Preface

This book summarizes state-of-the-art research on the control of self-organizing nonlinear systems by a selection of contributions from leading international experts in this new emerging field. The first focus concerns recent methodological developments from both the physical and the mathematical side, including control of networks and of noisy and time-delayed systems. As a second focus, the book features novel innovative concepts of application including control of quantum systems, soft condensed matter, biological systems, and complex networks. Special topics reflecting the active research in the field are the analysis and control of chimera states in classical networks and in quantum systems, the mathematical treatment of multiscale systems, the control of colloidal and quantum transport, and the control of epidemics and of neural network dynamics.

The International Conference on Control of Self-Organizing Nonlinear Systems held from August 25–28, August 2014 in Rostock-Warnemünde, Germany, was organized by the Collaborative Research Center (Sonderforschungsbereich) SFB 910 *Control of Self-Organizing Nonlinear System—Theoretical Methods and Concepts of Application*, Berlin, to provide a forum for such topics. We took this opportunity to assemble a list of world-leading experts which now enables us to present perspectives of the cutting-edge-research in this field. The book covers mathematical foundations as well as applications. The individual contributions summarize recent research results and also address the broader context. Thus, the presentation is kept accessible for a large audience. The 24 chapters cover various aspects, ranging from fundamental aspects like synchronization and control of complex networks, time-delayed feedback control, interplay of noise and delay, optimal control, effective models, and multiscale systems, to applications of feedback control and chimera patterns in quantum transport and photonics, colloidal systems and liquid films, neuroscience, epidemiology, and evolutionary dynamics. The chapters are grouped into two parts: I Theoretical Methods and II Concepts of Applications.

The first part addresses fundamental issues of controlling nonlinear dynamical systems. The contribution by Zakharova et al. discusses the interplay of structure,

noise, and delay in the control of chimera patterns, in particular amplitude chimeras and chimera death, in networks of Stuart–Landau oscillators. Olmi and Torcini analyze the synchronization transition of a globally coupled network of phase oscillators with inertia, whose natural frequencies are unimodally or bimodally distributed. Hövel et al. present an adaptive control scheme, based on the speed-gradient method, for in-phase and cluster synchronization in delay-coupled networks of Stuart–Landau oscillators, adapting the topology by changing the link weights. Atay investigates the problem of controlling oscillations in nonlinear systems by delayed feedback, thus driving the system to a stable limit cycle with prescribed amplitude and frequency. Purewal et al. treat global effects of time-delayed feedback control applied to the Lorenz system, and demonstrate the stabilization of one of its two saddle periodic orbits. Schneider and Fiedler study the symmetry-breaking stabilization of rotating waves, i.e., unstable periodic orbits in ring networks of Stuart–Landau oscillators, by time-delayed feedback control. D'Huys et al. focus on the interplay of noise and delay in delay-coupled oscillators, in particular on delay-induced multistability and noise-induced switching between different periodic orbits. Just et al. develop some basic analytical perturbation schemes for noisy dynamical systems with time delay, and apply this to time-delayed feedback control, coherence resonance, and the computation of power spectra. Li et al. develop a computationally efficient numerical method for the study of noise-induced bifurcations in nonautonomous dynamical systems, and apply it to explosive and dangerous stochastic bifurcations, characterized by sudden jumps of the response probability distribution. Ryll et al. deal with optimal control of traveling wave solutions of reaction–diffusion systems, in particular with the position control of selected spatiotemporal patterns. Curran et al. report recent rigorous results on reaction–diffusion equations with discontinuous hysteretic nonlinearities and treat the pattern formation mechanism of rattling as an application. Mielke develops mathematical tools for deriving effective models for multiscale systems via evolutionary Γ-convergence and applies them to perturbed gradient systems, e.g., the homogenization of reaction–diffusion systems. Kuehn presents a review of moment closure methods which enable the derivation of a closed hierarchy of coupled differential equations in the modeling of complex systems.

The second part discusses a number of recent innovative applications, starting with feedback control on the quantum scale. The contribution of Emary summarizes theoretical strategies to manipulate the properties of electron flows and states in quantum transport devices, covering both, measurement-based, and coherent control. Strasberg et al. present two measurement-based feedback schemes for a paradigmatic nonlinear quantum system and discuss their application on stabilization of steady states. The contribution of Bastidas et al. extends the phenomenon of chimera states, i.e., partially synchronized patterns, to the quantum regime, and uncovers intriguing quantum signatures of these states in the quantum correlations and the quantum information. Moving towards classical systems, Weicker et al. present a combined theoretical and experimental study of a time-delayed FitzHugh–Nagumo system exhibiting a threshold nonlinearity related to multirhythmicity. The

theoretical observations are supported by parallel experiments involving an electrical circuit. Based on a semiclassical approach, Böhm and Lüdge investigate small networks of semiconductor lasers with optical all-to-all coupling, focusing on synchronization patterns and the occurrence of chimera states. As a first application to soft condensed matter, Gernert et al. discuss feedback control strategies to manipulate transport properties and transport efficiency in colloidal systems, including systems with non-negligible interactions. Another type of soft-matter system, namely thin films containing self-propelled particles is discussed by Pototsky et al., focusing on the interplay of self-propulsion and linear stability of the film. On a more methodological level, Kraft and Gurevich address the formation and control of spatiotemporal patterns in a Swift–Hohenberg equation subject to time-delayed feedback. The contribution of Belik et al. involves control of a large-scale hospital network. Based on a large number of real, patient referral patterns they propose an agent-based computational model of hospital-related infections and analyze the model predictions including the effect of various control strategies. Ladenbauer et al. present an overview of control strategies with time-delayed feedback for neural networks, focusing on the impact of plasticity of synaptic coupling strengths and changes of neuronal adaptation properties. Finally, Claussen discusses examples of macroscopic evolutionary dynamics, particularly the stabilization of steady states of coexistence via payoff and global feedback.

Owing to the cross-disciplinary nature of the topic, we hope that this book will have substantial impact across field boundaries. It is aimed to bring together the nonlinear dynamics control concepts, the classical mathematical control theory, and quantum control. In particular, we envisage to stimulate future developments and interactions in the areas of control theory, functional differential equations, dynamical network science, hard and soft condensed matter, nonlinear optics, neuroscience, and socio-economic systems. This book thus provides a snapshot of the vibrant research related to controlling nonlinear systems from across different fields. It will not only be of great interest to specialists working on related problems, but also provide a valuable resource for other scientists and newcomers to the field.

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