Kyandoghere Kyamakya, Wolfgang A. Halang, Herwig Unger,
Jean Chamberlain Chedjou, Nikolai F. Rulkov, and Zhong Li (Eds.)

Recent Advances in Nonlinear Dynamics and Synchronization

Studies in Computational Intelligence, Volume 254

Editor-in-Chief
Prof. Janusz Kacprzyk
Systems Research Institute
Polish Academy of Sciences
ul. Newelska 6
01-447 Warsaw
Poland
E-mail: kacprzyk@ibspan.waw.pl

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Recent Advances in Nonlinear Dynamics and Synchronization, 2009
ISBN 978-3-642-04226-3

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Theory and Applications

Springer

Prof. Kyandoghere Kyamakya
Institute for Smart-Systems Technologies
Alpen-Adria Universität Klagenfurt
Universitätsstraße 65-67
9020 Klagenfurt
Austria
E-mail: kyandoghere.kyamakya@uni-klu.ac.at

Dr. Jean Chamberlain Chedjou
Institute for Smart-Systems Technologies
Alpen-Adria Universität Klagenfurt
Universitätsstraße 65-67
9020 Klagenfurt
Austria
E-mail: jean.chedjou@uni-klu.ac.at

Prof. Wolfgang A. Halang
FernUniversität in Hagen
Lehrgebiet Informationstechnik
Universitätsstraße 27 - PRG
58097 Hagen
Germany
E-mail: wolfgang.halang@fernuni-hagen.de

Prof. Nikolai F. Rulkov
Institute for Nonlinear Science
University of California, San Diego
9500 Gilman Drive
La Jolla, CA 92093-0402
USA
E-mail: nrulkov@ucsd.edu

Prof. Herwig Unger
FernUniversität in Hagen
Lehrgebiet Kommunikationsnetze
Universitätsstraße 27 - PRG
58097 Hagen
Germany
E-mail:herwig.unger@fernuni-hagen.de

Prof. Zhong Li
FernUniversität in Hagen
Lehrgebiet Informationstechnik
Universitätsstraße 27 - PRG
58097 Hagen
Germany
E-mail: zhong.li@fernuni-hagen.de

ISBN 978-3-642-04226-3 e-ISBN 978-3-642-04227-0

DOI 10.1007/978-3-642-04227-0

Studies in Computational Intelligence ISSN 1860-949X

Library of Congress Control Number: 2009934308

Typeset & *Cover Design:* Scientific Publishing Services Pvt. Ltd., Chennai, India.

Printed in acid-free paper

9 8 7 6 5 4 3 2 1

springer.com

Preface

In essence, the dynamics of real world systems (i.e. engineered systems, natural systems, social systesms, etc.) is nonlinear. The analysis of this nonlinear character is generally performed through both observational and modeling processes aiming at deriving appropriate models (mathematical, logical, graphical, etc.) to simulate or mimic the spatiotemporal dynamics of the given systems. The complex intrinsic nature of these systems (i.e. nonlinearity and spatiotemporal dynamics) can lead to striking dynamical behaviors such as regular or irregular, stable or unstable, periodicity or multi-periodicity, torus or chaotic dynamics. The various potential applications of the knowledge about such dynamics in technical sciences (engineering) are being intensively demonstrated by diverse ongoing research activities worldwide.

However, both the modeling and the control of the nonlinear dynamics in a range of systems is still not yet well-understood (e.g. system models with time varying coefficients, immune systems, swarm intelligent systems, chaotic and fractal systems, stochastic systems, self-organized systems, etc.). This is due amongst others to the challenging task of establishing a precise and systematic fundamental or theoretical framework (e.g. methods and tools) to analyze, understand, explain and predict the nonlinear dynamical behavior of these systems, in some cases even in real-time.

The full insight in systems' nonlinear dynamic behavior is generally achieved through approaches involving analytical, numerical and/or experimental methods. These approaches though complementary (since each of them can solve/depict some problems/aspects unsolved by its counterparts) are generally prone to some limitations when dealing with the analysis of complex, stiff and time varying dynamical systems. If it is generally tough/challenging to derive exact analytical solutions of models describing the dynamical behavior of such systems, numerical methods to analyze these systems are very time consuming and are exposed to accumulation of round-off errors during computations. Experimental studies are also limited by either the precision of physical components or calculators used or limitation in resources. These are some examples justifying the tremendous interest nowadays devoted to the development of a universal/unified framework which is robust to the underlined problems/drawbacks.

Due to the complex structural constitutions of real world systems which are generally made-up of autonomous and/or non-autonomous, coupled and/or uncoupled entities or sub-systems, the synchronization issue aims at achieving a general or global coordination/cooperation of the complete system as a whole. Basically, the realization and control of synchronization is a challenging task which appears far from being clearly understood and predicted in complex systems. Indeed, the synchronization phenomenon of is very widespread in nature as well as in complex technical systems. This phenomenon should be understood as the capacity of systems' entities (or sub-systems), either of the same or of different nature, to acquire a common operation regime which manifests itself by a general coordination (or global cooperation). This demonstrates the achievement of a given order or harmony in the behavior/motions of the systems or events. Some interesting applications can be found in urban area traffic control for instance, where phase synchronization of different traffic lights contribute to realize the so-called green waves and to optimize the overall throughput of the road network. In the fields of mechanics or electro-mechanics, the complete synchronization is exploited to make different sub-systems or coupled systems perform identical tasks. In the field of electronics, chaotic synchronization has been intensively exploited, for example in secure digital communications and in chaos-based cryptography. In medicine, synchronization has been exploited to regulate the cardiac beat. In biology, synchronization has been shown to be an important part of the function or dysfunction of a complex biological system. For instance, epileptic seizures correspond to a particular state of the brain in which too many neurons are desynchronized. Synchronization between these neurons leads to a correct functioning of the brain. These few applications of synchronization reveal the multiple interesting potential applications of synchronization and therefore justify the tremendous interest devoted on the investigation of this phenomenon.

The selected contributions of this book shed light on a series of interesting aspects related to nonlinear dynamics and synchronization with the aim of demonstrating some of their interesting applications in a series of selected disciplines. This book contains thirteenth chapters which are organized around five main parts. The first part (containing five chapters) does focus on theoretical aspects and recent trends of nonlinear dynamics and synchronization. The second part (two chapters) presents some modeling and simulation issues through concrete application examples. The third part (two chapters) is focused on the application of nonlinear dynamics and synchronization in transportation. The fourth part (two chapters) presents some applications of synchronization in security-related system concepts. The fifth part (two chapters) considers further applications areas, i.e. pattern recognition and communication engineering. The following lines present a brief and concise summary of each of the chapters included in this book.

The first chapter, ***"Recent Advances in Complex Networks Synchronization"***, by Guanong Chen, Xiaofan Wang, Xiang Li, and Jinhu Lü, addresses the issues of synchronization in complex dynamical networks. A brief overview of the state-of-the-art on synchronization issues in these networks is presented and a particular emphasis is devoted to the field of technical sciences. Synchronization is investigated in time-varying networks, and some mathematical formulas are derived to predict its occurrence. The “pinning” control technique (i.e. a permanent control or active control in real-time) is applied to particular nodes of some complex networks which cannot achieve self-synchronization in order to bring them into synchronization regime and some mathematical criteria are derived to predict the achievement/occurrence of synchronization.

The second chapter, ***“Network of Limit Cycle Oscillators with Parametric Learning Capability”***, by Julio Rodriguez and Max-Olivier Hongler, proposes a novel concept based on the application of a parametric learning approach to achieve synchronization in networks of interacting limit cycle oscillators. The method is applied to two types of networks namely the network of stable limit cycle oscillators and the network of mixed canonical-dissipative systems. The learning process is characterized analytically in both cases. Interestingly, it is shown the possibility of controlling/adjusting the natural frequencies of the oscillators by the learning method in networks of coupled oscillators as well as in networks of uncoupled oscillators as well.

The third chapter, ***“Ragged Synchronizability and Clustering in a Network of Coupled Oscillators”***, by Przemyslaw Perlikowsky, Andrzej Stefanski, and Tomasz Kapitaniak, investigates the issues of ragged synchronization and clustering in a network of three coupled in-line van der Pol oscillators. The modeling of this network is carried out and sets of equations are proposed (mathematical model) to describe the dynamics of the coupled network. These equations are used to explain the occurrence of ragged synchronization and clustering. Numerical and experimental studies are carried out to show the occurrence of ragged synchronization in both regular and irregular (i.e. chaotic) states of the network of coupled van der Pol oscillators. The study is extended to the case of a network of eight coupled in-line van der Pol oscillators and the occurrence of ragged synchronization is observed again.

The fourth chapter, ***“Cumulant Analysis of Strange Attractors -- Theory and Applications”***, by V. Kontorovitch and Z. Lovtchikova, presents both a theory and applications of the cumulant analysis of strange attractors. A theoretical description of a novel method/approach for the statistical analysis of strange attractors or chaos is carried out. The proposed method is applied to three classical and well-known self-sustained (or autonomous) nonlinear oscillators namely the Lorenz, Chua, and Rössler oscillators and various histograms are obtained for each of the oscillators. Theoretical results are compared with numerical results and a very good agreement is obtained as proof of concept of the proposed approach. Some applications of strange attractors are shown in the area of electrical engineering, specifically in communications.

The fifth chapter, ***“On Synchronization of Coupled Delayed Neural Networks”***, by Jinling Liang, Zidong Wang, and Xiaohui Liu, uses both continuous and discrete-time coupled neural networks schemes to investigate synchronization issues. Both linear and nonlinear couplings are considered in the case of a high dimensional system. The analytical study of the synchronization issues is carried out, and conditions are derived for the occurrence of both global synchronization and global exponential synchronization in the array of neural networks. Further, a numerical study is considered and the numerical results are compared with the analytical ones to illustrate the effectiveness (i.e. proof of concepts) of the proposed synchronization scheme.

The sixth chapter, ***"Multiset Agents in a Network for Simulation of Complex Systems"***, by V.K.Murthy and E.V.Krishnamurthy, analyses some key properties of complex systems and proposes models (mathematical and/or graphical) to understand the underlined properties. A concept based on the multiagent paradigm is proposed to simulate these properties. The methods agent based- modeling, simulation, and animation are considered and some advantages of these respective methods are described. Some application examples of these methods are further considered to investigate the swarm dynamics of ant colony, bacterial colonies, animal trails, etc. and the interest of developing the technology of agent modeling, simulation and animation to analyze biological phenomena is demonstrated.

The seventh chapter, ***"Simulation of Nonlinear Dynamics and Synchronization for Structural Control at Seismic Excitation"***, by Svetla Radeva addresses the modeling and simulation of earthquake phenomenon. The work relates to structural control systems in order to provide appropriate measurements necessary for reducing the destructive effects of seismic earthquakes on structures. The analysis of the nonlinear structural dynamics (or the structural behavior) during the vibrations caused by earthquakes is carried out. Using the modeling and computer simulation processes, some control algorithms are developed which are oriented to nonlinear structural dynamics. An elasto-mechanical model is proposed to describe the interaction between seismic waves, soil layers and the controlled structure. Some earthquake excitations are simulated, and the proposed model is exploited to study both structural control and synchronization mechanisms.

The eighth chapter, ***"Emergence of Synchronization in Transportation Networks with Biologically Inspired Decentralized Control"***, by Reik Donner, proposes a general concept for serving conflicting material flows in networks. Specifically, an approach is proposed which is based on a self-organized optimization for conflicting flows. The proposed approach is inspired by the oscillatory phenomena of pedestrian and animal flows at nodes/junctions. This approach is applied to some regular grid topologies and different synchronization regimes are obtained. The results obtained by the proposed approach are shown to be in very good agreement with those linked to the synchronization of the oscillatory service dynamics at different nodes in the network. The proposed approach is advantageous as it can easily be mapped to real-world traffic scenarios.

The ninth chapter, ***"Synchronization of Movements for Large-Scale Crowds"***, by Boris Goldengorin, Dmitry Krushinsky, and Alexander Makarenko, considers an approach based on cellular automata to analyze the movement of a large-scale crowd. Three main interdependent aspects/factors are considered. The first is the evacuation time, the second is the flow of pedestrians, and the last is the synchronization of a crowd. A framework based on a scenarios tree is proposed for modeling the optimal decision-making of pedestrians. Synchronization issues are investigated and it is shown that a more anticipating crowd might exhibit a less-complex behavior and might be more synchronized. The experimental study is considered and does show that increasing the probability characterizing a personal anticipation leads to maximizing the flow and minimizing the evacuation time of a crowd.

The tenth chapter, ***"Adaptive Synchronization of Chaotic Systems and Its Uses in Cryptanalysis"***, by Ying Liu and Wallace K. S. Tang, proposes a new design of an adaptive observer for adaptive synchronization of a class of chaotic systems with multiple unknown parameters. This design exploits a linear feedback control scheme and the dynamical minimization algorithm. Synchronization issues are investigated in chaotic systems and their stability as well. The exploitation of the new scheme designed in cryptanalysis for chaos-based communication systems is demonstrated. As proof of concept, the new scheme designed is used to solve diverse complex synchronization problems found in Lorenz, Rössler, and Genesio chaotic systems.

The eleventh chapter, ***"Trust-Based Collaborative Control for Teams in Communication Networks"***, by P. Ballal, F.L. Lewis, and G. R. Hudas, considers distributed networks in which issues related to trust establishment and consensus are addressed. The graphical modeling process is considered to represent collaboration between nodes through information exchange. Both continuous- and discrete-time trust update scheme for trust consensus are presented.

The twelfth chapter, ***"Investigating the Usability of SIFTfeatures in Biometrics"***, by Dakshina Ranjan Kisku, Ajita Rattani, Massimo Tistarelli, Jamuna Kanta Sing, addresses both usability and efficiency of the Scale Invariant Feature Transform (SIFT) features. A brief overview of biometric systems including face biometrics, fingerprint biometrics and multimodal biometrics is presented. Graph matching based face recognition approaches using SIFT features are discussed. The approach based on feature level fusion is proposed, where the SIFT-based face biometric and the minutiae based fingerprint biometric are fused at the feature extraction level.

The thirteenth chapter, ***"Coupled Oscillator Systems for Microwave Applications. Optimized Design Based on the Study and Control of the Multiple Coexisting Solutions in Systems with Symmetry"***, by Ana Collado and Apostolos Georgiadis, considers two oscillators architectures. The first architecture is made-up of arrays of linear coupled oscillators for beam steering applications. The second architecture is a structure of N-push oscillators for Radio frequency of High frequency (RF/HF) generation. The modeling process of the oscillators is described. These two oscillators architectures are examined and multiple coexisting solutions are identified as well as their stability analysis is carried out. The harmonic balance method is combined with the continuation method in order to optimize the coupling network. To ensure the appearance of only the desired traveling wave mode, stable regions of the modes are identified by simulation.

To finish, we would like to gratefully acknowledge and sincerely thank all the reviewers for their insightful comments and criticism of the manuscripts. Our thanks go also to the authors for their contributions and precious collaboration.

The Guest Editors

K. Kyamakya
W.A. Halang
H. Unger
J.C. Chedjou
N.F. Rulkov

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