of nonlinear systems and their control have been done. Many of them focus on time-delayed feedback control, a widely used method to achieve a qualitative change in the system dynamics. Pyragas introduced a feedback control scheme to stabilize an unstable orbit of a chaotic attractor to control deterministic chaos. In other investigations time-delayed feedback is used to control the coherence of noise-induced oscillations or to suppress limit cycle oscillations (amplitude death). In the present contribution the influence of time-delayed feedback on pattern formation in subexcitable media represented by a net of FitzHugh-Nagumo elements is studied. Without feedback wave fronts, which are either induced by special initial conditions or by additive noise, die out after a short propagation length (subexcitable net dynamics). Applying time-delayed feedback with appropriate feedback parameters pattern formation is sustained and the wave fronts may propagate through the whole net. The coherence of the patterns and the life time of the wave fronts are investigated dependent on the feedback strength and the delay time. It is shown that both the coherence of the patterns and the life time of the wave fronts are significantly larger, if feedback with appropriate parameters is applied.

DY 7.7 Mon 18:00 A 053

Control of delay-induced oscillatory firing patterns — •Gerald Hiller, Sebastian Brandstetter, Philipp Hövel, Markus A. Dahlem, and Eckehard Schöll — Institut für Theoretische Physik, Technische Universität Berlin

Using the FitzHugh-Nagumo model as a prototypical example of an excitable system, we investigate the emergence of oscillatory firing patterns as a result of delayed coupling between two units. The compound system becomes a bistable system being either at rest or in a state of sustained mutually driven oscillation.

We apply Pyragas' delayed feedback method to control the delay-induced bifurcation that renders the compound system oscillatory. We also investigate the robustness of the oscillator to white noise as well as colored noise and examine the possibility of using either noise or control to trigger the transition between the rest state and the oscillatory state.