Springer Complexity

Springer Complexity is an interdisciplinary program publishing the best research and academic-level teaching on both fundamental and applied aspects of complex systems – cutting across all traditional disciplines of the natural and life sciences, engineering, economics, medicine, neuroscience, social and computer science.

Complex Systems are systems that comprise many interacting parts with the ability to generate a new quality of macroscopic collective behavior the manifestations of which are the spontaneous formation of distinctive temporal, spatial or functional structures. Models of such systems can be successfully mapped onto quite diverse “real-life” situations like the climate, the coherent emission of light from lasers, chemical reaction-diffusion systems, biological cellular networks, the dynamics of stock markets and of the internet, earthquake statistics and prediction, freeway traffic, the human brain, or the formation of opinions in social systems, to name just some of the popular applications.

Although their scope and methodologies overlap somewhat, one can distinguish the following main concepts and tools: self-organization, nonlinear dynamics, synergetics, turbulence, dynamical systems, catastrophes, instabilities, stochastic processes, chaos, graphs and networks, cellular automata, adaptive systems, genetic algorithms and computational intelligence.

The three major book publication platforms of the Springer Complexity program are the monograph series “Understanding Complex Systems” focusing on the various applications of complexity, the “Springer Series in Synergetics”, which is devoted to the quantitative theoretical and methodological foundations, and the “SpringerBriefs in Complexity” which are concise and topical working reports, case-studies, surveys, essays and lecture notes of relevance to the field. In addition to the books in these two core series, the program also incorporates individual titles ranging from textbooks to major reference works.

Editorial and Programme Advisory Board

Understanding Complex Systems

Founding Editor: S. Kelso

Future scientific and technological developments in many fields will necessarily depend upon coming to grips with complex systems. Such systems are complex in both their composition – typically many different kinds of components interacting simultaneously and nonlinearly with each other and their environments on multiple levels – and in the rich diversity of behavior of which they are capable.

The Springer Series in Understanding Complex Systems series (UCS) promotes new strategies and paradigms for understanding and realizing applications of complex systems research in a wide variety of fields and endeavors. UCS is explicitly transdisciplinary. It has three main goals: First, to elaborate the concepts, methods and tools of complex systems at all levels of description and in all scientific fields, especially newly emerging areas within the life, social, behavioral, economic, neuro- and cognitive sciences (and derivatives thereof); second, to encourage novel applications of these ideas in various fields of engineering and computation such as robotics, nano-technology and informatics; third, to provide a single forum within which commonalities and differences in the workings of complex systems may be discerned, hence leading to deeper insight and understanding.

UCS will publish monographs, lecture notes and selected edited contributions aimed at communicating new findings to a large multidisciplinary audience.

More information about this series at
http://www.springer.com/series/5394

Santo Banerjee • Lamberto Rondoni
Editors

Applications of Chaos and Nonlinear Dynamics in Science and Engineering - Vol. 4

Springer

Editors
Santo Banerjee
Institute for Mathematical Research
University Putra Malaysia
Serdang
Malaysia

Lamberto Rondoni
Dipartimento di Scienze Matematiche
Politecnico di Torino
Torino
Italy

ISSN 1860-0832 ISSN 1860-0840 (electronic)
Understanding Complex Systems
ISBN 978-3-319-17036-7 ISBN 978-3-319-17037-4 (eBook)
DOI 10.1007/978-3-319-17037-4

Library of Congress Control Number: 2013938159

Springer Cham Heidelberg New York Dordrecht London

Printed on acid-free paper

Springer International Publishing AG Switzerland is part of Springer Science+Business Media (www.springer.com)

Preface

This is the fourth volume of the collection of essays entitled *Applications of Chaos and Nonlinear Dynamics in Science and Engineering*, which has been addressed to Master and Ph.D. Students, as well as to specialists of disciplines other than the hard sciences, in order to help them familiarize with the theory and the applications of nonlinearity, and its use in describing complex phenomena.

As illustrated in the previous volumes, terms such as nonlinear dynamics, chaos and complexity have pervaded the vocabulary of almost all fields of science and technology. As a matter of fact, current mathematical descriptions of evolving phenomena consist of nonlinear ordinary or partial differential equations, of various kinds of stochastic processes and of nonlinear space and time discrete iterative schemes. In the deterministic cases, a typical situation is that in which the propagation of uncertainties is exponential in time, a phenomenon known as sensitive dependence on initial conditions, and concisely and suggestively called deterministic chaos.

To understand the reasons why certain terms have become common in many different fields, it suffices to observe that nonlinearities appear in feedback phenomena, which are ubiquitous in nature, and generically in the evolution equations of systems consisting of interacting parts or interacting with an external environment. Furthermore, any measurement one may perform, like any estimate of the initial state of any material object, is bound to be affected by uncertainties, which propagate in time leading to the conclusion that a degree of unpredictability is intrinsic, in practice as well as in principle, to all time dependent phenomena. For this reason, the study of nonlinear evolutions is commonly associated with statistical concepts, and relies on measures such as the Lyapunov exponents and various kinds of dynamical entropies.

In the previous volumes, we have presented a vast collection of examples, treated explicitly and in moderately technical terms. Indeed, these concepts have in the past decades turned useful in countless practical applications—beyond the mathematical and physical literature in which they have been mostly developed—ranging from engineering to biology, medicine, computer and telecommunication sciences, etc. We have thus followed an approach which we deem suitable to a vast readership, proposing essays written in the form of tutorials. In this last volume, we complete our survey and introduction to nonlinear, chaotic and complex phenomena, considering some issues of higher theoretical content than in the previous volumes, but preserving the mildly technical style of the previous volumes.

Part I concerns nonlinearities in transport of energy and matter, with one contribution by L. Stricker and L. Rondoni on models of heat transport and their mechanical properties, one contribution on the general theory of diffusion, by G. Boffetta, G. Lacorata and A. Vulpiani, and one contribution by M. Colangeli on the relation between the Boltzmann equation and hydrodynamics.

In Part II, we have three contributions on chaos and synchronization in complex networks: one by J. Stroud, M. Barahona and T. Pereira on modular networks, one by P. Carl on the evolution of climate, and one by A. Tai and S. Jalan on the use of random matrices. The chapters are well illustrated with recent developments on the subject area and possible practical applications.

Part III has two contributions on phase space reconstruction and on biological patterns, respectively, by S. K. Palit, S. Mukherjee, S. Banerjee, M.R.K. Ariffin and D. K. Bhattacharya, and by M. Banerjee. The theories are well illustrated and supported with analytical and numerical results.

Part IV concerns the use of chaos in field programmable gate arrays. This chapter is very useful as an introduction to the subject area.

We hope that this collection of examples, combined with those reported in the previous three volumes have covered a sufficiently wide spectrum of subjects, in terms suitable to a wide audience, interested in importing dynamical concepts in their disciplines, without recourse to sophisticated mathematical tools. The concepts of nonlinear dynamics are indeed proving more and more useful in all fields of research.

Serdang, Malaysia S. Banerjee
Torino, Italy L. Rondoni
26 January 2015

Contents